WHO GUIDELINES FOR THE

SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER

VOLUME I

POLICY AND REGULATORY ASPECTS

World Health Organization

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GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER

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CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AIDS	acquired immunodeficiency syndrome
BOD_5	five-day biochemical oxygen demand
2,4-D	2,4-dichlorophenoxyacetic acid
DALY	disability adjusted life year
DDT	dichlorodiphenyltrichloroethane
HIV	human immunodeficiency virus
IWRM	integrated water resources management
MDG	Millennium Development Goal
NTU	nephelometric turbidity unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
P_{inf}	probability of infection
QMRA	quantitative microbial risk assessment
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
UN	United Nations
UNICEF	United Nations Children's Fund
UV	ultraviolet
WHO	World Health Organization
WTO	World Trade Organization

PREFACE

The United Nations General Assembly (2000) adopted the Millennium Development Goals (MDGs) on 8 September 2000. The MDGs that are most directly related to the safe use of wastewater, excreta and greywater in agriculture and aquaculture are "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability." The use of wastewater, excreta and greywater in agriculture and aquaculture can help communities to grow more food and make use of precious water and nutrient resources. However, it should be done safely to maximize public health gains and environmental benefits.

In 1973, the World Health Organization (WHO) produced the publication *Reuse of effluents: Methods of wastewater treatment and public health safeguards*. This normative document provided guidance on how to protect public health and how to facilitate the rational use of wastewater and excreta in agriculture and aquaculture. Technically oriented, the publication did not address policy issues per se.

A thorough review of epidemiological studies and other new information led to the publication of a second edition of this normative document in 1989: *Health guidelines for the use of wastewater in agriculture and aquaculture*. The guidelines have been very influential with respect to technical standard setting and also at the policy level, and many countries have adopted or adapted them for their wastewater and excreta use practices.

The present third edition of the Guidelines has been updated based on new health evidence, expanded to better reach key target audiences and reoriented to reflect contemporary thinking on risk management.

The use of wastewater, excreta and greywater in agriculture and aquaculture is increasingly considered a method combining water and nutrient recycling, increased household food security and improved nutrition for poor households. Recent interest in wastewater, excreta and greywater use in agriculture and aquaculture has been driven by water scarcity, lack of availability of nutrients and concerns about health and environmental effects. It was necessary to update the Guidelines to take into account scientific evidence concerning pathogens, chemicals and other factors, including changes in population characteristics, changes in sanitation practices, better methods for evaluating risk, social/equity issues and sociocultural practices. There was a particular need to conduct a review of both risk assessment and epidemiological data.

In order to better package the Guidelines for appropriate audiences, the third edition of the *Guidelines for the safe use of wastewater, excreta and greywater* is presented in four separate volumes: *Volume 1: Policy and regulatory aspects*; *Volume 2: Wastewater use in agriculture*; *Volume 3: Wastewater and excreta use in aquaculture*; and *Volume 4: Excreta and greywater use in agriculture.*

WHO water-related guidelines are based on scientific consensus and best available evidence; they are developed through broad participation. The *Guidelines for the safe use of wastewater, excreta and greywater* are designed to protect the health of farmers (and their families), local communities and product consumers. They are meant to be adapted to take into consideration national sociocultural, economic and environmental factors. Where the Guidelines relate to technical issues — for example, excreta and greywater treatment — technologies that are readily available and achievable (both from a technical viewpoint and in terms of affordability) are explicitly noted, but others are not excluded. Overly strict standards may not be sustainable and, paradoxically, may lead to reduced health protection, because they may be viewed as unachievable under local circumstances and, thus, ignored. By proposing procedures that are adaptable to specific circumstances, the Guidelines strive to maximize overall public health benefits and the beneficial use of scarce resources.

This edition of the Guidelines supersedes previous editions (1973 and 1989). The Guidelines are recognized as representing the position of the United Nations system on issues of wastewater, excreta and greywater use and health by UN-Water, the coordinating body of the 24 United Nations agencies and programmes concerned with water issues. This edition of the Guidelines further develops concepts, approaches and information in previous editions and includes additional information on:

- the context of the overall waterborne disease burden in a population and how the use of wastewater, excreta and greywater in agriculture and aquaculture may contribute to that burden;
- the Stockholm Framework for the development of water-related guidelines and the setting of health-based targets;
- risk analysis;
- risk management strategies, including quantification of different health protection measures;
- guideline implementation strategies.

The revised Guidelines will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health and water and waste management, including environmental and public health scientists, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

The use of wastewater, excreta and greywater in agriculture and aquaculture has policy relevance in relation to poverty reduction, the protection of public health and the environment, food security and energy reliance. In countries where the scale of current reuse practices is substantial or where a considerable reuse potential exists, there is a need to create a distinct policy framework for wastewater, excreta and greywater use. In other countries, the issue interfaces with a number of key policy areas, and its governance therefore calls for the harmonization of relevant policies on this subject and for its mainstreaming within the most crucial ones.

This volume of the Guidelines focuses on policy, regulation and institutional arrangements. Accordingly, its intended readership is made up of policy-makers and those with regulatory responsibilities. It provides guidance on policy formulation, harmonization and mainstreaming, on regulatory mechanisms and on establishing institutional links between the various interested sectors and parties. It also presents a synthesis of the key issues from Volumes 2, 3 and 4 in the executive summaries in the second part of this volume. It contains the index for all four volumes of the Guidelines, and a glossary of terms used in all four volumes is presented in Annex 1.

The information in this volume is meant to give policy-makers and regulators an overview of the risks and benefits associated with the use of wastewater, excreta and greywater in agriculture and aquaculture without going into technical detail. It also presents an overview of the nature and scope of options for protecting public health. This information should be useful in the development of national policies for the safe use of wastewater, excreta and greywater. Detailed technical information on health risk assessment, health protection measures and monitoring and evaluation is presented in Volumes 2, 3 and 4.

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1
POLICY ASPECTS

The ultimate aim of these Guidelines is to protect and promote public health. Adequate capacity is required at the national level to maximize the benefits of the use of wastewater, excreta and greywater in agriculture and aquaculture, to minimize the health risks involved and to promote proper environmental management, ensuring long-term sustainability. An essential element of this national capacity consists of an enabling policy environment. This chapter summarizes the information needed to formulate decision-making criteria, establish decision-making procedures and create effective institutional arrangements for their implementation.

1.1 Policies as a basis for governance

Good governance requires consistency in decision-making towards agreed objectives. Policies make up the framework to set national development priorities and provide decision-making criteria to guide the development process towards achieving them. Policies may lead to the creation of legislation. Legislation establishes the responsibilities and rights of different stakeholders — and, supported by the institutional arrangements created between agencies, this determines which agency has the lead responsibility for creating regulations and who has the authority to implement and enforce the regulations. Translating policy into strategy requires the allocation of human and financial resources in accordance with the policy objectives and the capacities of the stakeholders.

In developing a national policy framework to facilitate the safe use of wastewater, excreta and greywater in agriculture and aquaculture, it is important to define the objectives of the policies, assess the current policy environment, formulate new policies or adjust existing ones, and develop a national strategy.

The use of wastewater, excreta and greywater can have one or more of several objectives. Defining these objectives is the first step in developing a national policy framework. Assessing the existing or potential magnitude of wastewater, excreta and greywater use, in both absolute and relative terms for the different types of use, provides a key to the type of policy formulation or adjustment that may be needed.

Environmental protection is a policy goal in most countries, from the viewpoints of both conservation of natural resources and ecosystem services and public health protection. A sectoral view of wastewater, excreta and greywater in this context would consider them to be costly by-products of the process of urbanization, requiring substantial investments in treatment plants and disposal mechanisms. Yet such a view overlooks their value as a source of water and/or nutrients for plant production and fish cultivation.

For the governments of many developing countries, attaining and maintaining food security for the entire population are the key policy goals. To achieve these goals, some countries provide incentives for the increased use of available natural resources (including water resources) towards local food production; others may provide subsidies to farmers to maintain a critical human resource base for local agricultural production. Where national resources for food production are under pressure and essential foods have to be imported from abroad, governments often provide subsidies to ensure that the poor can meet their basic needs in terms of nutrition. In this context, the use of wastewater, excreta and greywater is of particular relevance. In situations of water stress, wastewater must be considered a valuable water resource and an important positive trade-off in the process of rapid urbanization. Where essential food items have to be imported, waste use to enhance local agricultural production will result in important import substitutes.

In light of the above, it is crucially important to map out the existing policy landscape and upgrade the map periodically, as a basis for judging whether the options and opportunities of wastewater, excreta and greywater use are being considered in their full potential and whether safe use practices are being promoted to maximum cost-effectiveness.

Policy appraisal should take place from two perspectives: that of the policy-maker, who will want to ensure that the national policies and associated legislation, institutional framework and regulations meet the wastewater, excreta and greywater use objectives (e.g. maximize economic returns without endangering public health or the environment); and that of the project manager, who will want to ensure that current and future waste use activities can comply, realistically, with all relevant national and local laws and regulations.

Depending on local conditions, policies for the use of wastewater, excreta and greywater may be emphasized within the food security or within the environmental protection policy framework. Whatever the case may be, for their *safe* use, effective links will have to be established with the national public health policy framework.

The main policy issues to investigate are:

- *Public health*: To what extent is waste management addressed in national public health policies? What are the specific health hazards and risks associated with the use of wastewater, excreta and/or greywater in agriculture and aquaculture? Is there a national health impact assessment policy? Is there a policy basis for non-treatment interventions in line with the concepts and procedures contained in the Stockholm Framework?
- *Environmental protection*: To what extent and how is the management of wastewater, excreta and greywater addressed in the existing environmental protection policy framework? What are the current status, trends and expected outlook with respect to the production of wastewater, excreta and greywater? What is the capacity to management wastewater, excreta and greywater? What are the current and potential environmental impacts? What are the options for reuse in agriculture or aquaculture?
- *Food security*: What are the objectives and criteria laid down in the national policies for food security? Is water a limiting factor in ensuring national food security in the short/medium/long term? Are there real opportunities for the use of wastewater, excreta and greywater in agriculture and aquaculture to (partially) address this problem? Is reuse currently practiced in the agricultural production system? Has an analysis of the benefits and risks of such waste use been carried out?

Policy-makers should use the updated evidence concerning health impacts associated with the use of wastewater, excreta and greywater in agriculture and aquaculture presented in these Guidelines to develop rational and cost-effective policies for protecting public health and maximizing the beneficial use of natural resources.

1.2 The international policy framework

With the adoption of the Millennium Declaration, signed by 147 heads of state, the 189 nations in attendance at the special session of the United Nations (UN) General Assembly in September 2000 established a comprehensive global framework to support concerted efforts towards poverty reduction and sustainable development. The Declaration led to the formulation of eight Millennium Development Goals (MDGs) to be achieved by 2015 that respond to the world's main development challenges.

The eight MDGs break down into 18 quantifiable targets that are measured by 48 indicators:

- Goal 1: Eradicate extreme poverty and hunger
- Goal 2: Achieve universal primary education
- Goal 3: Promote gender equality and empower women
- Goal 4: Reduce child mortality
- Goal 5: Improve maternal health
- Goal 6: Combat HIV/AIDS, malaria and other diseases
- Goal 7: Ensure environmental sustainability
- Goal 8: Develop a global partnership for development

The Millennium Declaration has been signed by heads of state, and it is the commitment at this level that determines its significance. For the first time, all public sectors are committed to contributing towards achieving the same goals. This is particularly important for the sectors responsible for the development, management and use of water resources. Fragmentation at the policy and operational levels has become a major bottleneck in dealing with water resources, as good-quality fresh water is becoming increasingly scarce. At the Johannesburg World Summit on Sustainable Development in 2003, integrated water resources management (IWRM) was included in the international policy framework, and a first goal was set for countries to establish national IWRM policy goals by 2005. For regions in the world where water scarcity levels are highest, the use of wastewater, excreta and greywater is an important component of IWRM. In developing national IWRM policies, it will have to be given serious consideration.

In brief, the MDGs:

- synthesize, in a single package, many of the most important commitments made separately at the international conferences and summits of the 1990s, including those for the safe use of wastewater, excreta and greywater in agriculture and aquaculture dating back to the 1992 UN Conference on Environment and Development in Rio de Janeiro;
- recognize explicitly the interdependence between growth, poverty reduction and sustainable development;
- acknowledge that development rests on the foundations of democratic governance, the rule of law, respect for human rights and peace and security;
- are based on time-bound and measurable targets accompanied by indicators for monitoring progress;
- bring together, in the eighth Goal, the responsibilities of developing countries with those of developed countries, founded on a global partnership endorsed at the International Conference on Financing for Development in Monterrey, Mexico, in 2002, and again at the Johannesburg World Summit on Sustainable Development in August 2003.

The links between the MDGs and the safe use of wastewater, excreta and greywater in agriculture and aquaculture are explored in Table 1.1.

1.3 Policy issues

In the policy formulation and adjustment process, several issues associated with the use of wastewater, excreta and greywater in agriculture and aquaculture deserve a closer look. They are listed below and will be discussed in the following subsections:

Table 1.1 The relationship between MDGs and wastewater, excreta and greywater use in agriculture and aquaculture

Millennium Development Goals and their targets	Relationship to wastewater, excreta and greywater use
Goal 1. Eradicate extreme poverty and hunger Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than US$ 1 a day Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	• Wastewater, excreta and greywater make up an important resource for intensive agricultural production by the urban and rural poor and thereby strengthen their livelihood opportunities. • Agricultural produce cultivated through the use of wastwater, excreta and greywater adds importantly to the food security of poor rural and urban communities. • Reduced downstream ecosystem degradation resulting from the use of wastewater, excreta and greywater makes livelihood systems of the poor more secure.
Goal 2. Achieve universal primary education Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	• No direct link to universal school attendance, but experiences in India demonstrate the value of the safe use of greywater to maintain a more hygienic school setting, an important factor in parents' collaboration to ensure that their children attend school. Reduction in diarrhoeal and parasitic diseases will result in increased school attendance.
Goal 3. Promote gender equality and empower women Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and to all levels of education no later than 2015	• The productivity of market gardens and other small-scale peridomestic agriculture is boosted by the use of wastewater, excreta and greywater, and in many parts of the world this particularly favours the economic position of women.
Goal 4. Reduce child mortality Target 5: Reduce by two thirds, between 1990 and 2015, the under-five mortality rate	• The combination of improved sanitation and the safe use of wastewater, excreta and greywater helps reduce the burden of sanitation and hygiene-associated ill-health. • Improved nutrition and food security reduce susceptibility to diseases in children.
Goal 5. Improve maternal health Target 6: Reduce by three fourths, between 1990 and 2015, the maternal mortality rate	• Improved health and nutrition associated with waste-fed agriculture and aquaculture reduce susceptibility to anaemia and other conditions that affect maternal mortality. • Improved nutrition and food security reduce susceptibility to diseases that can complicate pregnancy.
Goal 6. Combat HIV/AIDS, malaria and other diseases Target 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS Target 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	• Safe use of wastewater, excreta and greywater and basic sanitation help prevent water-related diseases, including diarrhoeal diseases, schistosomiasis, filariasis, trachoma,[a] intestinal worm infections and foodborne trematode infections. • Improved health and nutrition reduce susceptibility to/severity of HIV/AIDS and other major diseases. • Increased awareness and knowledge of better water management practices will support community-based environmental management approaches towards malaria transmission risk reduction.

Table 1.1 (continued)

Millennium Development Goals and their targets	Relationship to wastewater, excreta and greywater use
Goal 7. Ensure environmental sustainability Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources Target 10: Halve, by 2015, the proportion of people without sustainable access to safe drinking-water and basic sanitation Target 11: Achieve significant improvement in lives of at least 100 million slum dwellers by 2020	• The safe use of wastewater, excreta and greywater contributes to less pressure on freshwater resources and reduces health risks for downstream communities. • Improved sanitation in support of safe excreta use reduces flows of human waste into waterways, helping to protect human and environmental health. • Improved water management, including pollution control and water conservation, is a key factor in maintaining ecosystem integrity. • Waste-fed periurban agriculture can contribute importantly to improving the livelihood of slum settlers.
Goal 8. Develop a global partnership for development Target 12: Developing open trading and financial systems Targets 13 and 14: Addressing special needs of less developed countries, landlocked and small island developing countries Target 15: Managing debt relief and increasing official development assistance Target 16: Creating productive youth employment Target 17: Providing affordable medicine Target 18: Spreading benefits of new technologies, especially information and communications	• Development agendas and partnerships should recognize the fundamental role that safe use of wastewater, excreta and greywater in agriculture and aquaculture and basic sanitation play in economic and social development. • Options for self-employment are enhanced if the opportunities for the safe use of waste in agricultural production are stimulated. • Compliance with the methods and procedures in the WHO Guidelines facilitates international trade in waste-fed agricultural produce.

[a] Schistosomiasis is a chronic, usually tropical, disease characterized by disorders of the liver, lungs, urinary system or central nervous system. Filariasis is a disease caused by thread-like worms, which are transmitted by mosquitoes and invade the lymphatic vessels, causing chronic swelling of the lower extremities. Trachoma is a contagious infection of the cornea and conjunctiva caused by a bacterium and causing granulation and scar formation.

- Implementation of the WHO Guidelines will help to maximize the health and environmental benefits of using wastewater, excreta and greywater in agriculture and aquaculture.
- The use of wastewater, excreta and greywater in agriculture and aquaculture, both formally and informally, is widespread.
- Reuse can contribute to nutrient and water recycling and improved household nutrition and food security.
- There are international policy implications of waste-fed agriculture, in the context of international trade of safe food products.
- The practice can be associated with negative health impacts.
- Cost-effective interventions for different situations are available to control negative health impacts.
- National consumer protection legislation will have an international impact on the policies for the safe use of wastewater, excreta and greywater.

1.3.1 Implementation of WHO Guidelines to protect public health

The objective of these Guidelines is to maximize the health and environmental benefits associated with the use of wastewater, excreta and greywater in agriculture and aquaculture. This can be accomplished by preventing the transmission of disease and the exposure to hazardous chemicals. Health protection measures target large population groups, and, in local settings, they may be particularly focused on specific vulnerable groups. The Guidelines should be considered in the context of national environmental, social, economic and cultural conditions.

The approach followed in these Guidelines (see Box 1.1) is intended to support the establishment of national standards and regulations that can be readily implemented and enforced and are protective of public health. Each country should review its needs and capacities in developing a regulatory framework. Successful implementation of the Guidelines will benefit from a broad-based policy framework of incentives and sanctions to alter behaviour and monitor and improve situations. Intersectoral coordination and cooperation at national and local levels and the development of suitable skills and expertise will facilitate the Guidelines' implementation. Ultimately, the regulatory framework should adopt the format of a safe reuse of wastewater plan, in line with the concept of water safety plans in other areas of water quality management and health protection and promotion.

In many situations, it will not be possible to fully implement the Guidelines at one time or in the first stage. The Guidelines set target values designed in such a way as to allow progressive implementation and, therefore, to be achieved over time in a systematic, orderly and incremental way, depending on current realities and the existing resources of each individual country or region. The greatest threats to health should be prioritized and addressed first. Measures that are most cost-effective at an early stage may be substituted by others that become more cost-effective as the process of risk assessment and management proceeds. Over time, it should be possible to adjust the risk management framework to strive for the progressive improvement of public health conditions. In most countries, standards for regulating wastewater, excreta and greywater use have evolved over time into an infrastructure of management strategies. Simultaneously, new technologies have been developed. This is an important consideration when developing national policies for the safe use of wastewater, excreta and greywater in agriculture and aquaculture. They need to be flexible and responsive to new situations and developments.

1.3.2 Wastewater, excreta and greywater use

More than 10% of the world's population consumes foods produced by irrigation with wastewater. The percentage will be considerably higher among populations in low-income countries with arid and semi-arid climates. Both treated and untreated wastewater are used directly and indirectly (i.e. as faecally contaminated surface water) for irrigation in developed and less developed countries. In places where untreated wastewater or highly contaminated surface water is used for irrigation, health and environmental problems of the same nature and magnitude as those associated with direct wastewater use in agriculture may arise. Overall, population growth will be the main driving force for a further demand on water resources. There is a growing recognition that the production of wastewater will increase as an outcome of continued urbanization and that wastewater needs to be better incorporated into the overall management of water resources.

The traditional use of excreta in agriculture and aquaculture has occurred for centuries and continues in many countries. In urban and periurban agriculture in less industrialized countries, the use of untreated faecal sludges (i.e. from the contents of on-site sanitation

Box 1.1. What are the Guidelines?

The WHO Guidelines are an integrated preventive management framework for maximizing the public health benefits of wastewater, excreta and greywater use in agriculture and aquaculture. The Guidelines are built around a health component and an implementation component. Health protection is dependent on both elements.

Health component:
- establishes a risk level associated with each identified health hazard;
- defines a level of health protection that is expressed as a health-based target for each risk;
- identifies health protection measures that, used collectively, can achieve the specified health-based target.

Implementation component:
- establishes monitoring and system assessment procedures;
- defines institutional and oversight responsibilities;
- requires system documentation;
- requires confirmation by independent surveillance.

systems such as unsewered family and public toilets and septic tanks) is widespread. The vast majority of urban dwellers in these countries is served today and will be served in the future by such installations; hence, adequately treating these sludges by appropriate methods to attain safe biosolids or compost constitutes a crucial goal for improving public health. On-site sanitation systems not requiring off-site haulage and treatment, such as double-pit latrines with or without urine diversion (which are being promoted in rural and periurban settings in recent years), may also contribute to safeguarding public health. Systems that divert wastes into streams (e.g. urine and faeces) often require less water to operate and are increasingly being seen as alternatives to waterborne sewerage — especially in arid/semi-arid regions. These systems should be managed in such a way as to reduce the potential for disease transmission and maximize the beneficial use of resources.

Waste-fed aquaculture occurs mostly in parts of Asia. The intentional use of wastewater and excreta in aquaculture is declining due to urbanization, which reduces the amount of land available for ponds, and the switch to high-input aquaculture, which is not compatible with traditional waste-fed practices. The unintentional use of wastewater, excreta and greywater in aquaculture is probably increasing, because surface waters used for aquaculture are increasingly polluted with human waste, and overall aquacultural production is growing.

These trends may vary locally. Policy formulation, harmonization and adjustment call for a sound analysis of relevant trends in the local context and of the locally viable options for risk management solutions. This information should be the basis to develop decision-making criteria and procedures around the use of wastewater, excreta and greywater in agriculture and aquaculture. Adequate investment in trend analysis is a critical starting point to obtain optimal harmonization and avoid perverse policies.

1.3.3 Benefits of wastewater, excreta and greywater use

Wastewater, excreta and greywater are increasingly used for agriculture and aquaculture in both developing and industrialized countries. The principal forces driving this increased use are:

- increasing water scarcity and stress;
- expanding populations, with increasing environmental pollution from improper wastewater disposal;
- recognition of the resource value of wastewater, excreta and greywater.

It is estimated that within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity (Hinrichsen, Robey & Upadhyay, 1998). Growing competition between agriculture and urban areas for high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this resource. More fresh water is abstracted and used in agriculture in arid and semi-arid countries than for any other purpose (i.e. for domestic uses and industrial uses combined). In many cases, it is better to use wastewater, excreta and greywater in agriculture than to use higher-quality fresh water, because crops benefit from the nutrients they contain. Thus, wastewater, excreta and greywater can help to meet water demand and allow the preservation of high-quality water resources for drinking-water supplies.

Most population growth is expected to occur in urban and periurban areas in developing countries (United Nations Population Division, 2002). Population growth increases both the demand for fresh water and the amount of wastes that are discharged into the environment, thus leading to more pollution of clean water sources. The use of wastewater, excreta and greywater in agriculture and aquaculture can act as a low-cost treatment method that increases food production to supply growing urban and periurban populations. More use of wastewater, excreta and greywater will occur in urban and periurban agriculture, because this is where the wastewater is generated and available and where the demand for food is highest.

Wastewater, excreta and greywater are often reliable year-round sources of water, and they contain the nutrients necessary for plant and fish growth. Irrigation with wastewater can, in most situations, supply all the nutrients required for crop growth. The value of these substances has long been recognized by farmers worldwide. Their direct use in agriculture and aquaculture is a form of nutrient and water recycling, and this often reduces downstream environmental impacts on water resources and soil, as well as potential health impacts on downstream communities. The water and nutrient resources help people to grow more food without the costs of using more fertilizers. The reliability of the water supply means that crops can be grown year-round in warm climates. It also represents an important asset in situations where climate change will lead to significant changes in patterns of precipitation. The use of wastewater, excreta and greywater will be an important component of a package of coping strategies in areas affected by such change.

Policies to promote the beneficial application of wastewater, excreta and greywater should first of all operate at the national level. The policy framework should link environmental and health protection policies with food security and consumer protection policies to attain maximum health benefits in terms of improved nutrition while reducing health risks related to infectious diseases. Bilateral and multilateral development agencies, too, should formulate and implement policies aimed at promoting the safe use of wastewater, excreta and greywater in agriculture and aquaculture, as an integral part of their goals in the conservation and management of natural resources and the reduction of poverty.

1.3.4 International policy implications: international trade

The rules that govern international trade in food were agreed during the Uruguay Round of Multilateral Trade Negotiations and apply to all members of the World Trade Organization (WTO). With regard to food safety, rules are set out in the Agreement on the Application of Sanitary and Phytosanitary Measures. According to this agreement, WTO members have the right to take legitimate measures to protect the life and health of their populations from hazards in food, provided that the measures are not unjustifiably restrictive of trade (WHO, 1999). There have been documented cases where the import of contaminated vegetables has led to disease outbreaks in recipient countries. Pathogens can be (re)introduced into communities that have no natural immunity to them, resulting in important disease outbreaks (Frost et al., 1995; Kapperud et al., 1995). Guidelines for the international trade of wastewater-irrigated food products should be based on scientifically sound risk assessment and management principles.

The WHO Guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture are based on a risk analysis approach, which is recognized internationally as the fundamental methodology underlying the development of food safety standards that both provide adequate health protection and facilitate trade in food. Adherence to the WHO Guidelines in the application of wastewater, excreta and greywater for the production of food products destined for export will help to ensure an unencumbered international trade of safe food products. Clearly, this requires a sound monitoring process to ensure compliance with the risk management measures and appropriate quality control along the way from wastewater generation to produce consumption. The procedures for this monitoring process should be embedded into national policies and regulations for water quality that also apply to drinking-water quality, safe recreational waters and the concept of water safety plans in general.

1.3.5 Health implications of wastewater, excreta and greywater use

The health risks most studied in the context of the use of wastewater, excreta and greywater are those associated with excreta-related infectious diseases. The evidence base is less extensive for the transmission of vector-borne diseases and schistosomiasis through reuse activities. The health risks for each category (i.e. agriculture, aquaculture and general excreta and greywater use) are described in the subsections below.

The planning and development of projects for the use of wastewater, excreta and greywater in agriculture and aquaculture should include a health impact assessment or an environmental impact assessment with a sound health component. National environmental/health impact assessment policies should explicitly refer to this type of project and the associated risks in the screening criteria they list. Scoping of such projects for impact assessment should include the identification of vulnerable groups. Three different community groups are at risk from wastewater, excreta and greywater use activities in agriculture and aquaculture:

- farm or pond workers (and their families, if they all participate in the activities or live at the site where the activities take place);
- local communities in close proximity to activities, and people who otherwise may have contact with fields, ponds, wastewater, excreta, greywater or products contaminated by them;
- product consumers.

Agriculture

In countries or regions where poor sanitation and hygiene conditions prevail and untreated wastewater and excreta are widely used in agriculture, intestinal worms pose the most frequently encountered health risks. Other excreta-related pathogens may also pose health risks, as indicated by high rates of diarrhoea, other infectious diseases, such as typhoid and cholera, and incidence rates of infections with parasitic protozoa and viruses.

In countries where higher sanitation and hygiene standards prevail, infrastructure for waste treatment is available and treatment processes are well managed, viral illnesses pose greater health risks than other pathogens. This is partly because viruses are often difficult to remove through wastewater treatment processes due to their small size, but also because of the resistance of some viruses in the environment and their infectivity at low concentrations. Additionally, people living in conditions where higher sanitation and hygiene standards prevail often have no prior exposure to viral pathogens and therefore have no acquired immunity and are more vulnerable to viral infection and illness.

Aquaculture

Studies of health risks associated with waste-fed aquaculture have rarely been conducted. There is limited evidence that links exposure to waste-fed aquaculture or its produce to illness in product consumers and local communities in intense contact with contaminated pond waters. Skin diseases such as contact dermatitis (eczema) may also occur in farmers with high contact with faecally contaminated ponds while harvesting aquatic plants.

In general, fish and plants raised in contaminated waters may passively transmit pathogens on their surfaces to product handlers or consumers. The fact that fish concentrate bacteria and other microbes (including viruses and protozoa) in their intestines is, however, of greater public health importance. The greatest risk to consumers is likely to result from cross-contamination from the gut contents to the edible fish flesh during unhygienic fish processing. Unhygienic fish processing can increase the levels of microbial contamination by 100-fold or more in edible portions of the fish.

In certain regions of the world, foodborne trematodes may pose a significant health risk in relation to waste-fed aquaculture. In areas where such infections as clonorchiasis, opisthorchiasis, fascioliasis and fasciolopsiasis are common and where fish or plants are frequently eaten raw, incidence rates can be attributed to this practice. In vulnerable groups such as children, foodborne trematodes can cause severe illness and, occasionally, death. A number of animals may serve as reservoirs, and their presence will help to sustain their presence and transmission in affected areas. A recent systematic literature review indicates that foodborne trematode infections are on the rise in areas where freshwater aquaculture is also increasing (Keiser & Utzinger, 2005).

Excreta and greywater use

The risks associated with the use of excreta (including source-separated urine and faeces) stem mostly from excreta-related pathogens. Urine usually does not contain high concentrations of pathogens but may have some as a result of faecal cross-contamination during collection. Eggs of the parasitic blood fluke *Schistosoma haematobium* are an exception to this rule.

The use of faecal matter from on-site sanitation installations such as septic tanks and the pits of unsewered family and public toilets can pose significant health risks if it has not been adequately treated. The primary health hazard arises from the presence of worm eggs in areas where intestinal worms are common. The eggs of these parasites can survive for months or even years in the faecal matter and in the soil.

The health risks associated with the use of greywater in agriculture are considered to be lower than those for wastewater or faeces. Greywater generally has lower concentrations of pathogens in it than wastewater, but it may still contain some pathogens, which are introduced into the greywater from washing babies' diapers, laundry, personal hygiene or other sources.

1.3.6 Cost-effective strategies for controlling negative health impacts

The management of risk is facilitated by conducting an analysis of the entire production cycle from waste generation to consumption of the product. Knowledge of the system is then used to identify health protection measures that can reduce health risks at different points, in order to arrive at the agreed health-based targets.

Public health policies for interventions should ensure that the most cost-effective measures are applied in specific contexts. Measures from a range of categories may be applied at different points during the cycle, and they are normally used in combination to reach the desired goals:

- Treatment of wastewater, excreta and greywater is used to prevent the contaminants from entering the environment.
- Crop/produce restriction (i.e. only crops that are not eaten directly by people or that are always processed or cooked before they are eaten) is used to minimize health risks to product consumers.
- Waste application techniques (e.g. drip irrigation) and withholding periods aim to reduce contamination of the products or allow sufficient time for pathogen die-off in the environment prior to harvest.
- Exposure control methods (e.g. protective equipment, good hygiene) will prevent environmental contamination from reaching exposed groups.
- Produce washing/rinsing/disinfection and cooking reduce exposures for product consumers.
- Vector control reduces exposures for workers and local communities.
- Chemotherapy and immunization can either prevent illness for those who are exposed or treat those who are ill and thus reduce future pathogen inputs into the wastewater, excreta or greywater.

Determining the cost-effectiveness of different measures under local conditions requires an economic analysis, for which it is recommended to engage a health economist.

1.4 Policy formulation and adjustment: the step-by-step process

The development and maintenance of a national policy framework for the safe use of wastewater, excreta and greywater are part of a step-by-step, iterative process that should address the formulation and mainstreaming of new policies and the adjustment and harmonization of existing ones. At the heart of this process lies a productive policy dialogue among all interested parties. The steps of this process include:

- establishment of a mechanism for ongoing policy dialogue;
- defining objectives;
- situation analysis, policy appraisal and needs assessment;
- political endorsement, dialogue engagement and product legitimazation;
- research.

1.4.1 Establishment of a policy dialogue mechanism

Identification of stakeholders and interested parties will help define the best mechanism to initiate and maintain a productive and comprehensive policy dialogue. In some countries, this group will consist mainly of policy-makers of relevant ministries, and the establishment of an interministerial task force to engage in the dialogue will be sufficient action to ensure a rapid evolution of the policy framework required. In countries with a high degree of decentralization, mechanisms will have to be established for an effective feedback loop as part of the dialogue that ensures a meaningful involvement of policy- and decision-makers at the provincial and local administrative levels. There may be countries where decentralization has evolved to a level where policy-making is initiated at the district level, for example through district development councils, and this will require that the policy dialogue on the safe use of wastewater, excreta and greywater for agriculture and aquaculture is similarly initiated at that level, in districts where such use is a reality or has future potential. The engagement of civil society in policy debate helps create a strong platform of support for new policies. It requires additional mechanisms, such as special forums, focus group discussions and community consultation, to ensure that these broader views are reflected in the policy framework.

1.4.2 Defining objectives

Defining clear objectives is essential in developing a national policy framework (Mills & Asano, 1998). Generic policy goals are presented in section 1.1. More specifically, objectives of the use of wastewater, excreta and greywater for agriculture or aquaculture may be:

- increasing national or local economic development;
- increasing crop production;
- augmenting supplies of fresh water and otherwise take full advantage of the resource value of wastewater;
- disposing of wastewater in a cost-effective and environmentally friendly manner;
- improving household income, food security and/or nutrition.

Where wastewater is already used, subsidiary objectives may be the incorporation of health and environmental safeguards into management strategies or the improvement of product yields through better practice.

1.4.3 Situation analysis, policy appraisal and needs assessment

In most countries, a variety of policies will already exist, in a number of different sectors, that will influence decision-making over wastewater, excreta and greywater use in agriculture and aquaculture. As described in section 1.1, the appraisal of existing policies should be carried out with both a policy-maker's and the project coordinator's viewpoint in mind. A first mapping out of all relevant policies without qualifying attributions will provide a landscape of criteria and procedures that influence the subject under scrutiny. Next, an assessment of the potential of these policies to have positive or negative health effects sets the format for a needs assessment, whose outcome will provide recommendations for policy harmonization, policy adjustment and the formulation of additional, new policies that can fill gaps that have been identified.

The outcome of the situation analysis, policy appraisal and needs assessment provides the basis for designing the process along which to proceed. In some cases, the gaps identified may be of dimensions that direct the main focus of the ensuing process to be on the formulation of new policies; in other cases, there already may be a substantial body of policies that influence decision-making on the issue, but the individual policies in the different sectors may be poorly harmonized. Finally, a policy imbalance may be detected, with some sectors addressing health issues adequately in their policy framework, while the policies of others may show small, but significant, gaps.

1.4.4 Political endorsement, dialogue engagement and product legitimization

New policies and adjustment of existing policies will sooner or later have to be adopted by the political system. Political endorsement of the policy process at the earliest stage will contribute to ensuring a smooth acceptance and integration of policy proposals later on. The most obvious way to obtain this endorsement is the organization of a national seminar, where all stakeholders are invited to develop a policy process and anchor it in an action plan. At the end of the seminar the political leadership of all sectors involved is invited to review this plan, comment on it and endorse it. This endorsement will legitimize the participation of all involved in the process and ensure that the end product is in line with political expectations and sentiments.

Establishing a mechanism for policy dialogue is usually less of a challenge than keeping the process going. Review, formulation and negotiation may proceed slowly, particularly if the dialogue takes place in a multisectoral context. A task force should be established with clear terms of reference, and it should be adequately resourced so that periodic meetings can be organized and sub-tasks commissioned. Strong leadership will help expedite progress, but it will need to be sufficiently neutral to ensure the continued engagement of all parties.

The outcome of the policy process is a set of recommendations concerning new policies and the adjustment of existing ones. The report of the task force should be submitted to the authority that established it, with copies to all political leaders of different relevant sectors. After some final review and negotiations, the proposals are likely to be accepted, and the process of formalizing the additions and changes will begin. This process may be different in different countries. In some countries, a simple decree from the Prime Minister’s Office will be enough to establish the new policies. Elsewhere, the policy framework may have to pass through parliament successfully before it can become effective. It is sensible to keep the task force members actively involved at this stage, since the need for backup support or further work may suddenly arise. Once the policy has become effective, it is important to disseminate the relevant information to stakeholders at all levels.

1.4.5 Research

All policy development must be evidence based. Research on minimizing health impacts associated with the use of wastewater and excreta in agriculture should, therefore, be conducted at national institutions, universities or other research centres. It is important to conduct this research at the national or subnational level, because contextual data sets on risk assessment and management and on effective health protection measures will be valuable inputs into the policy-making process. Most of this information is very country specific. In countries where the use of wastewater and excreta for agriculture is newly introduced or has not been practised on a large scale, pilot schemes may be set up to collect the essential data sets. In situations where wastewater irrigation is practised in small-scale diffuse facilities, often at the household level, national research may be used to validate health protection measures. A systematic planning of pilot projects should ensure that the full range of non-treatment options is studied, so that policies can focus on the most critical interventions under local circumstances.

Another dimension is that of research policies. The safe use of wastewater, excreta and greywater in agriculture and aquaculture has in common with many other public health issues the multidisciplinary nature of the research that should strengthen the relevant knowledge base. It is therefore essential that national research policies focus on the promotion of multidisciplinary research and on the translation of the outcomes of such research into harmonized sectoral policies. Issues of research policy are usually dealt with by national science and technology councils.

1.5 Institutional arrangements

There are many actors influencing the decision-making process with respect to the use of wastewater, excreta and greywater in agriculture and aquaculture. At the national level, ministries and other public sector agencies with responsibilities for water management, waste management, agriculture and fisheries, public health, the environment, trade and industry and local government all have the potential to influence the planning, design and operations of wastewater, excreta and greywater use activities and to address the adverse consequences they may have. Some of the decision-making may be delegated to lower administrative levels: provincial, municipal or district authorities. Small-scale wastewater, excreta and greywater use projects may be completely informal, initiated by local communities with or without the help of local nongovernmental organizations.

The sectoral structure of governments works well to deal effectively with core societal issues, but the fragmentation is less conducive to the management of cross-cutting issues, of which the safe use of wastewater, excreta and greywater in agriculture and aquaculture is an example. The sectoral barriers are determined by the competition between different ministries for limited financial resources, and they come to expression in the missed conversations between professionals who speak different “languages.”

This chapter provides a brief introduction to the concept of intersectoral collaboration, possible mechanisms to promote such collaboration at the national level, integration at the local level and steps towards achieving effective institutional arrangements between sectors.

1.5.1 The concept of intersectoral collaboration

In the health sector, the concept of intersectoral collaboration obtained a high profile as a result of the 1978 Alma Ata Declaration. This joint WHO/UNICEF declaration (http://www.who.int/hpr/NPH/docs/declaration_almaata.pdf) provided the foundation for the Health for All goals, the strategy of primary health care (PHC) to achieve the goals and the eight pillars supporting this strategy, one of which is intersectoral collaboration. It recognizes the reality that the health status of communities results not just from health sector planning and action, but also, more importantly, from decision-making in other sectors. Such decisions have an impact on the environmental and social determinants of health, and, as a result, they have the potential to change the community health status, inadvertently, in a positive or negative way.

Clearly, the use of wastewater, excreta and greywater for agriculture and aquaculture is relevant in this context. Decisions about the use of these resources are made outside of the health sector, and if the intersectoral barriers are not overcome, the negative health impacts will increase the workload for the health services. In other words, the health sector will have to deal with an increased disease burden. Thus, the planning of wastewater projects without due attention to health risks and related health safeguards implies the transfer of hidden costs to the health sector and a costly burden to society at large.

Lessons learned from experiences in intersectoral action for health include the need

- to anchor the overall coordinating role with one ministry;
- to allocate adequate resources to the coordination itself;
- to carry out economic evaluations of intersectoral actions to document their relative cost–benefit;
- to specify allocation of responsibilities and obligations in a formal document of agreement;
- to keep the constituencies of the individual sectors well informed about the benefits gained from working intersectorally;
- to incorporate intersectoral negotiation and decision-making in curricula of tertiary learning institutes.

1.5.2 Mechanisms to promote intersectoral collaboration

A first step towards the creation of intersectoral collaboration is the preparation of an inventory of intersectoral mechanisms that already exist at the national level. In most countries, coordination between the various public sectors is centred on the implementation of national macroeconomic policies. Most developing countries have an economic and social council, with the remit to coordinate development planning in the light of poverty reduction (MDGs, poverty reduction strategy papers) and economic progress; this is a meeting point for all sectors. In countries with a strongly centralized economy, ministries of planning may continue to play a role in orchestrating the national planning process, again involving all other sectors.

The conservation of natural resources is another area of common interest in most countries. While ministries of environment may perform a standard-setting role and have responsibilities to look after the obligations that come from national and international legally binding instruments (legislation, international environmental conventions), most countries have an environmental protection agency that functions, in a more or less autonomous way, as the implementation extension of the environment ministry. Such agencies are, for example, responsible for environmental impact assessment and the ensuing environmental management plans. Similar responsibilities could be developed for the health aspects of the use of wastewater, excreta and greywater.

As already mentioned, the third type of structure where different sectors interact consists of national councils for science and technology. With their focus on research, they provide excellent forums to promote the strengthening of knowledge and evidence bases that support policy and regulation for effective safe use practices. They also offer existing links between the various public sectors and academia, with the opportunity to bring valid research questions to the attention of universities and to translate research outcomes into relevant policy and regulatory frameworks.

Some of the intersectoral coordination required for the safe use of wastewater, excreta and greywater may find a "home" in one or more of the above generic structures. Yet there will remain a need to create specific institutional arrangements between the relevant public sectors — in principle, agriculture, health and environment. A number of options exist:

- *Establishment of an intersectoral committee*: In many countries, this has time and again been the standard approach to tackling problems of an intersectoral nature. Yet it has also been, more often than not, an approach that has produced no or inadequate solutions. Intersectoral committees are generally not well resourced, are not mandated to make binding recommendations, often lack members in a leadership role and may be perceived by most members as one sector's way of special pleading for its own interests. So while the establishment of such a committee may give temporary relief from political pressures, it seldom provides an effective solution to an intersectoral problem.

- *Establishment of a memorandum of understanding*: This is a project-oriented rather than a strategic solution, but in the project context it has proved to be a valuable and effective way to achieve intersectoral action. By spelling out the nature of tasks at hand, defining responsibilities and determining resource flows, a memorandum of understanding provides a clear framework for intersectoral collaboration that can be easily monitored for compliance. It is a mechanism regularly instigated by bilateral or multilateral donors. Because of its time-limited nature, it is a context within which partners from different sectors have an opportunity to get to know each other, develop mutual trust and respect, and lay the foundations for more durable institutional arrangements.
- *Creation of special legislation*: Where the need for long-term interactions between sectors is foreseen, creating special legislation may be well worth the effort, because it entails an unmatched level of control over compliance through the judicial system. Legislation may also include a budget appropriation to cover the incremental costs of intersectoral action, which will ensure an incentive to sustain intersectoral links that overcome fragmentation. The creation of legislation can be time-consuming, and this approach is therefore most suitable to establish generic rather than project-specific institutional arrangements.
- *Targeted capacity building and informal networking*: A more informal approach to achieving intersectoral action is to implement a capacity-building programme for intersectoral negotiation and decision-making. Problem-based learning set in a realistic context (e.g. how to achieve the safe use of wastewater, excreta and greywater in agriculture and aquaculture) will bring professionals from different relevant sectors together to go through a systematic programme of critical decision-making. The bonding process that occurs during the courses may result in informal networking between people working at mid-level management in the different sectors. The creation of an enabling policy environment for intersectoral action is an essential element for the success of this approach.

Descending from the national level to subsidiary levels of administration, competition between sectors diminishes and opportunities for effective collaboration increase. Yet even in a decentralized governance structure, there may be constraints on different sectors collaborating at the community level if resource decisions continue to be anchored at higher levels. Sharing of resources may then be blocked and integrated approaches to development issues hampered.

In the case of safe use of wastewater for agriculture, for example, there is scope for relevant messages on health risk assessment and management to be transmitted to farmer communities through existing agricultural channels: the conventional agricultural extension programmes or the more participatory farmer field schools. This requires, as a start, good communications between health and agricultural authorities to review what messages could be effectively delivered and the way of delivery. Information packages will then need to be composed or, in the case of the farmer field schools, curricula prepared. The rationale of this intersectoral approach is that farmers are more likely to accept messages that will affect their farming practices from trustworthy extension workers than from health workers with little or no credibility in the domain of agriculture. From the extension workers' perspective, this implies that the messages delivered must be reliable and evidence-based, as a major concern would be that their credibility might be undermined by inaccurate or wrong information.

2
REGULATION

This section provides an overview of the technical issues that regulators should consider when developing new or modifying existing regulations for the safe use of wastewater, excreta and greywater in agriculture and aquaculture. The previous chapter provides guidance on how to put in place a policy framework conducive to the safe use of wastewater, excreta and greywater in agriculture and aquaculture. Once such a framework is in place, practical regulatory functions can be defined, and the mechanisms for their implementation designed. All functions have to be designed with broad policy objectives in mind, and they must be realistic in terms of capacity (or available capacity to be developed), capabilities and jurisdiction. This is the scope of the present chapter.

Essential functions in regulation include:

- identification of hazards;
- generating evidence for health risks and the effectiveness of possible health protection measures to manage them;
- establishing health-based targets to manage health risks;
- implementing health protection measures to achieve the health-based targets;
- system assessment and monitoring.

2.1 Identification of hazards

The primary health hazards associated with the use of wastewater, excreta and greywater in agriculture and aquaculture are excreta-related pathogens, some vector-borne diseases and certain chemicals. Health risks describe the probability, under specific circumstances, that these health hazards will indeed be able to influence human health adversely.

Pathogens can survive long enough in the environment (wastewater, water, soil, crops) to be transmitted viably to people. Some pathogens can multiply in the environment. Certain environmental factors contribute, to a greater or lesser measure, to the die-off of pathogens. These factors include time, temperature, moisture, exposure to light and ultraviolet (UV) radiation, presence of appropriate intermediate hosts, type of plant and others. Treatment of wastewater, excreta and greywater can significantly reduce the concentrations of some contaminants (e.g. excreta-derived indicator organisms, pathogens and some chemicals) and thus the risk of disease transmission. In many developing countries, wastewater treatment is not a feasible option, and non-treatment approaches need to be considered to prevent transmission of pathogens or exposure to hazardous chemicals. This is more demanding on regulators, as the measures entailed vary in time and space.

Hazards associated with the use of wastewater, excreta and greywater in agriculture and aquaculture are presented in Table 2.1. The regulatory framework needs to translate the broad policy guidance on hazard identification into system-specific actions that focus on concrete hazards and the effective contextual health protection measures that may be deployed to eliminate or reduce their negative effects.

2.2 Evidence for health risks

Depending on local circumstances, health hazards associated with wastewater, excreta and greywater use may turn into health risks. The probability of this occurring (i.e. the level of risk) has a number of environmental and social determinants and is based on available evidence. Key evidence for health risks associated with this practice in agriculture and aquaculture is summarized below.

Table 2.1 Examples of hazards and exposure routes associated with the use of wastewater, excreta and greywater in agriculture and aquaculture

Hazard	Exposure route	Comments
Excreta-related pathogens		
Bacteria (*Escherichia coli*, *Vibrio cholerae*, *Salmonella* spp., *Shigella* spp.)	Contact Consumption	Bacteria die off more rapidly on crops than some other pathogens (e.g. helminths) but may still present a health risk. Disease outbreaks of cholera, typhoid and dysentery have been associated with the use of wastewater, excreta or greywater for irrigation of vegetables. As these pathogens can survive in the environment sufficiently long to pose health risks, produce disinfection/washing and cooking are important health protection measures.
Helminths		
- Soil-transmitted helminths (*Ascaris*, *Ancylostoma*, *Necator*, *Hymenolepis*, *Strongyloides*, *Toxocara*, *Trichuris*, *Taenia* spp.)	Contact Consumption	Major risk in agriculture, especially where untreated wastewater and excreta are used and sanitation standards are low. Eggs can survive in the environment for a long time. Hookworm infections (*Ancylostoma duodenale*, *Necator americanus*) are common in some areas where farmers do not wear adequate shoes or boots.
- Trematodes (*Clonorchis*, *Opisthorchis*, *Fasciola*, *Schistosoma* spp.)	Contact Consumption	Major risk in aquaculture where trematode parasites are present. Distribution is limited to certain geographic areas. Foodborne trematodes are transmitted through food consumption (especially the consumption of raw, unprocessed fish); schistosomiasis is spread through skin contact with contaminated fresh water.
Protozoa (*Giardia*, *Cyclospora*, *Cryptosporidium*, *Entamoeba* spp.)	Contact Consumption	Have been found on wastewater-irrigated vegetables at the point of harvest and in the market. Protozoa can survive in the environment long enough to pose health risks.

Table 2.1 (continued)

Hazard	Exposure route	Comments
Viruses (hepatitis A and E viruses, adenovirus, rotavirus, norovirus)	Contact Consumption	Viruses are present in high numbers in wastewater and excreta, and some types can survive in the environment long enough to pose health risks. Contamination of crops has led to disease outbreaks.
Vector-borne pathogens (*Plasmodium* spp., dengue virus, *Wuchereria bancrofti*, Japanese encephalitis virus)	Vector contact	Risk for any water resource development activities in relevant geographic areas where vector-borne diseases are present. Most insect vectors breed in clean water, with the exception of vectors of lymphatic filariasis, which breed in organically polluted water.
Skin irritants	Contact	The causes of skin irritation such as contact dermatitis (eczema) are likely due to a mixture of microbial and chemical hazards.
Chemicals		
Antibiotics (chloramphenicol)	Consumption	Potential risk to consumers of aquacultural products where these substances are used in fish production.
Cyanobacterial toxins (microcystin-LR)	Contact Consumption	Potential risk to consumers of aquacultural products — especially blue-green algae nutritional supplements (*Spirulina*).
Heavy metals (arsenic, cadmium, lead, mercury)	Consumption	May accumulate in plants — both aquatic and terrestrial.
Phthalates and phenols	Consumption of water coming from aquifers recharged through wastewater irrigation	These compounds have been found in aquifers used for human drinking-water supplies that have been inadvertently recharged through wastewater irrigation. Some of these chemicals may have endocrine disrupting properties.
Halogenated hydrocarbons (dioxins, furans, PCBs)	Consumption	Not absorbed by plants, but may contaminate surfaces if plants are not peeled or washed before consumption. Potential for bioaccumulation in larger carnivorous fish raised in waste-fed aquacultural facilities.
Pesticides and their residues (e.g. aldrin, DDT)	Contact Consumption	Risk mostly related to pesticide application practices.

Sources: WHO (1995, 1999); BGS-CNA (1998); Chorus & Bartram (1999); Blumenthal et al. (2000a, 2000b); Gilroy et al. (2000); van der Hoek et al. (2005).

2.2.1 Agriculture

Epidemiological studies and quantitative microbial risk assessment (QMRA) have been used to estimate microbial risks and risks from hazardous chemicals for groups with different levels of exposure associated with the use of wastewater, excreta and greywater. The evidence is summarized in Tables 2.2 and 2.3.

Table 2.3 presents a summary of the QMRA evidence for the transmission of rotavirus infection due to different exposures. The risks of rotavirus transmission were always estimated to be higher than the risks associated with *Campylobacter* or *Cryptosporidium* infections.

Less evidence is available for health risks associated with chemicals. What we know is based on quantitative risk assessment and indicates that chemical uptake by plants is highly dependent on the types of chemicals and the physical and chemical properties of the soil. Chemical concentration limits based on health considerations are presented in Table 2.6 below.

2.2.2 Aquaculture

The health impacts of waste-fed aquaculture have rarely been studied. There is evidence that fish and plants grown under waste-fed conditions can become contaminated with human excreta-related pathogens on their surfaces and (in the case of fish only) in their intestines. The relationships reported between microbial water quality indicators and contamination of edible fish tissues are contradictory and controversial. The balance of evidence suggests that when fish are grown under stressful conditions (e.g. low dissolved oxygen, high ammonia concentrations or in overcrowded situations), there may be microbial penetration of edible fish tissues. However, the level of contamination is always very small and will generally be insignificant compared with the contamination of edible fish flesh that can occur during unhygienic fish cleaning or processing.

For trematodes, the evidence is clearer. If the trematode is present in the faeces of infected humans or animals, if there is a suitable intermediate host (certain species of aquatic snails) and if the fish or plant is consumed raw or inadequately cooked, transmission to humans can occur. Therefore, in areas where these conditions occur, a suitable microbial water quality indicator for fish ponds is the presence/absence of viable trematode eggs.

A study on health status and trends in communities practising waste-fed aquaculture indicated that heavy contact with waste-fed ponds and consumption of fish raised in these ponds could lead to measurable impacts on people’s health. Another study showed that farmers of aquatic plants in ponds contaminated with wastewater and industrial effluents often developed skin diseases such as contact dermatitis. These studies have been used to develop the health-based targets that have been included in Volume 3 of these Guidelines.

2.2.3 Excreta and greywater

Exposure to untreated faeces always has to be considered unsafe, due to the potential presence of high levels of disease-causing organisms; concentrations depend on their prevalence within a given population. The organisms include bacteria, viruses, parasitic protozoa and helminths. They can cause a range of infectious diseases, the vast majority of which affect the gastrointestinal system. Enteric viruses are now considered to be the cause of the majority of gastrointestinal infections in the industrialized countries (Svensson, 2000). In the rural zones of many developing countries, open defecation and the use of untreated faeces are often associated with the transmission of intestinal worms

Table 2.2 Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health threats		
	Helminths	**Bacteria/viruses**	**Protozoa**
Consumers	Significant risks of helminth infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms per 100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risks of helminth infection for both adults and children in contact with untreated wastewater; increased risk of hookworm infection to workers who do not wear shoes; risks for helminth infection remain, especially for children, even when wastewater is treated to <1 helminth egg per litre; adults are not at increased risk at this helminth concentration	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms per 100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection reported to be insignificant for contact with both untreated and treated wastewater; another study in Pakistan estimated a threefold increase in risk of *Giardia* infection for farmers using raw wastewater compared with irrigation with fresh water; increased risk of amoebiasis observed from contact with untreated wastewater
Nearby communities	Transmission of helminth infections not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (10^6–10^8 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4–10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data for transmission of protozoan infections during sprinkler irrigation with wastewater

Sources: Shuval, Yekutiel & Fattal (1984); Fattal et al. (1986); Shuval et al. (1989); Blumenthal et al. (2000a); Armon et al. (2002); Blumenthal & Peasey (2002); J.H.J. Ensink, W. van der Hoek & F.P. Amerasinghe (unpublished data, 2005).

to both farmers and product consumers. This is especially true for children under 15 years of age engaged in agricultural activities, who may have intense contact with fields fertilized with untreated excreta. In endemic areas where land is fertilized with untreated human faeces, workers without proper protection (e.g. gloves, shoes) are at a high risk of contracting hookworm infections. Risks of infectious diseases are significantly reduced when excreta are treated to the level suggested in Section 2.3, when farmers

Table 2.3 Summary of quantitative microbial risk assessment results for rotavirus[a] infection risks for different exposures

Exposure scenario	Water quality[b] (*E. coli*/100 ml of wastewater or 100 g of soil)	Median infection risks per person per year	Notes
Unrestricted irrigation (crop consumers)			
Lettuce	10^3–10^4	10^{-3}	100 g eaten raw per person every 2 days 10–15 ml wastewater remaining on crop
Onions	10^3–10^4	5×10^{-2}	100 g eaten raw per person per week for 5 months 1–5 ml wastewater remaining on crop
Restricted irrigation (farmers or other heavily exposed populations)			
Highly mechanized	10^5	10^{-3}	100 days' exposure per year 1–10 mg soil consumed per exposure
Labour intensive	10^3–10^4	10^{-3}	150–300 days' exposure per year 10–100 mg soil consumed per exposure

[a] Risks estimated for *Campylobacter* and *Cryptosporidium* are lower.
[b] Non-disinfected effluents. Use of disinfectant-sensitive index organisms would lead to underestimation of risk in disinfected systems.

use protection and practise good hygiene and when consumers wash and rinse their food products with clean water prior to consumption.

The use of source-separated urine in agriculture usually entails low health risks, as predicted by QMRA. Some pathogens, including *Leptospira interrogans*, *Salmonella typhi*, *Salmonella paratyphi*, *Schistosoma haematobium* and some viruses, are excreted with urine. The pathogenic bacteria and *Schistosoma* eggs die off quickly if the urine is stored under recommended conditions. Most health risks associated with the use of urine have their roots in cross-contamination with faecal material. The risks can be reduced to a very low level by storing the urine in a sealed tank or container. Depending on the crops to be fertilized, the ambient temperature and the storage temperature, urine needs to be stored for between one and six months prior to use for community systems but not for individual ones. The risks are in general much lower than those from the use of wastewater. Use of personal protective equipment is recommended when the urine is applied to the fields.

Similarly, the use of greywater in agriculture and aquaculture poses less health risk than the use of wastewater and faecal material. There may still be some health risks, generally related to faecal cross-contamination. Yet these can be reduced by health protection measures or adequate treatment. Greywater may contain considerable concentrations of easily degradable organic compounds, favouring the growth of faecal indicators. Testing for these indicators may, therefore, yield false-positive outcomes (Manville et al., 2001).

2.3 Health-based targets

Estimating the level of disease associated with the use of wastewater, excreta and greywater can be difficult. Some diseases or ill-health conditions can be measured to indicate the level of health risks. In most cases, measuring the outcome will not index risk, however, as many outcomes are multifactorial: they result from multiple transmission pathways (pathogens) or multiple exposures (hazardous chemicals). Diarrhoea and intestinal helminth infections are often measured as general indicators of excreta-related diseases. Trematode infections may be considered where they are present in the population. Diseases related to chemical exposures are harder to detect because the health outcomes may take longer to develop and are often caused by many different chemicals through a variety of exposure routes. Skin diseases can be measured among people who have heavy contact with wastewater — especially where the wastewater is inadequately treated and has high toxic chemical inputs from industry.

Health-based targets are used by regulators to develop appropriate health protective legislation; they establish a defined level of health protection for a given exposure. This can be based on a measure of disease (e.g. 10^{-6} DALY, or disability adjusted life year, per person per year) or the absence of a specific disease related to that exposure (e.g. no transmission of foodborne trematodes resulting from the consumption of waste-fed aquacultural products). After the health target is defined, a combination of health protection measures that could achieve the target is specified. These may include, for example, crop/produce restriction; waste application techniques; measures to control exposures to hazards; wastewater, excreta or greywater treatment processes or technologies; and other interventions to reduce risk (e.g. normal washing and rinsing of irrigated vegetables, cooking food thoroughly prior to consumption, etc.). Health-based targets should be set at the national level, feasible to implement in the local circumstances and part of the overall regulatory framework.

The health-based targets for agriculture, aquaculture and the general use of excreta and greywater are presented in the subsections below.

2.3.1 Wastewater use in agriculture

The health-based targets for wastewater use in agriculture are presented in Table 2.4. The combinations of health protection measures that can be used to achieve the health-based targets are presented in Figure 2.1. Table 2.5 describes different health protection measure combinations to achieve the health-based targets. For specific settings, both the health-based targets and the combination of health protection measures need to be adapted.

Figure 2.1 shows pathogen reductions achieved by several options for combining wastewater treatment and other health protection control measures to achieve the health-based target of a DALY loss of $\leq 10^{-6}$ per person per year. The options in Figure 2.1 represent typical combinations of health protection control measures, but they are illustrative only. Planners and designers of wastewater use schemes may wish to explore and use other combinations of health protection control measures, and new treatment technologies will offer the opportunity of developing new options.

Option A in Figure 2.1 shows that the required pathogen reduction is achieved by the combination of (a) wastewater treatment, which provides a 4 log unit pathogen reduction (approximately equivalent to an *E. coli* level of 10^3/100 ml in unchlorinated effluents), (b) a 2 log unit reduction due to pathogen die-off between the last irrigation and consumption, and (c) a 1 log unit reduction due to normal household washing of the salad crops or vegetables with water prior to consumption. This option, which provides a 7 log unit pathogen reduction, is suitable when root crops that may be eaten uncooked are irrigated with treated wastewater.

Option B has a lower degree of wastewater treatment than Option A (3 log units, rather than 4) combined with two post-treatment health protection control measures: a

Table 2.4 Health-based targets and helminth reduction targets for treated wastewater use in agriculture

Type of irrigation	Health-based target for viral, bacterial and protozoan pathogens	Microbial reduction target for helminth eggs
Unrestricted	≤10^{-6} DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Restricted	≤10^{-6} DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Localized (e.g. drip irrigation)	≤10^{-6} DALY per person per year[a]	(a) Low-growing crops:[d] ≤1 per litre (arithmetic mean) (b) High-growing crops:[d,e] No recommendation

[a] The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.

[b] When children under 15 years of age are exposed, additional health protection measures should be used.

[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.

[d] High-growing crops include fruit trees, olives, etc.

[e] No crops to be picked up from the soil.

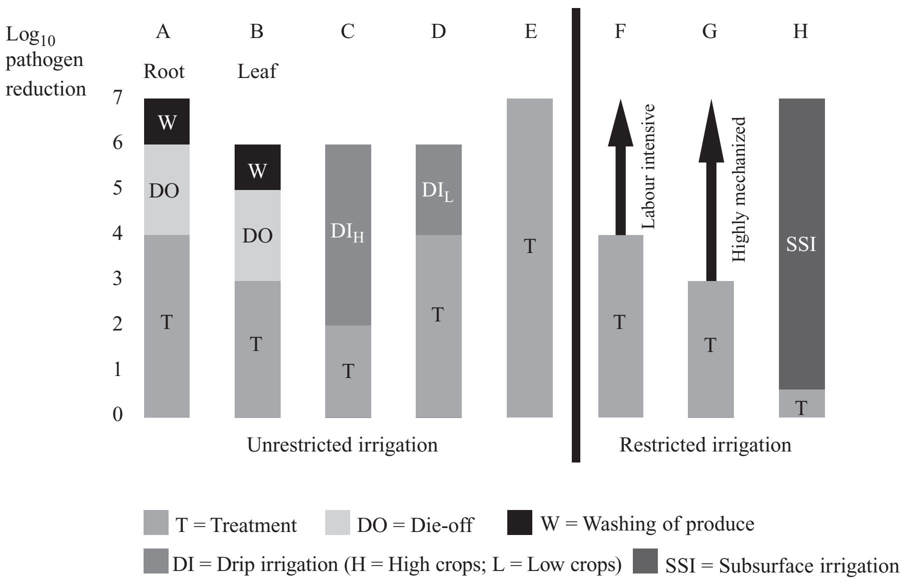

Figure 2.1

Examples of options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protection measures that achieve the health-based target of ≤10^{-6} DALY per person per year

Table 2.5 Verification monitoring[a] (*E. coli* numbers per 100 ml of treated wastewater) for the various levels of wastewater treatment in Options A–G presented in Figure 2.1

Type of irrigation	Option (Figure 2.1)	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 ml)	Notes
Unrestricted	A	4	$\leq 10^3$	Root crops
	B	3	$\leq 10^4$	Leaf crops
	C	2	$\leq 10^5$	Drip irrigation of high-growing crops
	D	4	$\leq 10^3$	Drip irrigation of low-growing crops
	E	6 or 7	$\leq 10^1$ or $\leq 10^0$	Verification level depends on the requirements of the local regulatory agency[b]
Restricted	F	3	$\leq 10^4$	Labour-intensive agriculture (protective of adults and children under 15 years of age)
	G	2	$\leq 10^5$	Highly mechanized agriculture
	H	0.5	$\leq 10^6$	Pathogen removal in a septic tank

[a] "Verification monitoring" refers to what has previously been referred to as "effluent standards" or "effluent guideline" levels.

[b] For example, for secondary treatment, filtration and disinfection: five-day biochemical oxygen demand (BOD_5), <10 mg/l; turbidity, <2 nephelometric turbidity units (NTU); chlorine residual, 1 mg/l; pH, 6–9; and faecal coliforms, not detectable in 100 ml (State of California, 2001).

2 log unit reduction due to die-off and a 1 log unit reduction due to washing the salad crops or vegetables with water prior to consumption. This option, which provides a 6 log unit pathogen reduction, is suitable for the irrigation of non-root salad crops (e.g. lettuce, cabbage) and vegetables eaten uncooked.

Option C combines an even lower degree of treatment (2 log units) with drip irrigation of high-growing crops (such as fruit trees, olives), which achieves the required remaining 4 log unit pathogen reduction.

Option D incorporates the drip irrigation of low-growing non-root crops (a 2 log unit reduction), so a greater degree of treatment (4 log units) is provided (a valid alternative would be, for example, a 2 log unit reduction by treatment followed by a 1 log unit reduction due to die-off and a 1-log unit reduction due to produce washing).

Option E relies solely on wastewater treatment to achieve the required 6–7 log unit reduction. A typical sequence of wastewater treatment processes to achieve this would comprise conventional wastewater treatment (e.g. primary sedimentation, activated sludge, including secondary sedimentation) followed by chemical coagulation, flocculation, sedimentation, filtration and disinfection (chlorination or UV irradiation). Such a sequence is used, for example, in California, USA, to ensure compliance with the state water recycling criteria for unrestricted irrigation (≤2.2 total coliforms per 100 ml and a turbidity of ≤2 NTU) (State of California, 2001). However, this option does not take into account pathogen reduction due to (a) natural die-off between final irrigation and consumption and (b) specific food preparation practices such as washing, disinfection, peeling and/or cooking. Moreover, the very high costs and operational complexity of the wastewater treatment processes required for this option will generally preclude its application in many developing countries.

Option F in Figure 2.1 represents labour-intensive restricted irrigation; the health-based target of an additional disease burden of $\leq 10^{-6}$ DALY loss per person per year is achieved by a 4 log unit pathogen reduction.

Option G represents restricted irrigation using highly mechanized agricultural practices (e.g. tractors, automatic sprinklers, etc.); wastewater treatment to 10^5–10^6 *E. coli* per 100 ml is required (i.e. a pathogen reduction of 3 log units).

Option H in Figure 2.1 illustrates a typical single-household or institutional situation: minimal treatment in a septic tank (0.5 log unit pathogen reduction) followed by subsurface irrigation via the soil absorption system for the septic tank effluent. There is no contact between the crop and the pathogens in the septic tank effluent, so the subsurface irrigation system is credited with the remaining 6.5 log unit pathogen reduction required for root crops.

As stated previously, each country can and should establish national criteria and procedures that suit its epidemiological, social and economic needs. These should allow for the optimal combination of risk reduction elements to be designed and implemented at the system level. The WHO Committee of Experts that reviewed and endorsed these Guidelines felt that the in-depth risk analyses provided a sound epidemiological basis to conclude that options A, B, C and D provide a high degree of health risk reduction, which should meet the needs of most countries in a reasonably cost-effective manner. It concluded that these new risk assessment studies and the extensive review and evaluation carried out by the group generally validated the 1989 WHO recommended guidelines for unrestricted wastewater use in agriculture of 1000 *E. coli*/100 ml.

2.3.2 Aquaculture

Health-based targets for different waste-fed aquacultural hazards are presented in Table 2.7. Because the risks associated with waste-fed aquaculture are not well defined, it is more difficult to set a meaningful tolerable risk level. However, different health-based targets can be developed for the prevention of a particular disease outcome (e.g. clonorchiasis transmission) from waste-fed aquaculture. A health-based target would then include combinations of different health protection measures that would lead to this outcome — for example, wastewater/excreta treatment, produce restriction, post-harvest fish processing (drying, salting, acid solution) and/or cooking fish before consumption.

For each exposure route (e.g. consumption, contact and vector transmission), a different health-based target is developed based on a relevant health outcome. This is important, because health outcomes differ by exposure route, as do health protection measures. For example, wastewater and excreta treatment may be effective in reducing diseases related to food consumption or contact with the water, but will do nothing to prevent vector-borne disease transmission. Similarly, hygienic fish processing may reduce cross-contamination with bacteria and viruses but will not reduce the risk associated with the presence of encysted trematode metacercariae that remain infective.

2.3.3 Excreta and greywater use

The pathogen reduction that is needed in the on-site and off-site treatment of excreta is expressed as both guideline values and performance targets for the treated faecal fraction and for faecal sludge. The guideline values refer to the context of helminth eggs and *E. coli*, where the numbers are harmonized with what is presented in volume 2. Likewise, harmonized guideline values for these parameters are given for the greywater quality, with a precaution due to the possibility of regrowth of *E. coli* on easily degradable

organics fractions in greywater. This allows for a relaxation of the guideline values, if the process is likely to occur or has been documented from similar conditions.
In addition, volume 4 emphasizes performance targets, to be accounted for both in the validation and verification monitoring, and of special value in operational monitoring. Performance targets are explicitly mentioned for source-separate urine, due to the possibility of false-negative results, if based on *E. coli*, as related to the die-off of pathogens. Performance targets are also used for treated faeces and faecal sludge. On-site treatment can never be fully monitored in relation to guideline values. Design criteria and validation will, on the other hand, take this into account. The performance target for treated excreta is based on a storage time of 6-24 months, depending on specific conditions. A withholding time of at least one month will further ensure safety of the agricultural produce for the consumers. This period applies where the treated excreta are applied as a fertilizer to soil conditioner, which differs from the wastewater values, where the water is mainly used for irrigation purposes.

Strauss & Blumenthal (1990) suggested that one year of storage was sufficient under tropical conditions (28–30 °C), whereas at lower average temperatures (17–20 °C) 18 months would be needed. Treatment of excreta, thermophilic digestion (50 °C for 14 days) and composting in aerated piles for one month at 55–60 °C (plus 2–4 months for further maturation) are procedures that will satisfy the reduction of pathogens to achieve the health-based target values.

In urine, faecal cross-contamination is the major source of microbial pathogens, if additional off-site treatment is applied. Measurements have indicated that it is usually less than 10^{-4} of excreta, thus similar to a 100-fold dilution of wastewater, with a need for a pathogen reduction of <4–5 log units as the performance target to achieve the tolerable additional disease burden of $\leq 10^{-6}$ DALY per person per year, in unrestricted irrigation.

For subsurface adsorption systems for greywater, no guidelines values apply. Siting should, however, not interfere with groundwater quality. Pond systems for greywater treatment carry the risk of mosquito vector breeding and much be evaluated on that account.

2.4 Health protection measures

To achieve the health-based targets described in section 2.3, the implementation of various health protection measures may be required. The regulatory framework should ensure that the correct measures are implemented in the correct settings.

Although in some cases one measure may be sufficient to achieve the health-based target (e.g. extensive treatment of wastewater), in practice it will usually be preferable to employ a combination of measures. For example, wastewater treatment plus a withholding period to allow pathogen die-off prior to harvest plus good food hygiene plus cooking of food may be sufficient to reduce health risks adequately. The combination of different health protection measures adds additional barriers for preventing exposures to the hazards and thus will reduce the potential health risks. The available health protection measures will vary according to the sociocultural, economic and environmental circumstances found in each situation. In practice, however, health protection measures can be taken to reduce potential health risks even in low-resource settings. In these situations, it may be necessary, however, to prioritize the health protection measures put into place so that exposure to the health hazards that pose the greatest risk (e.g. helminths in agriculture or foodborne trematodes in aquaculture) are dealt with first.

Detailed information on health protection measures is presented in Volumes 2, 3 and 4 of these Guidelines. An overview is presented in Table 2.8 below.

Table 2.6 Health-based targets for waste-fed aquaculture

Exposed group	Hazard	Health-based target[a]	Verification monitoring — pond water quality		Health protection measure
			E. coli **(arithmetic mean number per 100 ml)**	**Viable trematode eggs (number per 100 ml)**	
Consumers, workers and local communities	Excreta-related diseases	$\leq 10^{-6}$ DALY per person per year	$\leq 10^4$ (consumers) $\leq 10^3$ (contact)	Not detected	Wastewater treatment Excreta treatment Health and hygiene promotion Chemotherapy and immunization
Consumers	Excreta-related diseases	$\leq 10^{-6}$ DALY per person per year	$\leq 10^4$	Not detected	Produce restriction Waste application/ timing Depuration Food handling and preparation Produce washing/ disinfection Cooking foods
	Foodborne trematodes	Absence of trematode infections			
	Chemicals	Tolerable daily intakes as specified by the Codex Alimentarius Commission			
Workers and local communities	Excreta-related diseases	$\leq 10^{-6}$ DALY per person per year	$\leq 10^3$ (contact)		Access control Use of personal protective equipment Disease vector control Intermediate host control Access to safe drinking-water and sanitation at aquacultural facilities and in local communities Reducing vector contact (bed nets, repellents)
	Skin irritants	Absence of skin disease			
	Schistosomiasis	Absence of schistosomiasis		No viable schistosome eggs	
	Vector-borne diseases	Absence of vector-borne disease			

[a] Absence of disease associated with waste-fed aquaculture-related exposures.

2.5 Monitoring and system assessment

The three functions of monitoring are each used for different purposes at different times. Table 2.9 briefly describes each type of monitoring. *Validation* is performed at the beginning when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. *Operational monitoring* is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. *Verification* is used to show that the end product (e.g. treated wastewater and excreta; plant or fish) meets treatment targets (e.g. microbial quality specifications; no infective metacercariae in fish flesh) and ultimately the health-based targets (e.g. absence of trematode infections in the population exposed to waste-fed aquacultural activities). Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing). Table 2.10 presents the required verification monitoring of microbial water quality targets.

The most effective means of consistently ensuring safety in the use of wastewater, excreta and greywater is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps from waste generation, treatment and use to product use and consumption. The following components of this approach are important in the context of regulation for achieving the health-based targets: system assessment; identifying health protection measures and methods for monitoring them; and developing a management plan.

The first step in developing a risk management system is to form a multidisciplinary team of experts with a thorough understanding of local wastewater, excreta and greywater use practices. Typically, such a team would include agricultural and/or aquacultural experts, engineers, water quality specialists, environmental health specialists, public health authorities and food safety experts. In most settings, the team would include members from several institutions, and there should be some independent members, such as from universities.

Effective management of wastewater, excreta and greywater use activities requires a comprehensive understanding of the system, the range and magnitude of hazards that may be present and the ability of existing processes and infrastructure to manage actual or potential risks. It also requires an assessment of capabilities to meet targets. When a new system or an upgrade of an existing system is being planned, the first step in developing a risk management plan is the collection and evaluation of all available relevant information and consideration of what risks may arise during the entire waste use process. Figure 2.2 illustrates the development of a risk management plan.

The assessment and evaluation of the use of wastewater, excreta and greywater are enhanced through the development of a flow diagram. Diagrams provide an overview description of the system, including the identification of sources of hazards and health protection measures. It is important that the representation of the waste use system be conceptually accurate. If the flow diagram is not correct, it is possible to overlook potential hazards that may be significant. To ensure accuracy, the flow diagram should be validated by visually checking the diagram against features observed on the ground.

Data on the occurrence of hazards in the system combined with information concerning the effectiveness of existing controls enable an assessment of whether health-based targets can be achieved with the existing health protection measures. They also assist in identifying health protection measures that would reasonably be expected to achieve those targets if improvements are required.

To ensure accuracy of the assessment, it is essential that all elements of the waste use system are considered concurrently and that interactions and influences between each element and their overall effect are taken into consideration.

Table 2.7 Pathogen reductions achievable by various health protection measures

Control measure	Pathogen reduction (log units)	Notes
Excreta storage without fresh additions	6	The required pathogen reduction to be achieved by excreta treatment refers to stated storage times without addition of fresh untreated excreta. Pathogen reductions for different treatment options are presented in chapter 5 of Volume 4.
Greywater treatment	1–>4	Values relate to the relevant treatment options. Generally, the highest exposure reduction is related to subsurface irrigation.
Localized (drip) irrigation with urine (high-growing crops)	2–4	Crops where the harvested parts have not been in contact with the soil
Materials directly worked into the soil	1	Should be done at the time when faeces or urine is applied as a fertilizer
Pathogen die-off (withholding time one month)	4–>6	A die-off of 0.5–2 log units per day is cited for wastewater irrigation. Reduction values cited are conservative to account for a slower die-off of a fraction of the remaining organisms.
Produce washing with water	1	Washing salad crops, vegetables and fruit with clean water
Produce disinfection	2	Washing salad crops, vegetables and fruit with a weak disinfectant solution and rinsing with clean water
Produce peeling	2	Fruits, root crops
Produce cooking	6–7	Immersion in boiling or close-to-boiling water until the food is cooked ensures pathogen destruction

Sources: Beuchat (1998); Petterson & Ashbolt (2003); NRMMC & EPHCA (2005).

Table 2.8 Definitions of monitoring functions

Function	Definition
Validation	Testing the system and its individual components to prove that they are capable of meeting the specified targets (e.g. microbial reduction targets). Should take place when a new system is developed or new processes are added.
Operational monitoring	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a health protection measure is operating within design specifications (e.g. for wastewater treatment turbidity). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard break-through.
Verification	The application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and/or whether the system meets specified requirements (e.g. microbial water quality testing for *E. coli* or helminth eggs, microbial or chemical analysis of irrigated crops).

Table 2.9 Recommended minimum verification monitoring of microbial performance targets for wastewater and excreta use in agriculture and aquaculture

Activity/exposure	Water quality monitoring[a] parameters	
Agriculture	*E. coli* per 100 ml[b] (arithmetic mean)	Helminth eggs per litre[b] (arithmetic mean)
Unrestricted irrigation		
Root crops	$\leq 10^3$	≤ 1
Leaf crops	$\leq 10^4$	
Drip irrigation, high-growing crops	$\leq 10^5$	
Restricted irrigation		
Labour-intensive, high-contact agriculture	$\leq 10^4$	≤ 1
Highly mechanized agriculture	$\leq 10^5$	
Septic tank	$\leq 10^6$	
Aquaculture	*E. coli* per 100 ml[b] (arithmetic mean)	Viable trematode eggs per litre[b]
Produce consumers		
Pond	$\leq 10^4$	Not detected
Wastewater	$\leq 10^5$	Not detected
Excreta	$\leq 10^6$	Not detected
Workers, local communities		
Pond	$\leq 10^3$	No viable trematode eggs
Wastewater	$\leq 10^4$	No viable trematode eggs
Excreta	$\leq 10^5$	No viable trematode eggs

[a] Monitoring should be conducted at the point of use or the point of effluent discharge. Frequency of monitoring is as follows:

- Urban areas: one sample every two weeks for *E. coli* and one sample per month for helminth eggs.
- Rural areas: one sample every month for *E. coli* and one sample every 1–2 months for helminth eggs.

Five-litre composite samples are required for helminth eggs prepared from grab samples taken six times per day. Monitoring for trematode eggs is difficult due to a lack of standardized procedures. The inactivation of trematode eggs should be evaluated as part of the validation of the system.

[b] For excreta, weights may be used instead of volumes, depending on the type of excreta: 100 ml of wastewater is equivalent to 1–4 g of total solids; 1 litre = 10–40 g of total solids. The required *E. coli* or helminth numbers would be the same per unit of weight.

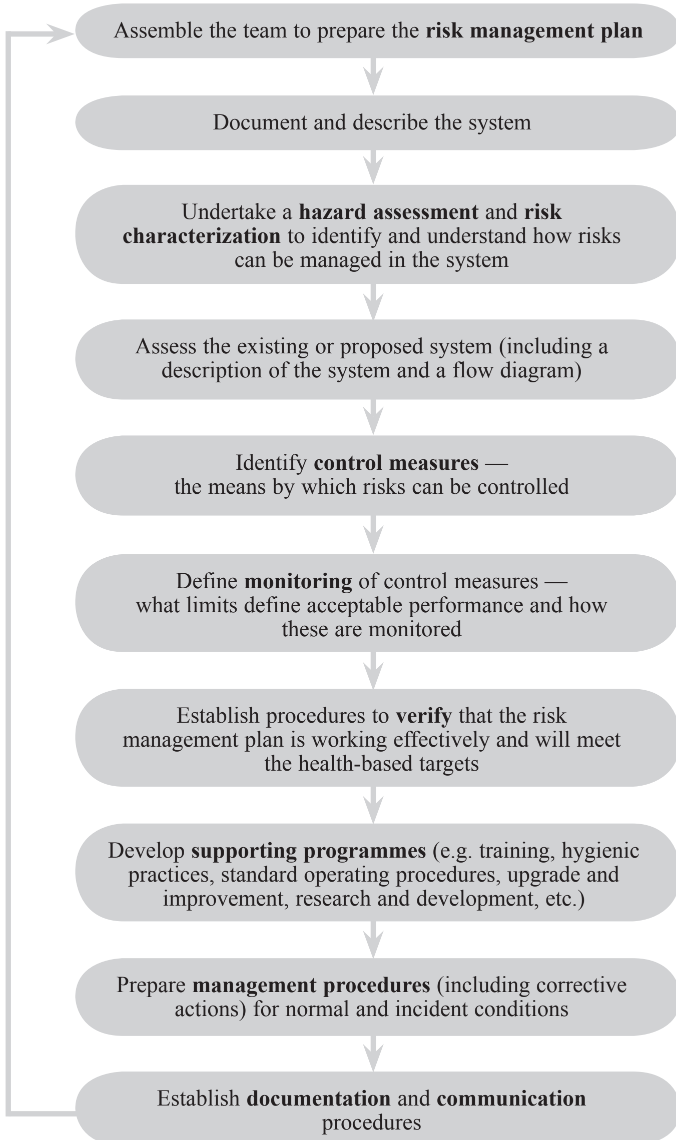

Figure 2.2
Development of a risk management plan (from WHO, 2004)

3
EXECUTIVE SUMMARY OF VOLUME 2

Volume 2 of the World Health Organization's (WHO) *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding the impact of wastewater use in agriculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each vulnerable group, and appropriate health protection measures to mitigate the risks are discussed.

The primary aim of the Guidelines is to maximize public health protection and the beneficial use of important resources. The purpose of this volume of the Guidelines is to ensure that the use of wastewater in agriculture is made as safe as possible, so that the nutritional and household food security benefits can be shared widely within communities whose livelihood depends on wastewater-irrigated agriculture. Thus, the adverse health impacts of wastewater use in agriculture should be carefully weighed against the benefits to health and the environment associated with these practices. Yet this is not a matter of simple trade-offs. Wherever wastewater use in agriculture contributes significantly to food security and nutritional status, the point is to identify associated hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing these risks.

Volume 2 of the Guidelines is intended to be used as the basis for the development of international and national approaches (including standards and regulations) to managing the health risks from hazards associated with wastewater use in agriculture, as well as providing a framework for national and local decision-making. The information provided is applicable to the intentional use of wastewater in agriculture and is also relevant where faecally contaminated water is used for irrigation unintentionally.

The Guidelines provide an integrated preventive management framework for safety applied from the point of wastewater generation to the consumption of products grown with the wastewater and excreta. They describe reasonable minimum requirements of good practice to protect the health of the people using wastewater or excreta or consuming products grown with wastewater or excreta and provide information that is then used to derive health-based targets. Neither the minimum good practices nor the health-based targets are mandatory limits. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including health-based targets, may vary depending on local social, cultural, environmental and economic conditions, as well as knowledge of routes of exposure, the nature and severity of hazards and the effectiveness of health protection measures available.

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health, water resources development and wastewater management. The target audience may include public health, agricultural and environmental scientists, agriculture professionals, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

3.1 Introduction

Wastewater is increasingly used for agriculture in both developing and industrialized countries, and the principal driving forces are:

- increasing water scarcity and stress, and degradation of freshwater resources resulting from improper disposal of wastewater;
- population increase and related increased demand for food and fibre;

- a growing recognition of the resource value of wastewater and the nutrients it contains;
- the Millennium Development Goals (MDGs), especially the goals for ensuring environmental sustainability and eliminating poverty and hunger.

It is estimated that, within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity. Growing competition between the agricultural and urban uses of high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this ever scarcer resource.

The United Nations Population Division expects most population growth to occur in urban and periurban areas in developing countries. Population growth increases both the demand for fresh water and the amount of wastes that are discharged into the environment, thus leading to more pollution of clean water sources.

Wastewater is often a reliable year-round source of water, and it contains the nutrients necessary for plant growth. The value of wastewater has long been recognized by farmers worldwide. The use of wastewater in agriculture is a form of nutrient and water recycling, and this often reduces downstream environmental impacts on soil and water resources.

The United Nations General Assembly adopted the MDGs on 8 September 2000. The MDGs most directly related to the use of wastewater in agriculture are "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability." The use of wastewater in agriculture can help communities to grow more food and conserve precious water and nutrient resources.

3.2 The Stockholm Framework

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. This provides a harmonized framework for the development of health-based guidelines and standards in terms of water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The Stockholm Framework provides the conceptual framework for these Guidelines and other WHO water-related guidelines.

3.3 Assessment of health risk

Three types of evaluations are used to assess risk: microbial and chemical laboratory analysis, epidemiological studies and quantitative microbial (and chemical) risk assessment.

Wastewater contains a variety of different pathogens, many of which are capable of survival in the environment (in the wastewater, on the crops or in the soil) long enough to be transmitted to humans. Table 3.1 presents a summary of the information available from epidemiological studies of infectious disease transmission related to wastewater use in agriculture. In places where wastewater is used without adequate treatment, the greatest health risks are usually associated with intestinal helminths.

Table 3.2 presents a summary of the quantitative microbial risk assessment (QMRA) evidence for transmission of rotavirus infection due to different exposures. The risks for rotavirus transmission were always estimated to be higher than the risks associated with *Campylobacter* or *Cryptosporidium* infections.

Table 3.1 Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health threats		
	Nematode infection	**Bacteria/viruses**	**Protozoa**
Consumers	Significant risk of *Ascaris* infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms/100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risk of *Ascaris* infection for both adults and children in contact with untreated wastewater; risk remains, especially for children, when wastewater treated to <1 nematode egg per litre; increased risk of hookworm infection in workers	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms/100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection was insignificant for contact with both untreated and treated wastewater; increased risk of amoebiasis observed with contact with untreated wastewater
Nearby communities	*Ascaris* transmission not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (10^6–10^8 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4–10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

Less evidence is available for health risks from chemicals. The evidence that is available is based on quantitative risk assessment and indicates that the uptake of chemicals by plants is highly dependent on the types of chemicals and the physical and chemical properties of soils.

3.4 Health-based targets

Health-based targets define a level of health protection that is relevant to each hazard. A health-based target can be based on a standard metric of disease, such as a DALY (e.g. 10^{-6} DALYs), or it can be based on an appropriate health outcome, such as the prevention of the transmission of vector-borne diseases resulting from exposures to wastewater used in agricultural practices. To achieve a health-based target, health protection measures are developed. Usually a health-based target can be achieved through a combination of health protection measures targeted at different components of the system. Figure

3.1 illustrates different combinations of health protection measures that can be used to achieve the 10^{-6} DALYs health-based target for excreta-related diseases.

Table 3.2 Summary of QMRA results for rotavirus[a] infection risks for different exposures

Exposure scenario	Water quality[b] (*E. coli*/100 ml wastewater or 100 g soil)	Median infection risks per person per year	Notes
Unrestricted irrigation (crop consumers)			
Lettuce	10^3–10^4	10^{-3}	100 g eaten raw per person every 2 days 10–15 ml wastewater remaining on crop
Onion	10^3–10^4	5×10^{-2}	100 g eaten raw per person per week for 5 months 1–5 ml wastewater remaining on crop
Restricted irrigation (farmers or other heavily exposed populations)			
Highly mechanized	10^5	10^{-3}	100 days' exposure per year 1–10 mg soil consumed per exposure
Labour intensive	10^3–10^4	10^{-3}	150–300 days' exposure per year 10–100 mg soil consumed per exposure

[a] Risks estimated for *Campylobacter* and *Cryptosporidium* are lower.
[b] Non-disinfected effluents.

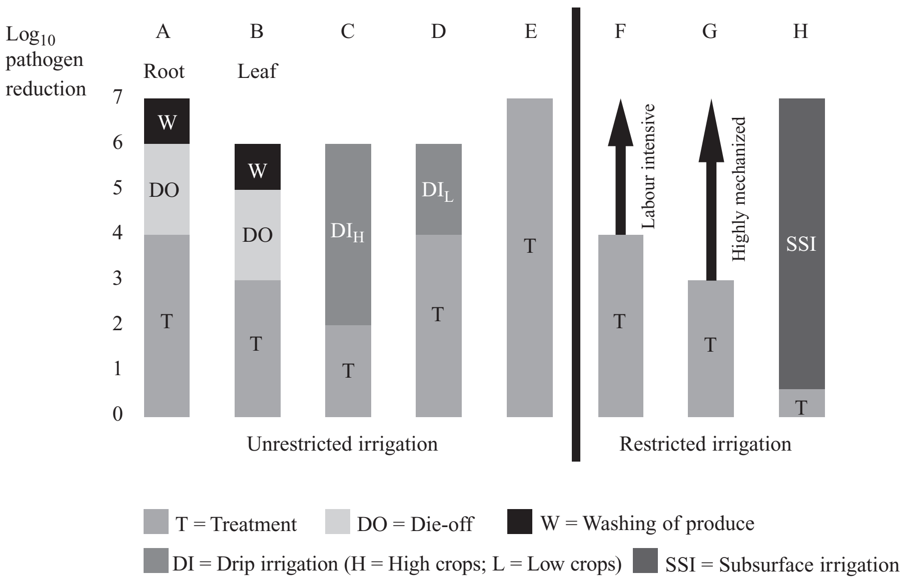

Figure 3.1
Examples of options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protection measures that achieve the health-based target of ≤10^{-6} DALYs per person per year

Table 3.3 describes health-based targets for agriculture. The health-based targets for rotavirus are based on QMRA indicating the $\log_{10}$ pathogen reduction required to achieve 10^{-6} DALY for different exposures. To develop health-based targets for helminth infections, epidemiological evidence was used. This evidence demonstrated that excess helminth infections (for both product consumers and farmers) could not be measured when wastewater quality of ≤1 helminth egg per litre was used for irrigation. This level of health protection could also be met by treatment of wastewater or by a combination of wastewater treatment and washing of produce to protect consumers of raw vegetables; or by wastewater treatment and the use of personal protective equipment (shoes, gloves) to protect workers. When children less than 15 years of age are exposed in the fields, either additional wastewater treatment (to achieve a wastewater quality of ≤0.1 helminth egg per litre) or the addition of other health protection measures (e.g. anthelminthic treatment) should be considered.

Table 3.3 Health-based targets for wastewater use in agriculture

Exposure scenario	Health-based target (DALY per person per year)	Log_{10} pathogen reduction needed[a]	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [a]		
Lettuce		6	≤1[b,c]
Onion		7	≤1[b,c]
Restricted irrigation	$\leq 10^{-6}$ [a]		
Highly mechanized		3	≤1[b,c]
Labour intensive		4	≤1[b,c]
Localized (drip) irrigation	$\leq 10^{-6}$ [a]		
High-growing crops		2	No recommendation[d]
Low-growing crops		4	≤1[c]

[a] Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.

[b] When children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤0.1 egg per litre, protective equipment such as gloves or shoes/boots or chemotherapy).

[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.

[d] No crops to be picked up from the soil.

Table 3.4 presents maximum soil concentrations for different chemicals based on health risk assessment. Concentrations of chemicals that impact agricultural productivity are described in Annex 1 of Volume 2.

3.5 Health protection measures

A variety of health protection measures can be used to reduce health risks to consumers, workers and their families and local communities.

Hazards associated with the consumption of wastewater-irrigated products include excreta-related pathogens and some toxic chemicals. The risk from infectious pathogens is significantly reduced if foods are eaten after thorough cooking. Cooking has little or no impact on the concentrations of toxic chemicals that might be present. The following health protection measures have an impact on product consumers:

Table 3.4 Maximum tolerable soil concentrations of various toxic chemicals based on human health protection

Chemical	Soil concentration (mg/kg)
Element	
Antimony	36
Arsenic	8
Barium[a]	302
Beryllium[a]	0.2
Boron[a]	1.7
Cadmium	4
Fluorine	635
Lead	84
Mercury	7
Molybdenum[a]	0.6
Nickel	107
Selenium	6
Silver	3
Thallium[a]	0.3
Vanadium[a]	47
Organic compound	
Aldrin	0.48
Benzene	0.14
Chlordane	3
Chlorobenzene	211
Chloroform	0.47
2,4-D	0.25
DDT	1.54
Dichlorobenzene	15
Dieldrin	0.17
Dioxins	0.000 12
Heptachlor	0.18
Hexachlorobenzene	1.40
Lindane	12
Methoxychlor	4.27
PAHs (as benzo[*a*]pyrene)	16
PCBs	0.89
Pentachlorophenol	14
Phthalate	13 733
Pyrene	41
Styrene	0.68
2,4,5-T	3.82
Tetrachloroethane	1.25
Tetrachloroethylene	0.54
Toluene	12
Toxaphene	0.0013
Trichloroethane	0.68

[a] The computed numerical limits for these elements are within the ranges that are typical for soils.

- wastewater treatment;
- crop restriction;
- wastewater application techniques that minimize contamination (e.g. drip irrigation);
- withholding periods to allow pathogen die-off after the last wastewater application;
- hygienic practices at food markets and during food preparation;
- health and hygiene promotion;
- produce washing, disinfection and cooking;
- chemotherapy and immunization.

Wastewater use activities may lead to the exposure of workers and their families to excreta-related diseases (including schistosomiasis), skin irritants and vector-borne diseases (in certain locations). Wastewater treatment is a control measure for excreta-related diseases, skin irritants and schistosomiasis but may not have much impact on vector-borne diseases. Other health protection measures for workers and their families include:

- use of personal protective equipment;
- access to safe drinking-water and sanitation facilities at farms;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

Local communities are at risk from the same hazards as workers, especially if they have access to wastewater-irrigated fields. If they do not have access to safe drinking-water, they may use contaminated irrigation water for drinking or for domestic purposes. Children may also play or swim in the contaminated water. Similarly, if wastewater irrigation activities result in increased vector breeding, then local communities may be affected by vector-borne diseases, even if they do not have direct access to the irrigated fields. To reduce health hazards, the following health protection measures for local communities may be used:

- wastewater treatment;
- restricted access to irrigated fields and hydraulic structures;
- access to safe recreational water, especially for adolescents:
- access to safe drinking-water and sanitation facilities in local communities;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

3.6 Monitoring and system assessment

Monitoring has three different purposes: validation, or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process to ensure that the system is achieving the specified targets.

The three functions of monitoring are each used for different purposes at different times. Validation is performed at the beginning when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated wastewater; crops) meets treatment targets (e.g. microbial quality specifications) and ultimately the health-based targets. Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing).

The most effective means of consistently ensuring safety in the agricultural application of wastewater is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process from waste generation to treatment and use of wastewater to product use or consumption. This approach is captured in the Stockholm Framework. Three components of this approach are important for achieving the health-based targets: system assessment, identifying control measures and methods for monitoring them and developing a management plan.

3.7 Sociocultural aspects

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce wastewater use schemes or to reduce disease transmission in existing schemes needs to be assessed on an individual project basis. Cultural beliefs vary so widely in different parts of the world that it is not possible to assume that any of the practices that have evolved in relation to wastewater use can be readily transferred elsewhere.

Closely associated with cultural beliefs is the public perception of wastewater use. Even when projects are technically well planned and all of the relevant health protection measures have been included, the project can fail if it does not account adequately for public perception.

3.8 Environmental aspects

Wastewater is an important source of water and nutrients for many farmers in arid and semi-arid climates. Sometimes it is the only water source available for agriculture. When wastewater use is well managed, it helps to recycle nutrients and water and therefore diminishes the cost of fertilizers or simply makes them accessible to farmers. Where wastewater treatment services are not provided, the use of wastewater in agriculture actually acts as a low-cost treatment method, taking advantage of the soil's capacity to naturally remove contamination. Therefore, the use of wastewater in irrigation helps to reduce downstream health and environmental impacts that would otherwise result if the wastewater were discharged directly into surface water bodies.

Nevertheless, wastewater use poses environmental risks. Possible effects and their relevance depend on each specific situation and how the wastewater is used. In many places, wastewater irrigation has arisen spontaneously and without planning — often the wastewater is untreated. In other situations, the use of wastewater in agriculture is strictly controlled. These practices will lead to different environmental impacts.

The properties of domestic wastewater and industrial wastewater differ. Generally, the use of domestic wastewater for irrigation poses less risk to the environment than the use of industrial wastewater, especially where industries use or produce highly toxic chemicals. Industrial discharges containing toxic chemicals are mixed with domestic wastewater in many countries, creating serious environmental problems and, where the wastewater is used for crop irrigation, endangering the health of the farmers and product consumers. Efforts should be made to reduce or eliminate practices that entail the mixing of industrial and domestic wastewater, particularly where wastewater is used for agriculture.

The use of wastewater in agriculture has the potential for both positive and negative environmental impacts. With careful planning and management, the use of wastewater in agriculture can be beneficial to the environment. Many of the environmental impacts (e.g. salinization of soil, contamination of water resources) can be reduced by good agricultural practices (as described in Annex 1 of Volume 2).

3.9 Economic and financial considerations

Economic factors are especially important when the viability of a new scheme for the use of wastewater is being appraised, but even an economically worthwhile project can fail without careful financial planning.

Economic analysis and financial considerations are crucial for encouraging the safe use of wastewater. Economic analysis seeks to establish the economic feasibility of a project and enables comparisons between different options. The cost transfers to other sectors (e.g. the health and environmental impacts on downstream communities) also need to be included in a cost analysis. This can be facilitated by the use of multiple-objective decision-making processes.

Financial planning looks at how the project is to be paid for. In establishing the financial feasibility of a project, it is important to determine the sources of revenues and clarify who will pay for what. The possibility to profitably sell products grown with wastewater or to sell the treated wastewater also needs analysis.

3.10 Policy aspects

The safe management of wastewater in agriculture is facilitated by appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels. In many countries where wastewater use in agriculture takes place, these frameworks are lacking.

Policy is the set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and associated strategies allocate resources for their implementation. Policies are implemented through four types of instruments: laws and regulations, economic measures, information and education programmes and assignments of rights and responsibilities for providing services.

In developing a national policy framework to facilitate safe wastewater use in agriculture, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach. National approaches for safe wastewater use practices based on the WHO Guidelines will protect public health the most when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water and adequate sanitation. Other complementary programmes, such as chemotherapy campaigns, should be accompanied by health promotion/education to change behaviours that would otherwise lead to reinfection (e.g. with intestinal helminths and other pathogens).

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but they should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced.

The use of wastewater in agriculture can have one or more of several objectives. Defining these objectives is important for developing a national policy framework. The right policies can facilitate the safe use of wastewater in agriculture. Current policies often already exist that impact these activities, both negatively and positively. Conducting an assessment of current policies is often helpful for developing a new national policy or for revising existing policies. The assessment should take place at two levels: from the perspective of both a policy-maker and a project manager. Policy-makers will want to assess the national policies, legislation, institutional framework and regulations to ensure that they meet the national wastewater use objectives (e.g. maximize economic returns without endangering public health or the environment). Project coordinators will want to ensure that current and future waste use activities will be able to comply with all relevant national and local laws and regulations.

The main considerations are:

- *Policy*: Are there clear policies on the use of wastewater? Is wastewater use encouraged or discouraged?
- *Legislation*: Is the use of wastewater governed in legislation? What are the rights and responsibilities of different stakeholders? Does a defined jurisdiction exist on the use of wastewater?
- *Institutional framework*: Which ministry/agency, organizations, etc. have the authority to control the use of wastewater at the national level and at the district/community level? Are the responsibilities of different ministries/agencies clear? Is there one lead ministry, or are there multiple ministries/agencies with overlapping jurisdictions? Which ministry/agency is responsible for developing regulations? Which ministry/agency monitors compliance with regulations? Which ministry/agency enforces the regulations?
- *Regulations*: Do regulations exist? Are the current regulations adequate to meet wastewater use objectives (protect public health, prevent environmental damage, meet produce quality standards for domestic and international trade, preserve livelihoods, conserve water and nutrients, etc.)? Are the current regulations being implemented? Is regulatory compliance being enforced? Which ministry/agency enforces the regulations?

It is easier to make regulations than to enforce them. In drafting new regulations (or in choosing which existing ones to enforce), it is important to plan for the institutions, staff and resources necessary to ensure that the regulations are followed. It is important to ensure that the regulations are realistic and achievable in the context in which they are to be applied. It will often be advantageous to adopt a gradual approach or to test a new set of regulations by persuading a local administration to pass them as by-laws before they are extended to the rest of the country.

3.11 Planning and implementation

Planning and implementation of wastewater irrigation programmes require a comprehensive progressive approach that responds to the greatest health priorities first. Strategies for developing national programmes should include elements on communication to stakeholders, interaction with stakeholders and the collection and use of data.

Additionally, planning for projects at a local level requires an assessment of several important underlying factors. The sustainability of wastewater use in agriculture relies on the assessment and understanding of eight important criteria: health, economic feasibility, social impact and public perception, financial feasibility, environmental impact, market feasibility, institutional feasibility and technical feasibility.

4
EXECUTIVE SUMMARY OF VOLUME 3

Volume 3 of the World Health Organization's (WHO) *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding the impact of waste-fed aquaculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each group at risk, and appropriate health protection measures to mitigate the risks are discussed.

The primary aim of the Guidelines is to maximize public health protection and the beneficial use of important resources. The purpose of this volume is to ensure that waste-fed aquacultural activities are made as safe as possible so that the nutritional and household food security benefits can be shared widely in affected communities. Thus, the adverse health impacts of waste-fed aquaculture should be carefully weighed against the benefits to health and the environment associated with these practices. Yet this is not a matter of simple trade-offs. Wherever waste-fed aquaculture contributes significantly to food security and nutritional status, the point is to identify associated hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing these risks.

This volume of the Guidelines is intended to be used as the basis for the development of international and national approaches (including standards and regulations) to managing the health risks from hazards associated with waste-fed aquaculture, as well as providing a framework for national and local decision-making.

The information provided is applicable to intentional waste-fed aquacultural practices but also should be relevant to the unintentional use of faecally contaminated waters for aquaculture.

The Guidelines provide an integrated preventive management framework for safety applied from the point of waste generation to the consumption of products grown with the wastewater and excreta. They describe reasonable minimum requirements of good practice to protect the health of the people using wastewater or excreta or consuming products grown with wastewater or excreta and provide information that is then used to derive health-based targets. Neither the minimum good practices nor the health-based targets are mandatory limits. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including health-based targets, may vary depending on local social, cultural, environmental and economic conditions, as well as knowledge of routes of exposure, the nature and severity of hazards and the effectiveness of health protection measures available.

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health, water resources development and wastewater management. The target audience may include environmental and public health scientists, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

4.1 Introduction

A number of forces are both negatively and positively impacting the development of waste-fed aquacultural production. Many of the areas where waste-fed aquaculture has been traditionally practised are shrinking due to urbanization, increasing surface water pollution and the development of high-input aquaculture to produce cash crops. Most of the traditional waste-fed aquacultural production has occurred in parts of Asia. Although intentional waste-fed aquaculture is in decline, the unintentional use of contaminated water in aquaculture may be increasing in some areas.

4.2 The Stockholm Framework

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. This provides a harmonized framework for the development of health-based guidelines and standards in terms of water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The Stockholm Framework provides the conceptual framework for these Guidelines and other WHO water-related guidelines.

4.3 Assessment of health risk

Three types of evaluations are used to assess risk: microbial and chemical laboratory analysis, epidemiological studies and quantitative microbial (and chemical) risk assessment. Overall, there are limited data on the health impacts associated with waste-fed aquacultural practices. The evidence suggests that pathogens are often present at significant levels in untreated wastewater and excreta; pathogens can survive long enough in the environment to be transmitted to humans; and waste-fed aquaculture-associated disease transmission can occur.

Foodborne trematode parasites, where they occur, pose significant health risks to consumers of raw or inadequately cooked fish or plants. Priority should be given to implementing control measures against the transmission of foodborne trematode infections, where relevant. Excreta-related pathogens pose health risks to product consumers and people who may have contact with the contaminated water. For product consumers, much of the health risk may be associated with poor fish cleaning practices that lead to cross-contamination between the gut contents and the edible flesh. Thus, improving market hygiene and fish processing/cleaning is an important health protection intervention.

4.4 Health-based targets

Health-based targets define a level of health protection that is relevant to each hazard. A health-based target can be based on a standard metric of disease, such as the disability adjusted life year or DALY (e.g. 10^{-6} DALY), or it can be based on an appropriate health outcome, such as the prevention of the transmission of foodborne trematode infection associated with waste-fed aquacultural practices. To achieve a health-based target, health protection measures are developed. Usually a health-based target can be achieved through a combination of health protection measures targeted at different components of the waste-fed aquacultural system. Health-based targets for different waste-fed aquacultural hazards are presented in Table 4.1.

4.5 Health protection measures

A variety of health protection measures can be used to reduce health risks to product consumers, workers and their families and local communities.

Hazards associated with the consumption of waste-fed aquacultural products include excreta-related pathogens, foodborne trematodes and some toxic chemicals. The risk from infectious diseases is significantly reduced if foods are eaten after thorough cooking. Cooking has little or no impact on the concentrations of toxic chemicals that might be present. Special considerations for managing trematode parasites (including *Schistosoma* spp.) may be required where they are present. The following health protection measures impact product consumers:

Table 4.1 Health-based targets for waste-fed aquaculture

Exposed group	Hazard	Health-based target[a]	Health protection measure
Consumers, workers and local communities	Excreta-related diseases	10^{-6} DALY	Wastewater treatment
			Excreta treatment
			Health and hygiene promotion
			Chemotherapy and immunization
Consumers	Excreta-related diseases	10^{-6} DALY	Produce restriction
			Waste application/timing
	Foodborne trematodes	Absence of trematode infections	Depuration
	Chemicals	Tolerable daily intakes as specified by the Codex Alimentarius Commission	Food handling and preparation
			Produce washing/disinfection
			Cooking foods
Workers and local communities	Excreta-related pathogens	10^{-6} DALY	Access control
			Use of personal protective equipment
	Skin irritants	Absence of skin disease	Disease vector control
	Schistosomes	Absence of schistosomiasis	Intermediate host control
	Vector-borne pathogens	Absence of vector-borne disease	Access to safe drinking-water and sanitation at aquacultural facilities and in local communities
			Reduced vector contact (insecticide-treated nets, repellents)

[a] Absence of disease associated with waste-fed aquaculture-related exposures.

- wastewater and excreta treatment;
- produce restriction;
- waste application withholding periods;
- control of trematode intermediate hosts;
- depuration;
- hygienic food handling and preparation;
- post-harvest processing;
- health and hygiene promotion;
- produce washing, disinfection and cooking;
- chemotherapy and immunization.

Workers and their families may be exposed to excreta-related diseases, skin irritants, schistosomiasis and vector-borne diseases through waste-fed aquacultural activities or contact with the hazards. Wastewater treatment and excreta treatment are control measures for excreta-related diseases, skin irritants and schistosomiasis but may not have much impact on vector-borne diseases. Other health protection measures include:

- use of personal protective equipment;
- access to safe drinking-water and sanitation facilities at aquacultural facilities;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

Local communities are at risk from the same hazards as workers, especially if they have access to waste-fed ponds. If they do not have access to safe drinking-water, they may use the contaminated water for drinking or for domestic purposes, such as washing clothes, dishes and themselves. Children may also play or swim in the contaminated water. Similarly, if waste-fed aquacultural activities result in increased vector breeding, then local communities can be affected by vector-borne diseases, even if they do not have access to the waste-fed aquacultural facilities. To reduce health hazards, the following health protection measures may be used:

- wastewater and excreta treatment;
- restricted access to aquacultural facilities;
- access to safe drinking-water and sanitation facilities at aquacultural facilities;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

4.6 Monitoring and system assessment

Monitoring has three different purposes: validation or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process to ensure that the system is achieving the specified targets.

The three functions of monitoring are each used for different purposes at different times. Validation is performed when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated wastewater/excreta/pond water; fish or plants) meets treatment targets (e.g. microbial reduction targets) and ultimately the health-based targets. Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. whether the efficiency of a specific process is improving or decreasing).

The most effective means of consistently ensuring safety in waste-fed aquaculture is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in waste-fed aquaculture, from the generation and use of wastewater and excreta to the product consumer. This approach is captured in the Stockholm Framework. Three components of this approach are important for achieving the health-based targets: system assessment; identifying control measures and methods for monitoring them; and developing a management plan.

4.7 Sociocultural, environmental and economic aspects

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce excreta or wastewater use schemes or to reduce disease transmission in existing schemes can be assessed only with a prior understanding of the cultural values attached to practices that appear to be social preferences, yet which facilitate disease transmission. Closely associated with cultural beliefs is the public perception of wastewater and excreta use.

Excreta and wastewater use schemes, if properly planned and managed, can have a positive environmental impact, as well as produce fish and plants. Environmental improvement may be related to:

- avoidance of surface water pollution;
- conservation or more rational use of freshwater resources, especially in arid and semi-arid areas: fresh water for urban demand, wastewater for aquacultural use;
- reduction in risks of flooding in urban areas, as wastewater-fed canals, ponds and lakes act as a "buffer" during heavy rains;
- reduced requirements for artificial fertilizers, with a concomitant reduction in energy expenditure and industrial pollution elsewhere.

The primary negative environmental impacts are often related to contamination of surface waters or groundwaters in proximity to waste-fed aquacultural facilities. Other impacts relate to general aquacultural practices (e.g. the introduction of non-indigenous species or destruction of mangroves) and are not specifically related to waste-fed aquaculture.

Economic factors are especially important when the viability of a new scheme for the use of wastewater and excreta is being appraised, but even an economically worthwhile project can fail without careful financial planning. Economic appraisal considers whether a project is worthwhile, whereas financial planning looks at how projects are to be paid for. Improvements to existing practices must be paid for in some way and therefore also require financial planning.

4.8 Policy aspects

The safe management of waste-fed aquacultural practices is facilitated by appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels. In many countries where waste-fed aquaculture takes place, these frameworks are lacking.

Policy is the set of procedures, rules, decision-making criteria and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and associated strategies allocate resources for their implementation. Policies are implemented through four types of instruments: laws and regulations; economic measures; information and education programmes; and assignments of rights and responsibilities for providing services.

In developing a national policy framework to facilitate safe waste-fed aquaculture, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach. National approaches for safe waste-fed aquacultural practices based on the WHO Guidelines will protect public health the most when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water and adequate sanitation. Other complementary programmes, such as chemotherapy campaigns, should be accompanied by health promotion/education to change behaviours that would otherwise lead to reinfection with foodborne trematodes or intestinal helminths.

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but they should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced.

4.9 Planning and implementation

Planning and implementation of waste-fed aquacultural programmes require a comprehensive progressive approach that responds to the greatest health priorities first. Strategies for developing national programmes should include elements on communication to stakeholders, interaction with stakeholders and the collection and use of data.

Additionally, planning for projects at a local level requires an assessment of several important underlying factors. The sustainability of waste-fed aquaculture relies on the assessment and understanding of eight important criteria: health, economic feasibility, social impact and public perception, financial feasibility, environmental impact, market feasibility, institutional feasibility and technical feasibility.

5
EXECUTIVE SUMMARY OF VOLUME 4

Volume 4 of the World Health Organization's (WHO) *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding the impact of excreta and greywater use in agriculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each group at risk, and appropriate health protection measures to mitigate the risks are discussed.

The primary aim of the Guidelines is to maximize public health protection and the beneficial use of important resources. The purpose of this volume is to ensure that the use of excreta and greywater in agriculture is made as safe as possible so that the nutritional and household food security benefits can be shared widely in affected communities. Thus, the adverse health impacts of excreta and greywater use in agriculture should be carefully weighed against the benefits to health and the environment associated with these practices. Yet this is not a matter of simple trade-offs. Wherever excreta and greywater use contributes significantly to food security and nutritional status, the point is to identify associated hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing these risks.

Volume 4 of the Guidelines is intended to be used as the basis for the development of international and national approaches (including standards and regulations) to managing the health risks from hazards associated with excreta and greywater use in agriculture, as well as providing a framework for national and local decision-making.

The information provided is applicable to the intentional use of excreta and greywater in agriculture, but it should also be relevant to their unintentional use.

The Guidelines provide an integrated preventive management framework for safety applied from the point of household excreta and greywater generation to the consumption of products grown with treated excreta applied as fertilizers or treated greywater used for irrigation purposes. They describe reasonable minimum requirements of good practice to protect the health of the people using treated excreta or greywater or consuming products grown with these for fertilization or irrigation purposes and provide information that is then used to derive health-based targets. Neither the minimum good practices nor the health-based targets are mandatory limits. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including health-based targets, may vary depending on local social, cultural, environmental and economic conditions, as well as knowledge of routes of exposure, the nature and severity of hazards and the effectiveness of health protection measures available.

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health, water resources development and wastewater management. The target audience may include public health, agricultural and environmental scientists, agriculture professionals, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

5.1 Introduction

Traditional waterborne sewerage will continue to dominate sanitation for the foreseeable future. Since only a fraction of existing wastewater treatment plants in the world are optimally reducing levels of pathogenic microorganisms and since a majority of people living in both rural and urban areas will not be connected to centralized wastewater treatment systems, alternative sanitation approaches need to be developed in parallel.

The United Nations General Assembly adopted the Millennium Development Goals (MDGs) on 8 September 2000 (United Nations General Assembly, 2000). The MDGs most directly related to the use of excreta and greywater in agriculture are "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability." The sanitation target in Goal 7 is to halve, by 2015, the proportion of people without access to adequate sanitation. Household- or community-centred source separation is one of the alternative approaches that is rapidly expanding in order to meet this target. It also helps to prevent environmental degradation and to promote sustainable recycling of the existing plant nutrients in human excreta for food production.

The principal forces driving the increase in use of excreta and greywater in agriculture are:

- increasing water scarcity and stress, and degradation of freshwater resources resulting from the improper disposal of wastewater, excreta and greywater;
- population increase and related increased demand for food and fibre;
- a growing recognition of the resource value of wastewater and the nutrients it contains;
- the MDGs, especially the goals for ensuring environmental sustainability and eliminating poverty and hunger.

Growing competition between agricultural and urban areas for high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this increasingly scarce resource. Most population growth is expected to occur in urban and periurban areas in developing countries (United Nations Population Division, 2002). Population growth increases both the demand for fresh water and the amount of wastes that are discharged into the environment, thus leading to more pollution of clean water sources. Household-centred source separation and the safe use of excreta and greywater in agriculture will help to alleviate these pressures and help communities to grow more food and conserve precious water and nutrient resources. The additional advantages of nutrient use from excreta as fertilizers are that this "product" is less contaminated with industrial chemicals than when wastewater is used and that it saves water for other uses.

This volume focuses mainly on small-scale applications. It is applicable to both industrialized and developing countries.

5.2 The Stockholm Framework

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. This provides a harmonized framework for the development of health-based guidelines and standards in terms of water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The Stockholm Framework provides the conceptual framework for these Guidelines and other WHO water-related guidelines.

5.3 Assessment of health risk

Three types of evaluations are used to assess risk: microbial analysis, epidemiological studies and quantitative microbial risk assessment (QMRA). Human faeces contain a variety of different pathogens, reflecting the prevalence of infection in the population; in contrast, only a few pathogenic species may be excreted in urine. The risks associated with both reuse of urine as a fertilizer and the use of greywater for irrigation purposes are related to cross-contamination by faecal matter. Epidemiological data for the assessment of risk through treated faeces, faecal sludge, urine or greywater are scarce and unreliable, while ample evidence exists related to untreated faecal matter. In addition, microbial analyses are partly unreliable in the prediction of risk due to a more rapid die-off of indicator organisms such as *Escherichia coli* in urine, leading to an underestimation of the risk of pathogen transmission. The opposite may occur in greywater, where a growth of the indicator bacteria on easily degradable organic substances may lead to an overestimation of the risks. Based on the above limitations, QMRA is the main approach taken, due to the range of organisms with common transmission characteristics and their prevalence in the population. Factors accounted for include:

- epidemiological features (including infectious dose, latency, hosts and intermediate host);
- persistence in different environments outside the human body (and potential for growth);
- major transmission routes;
- relative efficiency of different treatment barriers;
- risk management measures.

5.4 Health-based targets

Health-based targets define a level of health protection that is relevant to each hazard. A health-based target can be based on a standard metric of disease, such as a disability adjusted life year or DALY (i.e. 10^{-6} DALY), or it can be based on an appropriate health outcome, such as the prevention of exposure to pathogens in excreta and greywater anytime between their generation at the household level and their use in agriculture. To achieve a health-based target, health protection measures are developed. Usually a health-based target can be achieved by combining health protection measures targeted at different steps in the process.

The health-based targets may be achieved through different treatment barriers or health protection measures. The barriers relate to verification monitoring, mainly in large-scale systems, as illustrated in Table 5.1 for excreta and greywater. Verification monitoring is not applicable to urine.

Table 5.1 Guideline values for verification monitoring in large-scale treatment systems of greywater, excreta and faecal sludge for use in agriculture

	Helminth eggs (number per gram total solids or per litre)	*E. coli* (number per 100 ml)
Treated faeces and faecal sludge	<1/g total solids	<1000/g total solids
Greywater for use in:		
• Restricted irrigation	<1/litre	$<10^{5}$ [a] Relaxed to $<10^{6}$ when exposure is limited or regrowth is likely
• Unrestricted irrigation of crops eaten raw	<1/litre	$<10^{3}$ Relaxed to $<10^{4}$ for high-growing leaf crops or drip irrigation

[a] These values are acceptable due to the regrowth potential of *E. coli* and other faecal coliforms in greywater.

The health-based targets may also relate to operational monitoring, such as storage as an on-site treatment measure or further treatment off site after collection. This is exemplified for faeces from small-scale systems in Table 5.2.

Table 5.2 Recommendations for storage treatment of dry excreta and faecal sludge before use at the household and municipal levels[a]

Treatment	Criteria	Comment
Storage; ambient temperature 2–20 °C	1.5–2 years	Will eliminate bacterial pathogens; regrowth of *E. coli* and *Salmonella* may need to be considered if rewetted; will reduce viruses and parasitic protozoa below risk levels. Some soil-borne ova may persist in low numbers.
Storage; ambient temperature >20–35 °C	>1 year	Substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosome eggs (<1 month); inactivation of nematode (roundworm) eggs, e.g. hookworm (*Ancylostoma*/ *Necator*) and whipworm (*Trichuris*); survival of a certain percentage (10–30%) of *Ascaris* eggs (≥4 months), whereas a more or less complete inactivation of *Ascaris* eggs will occur within 1 year.
Alkaline treatment	pH >9 during >6 months	If temperature >35 °C and moisture <25%, lower pH and/or wetter material will prolong the time for absolute elimination.

[a] No addition of new material.

For collected urine, storage criteria apply that are derived mainly from compiled risk assessment studies. The information obtained has been converted to operational guidelines to limit the risk to a level below 10^{-6} DALY, also accounting for additional health protection measures. The operational guidelines are based on source separation of urine (Table 5.3). In case of heavy faecal cross-contamination, the suggested storage times may be lengthened. If urine is used as a fertilizer of crops for household consumption only, it can be used directly without storage. The likelihood of household disease transmission attributable to the lack of hygiene is much higher than that of transmission through urine applied as a fertilizer.

Table 5.3 Recommended storage times for urine mixture[a] based on estimated pathogen content[b] and recommended crops for larger systems[c]

Storage temperature (°C)	Storage time (months)	Possible pathogens in the urine mixture after storage	Recommended crops
4	≥1	Viruses, protozoa	Food and fodder crops that are to be processed
4	≥6	Viruses	Food crops that are to be processed, fodder crops[d]
20	≥1	Viruses	Food crops that are to be processed, fodder crops[d]
20	≥6	Probably none	All crops[e]

[a] Urine or urine and water. When diluted, it is assumed that the urine mixture has a pH of at least 8.8 and a nitrogen concentration of at least 1 g/l.

[b] Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessments, but are not normally recognized as a cause of any infections of concern.

[c] A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from whom the urine was collected.

[d] Not grasslands for production of fodder.

[e] For food crops that are consumed raw, it is recommended that the urine be applied at least one month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

For all types of treated excreta, additional safety measures apply. These include, for example, a recommended withholding time of one month between the moment of application of the treated excreta as a fertilizer and the time of crop harvest (Figure 5.1). Based on QMRA, this time period has been shown to result in a probability of infection well below 10^{-4}, which is within the range of a 10^{-6} DALY level.

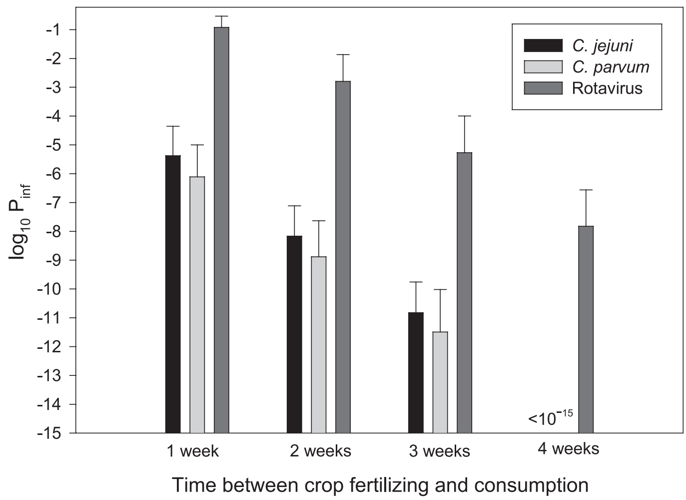

Figure 5.1
Mean probability of infection by pathogens following ingestion of crops fertilized with unstored urine with varying withholding periods (P_{inf} = probability of infection)

5.5 Health protection measures

A variety of health protection measures can be used to reduce health risks for local communities, workers and their families and for the consumers of the fertilized or irrigated products.

Hazards associated with the consumption of excreta-fertilized products include excreta-related pathogens. The risk from infectious diseases is significantly reduced if foods are eaten after proper handling and adequate cooking. The following health protection measures have an impact on product consumers:

- excreta and greywater treatment;
- crop restriction;
- waste application and withholding periods between fertilization and harvest to allow die-off of remaining pathogens;
- hygienic food handling and food preparation practices;
- health and hygiene promotion;
- produce washing, disinfection and cooking.

Workers and their families may be exposed to excreta-related and vector-borne pathogens (in certain locations) through excreta and greywater use activities. Excreta and greywater treatment is a measure to prevent diseases associated with excreta and greywater but will not directly impact vector-borne diseases. Other health protection measures for workers and their families include:

- use of personal protective equipment;
- access to safe drinking-water and sanitation facilities at farms;
- health and hygiene promotion;
- disease vector and intermediate host control;
- reduced vector contact.

Local communities are at risk from the same hazards as workers. If they do not have access to safe drinking-water, they may use contaminated irrigation water for drinking or for domestic purposes. Children may also play or swim in the contaminated water. Similarly, if the activities result in increased vector breeding, then vector-borne diseases can affect local communities, even if they do not have direct access to the fields. To reduce health hazards, the following health protection measures for local communities may be used:

- excreta and greywater treatment;
- limited contact during handling and controlled access to fields;
- access to safe drinking-water and sanitation facilities in local communities;
- health and hygiene promotion;
- disease vector and intermediate host control;
- reduced vector contact.

5.6 Monitoring and system assessment

Monitoring has three different purposes: validation, or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process to ensure that the system is achieving the specified targets.

The three functions of monitoring are each used for different purposes at different times. Validation is performed when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated excreta or greywater; crops) meets treatment targets and ultimately the health-based targets. Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring in larger systems can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing).

The most effective means of consistently ensuring safety in the agricultural use of excreta and greywater is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process from waste generation to treatment, use of excreta as fertilizers or use of greywater for irrigation purposes and product use or consumption. Three components of this approach are important for achieving the health-based targets: system assessment, identifying control measures and methods for monitoring them and developing a management plan.

5.7 Sociocultural aspects

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce excreta or greywater use schemes or to reduce disease transmission in existing schemes needs to be assessed on an individual project basis. Cultural beliefs and public perceptions of excreta and greywater use vary so widely in different parts of the world that one cannot assume that any of the local practices that have evolved in relation to such use can be readily transferred elsewhere. Even when projects are technically well planned and all of the relevant health protection measures have been included, they can fail if cultural beliefs and public perceptions have not been adequately accounted for.

5.8 Environmental aspects

Excreta are an important source of nutrients for many farmers. The direct use of excreta and greywater on arable land tends to minimize the environmental impact in both the local and global context. Reuse of excreta on arable land secures valuable fertilizers for crop production and limits the negative impact on water bodies. The environmental impact of different sanitation systems can be measured in terms of the conservation and use of natural resources, discharges to water bodies, air emissions and the impacts on soils. In this type of assessment, source separation and household-centred use systems frequently score more favourably than conventional systems.

Application of excreta and greywater to agricultural land will reduce the direct impacts on water bodies. As for any type of fertilizer, however, the nutrients may percolate into the groundwater if applied in excess or flushed into the surface water after excessive rainfall. This impact will always be less than that of the direct use of water bodies as the primary recipient of excreta and greywater. Surface water bodies are affected by agricultural drainage and runoff. Impacts depend on the type of water body (rivers, agricultural channels, lakes or dams) and their use, as well as the hydraulic retention time and the function it performs within the ecosystem.

Phosphorus is an essential element for plant growth, and external phosphorus from mined phosphate is usually supplied in agriculture in order to increase plant productivity. World supplies of accessible mined phosphate are diminishing. Approximately 25% of the mined phosphorus ends up in aquatic environments or is buried in landfills or other sinks. This discharge into aquatic environments is damaging, as it causes eutrophication of water bodies. Urine alone contains more than 50% of the phosphorus excreted by humans. Thus, the diversion and use of urine in agriculture can aid crop production and reduce the costs of and need for advanced wastewater treatment processes to remove phosphorus from the treated effluents.

5.9 Economic and financial considerations

Economic factors are especially important when the viability of a new project is appraised, but even an economically worthwhile project can fail without careful financial planning.

Economic analysis and financial considerations are crucial for encouraging the safe use of excreta. Economic analysis seeks to establish the feasibility of a project and enables comparisons between different options. The cost transfers to other sectors (e.g. the health and environmental impacts on downstream communities) also need to be included in a cost analysis. This can be facilitated by the use of multiple-objective decision-making processes.

Financial planning considers how the project is to be paid for. In establishing the financial feasibility of a project, it is important to determine the sources of revenues and clarify who will pay for what. The ability to profitably sell products fertilized with excreta or irrigated with greywater also needs analysis.

5.10 Policy aspects

Appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels facilitate safe excreta and greywater management practices. In many countries where such practices take place, these frameworks and regulations are lacking.

Policy is the set of procedures, rules, decision-making criteria and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and associated strategies allocate resources for their implementation. Policies are implemented through four types of instruments: laws and regulations; economic measures; information and education programmes; and assignments of rights and responsibilities for providing services.

In developing a national policy framework to facilitate the safe use of excreta as fertilizer, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach. National approaches for adequate sanitation based on the WHO Guidelines will protect public health optimally when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water.

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but they should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced.

5.11 Planning and implementation

Planning and implementation of programmes for the agricultural use of excreta and greywater require a comprehensive, progressive and incremental approach that responds to the greatest health priorities first. This integrated approach should be based on an assessment of the current sanitary situation and should take into account the local aspects related to water supply and solid waste management. A sound basis for such an approach can be found in the Bellagio Principles, which prescribe that stakeholders be provided with the relevant information, enabling them to make "informed choices." Thus, a wider range of decision-making and evaluation criteria for sanitation services can be applied.

In addition, project planning requires consideration of several different issues, identified through the involvement of stakeholders applying participatory methods and considering treatment, crop restriction, waste application, human exposure control, costs, technical aspects, support services and training, both for risk reduction and for maximizing the benefits from an individual as well as a community point of view.

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Notes
1. **Bold type** indicates references to tables; *italic* indicates references to figures.
2. Management summaries are not indexed.

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Annex 1
Glossary of terms used in Guidelines

This glossary does not aim to provide precise definitions of technical or scientific terms, but rather to explain in plain language the meaning of terms frequently used in these Guidelines.

Abattoir – Slaughterhouse where animals are killed and processed into food and other products.

Advanced or tertiary treatment – Treatment steps added after the secondary treatment stage to remove specific constituents, such as nutrients, suspended solids, organics, heavy metals or dissolved solids (e.g. salts).

Anaerobic pond – Treatment pond where anaerobic digestion and sedimentation of organic wastes occur; usually the first type of pond in a waste stabilization pond system; requires periodic removal of accumulated sludge formed as a result of sedimentation.

Aquaculture – Raising plants or animals in water (water farming).

Aquifer – A geological area that produces a quantity of water from permeable rock.

Arithmetic mean – The sum of the values of all samples divided by the number of samples; provides the average number per sample.

Biochemical oxygen demand (BOD) – The amount of oxygen that is required to biochemically convert organic matter into inert substances; an indirect measure of the amount of biodegradable organic matter present in the water or wastewater.

Blackwater – Source-separated wastewater from toilets, containing faeces, urine and flushing water (and eventually anal cleansing water in "washing" communities).

Buffer zone – Land that separates wastewater, excreta and/or greywater use areas from public access areas; used to prevent exposures to the public from hazards associated with wastewater, excreta and/or greywater.

Cartage – The process of manually transporting faecal material off site for disposal or treatment.

Coagulation – The clumping together of particles to increase the rate at which sedimentation occurs. Usually triggered by the addition of certain chemicals (e.g. lime, aluminium sulfate, ferric chloride).

Constructed wetlands – Engineered pond or tank-type units to treat faecal sludge or wastewater; consist of a filtering body planted with aquatic emergent plants.

Cost–benefit analysis – An analysis of all the costs of a project and all of the benefits. Projects that provide the most benefits at the least cost are the most desirable.

Cyst – Environmentally resistant infective parasitic life stage (e.g. *Giardia*, *Taenia*).

Cysticercosis – Infection with *Taenia solium* (pig tapeworm) sometimes leads to cysticerci (an infective life stage) encysting in the brain of humans, leading to neurological symptoms such as epilepsy.

Depuration – Transfer of fish to clean water prior to consumption in an attempt to purge their bodies of contamination, potentially including some pathogenic microorganisms.

Diarrhoea – Loose, watery and frequent bowel movements, often associated with an infection.

Disability adjusted life years (DALYs) – Population metric of life years lost to disease due to both morbidity and mortality.

Disease – Symptoms of illness in a host, e.g. diarrhoea, fever, vomiting, blood in urine, etc.

Disinfection – The inactivation of pathogenic organisms using chemicals, radiation, heat or physical separation processes (e.g. membranes).

Drain – A conduit or channel constructed to carry off stormwater runoff, wastewater or other surplus water. Drains can be open ditches or lined, unlined or buried pipes.

Drip irrigation – Irrigation delivery systems that deliver drips of water directly to plants through pipes. Small holes or emitters control the amount of water that is released to the plant. Drip irrigation does not contaminate aboveground plant surfaces.

Dual-media filtration – Filtration technique that uses two types of filter media to remove particulate matter with different chemical and physical properties (e.g. sand, anthracite, diatomaceous earth).

Effluent – Liquid (e.g. treated or untreated wastewater) that flows out of a process or confined space).

Encyst – The development of a protective cyst for the infective stage of different parasites (e.g. helminths such as foodborne trematodes, tapeworms and some protozoa, such as *Giardia*).

Epidemiology – The study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.

Escherichia coli **(*E. coli*)** – A bacterium found in the gut, used as an indicator of faecal contamination of water.

Excreta – Faeces and urine (see also faecal sludge, septage and nightsoil).

Exposure – Contact of a chemical, physical or biological agent with the outer boundary of an organism (e.g. through inhalation, ingestion or dermal contact).

Exposure assessment – The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent of exposure to one or more contaminated media.

Facultative pond – Aerobic pond used to degrade organic matter and inactivate pathogens; usually the second type of pond in a waste stabilization pond system.

Faecal sludge – Sludges of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies. Septage, the faecal sludge collected from septic tanks, is included in this term (see also excreta and nightsoil).

Flocculation – The agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means.

Geometric mean – A measure of central tendency, just like a median. It is different from the traditional mean (which is called the arithmetic mean) because it uses multiplication rather than addition to summarize data values. The geometric mean is a useful summary when changes in the data occur in a relative fashion.

Greywater – Water from the kitchen, bath and/or laundry, which generally does not contain significant concentrations of excreta.

Groundwater – Water contained in rocks or subsoil.

Grow-out pond – Pond used to raise adult fish from fingerlings.

Hazard – A biological, chemical, physical or radiological agent that has the potential to cause harm.

Health-based target – A defined level of health protection for a given exposure. This can be based on a measure of disease, e.g. 10^{-6} DALY per person per year, or the absence of a specific disease related to that exposure.

Health impact assessment – The estimation of the effects of any specific action (plans, policies or programmes) in any given environment on the health of a defined population.

High-growing crops – Crops that grow above the ground and do not normally touch it (e.g. fruit trees).

High-rate treatment processes – Engineered treatment processes characterized by high flow rates and low hydraulic retention times. Usually include a primary treatment step to settle solids followed by a secondary treatment step to biodegrade organic substances.

Hydraulic retention time – Time the wastewater takes to pass through the system.

Hypochlorite – Chemical frequently used for disinfection (sodium or calcium hypochlorite).

Indicator organisms – Microorganisms whose presence is indicative of faecal contamination and possibly of the presence of more harmful microorganisms.

Infection – The entry and development or multiplication of an infectious agent in a host. Infection may or may not lead to disease symptoms (e.g. diarrhoea). Infection can be measured by detecting infectious agents in excreta or colonized areas or through measurement of a host immune response (i.e. the presence of antibodies against the infectious agent).

Intermediate host – The host occupied by juvenile stages of a parasite prior to the definitive host and in which asexual reproduction often occurs (e.g. for foodborne trematodes or schistosomes, the intermediate hosts are specific species of snails).

Legislation – Law enacted by a legislative body or the act of making or enacting laws.

Localized irrigation – Irrigation application technologies that apply the water directly to the crop, through either drip irrigation or bubbler irrigation. Generally use less water and result in less crop contamination and reduce human contact with the wastewater.

Log reduction – Organism removal efficiencies: 1 log unit = 90%; 2 log units = 99%; 3 log units = 99.9%; and so on.

Low-growing crops – Crops that grow below, on or near the soil surface (e.g. carrots, lettuce).

Low-rate biological treatment systems – Use biological processes to treat wastewater in large basins, usually earthen ponds. Characterized by long hydraulic retention times. Examples of low-rate biological treatment processes include waste stabilization ponds, wastewater storage and treatment reservoirs and constructed wetlands.

Maturation pond – An aerobic pond with algal growth and high levels of bacterial removal; usually the final type of pond in a waste stabilization pond system.

Median – The middle value of a sample series (50% of the values in the sample are lower and 50% are higher than the median).

Membrane filtration – Filtration technique based on a physical barrier (a membrane) with specific pore sizes that traps contaminants larger than the pore size on the top surface of the membrane. Contaminants smaller than the specified pore size may pass through the membrane or may be captured within the membrane by some other mechanism.

Metacercariae (infective) – Life cycle stage of trematode parasites infective to humans. Metacercariae can form cysts in fish muscle tissue or on the surfaces of plants, depending on the type of trematode species.

Multiple barriers – Use of more than one preventive measure as a barrier against hazards.

Nightsoil – Untreated excreta transported without water, e.g. via containers or buckets; often used as a popular term in an unspecific manner to designate faecal matter of any origin; its technical use is therefore not recommended.

Off-site sanitation – System of sanitation where excreta are removed from the plot occupied by the dwelling and its immediate surroundings.

On-site sanitation – System of sanitation where the means of storage are contained within the plot occupied by the dwelling and its immediate surroundings. For some systems (e.g. double-pit or vault latrines), treatment of the faecal matter happens on site also, through extended in-pit consolidation and storage. With other systems (e.g. septic tanks, single-pit or vault installations), the sludge has to be collected and treated off site (see also faecal sludge).

Oocyst – A structure that is produced by some coccidian protozoa (i.e. *Cryptosporidium*) as a result of sexual reproduction during the life cycle. The oocyst is usually the infectious and environmental stage, and it contains sporozoites. For the enteric protozoa, the oocyst is excreted in the faeces.

Operational monitoring – The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is operating within design specifications (e.g. for wastewater treatment turbidity). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard break-through.

Overhanging latrine – A latrine that empties directly into a pond or other water body.

Pathogen – A disease-causing organism (e.g. bacteria, helminths, protozoa and viruses).

pH – An expression of the intensity of the basic or acid condition of a liquid.

Policy – The set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities and often allocate resources for their implementation. Policies are implemented through four types of policy instruments: laws and regulations; economic measures; information and education programmes; and assignment of rights and responsibilities for providing services.

Primary treatment – Initial treatment process used to remove settleable organic and inorganic solids by sedimentation and floating substances (scum) by skimming. Examples of primary treatment include primary sedimentation, chemically enhanced primary sedimentation and upflow anaerobic sludge blanket reactors.

Quantitative microbial risk assessment (QMRA) – Method for assessing risk from specific hazards through different exposure pathways. QMRA has four components: hazard identification; exposure assessment; dose–response assessment; and risk characterization.

Regulations – Rules created by an administrative agency or body that interpret the statute(s) setting out the agency’s purpose and powers or the circumstances of applying the statute.

Restricted irrigation – Use of wastewater to grow crops that are not eaten raw by humans.

Risk – The likelihood of a hazard causing harm in exposed populations in a specified time frame, including the magnitude of that harm.

Risk assessment – The overall process of using available information to predict how often hazards or specified events may occur (likelihood) and the magnitude of their consequences.

Risk management – The systematic evaluation of the wastewater, excreta or greywater use system, the identification of hazards and hazardous events, the assessment of risks and the development and implementation of preventive strategies to manage the risks.

Secondary treatment – Wastewater treatment step that follows primary treatment.

Involves the removal of biodegradable dissolved and colloidal organic matter using high-rate, engineered aerobic biological treatment processes. Examples of secondary treatment include activated sludge, trickling filters, aerated lagoons and oxidation ditches.

Septage – Sludge removed from septic tanks.

Septic tank – An underground tank that treats wastewater by a combination of solids settling and anaerobic digestion. The effluents may be discharged into soak pits or small-bore sewers.

Sewage – Mixture of human excreta and water used to flush the excreta from the toilet and through the pipes; may also contain water used for domestic purposes.

Sewer – A pipe or conduit that carries wastewater or drainage water.

Sewerage – A complete system of piping, pumps, basins, tanks, unit processes and infrastructure for the collection, transporting, treating and discharging of wastewater.

Sludge – A mixture of solids and water that settles to the bottom of latrines, septic tanks and ponds or is produced as a by-product of wastewater treatment (sludge produced from the treatment of municipal or industrial wastewater is not discussed).

Source separation – Diversion of urine, faeces, greywater or all, followed by separate collection (and treatment).

Subsurface irrigation – Irrigation below the soil surface; prevents contamination of aboveground parts of crops

Surface water – All water naturally open to the atmosphere (e.g. rivers, streams, lakes and reservoirs).

Thermotolerant coliforms – Group of bacteria whose presence in the environment usually indicates faecal contamination; previously called faecal coliforms.

Tolerable daily intake (TDI) – Amount of toxic substance that can be ingested on a daily basis over a lifetime without exceeding a certain level of risk

Tolerable health risk – Defined level of health risk from a specific exposure or disease that is tolerated by society, used to set health-based targets.

Turbidity – The cloudiness of water caused by the presence of fine suspended matter.

Ultraviolet (UV) radiation – Light waves shorter than visible blue-violet waves of the spectrum (from 380 to 10 nanometres) used for pathogen inactivation (bacteria, protozoa and viruses).

Unrestricted irrigation – The use of treated wastewater to grow crops that are normally eaten raw.

Upflow anaerobic sludge blanket reactor – High-rate anaerobic unit used for the primary treatment of domestic wastewater. Wastewater is treated during its passage through a sludge layer (the sludge “blanket”) composed of anaerobic bacteria. The treatment process is designed primarily for the removal of organic matter (biochemical oxygen demand).

Validation – Testing the system and its individual components to prove that it is capable of meeting the specified targets (i.e. microbial reduction targets). Should take place when a new system is developed or new processes are added.

Vector – Insect that carries disease from one animal or human to another (e.g. mosquitoes).

Vector-borne disease – Diseases that can be transmitted from human to human via insects (e.g. malaria).

Verification monitoring – The application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and/or whether the system meets specified requirements (e.g. microbial water quality testing for *E. coli* or helminth eggs, microbial or chemical analysis of irrigated crops).

Waste-fed aquaculture – Use of wastewater, excreta and/or greywater as inputs to aquacultural systems.

Waste stabilization ponds (WSP) – Shallow basins that use natural factors such as sunlight, temperature, sedimentation, biodegradation, etc., to treat wastewater or faecal sludges. Waste stabilization pond treatment systems usually consist of anaerobic, facultative and maturation ponds linked in series.

Wastewater – Liquid waste discharged from homes, commercial premises and similar sources to individual disposal systems or to municipal sewer pipes, and which contains mainly human excreta and used water. When produced mainly by household and commercial activities, it is called domestic or municipal wastewater or domestic sewage. In this context, domestic sewage does not contain industrial effluents at levels that could pose threats to the functioning of the sewerage system, treatment plant, public health or the environment.

Withholding period – Time to allow pathogen die-off between waste application and harvest.

The third edition of the WHO ***Guidelines for the safe use of wastewater, excreta and greywater*** has been extensively updated to take account of new scientific evidence and contemporary approaches to risk management. The revised Guidelines reflect a strong focus on disease prevention and public health principles.

This new edition responds to a growing demand from WHO Member States for guidance on the safe use of wastewater, excreta and greywater in agriculture and aquaculture. Its target audience includes environmental and public health scientists, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

The Guidelines are presented in four separate volumes: ***Volume 1: Policy and regulatory aspects; Volume 2:Wastewater use in agriculture; Volume 3: Wastewater and excreta use in aquaculture; and Volume 4: Excreta and greywater use in agriculture.***

Volume 1 of the Guidelines presents policy issues and regulatory measures distilled from the technical detail found in volumes 2, 3 and 4. Those faced with the need to expedite the development of policies, procedures and regulatory frameworks, at national and local government levels, will find the essential information in this volume. It also includes summaries of the other volumes in the series.

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