GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER

Volume 4
Excreta and greywater use in agriculture

World Health Organization

WHO Library Cataloguing-in-Publication Data

WHO guidelines for the safe use of wastewater, excreta and greywater / World Health Organization.

v. 1. Policy and regulatory aspects — v. 2. Wastewater use in agriculture — v. 3. Wastewater and excreta use in aquaculture — v. 4. Excreta and greywater use in agriculture.

1. Water supply. 2. Water supply - legislation. 3. Agriculture. 4. Aquaculture. 5. Sewage. 6. Wastewater treatment plants. 7. Guidelines. I. World Health Organization. II. Title: Safe use of wastewater, excreta and greywater. III. Title: Policy and regulatory aspects. IV. Title: Wastewater use in agriculture. V. Title: Wastewater and excreta use in aquaculture. VI. Title: Excreta and greywater use in agriculture.

ISBN 92 4 154686 7 (set) (NLM classification: WA 675)
ISBN 92 4 154682 4 (v. 1)
ISBN 92 4 154683 2 (v. 2)
ISBN 92 4 154684 0 (v. 3)
ISBN 92 4 154685 9 (v. 4)

Printed in France.

CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AIDS	acquired immunodeficiency syndrome
BKV	BK (polyoma)virus
BOD	biological oxygen demand
BOD_x	x-day biological oxygen demand
cfu	colony forming unit
COD	chemical oxygen demand
DALY	disability adjusted life year
EHEC	enterohaemorrhagic *E. coli*
EIEC	enteroinvasive *E. coli*
EPEC	enteropathogenic *E. coli*
ETEC	enterotoxigenic *E. coli*
FAO	Food and Agriculture Organization of the United Nations
FS	faecal sludge
HIV	human immunodeficiency virus
ID_{50}	median infectious dose
ISO	International Organization for Standardization
JCV	JC (polyoma)virus
MDG	Millennium Development Goal
PHAST	Participatory Hygiene and Sanitation Transformation
P_{inf}	probability of infection
QMRA	quantitative microbial risk assessment
SARAR	Self-esteem, Associative strengths, Resourcefulness, Action-planning, and Responsibility
T_{90}	number of days required for a decimal (90%) reduction (one log reduction)
VIP	ventilated improved pit latrine
VU	viral unit
WHO	World Health Organization
WSSCC	Water Supply and Sanitation Collaborative Council
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 excreta and greywater in agriculture are "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability." The use of excreta and greywater in agriculture 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.

To protect public health and facilitate the rational use of wastewater and excreta in agriculture and aquaculture, in 1973, the World Health Organization (WHO) developed guidelines for wastewater use in agriculture and aquaculture under the title *Reuse of effluents: Methods of wastewater treatment and health safeguards* (WHO, 1973). After a thorough review of epidemiological studies and other information, the guidelines were updated in 1989 as *Health guidelines for the use of wastewater in agriculture and aquaculture* (WHO, 1989). These guidelines have been very influential, and many countries have adopted or adapted them for their wastewater and excreta use practices.

The use of excreta and greywater in agriculture is increasingly considered a method combining water and nutrient recycling, increased household food security and improved nutrition for poor households. Recent interest in excreta and greywater use in agriculture 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 (from both technical and economic standpoints) 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. The Guidelines therefore strive to maximize overall public health benefits and the beneficial use of scarce resources.

Following an expert meeting in Stockholm, Sweden, WHO published *Water quality: Guidelines, standards and health — Assessment of risk and risk management for water-related infectious disease* (Fewtrell & Bartram, 2001). This document presents a harmonized framework for the development of guidelines and standards for water-related microbial hazards. This framework involves the assessment of health risks prior to the setting of health targets, defining basic control approaches and evaluating the impact of these combined approaches on public health status. The framework is flexible and allows countries to take into consideration health risks that may result from microbial exposures through drinking-water or contact with recreational or occupational water. It is important that health risks from the use of excreta and greywater in agriculture be put into the context of the overall burden of disease within a given population.

This volume of the *Guidelines for the safe use of wastewater, excreta and greywater* provides information on the assessment and management of risks associated with microbial hazards. It explains requirements to promote the safe use of excreta and greywater in agriculture, including minimum procedures and specific health-based targets, and how those requirements are intended to be used. This volume also describes the approaches used in deriving the guidelines, including health-based targets, and includes a substantive revision of approaches to ensuring microbial safety.

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 excreta and greywater in agriculture may contribute to that burden;
- the Stockholm Framework for 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.

ACKNOWLEDGEMENTS

The World Health Organization (WHO) wishes to express its appreciation to all those whose efforts made possible the production of the *Guidelines for the safe use of wastewater, excreta and greywater, Volume 4: Excreta and greywater use in agriculture*, in particular Dr Jamie Bartram (Coordinator, Water, Sanitation and Health, WHO, Geneva), Mr Richard Carr (Technical Officer, Water, Sanitation and Health, WHO, Geneva) and Dr Thor Axel Stenström (Head of Water and Environmental Microbiology, Swedish Institute for Infectious Disease Control, Stockholm), who coordinated the development of this volume.

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Thanks are also due to Marla Sheffer for editing the complete text of the Guidelines, Windy Prohom and Colette Desigaud for their assistance in project administration and Peter Gosling, who acted as the rapporteur for the Final Review Meeting for the Finalization of the Third Edition of the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Geneva.

The preparation of these Guidelines would not have been possible without the generous support of the United Kingdom Department for International Development, the Swedish International Development Cooperation Agency (Sida) through the Stockholm Environment Institute, the Norwegian Ministry of Foreign Affairs, the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and the Dutch Ministry of Foreign Affairs (DGIS) through WASTE (advisors on urban environment and development).

EXECUTIVE SUMMARY

This volume 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.

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 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.

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 excreta 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.

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.

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.

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 1 for excreta and greywater. Verification monitoring is not applicable to urine.

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 2.

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 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 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. co li* (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.

Table 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 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 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.

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.

Table 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.

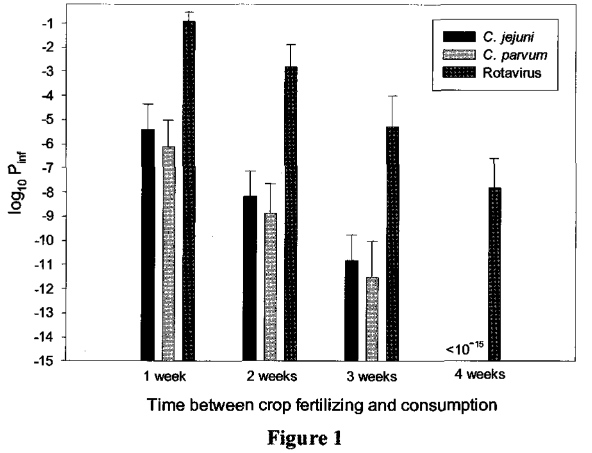

Figure 1

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

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 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.

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.

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.

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.

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.

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.

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.

Planning and implementation periode

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.