WHO GUIDELINES FOR SAFE WASTEWATER USE—MORE THAN JUST NUMBERS†

RICHARD CARR*†
World Health Organization, Geneva, Switzerland

ABSTRACT

The use of wastewater in agriculture is occurring more frequently because of water scarcity and population growth. Often the poorest households rely on this resource for their livelihood and food security needs. However, there are negative health implications of this practice that need to be addressed. WHO developed Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture in 1989. The Guidelines are currently being revised based on new data from epidemiological studies, quantitative microbial risk assessments and other relevant information. WHO Guidelines contain both microbial guideline values and good practices to reduce health risks. They must be practical and offer feasible risk management solutions that will minimize health threats and allow for the beneficial use of scarce resources. It is important that the Guidelines are based on actual health risks and an evaluation of what is a tolerable risk. This will vary from country to country. WHO Guidelines, therefore, need to be adapted to the unique social, economic and environmental factors in each situation.

To achieve the greatest impact on health, guidelines should be implemented with other health measures such as: health education, hygiene promotion, provision of adequate drinking water and sanitation, and other measures such as vaccination. Copyright © 2005 John Wiley & Sons, Ltd.

KEY WORDS: agriculture; guidelines; health protection; sanitation; wastewater use/reuse; WHO

RÉSUMÉ

L’utilisation d’eaux usées dans l’agriculture se produit plus fréquemment à l’heure actuelle en raison du manque d’eau et de la croissance démographique. Ce sont souvent les foyers les plus démunis qui dépendent de cette ressource pour leurs moyens d’existence et leurs besoins en sécurité alimentaire. Toutefois, cette pratique présente pour la santé des implications négatives qu’il faut aborder. L’OMS a rédigé des Directives de santé relatives à l’utilisation des eaux usées dans l’agriculture et l’aquaculture en 1989. Ces directives sont en ce moment mises à jour à partir de nouvelles données originales d’études épidémiologiques, d’évaluations quantitatives des risques microbiens et d’autres informations pertinentes. Les directives de l’OMS comportent à la fois des valeurs microbiennes indicatives et des méthodes adéquates pour réduire les risques de santé. Ces directives doivent être pratiques et offrir des solutions faisables de gestion des risques susceptibles de minimiser les menaces pour la santé, tout en tenant compte de la nécessité d’utiliser les ressources rares à bon escient. Il est important que ces directives se basent sur les risques de santé réels et sur une évaluation de ce qu’est un risque tolérable, évaluation qui variera d’un pays à l’autre. C’est pourquoi les directives de l’OMS doivent être adaptées aux facteurs sociaux, économiques et environnementaux uniques à chaque situation.

*Correspondence to: Richard Carr, World Health Organization, WSH/PHE/SDE, 20 Avenue Appia, CH-1211 Geneva 27, Switzerland.
E-mail: Carrr@who.int
†Directives de l’OMS pour une utilisation sans risque des eaux usées—plus que de simples chiffres.
‡The opinions expressed in this paper are those of the author and do not necessarily reflect the views and policies of WHO.

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Pour obtenir un impact maximum sur la santé, les directives doivent être mises en œuvre avec d’autres mesures de santé telles que: l’éducation à la santé, la promotion de l’hygiène, la fourniture d’eau potable et d’installations sanitaires adéquates, ainsi que d’autres mesures telles que la vaccination. Copyright © 2005 John Wiley & Sons, Ltd.

MOTS CLÉS: agriculture; directives; protection de la santé; installations sanitaires; utilisation/réutilisation des eaux usées; OMS

INTRODUCTION

The importance of increasing access to sanitation for unserved populations has been given renewed emphasis with the adoption by the United Nations General Assembly of the Millennium Development Goals in 2000 and similar International Development Targets developed at the World Summit on Sustainable Development in Johannesburg in 2002. Because much of the future population growth is expected to occur in or around urban centres, increased sanitation coverage will often take the form of sewerage with a subsequent increase in the generation of wastewater. The use of wastewater in agriculture may actually help to prevent some of the downstream health and environmental impacts especially when the alternative is to discharge wastewater (frequently without adequate treatment) directly into surface waters.

The use of wastewater in agriculture is growing due to water scarcity, population growth and the recognition of its resource value. Wastewater can be used to substitute for other better quality water sources, especially in agriculture. However, the uncontrolled use of wastewater in agriculture has important health implications for product consumers, farmers and their families, produce vendors, and communities in wastewater irrigated areas. Negative health impacts from the use of untreated or inadequately treated wastewater have been documented in many studies. Less attention has been paid to the positive health impacts of the use of wastewater in agriculture that may arise because of improved household food security, better nutrition and increased household income.

WHO Guidelines contain both microbial guideline values and good practices to reduce health risks. They offer feasible risk management solutions that will minimize health threats and allow for the beneficial use of scarce resources. The Guidelines are based on actual health risks and an evaluation of what is a tolerable risk. This will vary from country to country. WHO Guidelines are meant to be adapted to the unique social, economic and environmental factors in each situation.

This paper will look at some of the issues surrounding the use of wastewater in agriculture, the history and philosophy of the WHO Guidelines, health issues, risk management strategies, and guideline implementation.

BACKGROUND

At least one-tenth of the world’s population is thought to consume foods produced by irrigation with wastewater (Smit and Nasr, 1992). In many countries, wastewater and excreta used in crop production are not adequately treated. It has been estimated that at least 20 million ha in 50 countries are irrigated with raw or partially treated wastewater (van der Hoek, 2004; Hussain et al., 2001). Wastewater and excreta are also used in urban agriculture which often supplies a large proportion of the fresh vegetables sold in many cities, particularly in developing countries. For example in Dakar, Senegal, more than 60% of the vegetables consumed in the city are grown in urban areas using a mixture of groundwater and untreated wastewater (Faruqui et al., 2004).

WHO/UNICEF (2000) estimates the median percentage of wastewater treated by effective treatment plants to be 35% in Asia, 14% in Latin America and the Caribbean, 90% in North America and 66% in Europe. Other figures are even lower: for example, Homsi (2000) estimates that only around 10% of all wastewater in developing countries receives treatment. Given these circumstances, WHO Guidelines must include feasible strategies for maximizing health protection when untreated wastewater is used in agriculture.

The safe use of wastewater and excreta also has social equity issues. A significant percentage of wastewater and excreta use in agriculture occurs at the subsistence level. Wastewater and excreta are often seen as resources which help to improve food security and positively impact household nutrition and, thus, health.
The regulation of water quality for irrigation is of international importance because agricultural products grown with contaminated water may cause health effects at both the local and international levels. International trade in agricultural products across regions is growing. Exports of contaminated fresh produce from different geographical regions can facilitate the spread of both known pathogens and strains with new virulence characteristics into areas where the pathogens are not normally found or have been absent for many years (Beuchat, 1998).

For food exports, it is important that the wastewater is treated to the WHO recommended levels for unrestricted irrigation. This is to ensure that the risks of consuming such food are low for consumers who may not have immunity to locally endemic diseases. For food products to be consumed locally, national authorities may adapt the guideline values to fit their own circumstances.

**HISTORY OF WHO GUIDELINES**

To protect public health and facilitate the rational use of wastewater and excreta in agriculture and aquaculture, WHO developed the document ‘Reuse of Effluents: Methods of Wastewater Treatment and Public Health Safeguards’ during the period up to 1973. The first WHO Guidelines (WHO, 1973) were developed in the absence of good epidemiological studies and borrowed essentially a low-risk approach from the USA. The Guidelines specified a low microbial limit (100 coliforms 100 ml$^{-1}$) and gave specific recommendations on treatment (Havelaar et al., 2001).

In the two decades after the initial Guidelines were developed, the use of wastewater in agriculture expanded in many arid and semi-arid countries. Increasing use and the health and safety questions concerning this practice became driving forces for conducting a number of epidemiological studies. A thorough review of epidemiological studies was prepared by Shuval et al. (1986). As epidemiological evidence was compiled it became clear that the previous Guidelines needed to be revised. The following issues needed to be considered:

- Current bacterial standards were overly conservative and not based upon actual health risks as determined by epidemiological studies;
- Overly strict standards were impossible to achieve in many situations and were often ignored and
- Guidelines needed to include risk management approaches which would complement available treatment processes or could be used in the absence of wastewater treatment to reduce health risks.

Based upon these considerations the WHO Guidelines were updated in 1989 (WHO, 1989; Mara and Cairncross, 1989). These Guidelines have been very influential and many countries have adopted or adapted them for their wastewater and excreta-use practices. WHO is currently updating the 1989 Guidelines to incorporate new health evidence including risk assessment. The revised Guidelines will include more information about defining tolerable risks to society based upon the actual disease situation in any given country. This will help policy makers to better evaluate the risks in their countries and develop strategies to address the greatest health risks first.

In order to better package the Guidelines for appropriate audiences it was decided to present the Guidelines in three separate volumes: Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Guidelines for the Safe Use of Wastewater in Agriculture; Guidelines for the Safe Use of Excreta and Grey Water.

**WHO GUIDELINE PHILOSOPHY**

WHO Guidelines are based upon best available scientific evidence and broad participation. The Guidelines incorporate a risk–benefit approach and are developed around “good practices”. The Guidelines are meant to be adapted to local social, economic and environmental factors. Where the Guidelines relate to technical issues, for example wastewater treatment, technologies that are readily available and achievable (from both technical and economic standpoints), are explicitly noted. Overly strict standards may not be sustainable and, paradoxically, may lead to less 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.
It is important to recognize that in many situations where wastewater is used in agriculture, effective treatment of wastewater may not be available for many years. WHO Guidelines must therefore be practical and offer feasible risk management solutions that will maximize health protection and facilitate the beneficial use of scarce resources. To achieve the greatest benefits to health, Guidelines should be implemented with other health measures such as: health education, hygiene promotion, provision of adequate drinking water and sanitation, and other health-care measures.

In order to properly interpret and apply the Guidelines in a manner appropriate to local conditions, a broad-based policy approach is required that will include legislation as well as positive and negative incentives to alter behaviour and monitor and improve situations. Local, national and international standard-setting bodies may develop standards that differ between regions and within regions according to differences in these factors.

**EVIDENCE FOR HEALTH IMPACTS**

In 1989, the evidence at that time suggested that the use of untreated wastewater in agriculture presented a high actual risk of transmission of intestinal nematodes and bacterial infections especially to product consumers and farm workers; there was limited evidence that the health of people living near wastewater irrigated fields was affected. There was less evidence for the transmission of viruses and no evidence for the transmission of parasitic protozoa to farm workers, consumers or nearby communities. The review of epidemiological evidence by Shuval et al. (1986) also indicated that irrigation with treated wastewater did not lead to excess intestinal nematode infections among field workers or consumers (WHO, 1989).

In 2002, Blumenthal and Peasey completed a critical review of epidemiological evidence of the health effects of wastewater and excreta use in agriculture for WHO (Blumenthal and Peasey, 2002). This review was used as a basis for estimating threshold levels below which no excess infection in the exposed population could be expected. Further information on the risks of infection attributable to the exposure, and in particular the proportion of disease in the study population attributable to exposure (and therefore potentially preventable through improvement in wastewater quality), was used to inform proposals on appropriate microbiological guidelines for wastewater reuse in agriculture. The results of this epidemiological review are presented in Table I.

In many countries, industrial wastewater is often mixed with municipal wastewater and is used for irrigation. Industrial wastes may contain toxic organic and inorganic chemicals that can be taken up by crops or enter groundwater resources. It is difficult to assess the impacts on health because of the problem of associating chronic exposure to chemicals with diseases having long latency periods. However, health effects from both organic chemicals and heavy metals have been observed in some countries where industrial wastewater has been used for irrigation. The health risks associated with chemicals found in wastewater and sludge may need to be given more attention, particularly as industrialization increases in developing countries. The best defence against exposure to toxic chemicals during crop irrigation is to prevent their addition to the wastewater in the first place. This can be achieved by treating industrial wastewater separately, preventing it from being discharged into municipal wastewater streams or requiring pretreatment of the industrial wastewater before it is added to the municipal wastewater stream.

In general, wastewater of domestic origin is not likely to contain toxic chemicals in concentrations likely to lead to health problems for either the farmers or the crop consumers.

**WHO GUIDELINES AND RISK MANAGEMENT**

The protection of public health can best be achieved by using a “multiple barrier” approach that interrupts the flow of pathogens from the environment (wastewater, crops, soil, etc.) to people (Figure 1). Human pathogens in the fields do not necessarily represent a health risk if other suitable health protection measures can be taken. These measures may prevent pathogens from reaching the worker or the crop or, by selection of appropriate crops (cotton, for example), may prevent pathogens on the crop from affecting the consumer (WHO, 1989; Mara and Cairncross, 1989). The available measures come under five main categories:
It will often be desirable to apply a combination of several methods. Sometimes partial treatment to a less demanding standard may be sufficient if combined with other measures such as crop restriction, but it may need to be supplemented by additional measures to protect agricultural workers.

**Waste treatment**

The removal or inactivation of excreted pathogens is the principal objective of wastewater treatment; and treatment to levels proposed by Blumenthal et al. (2000a) should be adequate to protect public health. Conventional wastewater treatment options (primary and secondary treatments) are often better at removing environmental pollutants than removing pathogens, however, and many of these processes may also be difficult and costly to operate properly in developing country situations. Waste stabilization ponds (WSP), when designed and operated properly, are highly effective at removing pathogens and can be operated at low cost where inexpensive land is available. They are designed to use natural processes of biodegradation, disinfection by sunlight, and particle settling under gravity, to purify the water. They form a series of shallow ponds linked together to maximize retention time. However, WSPs should be designed, operated and maintained in such a way as to prevent disease vectors from breeding in the ponds.

Where effective treatment is not available, it may be possible to consider other options that improve microbial water quality, such as storage reservoirs to partially treat wastewater or water abstraction from surface waters some
distance from wastewater discharges where dilution has already taken place. For example, in Mexico, irrigation with untreated wastewater was frequently associated with *Ascaris* infections and diarrhoea in farm workers and their families, which could be prevented by using wastewater that had been retained in a series of reservoirs (Cifuentes et al., 2000). If reservoirs are designed specifically to increase residence time they can be effective in improving microbial water quality. Reservoirs have the added advantage of storing the wastewater for use in the dry season—often a time of peak demand.

There is a need for research and development work to improve the helminth-egg removal efficacy of wastewater treatment systems to meet the microbial standards. In some situations, the quality of primary or secondary-treated effluents can be improved by further treatment in a single polishing (maturation) pond of 5 days’ retention time (Blumenthal et al., 2000b).

**Crop restriction**

Water of poorer quality can be used to irrigate non-vegetable crops such as cotton or crops that will be cooked before consumption (e.g. potatoes). However, crop restriction may protect the health of consumers but not farm workers and their families. It is therefore not an adequate single control measure, but should be considered within an integrated system of control (Blumenthal et al., 2000b). In Chile the use of crop restriction when implemented with a general hygiene education programme significantly reduced the transmission of cholera from the consumption of raw vegetables; it has also been used effectively in Mexico and Peru (Blumenthal et al., 2000b; Peasey et al., 2000).

**Irrigation technique**

Because of the formation of aerosols, spray/sprinkler irrigation has the highest potential to spread contamination on crop surfaces and affect nearby communities. Where spray/sprinkler irrigation is used with wastewater it may
be necessary to set up a buffer zone (e.g. 50–100 m from houses and roads) to prevent a health risk for local communities.

Farm workers and their families are at the highest risk when flood or furrow irrigation techniques are used, particularly when protective clothing is not worn and earth is moved by hand. Localized irrigation techniques (e.g. bubbler, drip, trickle) offer farm workers the most health protection because the wastewater is applied directly to the plants; but are problematical if the wastewater has suspended material in it which clogs the water emitters. Although these techniques are generally the most expensive to implement, drip irrigation has recently been adopted by some farmers in Cape Verde and India (FAO, 2001; Kay, 2001). Drip irrigation also improves crop yields and reduces water use.

Cessation of irrigation for 1–2 weeks prior to harvest can be effective in reducing crop contamination. Many vegetables need watering nearly until harvest to increase their market value, but this option may be possible with some fodder crops that do not have to be harvested at the peak of their freshness.

**Human exposure control**

Four groups of people are at potential risk:

- agricultural field workers and their families
- crop handlers
- consumers (of crops, meat and milk), and
- those living near the affected fields.

Agricultural field workers are at high risk of parasitic infections. Exposure to hookworm infection can be reduced, even eliminated, by the use of less contaminating irrigation methods (as above) and by the use of appropriate protective clothing (i.e. shoes for field workers and gloves for crop handlers). A rigorous health education programme that targets consumers, farm workers, produce handlers and vendors is needed. Hand washing with soap is a very important behaviour that needs to be emphasized. The simple act of handwashing with soap can reduce the transmission of diarrhoeal disease by up to 33% (WHO, 1993). Field workers should be provided with adequate sanitation facilities and safe water for drinking and hygiene purposes, in order to avoid the consumption of, and contact with, wastewater. Similarly, sanitation facilities and safe water should be provided at markets for washing and "freshening" produce. Vendors need to practise good personal and food hygiene. Consumers can cook vegetables, meat and milk, and practise good personal and domestic hygiene to protect their health. Meat should be inspected and carcasses infected with tapeworm larvae should be rejected (WHO, 1989; Mara and Cairncross, 1989).

**Chemotherapy and vaccination**

Anti-helminthic treatment and immunization cannot normally be considered as an adequate strategy to protect farm workers and their families. Immunization against helminthic infections and most diarrhoeal diseases is currently not feasible. However, for highly exposed groups or sensitive subpopulations (e.g. tourists), immunization against typhoid and hepatitis A may be worth considering. Anti-helminthic treatment of intense nematode infections in children and the control of anaemia in both children and adults, especially women and post-menarche girls, is important. Treatments must be reapplied at regular intervals to be effective—several times a year for children living in endemic areas (Blumenthal *et al.* 2000b; Peasey *et al.*, 2000).

**HOW THE GUIDELINES ARE IMPLEMENTED**

It is important to consider the health implications of any standards or regulations which are enacted. In countries where low sanitation standards prevail very little of the faecal–oral disease may actually be associated with the use of wastewater irrigation. Thus, even enacting stringent standards on the use of wastewater may not have a
measurable impact on disease transmission. Therefore, an attempt to define a tolerable risk to society may be necessary for prioritizing the greatest health risks first. The revised Guidelines include discussion of tolerable risks and methods for prioritizing health threats.

Phased implementation of the WHO Guidelines may be necessary as treatment is gradually introduced and improved over a period of time (e.g. 1–15 years). Implementation of the WHO Guidelines will protect public health most when it is integrated into a comprehensive public health programme that includes other sanitary measures such as personal and domestic hygiene education. For example, it may be possible to link health education and hygiene promotion to agricultural extension activities or other health programmes (e.g. immunization programmes).

Guideline implementation will be different in each setting. For example, urban and peri-urban areas are likely to pose challenges because of the dispersed nature of agriculture in these areas and the greater number of small plots. Inspectors may have a hard time ensuring that effective crop restriction is taking place or visiting all of the areas where wastewater is used in agriculture. Crop restriction will be more effective if the types of crops that can be grown are in demand and command an adequate price (e.g. potatoes or maize) in the local market. However, markets may offer additional points of intervention where local authorities may have more control over water supplies, hygiene and sanitation facilities.

The key to guideline implementation is setting realistic standards and flexibility. WHO Guidelines need to be adapted for the social, economic and environmental conditions of each country. When countries with high levels of excreta-related disease background levels and inadequate resources for wastewater treatment adopt overly strict water quality standards for use in agriculture, it may lead to a lower level of health protection because, in these circumstances, the standards may not significantly change the background level of disease and/or may be viewed as unachievable and thus ignored entirely.

Flexible solutions are needed. Wastewater treatment could be in the form of small, locally developed, decentralized facilities closer to where the wastewater is generated. An initial aim of partial treatment—e.g. to meet the WHO helminth guideline value—may be required, eventually phasing in the other requirements over a period of years as the infrastructure becomes available. For example, in Mexico, the wastewater treatment infrastructure was often not able to reduce nematodes to the guideline value of less than one viable intestinal nematode egg per litre, so they established the standard at less than five eggs per litre. Improving the water quality to the standard of five may still yield some health benefits and when combined with aggressive anti-helminthic campaigns targeted at farmers this can help to mitigate some of the negative health consequences (Blumenthal et al., 2000a; Peasey et al., 2000).

Similarly, in order to gain acceptance by local farmers, crop restriction requirements in Mexico had to be flexible to allow farmers to grow chillies (a crop often eaten raw) with water that did not meet unrestricted standards. If this was not the case it is likely that crop restriction would have failed entirely in this situation.

CONCLUSIONS

WHO Guidelines are based upon scientific evidence and built around good practices. WHO Guidelines are meant to maximize the protection of public health and allow for the safe use of important resources. Countries should use the WHO Guidelines as a scientific point of departure and adapt the Guidelines to their own special situations.

The use of wastewater in agriculture can be managed in a way that makes it safer—even when adequate wastewater treatment is unavailable. Strategies for managing health risks to achieve the health targets include wastewater treatment to achieve appropriate microbiological quality guidelines, crop restriction, waste application methods, control of human exposure, chemotherapy and vaccination. A combination of the above strategies will offer the most health protection. In situations where resources are very limited, steps should be taken to address the greatest health risks first. For example, in many areas partially treating wastewater to remove helminth eggs will offer some health protection. Phased implementation of the WHO microbial water quality standards may be necessary as treatment is gradually introduced and improved over a period of time (e.g. 1–15 years). For maximal public health effect, the Guidelines should be co-implemented with other health interventions such as hygiene promotion, provision of adequate drinking water and sanitation, and other health-care measures.
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