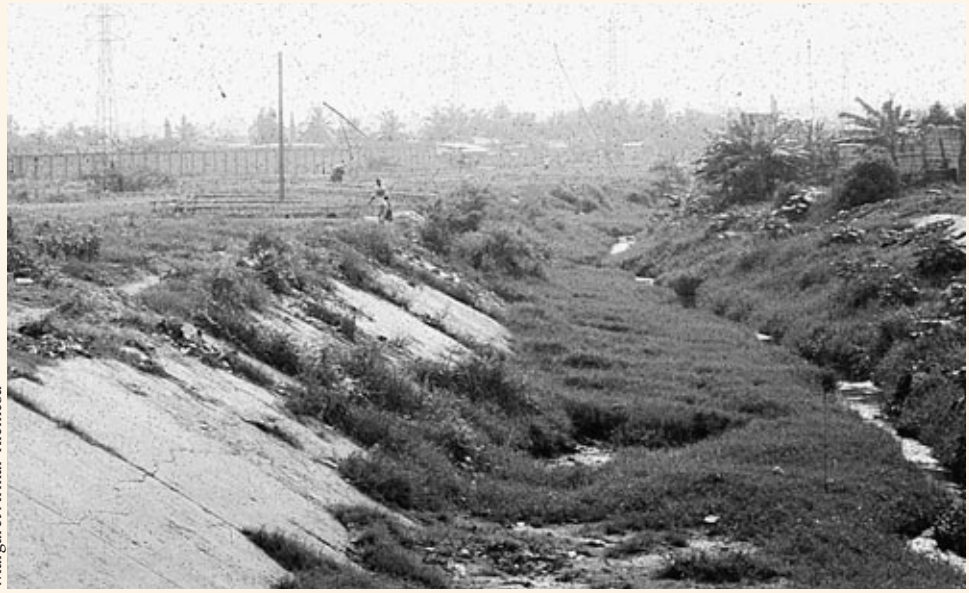
Reducing the Health Risks of Using Wastewater in Agriculture

Recommended Changes to WHO Guidelines



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Major drains carrying domestic and other waste in Accra

In many areas of the world, urban agriculture depends on water supplies for irrigation. Water is often extracted from rivers, and these may be contaminated with wastewater, discharged into the river with little or no prior treatment. In some areas, untreated wastewater is used for irrigation directly. Use of both can increase the risk of gastrointestinal diseases for farm workers and their families, and for the consumers of the crops. Policy makers and farmers need to know what quality of water they can use, and what forms of wastewater treatment (or other health protection measures) can be employed. As the water available for irrigation often does not meet national standards or international guidelines for wastewater reuse, this poses a challenge to the safe development of urban agriculture.

Standards for wastewater reuse in many countries have been influenced by the WHO (1989) health guidelines (table 1), and the USEPA/USAID (1992) guidelines (which are much stricter). The WHO guidelines are proposed as a guide for policy makers as to which wastewater treatment processes, crops and irrigation methods are appropriate for safe agricultural production. They are not meant as standards for daily water monitoring at a local level. The WHO guidelines recognise the benefits that can be gained from using appropriately treated wastewater in agriculture, and aim to promote safe use of wastewater, and take into account the social, epidemiological and economic conditions that occur in specific countries.

Guideline standards are set for microbiological indicators of faecal pollution: faecal coliform bacteria and for nematode eggs. The first is intended to protect exposed persons from bacterial and viral infections (e.g. salmonella) and the latter, from helminth (and protozoal) infections.

The WHO guidelines have been influential in setting the standard in parts of Europe, Asia, and Latin America. They have been successful in raising awareness of the need for wastewater treatment and wastewater quality standards for agriculture and in proposing guideline limits that are achievable through comparatively low-cost treatment methods. However, many countries have not set wastewater standards whereas other countries do not possess the structural capacity or financial resources to apply appropriate wastewater treatment to achieve them.

Glossary of terms

- *Enteric infections* – infections of the alimentary canal (gut)
- *Guideline limits* – level at which persons exposed to water of this quality would not be at risk of infection
- *Faecal coliforms* – bacteria found in the faeces of warm blooded animals; the numbers found in water indicate the level of faecal or sewage pollution and the numbers found in treated wastewater indicate the effectiveness of wastewater treatment
- *Nematode* – round worm
- ≤ less than or equal to

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WHO is currently revising the 1989 guidelines to take into account new evidence. This paper summarises the main recommendations of a review of epidemiological, microbiological and risk assessment studies and their implications for the WHO guidelines (Blumenthal et al, 1999, Blumenthal et al 2000). The article gives recommendations for changing the guidelines and proposes appropriate wastewater treatment methods that can be used to achieve the new microbiological guideline limits. The results of the official WHO review should be available in early 2002. Policy makers need to regulate the use of water for irrigation, according to the degree of treatment and the type of crops grown. Plans may need to be made for providing wastewater treatment or restricting the type of crops which farmers can grow. Farmers need to be made aware that they are putting their health at risk by using contaminated water and they may wish to put pressure on their municipalities to provide them with safe water for agricultural use.

SETTING MICROBIOLOGICAL GUIDELINES

Currently three methods are used for establishing microbiological-quality guidelines and standards for treated wastewater reuse in agriculture: (I) the measurement of faecal indicator organisms in the wastewater, (II) the determination of (excess) cases of associated diseases in the exposed population, and (III) the use of a model-generated estimated risk. In the review of the guidelines, method II, (using epidemiological studies and microbiological studies) and method III, (using model-based quantitative microbial risk assessment) were used.

In the following, the wastewater guideline standards for unrestricted and restricted irrigation will be considered here. Firstly the current standards will be discussed, and whether evidence suggests that these are appropriate (sufficient) for limiting health risks. Subsequently, some examples of studies of wastewater quality monitoring will be given, and whether they indicate that the standards need to be changed. The 1989 WHO Guidelines are given below. In the text, the reader is referred to this table and to the table at the back of this article, in which revisions to these guidelines are proposed.

UNRESTRICTED IRRIGATION

This refers to the situation where water may be used to grow any crops using any irrigation method without health risks including crops that can be eaten raw.

Category A: Faecal Coliform (FC) guideline limit ≤1000 per 100ml

The results of studies on consumer risks do not suggest the need to change the WHO guideline, of $\leq 10^3$ FC/100ml for unrestricted irrigation.

Epidemiological studies suggest that risks of infections are significant only when the guideline is exceeded by a factor 13. Microbiological studies in Portugal (Vaz da Costa Vargas et al 1996) indicate that the *crop quality,* of crops irrigated with *water* just exceeding the guideline value, remained within the recommendations of the International Commission on Microbiological Specifications for Foods (1974), which is set at $\leq 10^5$ FC per 100g fresh weight for vegetables eaten uncooked. This suggests that the WHO guideline is appropriate in hot climates. Nevertheless, in situations where there are insufficient resources to reach the standard of 1000 FC/100ml for irrigation water, a more relaxed guideline of

Table 1. The 1989 WHO guidelines for the use of treated wastewater in agriculture[a]

Category	Reuse conditions	Exposed group	Intestinal nematode *(arithmetic mean no. eggs per litre)*[c]	Faecal coliforms *(geometric mean no. per 100ml)*[c]	Wastewater treatment expected to achieve the required microbiological guideline
A	*Irrigation of crops likely to be eaten uncooked, sports fields, public parks*[d]	*Workers, consumers, public*	*≤ 1*	*≤ 1000*	*A series of stabilisation ponds designed to achieve the microbiological quality indicated, or equivalent treatment*
B	*Irrigation of cereal crops, industrial crops, fodder crops, pasture and treese*	*Workers*	*≤ 1*	*No standard recommended*	*Retention in stabilisation ponds for 8-10 days or equivalent helminth and faecal coliform removal*
C	*Localized irrigation of crops in category B if exposure to workers and the public does not occur*	*None*	*Not applicable*	*Not applicable*	*Pretreatment as required by irrigation technology, but not less than primary sedimentation*

[a] *In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account and the guidelines modified accordingly.*

[b] *Ascaris and Trichuris species and hookworms.*

[c] *During the irrigation period.*

[d] *A more stringent guideline (≤ 200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may cone into direct contact.*

[e] *In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should be used.*

10^4 FC/100ml could be adopted. This should be supplemented by other health protection measures.

Nematode egg guideline limit ≤1 egg/litre

This guideline limit appears to be adequate to protect consumers of cultivated vegetables, which are spray-irrigated with effluent of consistent quality and at high temperatures. This is not necessarily the case for consumers of vegetables, which are surface-irrigated with such effluent at lower temperatures.

Studies show that irrigation with wastewater of the WHO category A guideline quality resulted in no contamination of lettuce at harvest or very slight contamination on a few plants (6%) with eggs that were either degenerate or not infective. In Brazil it was shown, that a few nematode eggs on harvested plants were viable but not embryonated (<0.1 Ascaris galli eggs per plant irrigated with 1-10 eggs per litre). So crops with a long shelf life might represent a potential risk to consumers if these eggs had time to become infective.

Epidemiological data indicate that factors in the field may alter the situation. Children who ate field vegetables irrigated with water of (1 nematode egg/litre within the guideline), had a similar prevalence of *Ascaris* infection as when the irrigation was with untreated wastewater (Peasey et al, 2000). It is therefore recommended that a stricter guideline of ≤0.1 eggs per litre is adopted. A guideline of ≤1 nematode-egg/litre may be adequate where crops with a short shelf life are grown (e.g. salad crops), or where the aim is to control disease intensity instead of trying to prevent transmission of infection.

RESTRICTED IRRIGATION

This applies to water used for irrigating a restricted range of crops, for example, cereals, fodder crops, pasture, trees, and crops, which are processed before consumption.

Category B: Faecal Coliform guideline limit not set

The WHO Guidelines do not include a limit for faecal coliform bacteria for this category, due to the lack of evidence of a risk of bacterial and viral infections for farm workers and nearby residents.

Recent evidence of enteric infections in farming families in direct contact with partially treated wastewater and in populations living near sprinkler irrigated fields, suggests that a FC guideline should be added when the water quality exceeds 10^6 FC/100ml.

Data from prospective epidemiological studies in Israel and the USA, suggest that a level of ≤10^5 FC per 100 ml would protect both farm workers and nearby population groups from infection via direct contact or wastewater aerosols when spray/sprinkler irrigation was used (Shuval et al., 1989 and Camann et al. 1986). This refers to category B1 in the table.

Data from Mexico, however, show that in a situation under flood and furrow irrigation with partially treated wastewater from urban areas, with direct contact, there may still be a risk of diarrhoeal disease at a level of 10^3-10^4 FC per 100ml (Blumenthal et al, 1998). Therefore, a reduced guideline level of ≤10^3 FC per 100ml would be safer where adult farm workers are engaged in flood or furrow irrigation (Category B2 in the table) or where children are regularly exposed (Category B3).

Where there are insufficient resources to provide treatment to reach this stricter guideline, a guideline of 10^5 FC per 100ml should be supplemented by other health protection measures (for example, health education concerning wastewater, and the importance of hand washing with soap after wastewater contact).

Nematode Egg: guideline limit ≤1 egg/litre

The guideline limit is adequate if no children are exposed (Category B1 and B2), but a revised guideline of ≤0.1 egg per litre is recommended if children are in contact with the wastewater through irrigation or play (Category B3).

Children in contact with effluent from a storage reservoir which met WHO Guidelines had increased prevalence and intensity of *Ascaris* infection, but when the effluent had been stored in two reservoirs and no nematode eggs were detectable, there was very little excess *Ascaris* infection in any age group (Cifuentes, 1998). Here also a stricter guideline of ≤0.1 eggs per litre is recommended where children are exposed to irrigation water.

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Alternatively, a country with limited resources aiming at disease control could adopt a less strict guideline and adopt additional health protection measures; such as, human exposure control and drug treatment

WASTEWATER TREATMENT AND OTHER HEALTH PROTECTION MEASURES

Appropriate wastewater treatment is essential to ensure that the wastewater microbiological quality guidelines are achieved. In many situations in developing countries, wastewater treatment in *waste stabilisation ponds* is recommended. These systems comprise one or more series of anaerobic, facultative and maturation ponds. They are shallow, usually rectangular, "lakes" into which wastewater continuously flows and from which an effluent is discharged. Anaerobic and facultative ponds are primarily for the removal of organic matter, although they are very effective in removing intestinal nematode eggs and *Vibrio cholerae* (Ayres et al, 1992, Oragui et al, 1993). Maturation

Table 2 Recommended revised microbiological guidelines for treated wastewater use in agriculture[a]

Category	Reuse Conditions	Exposed group	Irrigation technique	Intestinal nematodes [b] (arithmetic mean no. of eggs per litre [c])	Faecal coliforms (geometric mean no. per 100ml [d])	Wastewater treatment expected to achieve required microbiological quality
A	***Unrestricted irrigation***					*Well designed series of waste stabilisation ponds (WSP), sequential batch-fed wastewater storage and treatment reservoirs (WSTR) or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration and disinfection)*
	A1 *Vegetable and salad crops eaten uncooked, sports fields, public parks [e]*	*Workers, consumers, public*	*Any*	*≤ 0.1 [f]*	*≤ 10^3*	
B	***Restricted irrigation***					
	Cereal crops, industrial crops, fodder crops, pasture and trees [g]	***B1*** *Workers (but no children <15 years), nearby communities*	*(a) Spray/ sprinkler*	*≤ 1*	*≤ 10^5*	*Retention in WSP series incl. one maturation pond or in sequential WSTR or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration)*
		B2 *As B1*	*(b) Flood/ furrow*	*≤ 1*	*≤ 10^3*	*As for Category A*
		B3 *Workers including children <15 years, nearby communities*	*Any*	*≤ 0.1*	*≤ 10^3*	*As for Category A*
C	*Localised irrigation of crops in category B if exposure of workers and the public does not occur*	*None*	*Trickle, drip or bubbler*	*Not applicable*	*Not applicable*	*Pretreatment as required by the irrigation technology, but not less than primary sedimentation,*

a In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account and the guidelines modified accordingly.
b Ascaris and Trichuris species and hookworms; the guideline is also intended to protect against risks from parasitic protozoa.
c During the irrigation season (if the wastewater is treated in WSP or WSTR which have been designed to achieve these egg numbers, then routine effluent quality monitoring is not required).
d During the irrigation season (faecal coliform counts should preferably be done weekly, but at least monthly).
e A more stringent guideline (≤200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
f This guideline can be increased to ≤1 egg per litre if (i) conditions are hot and dry and surface irrigation is not used, or (ii) if wastewater treatment is supplemented with anthelmintic chemotherapy campaigns in areas of wastewater re-use.
g In the case of fruit trees, irrigation should cease two weeks before fruit is picked and no fruit should be picked off the ground. Spray/sprinkler irrigation should not be used.

ponds are used mainly for the removal of excreted bacteria and viruses. In arid and semiarid areas the use of *wastewater storage and treatment reservoirs* is beneficial as they permit "the whole year's" wastewater to be used for irrigation (rather than that produced during the irrigation season only). This enables an area two to three times bigger to be irrigated. A single reservoir, receiving anaerobic pond effluent is suitable if the reservoir contents are used only for restricted irrigation, as the long retention time ensures the settlement of all helminth eggs (and as long as no children are exposed to the effluent). Three parallel reservoirs, operated as sequential batch systems, are needed to permit unrestricted irrigation.

Design criteria for both systems are given by Mara (1997). Conventional treatment processes often still require secondary treatment, filtration and disinfection, to meet the revised guidelines. The high cost and difficulty in operating conventional treatment plants, means they are not recommended where the other two systems can be used. Sufficient land may not be available for building waste stabilisation ponds in the town or city itself, but may be available in the peri urban areas.

Even though it is the best health protection option, wastewater treatment for unrestricted irrigation may not be possible whereas that for unrestricted irrigation is (often for reasons of cost). Use of localised irrigation does not require achievement of water quality but it is an expensive system. Worker protection can theoretically be achieved at low cost by the provision of obligatory footwear, but can be difficult to achieve in practice. The hygienic handling of harvested crops is also important; recommendations are given by WHO (1998). Examples of the use of other health protection measures in a specific country setting are given by Peasey et al (1999). Community interventions using health promotion programmes and/or regular drug treatment programmes can be considered, in particular where no wastewater treatment is provided or where there is a time delay before treatment plants can be built.