The safe use of urban wastewater in agriculture

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In most developing countries, where wastewater is used for irrigation, it is commonly used without adequate treatment. The WHO brought out guidelines on the agricultural use of wastewater that are now being updated. The different levels of water treatment required for which crops and under what conditions this water should be used are given in the guidelines, and outlined here.

WHO published *Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture* in 1989. The *Guidelines* have been very influential and many countries have adopted or adapted them for their wastewater and excreta-use practices (e.g., France, Mexico). It is now necessary to update the *Guidelines* to take into account recent scientific evidence and to address changes in sanitation practices; in particular, both risk assessment and epidemiological data are to be reviewed. New practices such as ecological sanitation and urine separation/diversion also need closer scrutiny.

To help the *Guidelines* reach the appropriate audiences, three separate volumes will be developed: *Guidelines for the Safe Use of Wastewater in Agriculture*; *Guidelines for the Safe Use of Wastewater and Excreta in Aquaculture*; and *Guidelines for the Safe Use of Excreta and Grey Water*. It is anticipated that the *Guidelines* will be completed in 2005.

Blumenthal et al. (2000a)[1] recommend revised guideline values for a variety of agricultural situations, as shown in Table 1. These are general rules, in specific cases local epidemiological, sociocultural and environmental factors should be taken into account and the guidelines modified accordingly.

Adaptation of the WHO *Guidelines* for national use

France. WHO guidelines serve as a scientific point of departure for French National Recommendations for the use of wastewater in agriculture. France has retained the WHO recommended microbial guidelines (Table 1, numbers in brackets) but complements them with strict application requirements for specific situations. Authorities retain the right to restrict wastewater use based on a case-by-case review of very detailed site-specific information.[2]

*Mexico***.** Mexican standards for wastewater use in agriculture are also based on WHO recommended microbial guideline values with some slight modifications. Microbial values for unrestricted irrigation are the same, but for restricted irrigation the faecal coliform limits are stricter while the requirements for intestinal nematode eggs are looser. This change is based on the realization that current treatment infrastructure in Mexico cannot meet the stricter nematode standards.[3]

Health effects

Health effects can be both negative and positive. Domestic wastewater contains a wide range of human pathogens (see Table 2) that can survive in the environment for long enough to be transmitted to humans via water and food. Irrigation with inadequately treated wastewater has been linked to disease outbreaks and may also cause some of the background disease in some countries – especially helminth infections. The people at most risk are the farmers and their families (through contact with the wastewater and consumption of the produce), the crop handlers and the product consumers.

In many countries, industrial wastewater is often mixed with municipal wastewater and is used for irrigation. Industrial wastes may contain toxic

Treated wastewater is often used to irrigate public spaces Credit: WHO photo library

Table 1. Recommended revised microbiological guidelines for treated wastewater use in agriculture (values in brackets are the 1989 *Guideline* values)[1]

Category	Reuse conditions	Exposed group	Irrigation technique	Intestinal nematodes[a] (arithmetic mean no. eggs per litre[b])	Faecal coliforms (geometric mean no. per 100 m)[c]	Wastewater treatment expected to achieve required microbiological quality
A	Unrestricted irrigation A1 Vegetable and salad crops eaten uncooked, sports fields, public parks[d]	Workers, consumers, public	Any	$\leq$ 0.1 [$\leq$ 1][e]	$\leq 10^3$	Well-designed series of waste stabilization 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)
B	Restricted irrigation Cereals, industrial crops, fodder, pasture and trees[f]	B1 Workers (but no children <15 years), nearby communities	(a) Spray/ sprinkler	$\leq$ 1	$\leq 10^5$ [no standard]	Retention in WSPs including 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	$\leq$ 1	$\leq 10^3$ [no standard]	As for Category A
		B3 Workers including children < 15 years, nearby communities	Any	$\leq$ 0.1 [$\leq$ 1]	$\leq 10^3$ [no standard]	As for Category A
C	Localized irrigation of crops in category B if workers and public are not exposed	None	Trickle, drip or bubbler	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation.

Notes
a *Ascaris* and *Trichuris* species and hookworms; the guideline is also intended to protect against risks from parasitic protozoa.
b Measured 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).
c During the irrigation season (faecal coliform counts should preferably be done weekly, but at least monthly).
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 come into direct contact.
e 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 anti-helminthic chemotherapy campaigns in areas of wastewater reuse.
f 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.

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 use of wastewater in agriculture also has positive benefits on health and the environment that are often overlooked. Wastewater can be an important resource for poor farmers, especially when there is no other source of water and/or when the farmers are too poor to afford fertilizers. Wastewater irrigation can therefore contribute to better nutrition and household food security. Using wastewater for irrigation can also control the pollution of water resources, which has indirect health benefits.

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. 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.[4] The available measures come under five main categories:

- waste treatment
- crop restriction
- irrigation technique

Table 2. Examples of pathogens found in untreated urban wastewater

Agent	Illness/disease
Bacteria	
Escherichia coli (some types)	Gastroenteritis
Salmonella typhi	Typhoid
Shigella (several serotypes)	Dysentery
Vibrio cholerae	Cholera
Helminths	
Ascaris (roundworm)	Ascariasis – roundworm infection
Ancylostoma (hookworm)	Hookworm infection/anaemia
Fasciola (liver fluke)	Fascioliasis – liver damage
Taenia (Tapeworm)	Taeniasis – tapeworm infection
Protozoa	
Cryptosporidium parvum	Cryptosporidiosis, diarrhoea, fever
Entamoeba histolytica	Dysentery (bloody diarrhoea)
Giardia lamblia	Giardiasis (gastroenteritis)
Viruses	
Enteroviruses (many types)	Gastroenteritis, various
Hepatitis A and E viruses	Infectious hepatitis
Norovirus	Gastroenteritis, various
Rotavirus (several types)	Gastroenteritis

- human exposure control
- chemotherapy and vaccination.

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.

Treatment

The removal or inactivation of excreted pathogens is the principal objective of wastewater treatment; and treatment to levels proposed by Blumenthal et al. (Table 1) should be adequate to protect public health. Conventional wastewater treatment options (primary and secondary treatments) are often better at removing environmental pollutants (e.g. those resulting in biological oxygen demand) 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 – see Technical Brief in this edition of *Waterlines*), 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 such as sunlight, pH, temperature and particle settling to purify the water.

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. 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 retaining wastewater in two reservoirs linked in series.[5] 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 conventional 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 with 5 days' retention time.[4]

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. 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.

Waste application methods

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 furrow or flood 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. Although these techniques are generally the most expensive to implement, drip irrigation has recently been adopted by some farmers in Cape Verde and India.[6]

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 are at potential risk:

- agricultural field workers and their families
- crop-handlers
- consumers (of crops, meat and milk)
- 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 should be emphasized. Field workers should be provided with adequate water for drinking and hygiene purposes, to avoid the consumption of, and contact with, wastewater.

Similarly, safe water should be provided at markets for washing and 'freshening' produce. 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.

Chemotherapy and vaccination

Chemotherapy 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 sub-populations (e.g. tourists), immunization against typhoid and hepatitis A may be worth considering. Chemotherapeutic control of intense nematode infections in children and the control of anaemia in both children and adults, especially women and post-menarche girls, is important. Chemotherapy must be reapplied at regular intervals to be effective – several times a year for children living in endemic areas.

How the *Guidelines* are implemented

Phased implementation of the WHO guidelines may be necessary as treatment is gradually introduced and improved over (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 including 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 for inspectors because of the dispersed nature of agriculture in these areas and the greater number of small plots. 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 keys to guideline implementation are setting realistic standards and flexibility.[8] Microbial water quality 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 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, can help to mitigate some of the negative health consequences.[3]

About the author

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