USE OF TREATED WASTEWATERS IN AGRICULTURE

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ABSTRACT
Wastewaters used for crop irrigation, if treated to the WHO microbiological guidelines, do not pose significant health risks. Multi-trial Monte Carlo simulations of microbial risk calculation have shown that the risks associated with the consumption of wastewater-irrigated salad crops are less than WHO's tolerable risk of waterborne infection from drinking fully treated drinking water. The risks are higher for fieldworkers, but of the same order as the incidence of diarrhoeal disease in the general population in developing countries. Provided wastewaters comply with FAO's recommendations for the physicochemical quality of irrigation waters, crop yields are not reduced. Treatment of domestic wastewaters in either waste stabilization ponds or wastewater storage and treatment reservoirs is likely to be most appropriate in most cases in developing countries, as they readily and cost-effectively achieve the required microbiological quality

KEYWORDS
Irrigation, reuse, risk analysis, wastewater.

INTRODUCTION
Water scarcity is increasingly affecting all parts of our world, especially developing countries – where, if the WHO/UNICEF target of Water and Sanitation for All by 31 December 2025 is to be met, ~2.9 billion people will need to receive an improved water supply during 2001–2025 (WHO, 2000).

Agriculture uses ~70 percent of the world’s freshwater for irrigation – and much of this use is wanton (through grossly inefficient irrigation) and, more importantly, uneconomic or, at least, not economically optimal. In his analysis of water resource availability, development and use in the Middle East, Beaumont (2000) found that each cubic metre of water used by industry and the service sector generates at least 200 times more wealth than a cubic metre of water used in agriculture, and he concludes that “as water shortages increase, many countries will be best served by the reallocation of irrigation water to meet the growing water needs of the urban regions.” So in water-short areas it should be (and will have to be) “Water for Cities, Treated Wastewater for Agriculture.” In fact, provided the wastewater is domestic (or nearly so) and properly treated to reduce the health risks, treated wastewater is better for agriculture than freshwater since, in addition to its water, it contains nutrients (principally nitrogen and phosphorus) which reduce the need to buy energy-intensive artificial fertilizers. In rural Mexico, for example, this saving is around US$ 135 per ha per year, which is a significant amount of money for subsistence farmers (Future Harvest, 2001).

Microbiological quality of wastewaters used for irrigation – protection of human health
The World Health Organization’s guidelines for the microbiological quality of wastewaters used in agriculture (WHO, 1989) are currently under revision. The new guidelines, due to be published in 2004, are likely to be:

(a) Restricted irrigation (ie, excluding salad crops and vegetables that may be eaten uncooked):

≤10^5 E. coli per 100 ml, and
≤1 human intestinal nematode egg per litre, but reduced to ≤0.1 egg per litre when children under the age of 15 are exposed.
(b) **Unrestricted irrigation** (ie, including salad crops and vegetables eaten uncooked):

\[ \leq 1000 \text{ E. coli per 100 ml, and the same nematode egg guideline, including the reduction to } \leq 0.1 \text{ egg per litre when local children are exposed through consuming crops brought home by their fieldworker parents (but this reduction does not apply when such crops are purchased in shops and markets in neighbouring towns and cities).} \]

The changes to the 1989 guidelines are the introduction of an *E. coli* guideline value for restricted irrigation and the reduction of the egg guideline value to \( \leq 0.1 \) per litre when children under 15 are exposed (see Blumenthal *et al.*, 2000; Blumenthal and Peasey, 2003).

Recent work by Mara *et al.* (2003) on evaluating the health risks associated with using wastewaters of various qualities (expressed as numbers of *E. coli* per 100 ml) for unrestricted irrigation (using the exposure scenario of Shuval *et al.*, 1997, for the consumption of wastewater-irrigated lettuce) has shown that the risk of infection with rotavirus is \( \sim 1 \times 10^{-3} \) per person per year, and for infection with *Campylobacter* and *Cryptosporidium* \( \sim 3-7 \times 10^{-5} \) per person per year, when the *E. coli* count is \( 10^3-10^4 \) per 100 ml (ie, exceeding the WHO guideline for unrestricted irrigation by up to one order of magnitude, as might occur in practice). Such risks are very low, especially when considered in relation to WHO's tolerable risk of waterborne infection from drinking fully treated drinking water of \( 10^{-3} \) per person per year (WHO, 2003).

With restricted irrigation the risk of infection is much higher: Mara *et al.* (2003), using an exposure scenario of involuntary soil ingestion, found it to be \( \sim 0.5 \) per person per year for rotavirus, but only 0.02 for *Campylobacter*, when the *E. coli* count was \( 10^5-10^6 \) per 100 ml. Given that the actual incidence of diarrhoeal disease in developing countries is \( \sim 1.3 \) per person per year (Murray and Lopez, 1996; see also Kosek *et al.*, 2003), at worst the rate might increase to \( \sim 1.8 \) per person per year for those working in wastewater-irrigated fields. This means, in effect, that fieldworkers might have 18, rather than 13, episodes of diarrhoea per 10 years – an increase of 5 episodes per 10 years compared with non-fieldworkers. Such an increase should be viewed not with alarm, but rather as a cost of their employment as fieldworkers.

In general, therefore, the risks to human health from the consumption of foods irrigated with wastewaters complying with the WHO guideline value of \( \leq 1000 \text{ E. coli per 100 ml are negligible; and the risks to fieldworkers' health, in the case of restricted irrigation, while much higher, are not unacceptably high.} \)

**Physicochemical quality of wastewaters used for irrigation – crop 'health'**

Treated wastewaters used for irrigation should comply with the recommendations of FAO for the quality of waters used for irrigation (Ayers and Westcot, 1989). For mainly domestic wastewaters there are five main parameters that need to be checked: electrical conductivity, sodium absorption ratio, total nitrogen, boron and pH. Full details are given in Ayers and Westcot.

**Wastewater treatment for agricultural reuse**

In developing countries the two most appropriate wastewater treatment technologies, which readily and at low cost achieve the WHO reuse guideline values, are waste stabilization ponds (WSP) and wastewater storage and treatment reservoirs (WSTR), although in ‘megacities’ energy-intensive electromechanical treatment systems, such as activated sludge, may have to be used. Comprehensive design methodologies for WSP and WSTR are given in Mara (2004).

The reuse of treated wastewater in agriculture is an integral part of sustainable water resources management in many parts of both industrialized and developing countries. In Valle del Cauca,
Colombia, for example, the major crops are sugar cane, rice and cotton, all of which grow very well with wastewater irrigation. This is restricted irrigation and therefore treatment to only \( \leq 10^5 \) \( E. \) coli per 100 ml is required, for which maturation ponds are not required, so that wastewater treatment costs are much reduced.

**CONCLUDING REMARKS**

- Treated domestic wastewater should be considered a dependable and economically advantageous water resource for use in agriculture.

- Provided the wastewater is treated to the WHO microbiological quality guideline values, and it complies with the FAO physicochemical quality guidelines, the effects on human health and on the crops are negligible (or, in the case of restricted irrigation, the effects on fieldworkers’ health are not unacceptably high).

- Treatment to meet these WHO and FAO guideline values is most appropriately achieved in waste stabilization ponds or wastewater storage and treatment reservoirs.

**REFERENCES**


