WATER REUSE FOR IRRIGATION – CAN DEVELOPING COUNTRIES AFFORD A TOLERABLE DISEASE BURDEN OF NO MORE THAN 10^{-6} DALY PPPY?

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Key words: DALY, reuse, wastewater, irrigation, guidelines, standards.

Abstract

DALYs are a measure of the health of a population or burden of disease due to a specific disease or risk factor. It evaluates the time lost because of disability or death from diseases compared with a long life free of disability in the absence of disease. DALYs are calculated as the sum of years of life lost by premature mortality (YLL) and years of healthy life lost in states of less than fully health, i.e., years lived with a disability (YDL), which are standardized by means of severity weights, thus: DALY=YLL+YLD.
WHO has established for wastewater use in irrigation (1) the same reference level of health protection as established for drinking water quality (2), i.e., the additional burden of disease from consuming water irrigated food should not exceed 10^{-6} DALY(Disability-Adjusted Life Years) loss per person per year (pppy). This level of risk means that a single additional case of disease may occur in a population of 1 million, during a life time (70 years). In a individual basis is equivalent to the occurrence of a mild disease during about 31,5 seconds.
Such a restrictive risk is almost impossible to be attained in most developing countries which may not be able to afford the cost of wastewater treatment and of other protective measures, even for restrict irrigation.
This paper presents proposals to adapt the reference level of risk to local technical, cultural, economical and social conditions of developing countries on the basis of a risk benefit approach.

1. Introduction - The DALY Concept

The concept of "Global Burden of Diseases and Injuries" describes the burden from 107 diseases and injuries and 10 factors of risk or risk groups for various age groups and geographical regions (3). The new concept led to the introduction of the DALY, the Disability Adjusted Life Years, a new common measure for examining diverse disease outcomes. This new parameter allows comparison to be made between different health outcomes and quantification of non fatal outcomes. Traditionally, public health policies has concentrated in mortality, and the severity of disease was expressed mainly in death rates of specific causes of death. However, many diseases do not led to premature mortality, but may be a significant cause of morbidity. The DALY concept encompass both effects, since it measures the difference between the current health conditions of a population and a selected health target, for example, an ideal health status. This integrated measure combines years of life lost by premature mortality (YLL) with years lived with a disability (YLD). On a population basis the YLL is evaluated by combining the age-specific mortality rate with the life expectancy of the fatal cases, had they not developed the

disease. To estimate YLD on a population basis, the number of cases must be multiplied by the average duration of the disease and a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (death). When the outcome of a disease is death the "duration of the event" is taken as the difference between the local life expectancy and the age at which the death has occurred.(4).
Therefore, the DALY is a single metric unit applicable regardless of the type of disease, regardless of their chemical, biological or radiological etiology. Besides that, it focuses attention on actual rather than potential hazards and thereby promotes and enables rational and direct public health priority setting. (2).

Thus:

$$DALY = YLL + YLD \quad (1)$$

where:

$$YLL = \sum_i e^*(a_i) \sum_j d_{ij} \quad (2)$$

i = index for different age classes;

$e^*(a_i)$ = the mean life expectancy in that age class

j = index for different disease categories;

d_{ij} = number of fatal cases per age class

$$YLD = \sum_j N_j \; T_j \; P_j \quad (3)$$

J = index for different disease categories;

N = number of patients;

T = duration of the disease;

P = severity weight of the disability (between 0 and 1).

2. Health Based Targets for Treated Wastewater Use in Agriculture

WHO has adopted a tolerable burden of waterborne disease from consuming drinking water of $\leq 10^{-6}$ DALY per person per year (WHO, 2004). This level of disease burden can be compared with a mild diarrhea at an annual disease risk of 10^{-3}, which is equivalent to 1 occurrence in a population of 1000, during a life time. Such a high level of health protection has been adopted by WHO (WHO,2006) as a tolerable burden of disease for wastewater use in agriculture, by assuming that food crops irrigated with treated wastewater , especially those eaten uncooked, are also expected to be as safe as drinking water by those who eat them. Under this approach the related health-based targets are shown in Table I, according to the corresponding exposure scenario.

Table I. Health-based targets for treated wastewater use in agriculture.

Exposure scenario	Health-based target DALY (pppy)	Log_{10} pathogen reduction needed	Number of helminth eggs per liter
Unrestricted irrigation:	$\leq 10^{-6}$		
Lettuce		6	≤ 1
Onion		7	≤ 1
Restricted Irrigation:	$\leq 10^{-6}$		
Highly mechanized		3	≤ 1
Labor intensive		4	≤ 1
Localized (drip) irrigation:	$\leq 10^{-6}$		
High-growing crops		2	No recommendations
Low-growing crops		4	≤ 1

Source (1)

Appropriate health protection measures can be applied to attain the pathogen reduction needed, according to Table I. The recommended measures, associated with their respective potential for pathogen reduction in terms of log unit reduction are listed and commented in Table II. The most important measure is wastewater treatment which can, if fully applied, achieve a log reduction of 6 units. While capable of allowing for 6 to 7 log units reduction of pathogens, cooking is a limited control measure since it is only applicable to part of the agricultural production. In order to achieve a 6-7 log units reduction a combination of the protection measures and their respective log reduction is made according to local conditions and constraints.

Figure 1 shows several options to combine protective measures to achieve the health target of $\leq 10^{-6}$ pppy in actual reuse schemes. For unrestricted irrigation, option C requires a minimum treatment of 2 log units which can be easily attained by stabilization pond systems, in terms of viral, bacterial and protozoan pathogens, as well as helminth eggs. Option H, for restricted irrigation, depicts a single household or a small community, requiring a septic tank (0.5 log unit pathogen reduction) and a sub-surface irrigation system allowing for the remaining 6.5 log unit pathogen removal required for root crops. The remaining options shown in Figure 1 require higher levels of wastewater treatment, in combination with other protective measures such as die-off, washing of the produce, irrigation techniques and the protection of the groups at risk through highly mechanized agriculture.

2. Daly Values (pppy) Worldwide

Both in developing as well as in the industrialized world the incidence of diarrhea, a disease strongly associated with the use of wastewater for irrigation, has shown to be extremely high.

Table III (5) shows the actual incidence of diarrheal diseases by ages and by regions in pppy. The global average (0,7 pppy) is $7x10^{5}$ higher than the guideline value of $\leq 10^{-6}$ DALY established by WHO.
Under this international scenario should such a restrictive health risk be imposed to developing countries? Can they afford the capital and maintenance costs associated with the implementation of the proposed protective measures, to achieve an additional burden of disease not exceeding 10^{-6} DALY, from consuming wastewater irrigated food?

Table II. Pathogen reductions achieved by various health protection measures

Control measure	Pathogen Reduction (log units)	Notes
Wastewater treatment	1-6	The required pathogen reduction to be achieved by wastewater treatment depends on the combination of health protection measures selected.
Localized (drip) irrigation (low-growing crops)	2	Root crops and crops such as lettuce that grow just above, but partially in contact with the soil.
Localized (drip) irrigation (high-growing crops)	4	Crops such as tomatoes, the harvested parts of which are not in contact with the soil.
Spray drift control (spray irrigation)	1	Use of micro-sprinklers, anemometer-controlled direction-switching sprinklers, inward-throwing sprinklers, etc.
Spray buffer zone (spray irrigation)	1	Protection of residents near spray or sprinkler irrigation. The buffer zone should be 50-100 m.
Pathogen die-off	0.5-2 per day	Die-off on crop surfaces that occurs between last irrigation and consumption. The log unit reduction achieved depends on climate (temperature, sunlight intensity, humidity), time, crop type, etc.
Produce washing with water	1	Washing salad crops, vegetables and fruits with clean water.
Produce disinfection	2	Washing salad crops, vegetables and fruit with a week disinfection solution and rising with clean water.
Produce peeling	2	Fruits, root crops.

Produce cooking	6-7	Immersion in boiling or close-to-boiling water until the food is cooked ensures pathogen destruction.

Sources: Beuchat (1998); Petterson & Ashbolt (2003); NRMMC & EPHCA (2005), apud (1)

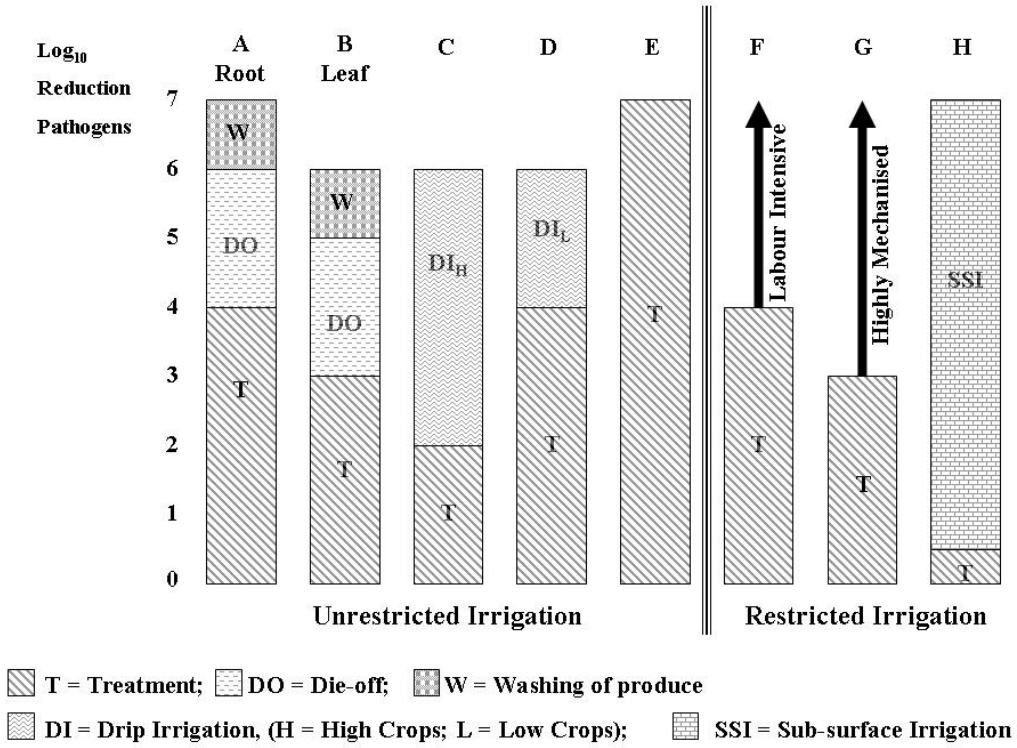

Figure 1. Examples of options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protective measures that achieve the health based target of $\leq 10^{-6}$ DALY per person per year . Source (1).

Table III. Diarrheal disease incidence by ages and by regions in pppy.

Region	All ages	0 - 4 years old	5 - 80 years old
Industrialized countries	O.2	0.2 – 1.7	0.1 – 0.2
Developing countries	0.8 – 1.3	2.4 – 5.2	0.4 – 0.6
Global average	0.7	3.7	0.4

Source (5)

The following examples from highly developed countries (6) shows even higher values than indicated in Table III for industrialized countries: ~0.9 pppy in Australia and ~0.8 in the State of California, USA.

3. Proposal of a tolerable disease burden of $\leq 10^{-4}$ pppy for developing countries.

Guidelines are not aimed to absolute and direct application in every country. They are intended for establishing a health basis and the corresponding health risk, and as such they provide a common background on which national standards can be derived. (7)

The purpose of developing national standards is to establish limits related to specific practices which will minimize detrimental effects without affecting the benefits. These limits have no absolute value, nor can they be definitely established. They will vary with technical and economic constraints and status as well as with the changing tendencies towards acceptance or rejection of practices affecting the cultural values of a society. Standards are legal instruments enacted by countries after adapting guidelines to their national priorities and taking in account their economic, technical, social, cultural and political situation. They are to be established, regulated and enforced by competent national authorities by adopting a risk benefit approach.

Unfortunately many countries from the developing world have been neglecting these basic statements, preferring the adoption of guidelines or foreign regulations without the needed adaptation to local conditions and constraints, leading to unrealistic standards which are difficult to be accepted by users and to be enforced by authorities.

In order to provide a realistic standard for the use of treated wastewater in irrigation the following considerations are made about the protective measures listed in Table II, aiming at the identification of those which could effectively be implemented and the ones which would provide little results or are impracticable under developing countries conditions:

- Wastewater treatment is the most expensive protective measure, but it can be made feasible by adopting a simplified stabilization pond system, which is the technology of choice for agricultural reuse schemes in developing countries. The system would be designed with an anaerobic pond plus a facultative pond (or a single facultative pond) but without the maturation pond which is, usually very large. Such a system would provide a 2 log unit pathogen removal and an effluent with less than 1 helminth egg per liter, if the facultative pond is designed with at least three compartments in series;
- Drip and spray irrigation involves high costs of installation and maintenance. Besides that, it is necessary to filter the effluents from any biological system utilized, in order to avoid clogging of water distribution orifices. The technology of choice in developing countries is ridge and furrows systems, so no log unit pathogen removal are attributable to drip and spray irrigation;
- Spray buffer zones does not protect field workers or consumers from contamination by pathogen organisms. They work indirectly, protecting people living in the neighborhood of wastewater irrigated fields, so no log unit pathogen removal is attributed to this measure;
- Due to the favorable climatic conditions prevailing in most developing countries, pathogen die-off can be very effective, so a 2 log unit pathogen removal is attributed to this protective measure;

- Adequate produce washing with water and produce disinfection seems not to be a practice fully integrated in the cultural behavior of many developing countries, so no log unit pathogen removal is attributed to this protective measure. In this respect health education programs, when adequately implemented will play a dominant role in making this protective measure more effective in developing countries;
- Since produce peeling and produce cooking are associated with a small part of crops produced no log unit pathogen removal are attributed to these protective measures.

Therefore the log removal allowed from realistic conditions prevailing in developing countries is 4 log units, being 2 from the wastewater treatment by pond systems and 2 from pathogen die-off. Based on these considerations it is proposed that the tolerable additional burden of disease of $\leq 10^{-4}$ DALY per person per year is adopted as national standard for the use of treated wastewater in developing countries.
Once a standard value is adopted countries may develop demonstration projects of wastewater use for irrigation, in which the proposed control measures are implemented. The assessment of risks should be done through epidemiological studies following the experimental procedure in which two groups are established. One of the groups is assigned to the exposure of the demonstration project; the other group is the control and the health outcomes for the groups are compared (8).

4. Conclusions and Recommendations

DALY is a single metric unit applicable regardless of the type of disease, focusing attention on actual rather than potential hazards and as such provides an important tool for the establishment of national standards for agricultural water reuse systems;

WHO has established for wastewater use in irrigation the same reference level of health protection as established for drinking water quality, i.e., the additional burden of disease from consuming water irrigated food should not exceed 10^{-6} DALY(Disability-Adjusted Life Years) loss per person per year (pppy). Such a restrictive risk is almost impossible to be attained in most developing countries which may not be able to afford the cost of wastewater treatment and of other protective measures, even for restricted irrigation.

Guidelines are not aimed to absolute and direct application in every country. In order to provide realistic national standards, they should be enacted by adapting guidelines to their national priorities and taking in account their economic, technical, social, cultural and political situation.

A critical analysis of the usual protective measures utilized for health protection in agricultural reuse schemes led to the proposal that the tolerable additional burden of disease of $\leq 10^{-4}$ DALY per person per year is adopted as national standard for agricultural use of treated wastewater in developing countries.

The assessment of risks associated to the proposed tolerable burden of disease should be done through demonstration projects, complemented with epidemiological studies following the experimental procedure in which a exposed group and a control group are assigned and the health outcomes for the groups are compared.

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