Reducing health risks from wastewater use in urban and peri-urban sub-Saharan Africa: applying the 2006 WHO guidelines

P. Drechsel, B. Keraita, P. Amoah, R. C. Abaidoo,
L. Raschid-Sally and A. Bahri

ABSTRACT

Where rapid urbanization is outpacing urban capacities to provide sound sanitation and wastewater treatment, most water sources in city vicinity are heavily polluted. This is of great concern as many of the leafy vegetables eaten raw in the cities are produced in these areas. Following the new WHO guidelines, different non-treatment options at farm, market, and kitchen level were field tested for health risk reduction with special consideration to efficiency and adoption potential. As most households are used to vegetable washing (although ineffectively), an important entry point for risk reduction is the increased emphasis of the new guidelines on food preparation measures. A combination of safer irrigation practices (water fetching, on-farm treatment, and application), the allocation of farmland with better water sources, and improved vegetable washing in kitchens appear to be able to reduce the potential risk of infections significantly, although it might not be possible to reach the ideal threshold without some kind of wastewater treatment. The on-farm trials carried out in Ghana also explored the limitation of other risk reduction measures, such as drip irrigation, crop restrictions and cessation of irrigation under local circumstances considering possible incentives for behaviour change.

Key words | Africa, health risk reduction, non-treatment options, urban and peri-urban agriculture, vegetables, WHO guidelines

P. Drechsel
B. Keraita
P. Amoah
L. Raschid-Sally
A. Bahri
International Water Management Institute (IWMI),
Africa Office,
PMB CT 112, Accra,
Ghana
E-mail: *p.drechsel@cgiar.org*;
b.keraita@cgiar.org;
p.amoah@cgiar.org;
l.raschid@cgiar.org;
a.bahri@cgiar.org

R. C. Abaidoo
Kwame Nkrumah University of Science and Technology (KNUST),
University Mail Box, Kumasi,
Ghana
E-mail: *Rcabaidoo@yahoo.com*

INTRODUCTION

In most developing countries, the urban supply of perishable leafy vegetables largely depends on farming in city proximity. A major food safety challenge is posed by the use of irrigation water from surface water sources in the city vicinity with a high level of water pollution caused by inadequate sanitation and waste disposal. Crop contamination is especially high in West Africa where overhead irrigation with watering cans is carried out twice a day unless there is rain. The resulting predominantly bacteriological crop contamination ranges between 10^3 and 10^8 MPN faecal coliforms per 100 g wet weight as determined for salad crops (Amoah *et al.* 2005, 2007). Heavy metal contamination, for example from tanneries, is seldom (Binns *et al.* 2003).

Given that irrigated urban and peri-urban agriculture has a niche function for urban food supply and in this context also provides livelihoods benefits and contributes to poverty alleviation, it is important that safety issues be addressed without threatening this aspect (Drechsel *et al.* 2002). The difficulty in developing countries to achieve suitable treatment of wastewater prior to disposal has resulted in authorities attempting to impose bans on cultivation with polluted water sources, quoting the previous irrigation water quality guidelines of WHO which were based on water quality norms

doi: 10.2166/wst.2008.245

for coliform and helminth concentrations. These bans proved to be ineffective, and reducing health risks remained an unachievable objective.

Instead of focusing on the quality of wastewater at its point of use, the new guidelines (WHO 2006) recommend defining realistic health-based targets and assessing and managing risks at different barriers along the entire continuum–from wastewater generation to consumption of produce cultivated with wastewater–to achieve those targets. This allows national authorities to develop a regulatory and monitoring system in line with national socio-economic realities. Based on the exposure scenarios of vegetable consumption and relevant epidemiological evidence, WHO recommends a performance target of 6-7 log units reduction in order to achieve the tolerable additional disease burden from wastewater use of $\leq 10^{-6}$ Disability Adjusted Life Years (DALY) per person per year (WHO 2006). This performance target can easily be achieved by effective wastewater treatment. However, in most low-income countries to date, conventional treatment systems have invariably failed for a variety of reasons (Nhapi & Gijzen 2004; Obuobie *et al.* 2006). Therefore, the multiple barrier approach emphasises non-treatment options as response to this deficit.

In a project funded by the CGIAR Challenge Program on Water & Food, different non-treatment options to enhance food safety for consumers were investigated. In a follow-up project funded by WHO-FAO-IDRC, the institutionalization potential of these options in particular and the WHO guidelines in general are currently being tested. This paper summarizes key results from the field trials so far and their applicability in these contexts. These focused on three points along the production-consumption continuum for health risk reduction: farm, market, and kitchen.

MATERIALS AND METHODS

The field studies were carried out in Accra, Kumasi and Tamale, the three major cities of Ghana, where vegetable cultivation with wastewater is widespread and where the population at risk is considerable (Obuobie *et al.* 2006; Amoah *et al.* 2007). Health risk reduction measures focused on common WHO recommendations as well as locally developed options, such as the provision of safer irrigation water sources, alternative crops, safer irrigation practices (drip kits, furrow irrigation, improved overhead irrigation), on-farm water treatment (sedimentation, filter), and cessation of irrigation. At the market level, the water used to refresh or cool vegetables was targeted and in street food kitchens, common and improved ways of vegetable washing. Indicators used were reductions in fecal coliform counts and number of helminth eggs from an average contamination level of 10^6 to 10^7 fecal coliform counts per 100 ml and 5 eggs per litre in the irrigation water. In washing trials the log reduction was related to lettuce fresh weight with a start contamination of 10^5–10^6 fecal coliform counts and in average 8–9 eggs per 100 g. The Most Probable Number (MPN) method was used to determine fecal coliform counts. A set of triplicate tubes of MacConkey broth supplied by MERCK (Darmstadt, Germany) was inoculated with sub-samples from each dilution and incubated at 44°C for 24 to 48 hours (APHA-AWWA-WEF 1998). The number and distribution of positive tubes (*acid or gas production or color change in both*) were used to obtain the population of coliform bacteria in water samples from the MPN table. Helminth eggs were enumerated using the USEPA modified concentration method (Schwartzbrod 1998) and identified using the WHO Bench Aid (WHO 1994). For further details on the laboratory methodologies see Amoah *et al.* (2005, 2007).

RESULTS AND DISCUSSION

In the following, the effectiveness and potential of various options tested so far are described. Some field studies are still ongoing as the results reported here require further verification.

Alternative farmland and/or safer irrigation water

The wastewater problem could drastically be reduced if authorities have the possibility to provide farmers with safer irrigation water or an alternative location where water is not polluted. In the frame of this project, geophysical studies were carried out to assess the availability of groundwater on urban farming sites. In Accra, groundwater was found at a convenient depth for treadle pumps, but the water was saline due to salt intrusion from the sea. In Kumasi and Tamale, the groundwater level was on many sites too deep (more than 15 m) to make borehole drilling an economic option for farmers. However, Ghana's Ministry of Food and Agriculture extended their national initiative to support small-scale irrigation and started borehole drilling on several urban farming sites. This risk mitigation strategy was successful in Benin where city authorities of Cotonou and Seme-Kpodji and various national ministries agreed to allocate about 400 ha of alternative farmland to urban and peri-urban farmers. The new site has shallow non-saline groundwater, which can easily be lifted by treadle pump for all-season irrigation. About 1,000 farmers have declared their interest to move to this site (Drechsel *et al.* 2006).

Changes in choice of crops grown

The standard recommendation to switch to crops not eaten raw has a very limited application potential as perception studies among wastewater farmers in Kumasi and Accra clearly showed (Keraita & Drechsel 2007), unless the alternative crops are of similar short-term profitability as the commonly planted exotic vegetables. Moreover, the enforcement of such a regulation would be difficult in the informal urban and peri-urban farming sector.

Safer irrigation practices

In many parts of West Africa, the use of low-cost watering cans is common among urban farmers. However, overhead irrigation enhances the contamination of leafy vegetables. Irrigation techniques which apply water to the root zone (such as drip irrigation) are recommended. In this study, we tested on farmers' fields alternatives and modifications to common irrigation practices:

Drip kits and furrow irrigation

Comparing low-cost drip kits and furrow irrigation to watering cans, the drip kits recorded the lowest levels of contamination with an average faecal coliform reduction of 4 $\log_{10}$ units per 100 g of lettuce wet weight compared to watering cans. However, the disadvantages were clogging of pipes, significantly lower cropping densities and interference with other routine activities like weeding etc. The use of furrow could reduce coliform counts by 1–2 $\log_{10}$ units but as with the drip kits, also reduced common planting density and yields. Thus both options were not acceptable to the farmers who asked for other types of drip kits that allow higher planting densities.

Changing height of water application and use of watering rose

Slightly changing the preferred practice of using watering cans, by capping with a perforated shower rose, and irrigating from a height of less than 0.5 m, showed a combined average reduction of 2.5 log units of faecal coliforms and more than 2 helminth eggs per 100 g^{-1} lettuce compared to the practice of uncapped spouts lifted more than 1 m high for irrigating. The effect was explained by reduced splash and related lettuce contamination via already contaminated soil particles. Soil contamination derives from fresh poultry manure and previous irrigation.

Cessation of irrigation before harvesting

Cessation of irrigation before harvesting is a very simple and an effective measure. The field trials showed that on average, a reduction of 0.65 $\log_{10}$ units of faecal coliforms and 0.4 helminth eggs per 100 g of fresh weight of lettuce were obtained for each non-irrigated day in the dry season. However, a corresponding daily loss of 1.4 tons/ha of fresh weight of lettuce was also recorded. Although 4 to 5 days without irrigation would increase food safety drastically, a yield loss of about 25% was not acceptable for the farmers. A compromise with higher adoption potential would be a cessation of two days which correspond to a yield reduction of 10%. As the traders harvest the most productive vegetable beds themselves, any planned cessation requires the consent of farmers and traders on the exact day when the trader will come.

On-farm treatment

Turning reservoirs into sedimentation ponds

Dugout ponds are widely used in irrigated urban vegetable farming sites in Ghana. In most cases, they are used as intermediate water storage reservoirs filled either by surface runoff or by pumping water from polluted urban streams. Such reservoirs not only significantly reduce the walking distance to the stream, they also have a potential to reduce pathogens in irrigation water through die-off and sedimentation. Careful collection of irrigation water without disturbing the sediment reduced helminth egg counts in irrigation water by 70%. Most removal of helminth eggs took place on the first day of sedimentation. After three days without disturbance of the pond its average number of eggs was less than 1 egg per litre (Keraita, pers. communication). Removal of fecal coliforms in the same 3 day period was about 2 $\log_{10}$ units due to natural die-off. In contrast to the reduction of worm egg, the die-off of coliforms was only significant during the dry season. However, farmers in Ghana have to irrigate continuously due to high temperatures and use the dugouts regularly in the morning and afternoon on most sunny days without rain, thus disturb the water continuously. Despite this, it was verified that the crucial feature was to avoid sediment contact. Some farmers use wooden logs across the ponds to avoid entering the water. Water fetching can be done through lowering the watering can with a rope - instead of stepping in the pond or if this is unavoidable by deeper pond designs that prevent the watering can from touching the sediment layer during water fetching.

Water filtering

Simple low-cost methods for filtering the polluted water, like drums filled with sand, or covering the intake hole of the watering can with cloth or mosquito netting, will hold back organic debris with attached pathogens. The risk reduction potential is being assessed. Sand filters showed a 50–90% reduction of helminth eggs in the water used but require extra time for filtering and filter infrastructure (like a bucket with tap, filled with sand). As most urban farmers use Governmental land along streams, there is no tenure security and incentive to invest in infrastructure or equipment. Often farmers do not live in farm proximity and do not know where to store equipment without risk of theft. This limits the acceptability of options which require installations on farm.

Reducing contamination at market level

In IWMI studies in Pakistan, where the initial crop contamination on farm was moderate, in part due to furrow irrigation, post-harvest contamination in markets was significant (Ensink, pers. communication). In Ghana, on the other hand, the initial contamination was very high and no additional contamination in wholesale markets and retail outlets could be verified (Amoah *et al.* 2007). However, market traders use water to clean and/or cool or refresh their displayed vegetables. In most markets this water is not changed over the day. A first empirical comparison between two markets in Kumasi showed that changing the water for refreshing lettuce once during the day can decrease the average coliform counts by one $\log_{10}$ unit from 10^4 to 10^3. Also the removal of outer leaves can reduce the coliform counts by half a $\log_{10}$ unit (lettuce) to one unit (cabbage).

Improving vegetable washing before serving

While the large majority of traditional vegetables are consumed in a cooked state, exotic vegetables complement as raw salad common urban fast food like “rice and chicken”. More than 90% of the produced lettuce enters the street food sector, restaurants and canteens. Surveys in Accra showed that at least 200,000 dwellers of all classes of life consume in this way, everyday, lettuce or cabbage irrigated with polluted water (Obuobie *et al.* 2006).

Washing of raw vegetables before consumption is very common in Ghana and its neighboring countries but many methods used proved to be inadequate (Amoah, pers. communication; Mensah *et al.* 2002). Methods vary widely within and between Anglophone and Francophone West Africa and showed significantly different log reductions depending on the method, contact time and water temperature used. Several common methods (water, salt solutions, low vinegar concentrations) do not reduce coliform counts to any desirable level. Others, like “Eau de Javel” (household bleach), chlorine tables and potassium permanganate, which are commonly used in Francophone West Africa but hardly known in Ghana, achieve 2–3 $\log_{10}$ units reduction. Concentrated vinegar solutions (one part vinegar on five parts water) proved to be even more effective (4 $\log_{10}$ units$_)$, but are more expensive and can suit only mid- and high-class restaurants.

The effective removal of helminth eggs requires good agitation and rubbing of the leaves. Comparing washing in a bowl to washing in running water (independent of sanitizing solution used) the latter was more effective. But even washing in a bowl reduced the helminth egg population by at least half, while running water reduced the contamination level from 8–9 eggs to 1 egg per 100 g lettuce wet weight.

CONCLUSIONS

The new WHO guidelines on safe wastewater irrigation address better the reality in developing countries where wastewater treatment is rarely an effective option than the previous edition. They support a variety of alternative non-treatment options for health risk reduction which can complement each other and cumulatively achieve the target desired. This is fresh thinking in the approach top safe-guarding public health and provides authorities with new avenues for risk reduction. However, so far the guidelines only give limited options for non-treatment options, such as choice of crops and drip irrigation. These options are applicable only under certain conditions. The research community is therefore encouraged to identify other methods which could be successful in a given local or regional context and to verify their risk reduction and adoption potential. The findings of the herein described studies show that it is indeed possible to use a variety of simple, low-cost methods for effective reduction of severe crop contamination as typified in many low-income countries.

If used alone or preferably in combination according to local possibilities, typical faecal coliform concentration analyzed in Ghana on irrigated lettuce (10^6 fecal coliform counts per 100 g fresh weight) could be reduced at the

- Farm level by 2–4 $\log_{10}$ units
- Market level by at least 1 $\log_{10}$ unit
- Kitchen level by 2–3 $\log_{10}$ units

A significant reduction of helminth eggs was also achieved at both farm and kitchen level. At the farm level, simple filters and sedimentation can effectively reduce the egg count, while at the kitchen level, washing under running tap water - where available - appears even more effective and probably easier to promote.

All options recommended here require both training and behavior change. To increase the sustainability of any change it is important to analyse as early as possible local factors and opportunities which might support or constrain their adoption. A certification program for "safer crops" combined with exclusive marketing channels, or awards for innovative farmers might be possible incentives for change. Farmers with safe produce could then be linked directly to large consumer establishments like hotels or supermarkets. They can also have known 'safe food' selling points in markets for the general public. These efforts have to be supported by awareness campaigns to increase the demand for safer crops.

Other incentives could be institutional support from government agencies like provision of extension services, training, loans, and improved tenure security. Perhaps good media publicity will also encourage farmers to adopt practices for safer vegetable production. Although it is unlikely that all farmers will change their practices, some farmers might offer consumers an alternative.

The promotion of good washing practices prior to vegetable preparation (at home or in restaurants and food stalls) will remain an additional crucial risk barrier also taking care of post-harvest contamination through handling and marketing. Since many fast food sellers are not registered, do not have permanent stands, and are not members of any association, they are particularly difficult to reach. Health initiatives and campaigns broadcasted through radio, TV, or newspapers have to consider the right balance between the provision of incentives (rewards, recognition in tourist guides, etc.) and applying gentle pressure to comply with hygiene standards.

In spite of efforts, incentives and restrictions might fail or only work over certain periods. Therefore it is essential to explore possibilities of combining options of non-treatment and treatment. While the conventional centralised treatment options seem not to have succeeded in the past in the majority of developing countries, there are many possibilities of decentralized low-cost wastewater treatment including constructed wetlands at the household or neighbourhood level or in the interfaces between sources, rivers, and farm which can achieve significant complementary log reductions (Rose 1999; Morel & Diener 2006).

REFERENCES

Amoah, P., Drechsel, P. & Abaidoo, R. C. 2005 Irrigated urban vegetable production in Ghana: Sources of pathogen contamination and health risk elimination. *Irrigation and Drainage* **54** (special issue), 49–61.

Amoah, P., Drechsel, P., Henseler, M. & Abaidoo, R. C. 2007 Irrigated urban vegetable production in Ghana: Microbiological contamination in farms and markets and associated consumer risk groups. *Journal of Water and Health* **5**(3), 455–466.

APHA–AWWA–WEF 1998 *Standard Methods for the Examination of Water and Wastewater*, 20th Edition, APHA/AWWA/WEF, Washington, DC, USA.

Binns, J. A., Maconachie, R. A. & Tanko, A. I. 2003 Water, land and health in urban and peri-urban food production: the case of Kano, Nigeria. *Land Degradation and Development* **14**, 431–444.

Drechsel, P., Blumenthal, U. J. & Keraita, B. 2002 Balancing health and livelihoods: Adjusting wastewater irrigation guidelines for resource-poor countries. *Urban Agriculture Magazine* **8**, 7–9.

Drechsel, P., Graefe, S., Sonou, M. & Cofie, O. O. 2006 *Informal Irrigation in Urban West Africa: An Overview*, *IWMI Research Report 102*. IWMI, Colombo, www.iwmi.cgiar.org/pubs/pub102/RR102.pdf (accessed 16 June 2007).

Keraita, B. & Drechsel, P. 2007 Safer options for wastewater irrigated urban vegetable farming in Ghana. *LEISA 23.3* (in press).

Mensah, P., Yeboah-Manu, D., Owusu-Darko, K. & Ablordey, A. 2002 Street foods in Accra, Ghana: how safe are they? *Bulletin of WHO* **80**, 546–554.

Morel, A. & Diener, S. 2006 *Greywater management in low- and middle-income countries. Review of different treatment systems for households and neighbourhoods*. EAWAG, Duebendorf, Switzerland, pp. 96.

Nhapi, I. & Gijzen, H. J. 2004 Wastewater management in Zimbabwe in the context of sustainability. *Water Policy* **6**, 501–517.

Obuobie, E., Keraita, B., Danso, G., Amoah, P., Cofie, O. O., Raschid-Sally, L. & Drechsel, P. 2006 *Irrigated urban vegetable production in Ghana: Characteristics, benefits and risks*. IWMI-RUAF-IDRC-CPWF, IWMI, Accra, Ghana, pp. 150, http://www.cityfarmer.org/GhanaIrrigateVegis.html (accessed 16 June 2007).

Rose, G. D. 1999 *Community-based technologies for domestic wastewater treatment and re-use: options for urban agriculture*, *Cities Feeding Peoples Series 27*. IDRC, Ottawa, Canada, pp. 75.

Schwartzbrod, J. 1998 *Methods of analysis of helminth eggs and cysts in wastewater, sludge, soils and crops*. University Henry Poincare, Nancy, France.

WHO 1994 *Bench Aids for the Diagnosis of Intestinal Parasites*. World Health Organization, Geneva, ISBN 92 4 154476 7.

WHO 2006 *Guidelines for the safe use of wastewater, excreta and grey water: Wastewater use in agriculture (volume 2)*. World Health Organization, Geneva, pp. 219.