16 Confronting the Realities of Wastewater Use in Irrigated Agriculture: Lessons Learned and Recommendations

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Abstract

This concluding chapter synthesises results and lessons learned throughout this volume, which deals with the reality of wastewater use in agriculture in developing countries. It then extrapolates from these lessons, to make pragmatic recommendations aimed at protecting both the public health and farmers' livelihoods. Addressing these lessons in a significant fashion is becoming ever more necessary, as it is likely that wastewater use will increase in many less-developed countries, due to growing urban and peri-urban populations and their matching demands for produce. The practice also deserves recognition for its potential socio-economic benefits, since some farmers would be unable to earn a living without using wastewater, and for others, its use increases the income they would normally make, lifting them out of poverty. However, unregulated wastewater use also raises serious concerns about the health of both consumers and farmers, creating the competing need to balance health impacts against livelihood needs. This chapter elucidates lessons learned, and makes four recommendations to policy-makers and practitioners: 1. to develop and apply appropriate guidelines for wastewater use, 2. to treat wastewater and control pollution at source, 3. to apply a range of non-treatment management options, and 4. to conduct research to both improve understanding of the practice, and to identify opportunities and constraints to the adoption of these recommendations.

Introduction

This book set out to describe the reality of wastewater use in agriculture in developing countries, and to make pragmatic recommendations aimed at protecting both the public health and farmers' incomes. The thematic chapters explored a number of issues that are necessary to understand the different dimensions of the problem, including a suggested classification of the different types of wastewater use, the need to take a livelihood-based approach focused on farmers, the need for public health guidelines, and an analysis of the cost-effectiveness of treatment required to meet guidelines. The case studies demonstrated the wide range of wastewater use practices around the world, and illustrated the futility of prescribing a single, rigid management approach. They also revealed

 Wastewater Use in Irrigated Agriculture (eds C.A. Scott, N.I. Faruqui and L. Raschid-Sally)

common obstacles to improving the practice, and from these it has been possible to identify key issues that must be addressed in order to maximise the potential benefits, while minimising the potential costs that wastewater use offers.

This concluding chapter now summarises these lessons learned, makes recommendations, and points to future research needs, that could contribute to safe and sustainable wastewater use under the diverse conditions that we have seen.

Extent

The first lesson forms the fundamental basis from which we must proceed, and it is that the general lack of knowledge of the importance of wastewater use impedes its inclusion as a priority issue to be considered in policy-making. Case studies from this volume illustrate this aspect and it is estimated that up to one-tenth of the world's population eats food produced using wastewater (Lunven, 1992). As popula-

Lessons Learned

The complex challenges of managing wastewater require a pragmatic, proactive and forward-looking perspective. The lessons learned from past experience with wastewater use and management suggest that:

- Comprehensive realisation of the importance of wastewater use in agriculture is still on the peripheral edges of public awareness, and is not always clear to many policy-makers and donors;
- There is insufficient understanding of the social and economic factors that drive farmers to use wastewater, and thus inadequate consideration of these in policy formulation;
- The protection of public health and the alleviation of poverty are not mutually exclusive outcomes when it comes to wastewater use, however, one may have to be given greater emphasis than the other in different contexts;
- Effective measures do exist to protect health and environmental quality, particularly when these are included in integrated, multi-barrier approaches to wastewater management;
- Rigid wastewater use guidelines tend to become targets rather than norms;
- Effective, lower-cost, decentralised treatment systems exist; conventional, northern treatment technologies tend to be unsustainable, in part because of high capital and recurring costs;
- Many forms of wastewater use are practised in various contexts for different reasons, and individual socioeconomic contexts contribute to varying levels of acceptability of wastewater use;
- Increasing year-round demand for fresh fruits and vegetables in developed countries, and increasing tourism in a globalised world, make wastewater use an issue for more than just developing countries;
- Sound legal and regulatory frameworks require sustained application and enforcement;
- Insecure land tenure mitigates against farmer investment in safer and more efficient wastewater irrigation technologies;
- The informal nature of wastewater irrigation tends to leave it in institutional no-man's land; and
- A lack of coordination among institutions within and outside of government, and the tendency towards isolated, uni-disciplinary research on wastewater, has inhibited the testing and design of integrated, workable solutions.

A successful approach to wastewater management that incorporates these lessons may be incremental if necessary, i.e. building and sustaining individual components, but above all it must be sustained institutionally over the long term. The following sections provide more details on the lessons learned.

tions continue to grow and more freshwater is diverted to cities for domestic use – 70% of which later returns as wastewater – the use of wastewater is certain to increase, both in terms of the areas irrigated, and in the volumes applied. For instance, as outlined by Huibers *et al.* (Chapter 12, this volume), the amount of wastewater used in and around Cochabamba, Bolivia, is expected to double over the next twenty years.

However, the quality of the wastewater used and the nature of its use can vary enormously, both between and within countries. In many low-income countries in Africa, Asia, and Latin America, the wastewater tends to be used untreated, while in middle-income countries such as Tunisia and Jordan, treated wastewater is used. These disparities render direct case comparisons difficult, and even estimating the extent of the practice within countries is problematic – global figures even more so. Here, van der Hoek's suggested classifications, in Chapter 2 of this volume, of the different types of wastewater use – direct, indirect, treated, untreated, planned, and unplanned – will be very useful in comparing different cases, and in developing more meaningful and accurate estimates.

Scenarios of Use

Local socioeconomic conditions and culture are also factors that influence the choice of crops that farmers irrigate, and this has further divergent health impacts. For instance, most vegetables irrigated with wastewater in Pakistan are eaten cooked, whereas in Dakar (Faruqui *et al.*, Chapter 10, this volume), most are normally eaten raw. Additionally, the rationale for using wastewater varies enormously in different contexts. In Tunisia or Jordan, many farmers would be unable to earn a livelihood without using wastewater – they have no other choice. In other cases, for example, in Vietnam (Raschid-Sally *et al.*, Chapter 7, this volume), two different scenarios can occur – in some cases, farmers may inadvertently use wastewater even when they do have an adequate supply of water, because of unplanned discharges into natural water courses and canals, while in others, wastewater may be deliberately pumped into irrigation canals by authorities, when there is inadequate water at the tail-end of irrigation schemes.

Livelihoods and Profitability

In contrast, in situations such as Dakar and Pakistan, farmers prefer wastewater even when freshwater is available, because they earn higher profits using wastewater. As both cases demonstrate, wastewater can be a more reliable source, both in terms of availability and volume, than either rain or freshwater supply from irrigation systems. In these cases, it also allows them to crop more than once a year, sometimes up to 3 crops per year, depending on the crop. In Pakistan (Ensink *et al.*, Chapter 8, this volume), farmers using wastewater earned approximately US$300 per year more than those using freshwater. Furthermore, in addition to generating income for farmers, wastewater use in urban and peri-urban agriculture also provides jobs and income for merchants who sell the produce. In Ghana, it is estimated that using only 10% of the wastewater in urban and peri-urban agriculture (UPA) could generate employment for up to 25,000 farmers, worth US$18 million per year (Sam Agodzo, personal communication).

Given that farmers can earn higher profits by using wastewater, it is becoming increasingly evident that they are also willing to pay for it. In Pakistan, the rent for land with access to wastewater can be two to six times more expensive than for land without such access. For example, in Quetta, which depends on a fossil aquifer projected to run out within 20 years (OCHA IRIN, 2002), the average rent for land with access to wastewater is US$940/ha, compared to US$170/ha for land irrigated with freshwater (Ensink *et al.*, Chapter 8, this volume). In Jordan, the Aqaba wastewater plant is a viable enterprise. Reclaimed water is sold at prices that cover the operation and maintenance costs of delivery, and farmers growing date palms using effluent from the plant continue to renew their contracts (McCornick *et al.*, Chapter 14, this volume).

Environmental Impacts and Health Risks

However, the current practice of wastewater use threatens public health and the environment, and possibly limits its long-term sustainability. The major threat to farmers and their families is from intestinal parasites – most often worms. In Pakistan, farmers using raw wastewater are five times more likely than those using canal water to be infected by hookworms. Living in the small intestine, hookworms cause heavy blood losses, and anaemia and retardation in children (Ensink *et al.*, Chapter 8, this volume). In Dakar, 60% of the farmers using raw wastewater were infected with either amoebae, which cause amoebic dysentery, roundworms, which cause ascariasis, whipworm, or threadworms. The farmers who used a combination of wastewater and groundwater had a lower infection rate of 40%. (Faruqui *et al.,* Chapter 10, this volume). Another health threat is bacterial and viral infections, both minor and serious, which can occur after the consumption of raw vegetables contaminated with faecal matter – the cause of the 1970 cholera epidemic in Jerusalem (Fattal *et al.*, Chapter 5, this volume) and typhoid epidemics in Santiago (1983) (Fattal *et al.,* Chapter 5, this volume), and Dakar (1987) (Faruqui *et al*., Chapter 10, this volume), were all isolated to urban and peri-urban agriculture (UPA). As Buechler points out in Chapter 3, this volume, health risks also vary according to gender, class, and ethnicity. For instance, women often perform the tasks requiring the most extensive contact with wastewater, such as transplanting and weeding in flooded areas like paddy fields, in both Latin America and South Asia. Furthermore, the children of farmers or farm workers, who have not yet built up immunity, tend to be most at risk to gastrointestinal problems.

In terms of environmental impact, wastewater use over a long period of time can result in heavy metal accumulation, especially with industrial wastewater sources. Irrigation with industrial wastewater has been associated with a 36% increase in enlarged livers and 100% increases in both cancer and congenital malformation rates in China, compared to control areas where industrial water was not used for irrigation (Yuan, 1993, cited in Carr *et al.*, Chapter 4, this volume). In Japan, chronic cadmium poisoning as a result of wastewater use has caused Itai-itai disease, a bone and kidney disorder (WHO, 1992). Ironically, in some of the cases, including Haroonabad, Pakistan, and Dakar, Senegal, groundwater contamination from microbial pathogens or nitrates is not a concern, because the groundwater is already too polluted or saline to serve as a drinking water supply.

Finally, the long-term use of wastewater can become self-limiting due to soil damage. Although the organic matter in wastewater can help improve soil texture and water-holding capacity, wastewater also has harmful effects, particularly in arid environments, by causing soil salinisation, blocking soil interstices with oil and grease, and accumulating heavy metals. So far, in most of the cases presented, the environmental impacts have been minor or undetectable. However, in Pakistan, over-applied wastewater with insufficient drainage (also the case with freshwater irrigation) has resulted in signs of degrading soil structure, visible soil salinity, and the delayed emergence of wheat and sorghum due to an excess of applied nutrients. Although such concrete impacts on soil are generally not yet measurable, these effects are likely to occur, given continued application and greater wasteloads. In some places such as Dakar, where groundwater is highly saline, if it were used for irrigation instead of wastewater, the impacts on soil could arguably be worse.

Change in Attitudes and Its Implications

Notwithstanding these impacts, attitudes towards wastewater use are changing among researchers and policy makers. First, there is a growing recognition that its use can also generate some positive health impacts. Food security is enhanced for both producers and consumers, as the increased agricultural output generates higher incomes for farmers, and provides more affordable fresh fruits and vegetables to the poor. In both cases, this increased food security can combat malnutrition, a leading factor in half of the deaths of children in developing countries (WHO, 2000), and also a cause of stunted physical and

cognitive growth (Berkman *et al.*, 2002, cited in Carr *et al.*, Chapter 4, this volume). Increased incomes are associated with better health, even when wastewater irrigation leads to more disease risks. Carr *et al.* reference a study in which a village with a rice irrigation scheme had more malaria vectors than a nearby village in Tanzania, but a lower level of malaria transmission – because the first village had more resources to buy food, children were better nourished, and the villagers could afford mosquito nets (Ijumba, 1997, cited in Carr *et al.*, Chapter 4, this volume).

Second, even those updating the World Health Organization (WHO) *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture* (WHO, 1989) acknowledge that at times the current guidelines may be too strict. In the analysis presented by this volume's theme papers, Fattal *et al.*, conclude in Chapter 5 that the current WHO wastewater effluent guidelines provide a safety factor one to two orders of magnitude greater than that called for by the United States-Environmental Protection Agency (USEPA) for microbial standards for drinking water. The paper by Richard Carr of the WHO (Carr *et al.*, Chapter 4, this volume) makes clear that managing health risks should be a holistic exercise, accounting for risks from all water-related microbial exposures. Future WHO guidelines will be based on the Stockholm Framework (Carr *et al.*) which suggests that countries adapt the guidelines to their own social, economic, and environmental circumstances. This framework requires that the risk of gastrointestinal illness be considered *within the context of all possible exposures*, including water supply, sanitation and contaminated food, which facilitates decision-making that addresses the greatest risks first. As an example, Fattal *et al.*, provide estimates that show for a city of one million using untreated wastewater, that treating the wastewater to the current WHO unrestricted guidelines would cost US$125 per incidence of disease prevented. From a health perspective, the question here is whether some other measure applied to improving water supplies, or towards health education, could be equally or more effective at preventing disease, at a lower cost.

An example in this volume given by Carr *et al.* (Chapter 4) helps demonstrate the point that full wastewater treatment is not necessarily the most cost-effective way of protecting public health: consider a river basin in which the background level of acute gastrointestinal illness is 0.8 episodes per person per year – the typical rate amongst adults worldwide. In this case, using wastewater treated to the current WHO guidelines (10^3 faecal coliforms (FC)/100 ml) in urban farming would, at maximum, increase the incidence rate to 0.8001 episodes per person annual. Such a small difference is undetectable, and contributes virtually nothing to the background level of diarrhoea. In other words, there is no additional increase in risk associated with using wastewater treated to the current WHO standard. In contrast, the use of untreated wastewater, which contains about 10^8 FC/100 ml, could increase the incidence of diarrhoea by up to 76%, i.e. to about 1.4 episodes/person/year. Almost doubling the risk level by using untreated wastewater may be inappropriate, but with limited funds, it may simply be too expensive to pursue a policy of zero incremental risk by treating to the current WHO guidelines. In such cases, it may be pragmatic to accept a level of risk that is lower than one from using untreated wastewater, but that is slightly higher than the typical background level of illness. For example, one could follow instead the suggested future WHO restricted irrigation guideline of treating the wastewater to the level of 10^5 FC/100 ml, which necessitates a lower level of treatment than the current ones. The money saved by not adopting full treatment could then be more effectively spent on other measures to reduce gastrointestinal illness, such as improving drinking water quality. An extreme example from the southern Punjab in Pakistan illustrates this point: in this basin, where the only source of drinking water is from irrigation canals with *Escherichia coli*/100 ml, levels that far exceed the WHO drinking water standard (Carr *et al.* Chapter 4, this volume), it would be inappropriate to expect that the wastewater be treated to a higher quality than the water that people are drinking.

In an ideal world, policy decisions would be made based on scientific analysis showing the actual risk levels, as described above. However, public perception of risk must also be considered. While serious chronic gastrointestinal

illnesses such as amoebic dysentery, roundworm, and hookworm, are endemic throughout the developing world, large-scale epidemics and serious illnesses such as cholera and typhoid have been less common. Past cholera epidemics isolated to raw wastewater use, such as the ones that occurred in 1970 in Jerusalem, 1984 in Dakar, and 1983 in Santiago, have faded from public memory. Yet, global public awareness of health impacts will have a greater reach today than in 1984, due to the advances in information and communication technologies made in the last 20 years. In effect, an epidemic would quickly generate worldwide publicity through the Internet, and magnify local knowledge of the issue. The public reaction to the 2003 SARS epidemic greatly exceeded the actual risk level, and generated devastating impacts on the economies of affected cities, including Hong Kong, Hanoi, and Toronto. For this reason, although Saudi Arabia's ban on vegetable imports from Jordan (see McCornick *et al*., Chapter 14, this volume) may be dubious from the viewpoint of scientific risk assessment, it is understandable from a political viewpoint, in terms of the impact that negative public perception could have. Furthermore, awareness of the risks associated with consuming contaminated produce is growing within industrialised countries. For instance, 23% of the fresh fruits and vegetables consumed by Americans are imported, and this figure is growing. A recent *New York Times* article (Burros, 2003) stated that contaminated green onions imported from Mexico were linked to recent outbreaks of hepatitis A, which killed three people and sickened hundreds. The same article made reference to recent outbreaks of food-borne illness traced to Guatemalan raspberries, and to salmonella that was traced to Mexican cantaloupes (Burros, 2003). Even if actual risk levels are low, media attention and public reaction could spell trouble for developing countries, whose food exports may be irrigated with wastewater.

Even farmers in countries that do not export vegetables could suffer devastating impacts, if another crisis generated enough publicity so that the public, including tourists, refused to consume vegetables that may or may not have been irrigated with wastewater. Several agencies including the Ghana Tourist Board, have expressed concerns about the hygienic cultivation of vegetables in Ghana, and launched a campaign for safer vegetable production (Sonou, 2001). Thus, another tradeoff that must be addressed is the public perception of risk versus the actual risk.

It becomes clear that in seeking realistic solutions, policy-makers must account for both untreated and treated wastewater use, and make policy choices that protect farmers' livelihoods and the public health. Bharmoriya's Chapter 11, this volume neatly illustrates the conundrum: About 100 villages downstream of Vadodara practise untreated wastewater use, as they have few other options to support their livelihoods. This generates about US$5.5 million annually, but the practice threatens their own health, and that of the roughly 1.5

Table 16.1. Timeframe for meaningfully implementing recommendations in the least developed countries (LDCs).

Recommendation	Timeframe for meaningful implementation
Develop and apply guidelines	Medium to long term
Treat wastewater and control at source	Medium to long term
Apply other management options	
• Increase farmer and public awareness	Short to medium term
• Minimise human exposure	Short to medium term
• Treat infections	Short to medium term
• Use safer irrigation methods	Short to medium term
• Restrict crops	Short to medium term
• Improve institutional coordination	Medium to long term
• Increase security of land tenure	Medium to long term
• Increase funding	Short, medium and long term
Conduct research	Short, medium and long term

million residents in and around the city. The following section suggests recommendations to tackle such difficult cases as this one.

Recommendations

The following recommendations, summarised in Table 16.1, are organised into four categories: develop and apply guidelines, treat wastewater and control at source, apply other management options, and conduct research. Note that Table 16.1 also outlines when each recommendation can be meaningfully implemented in the least-developed countries.

Depending upon the context and stakeholder views, it is suggested that policy-makers take a holistic and integrated approach, and act immediately on those recommendations requiring little or no further study. For instance, in Tunisia, where risk of exposure from drinking water sources and contaminated food is low, appropriate guidelines are already in place, and Shetty *et al.* (Chapter 15, this volume) outline that the focus there ought to be on continuing improvement of institutional coordination, increasing farmer education, and safer, more sustainable irrigation methods. Similarly, in Jordan, a major focus should be on improving institutional coordination, and on collecting and treating wastewater with improved source control – part of which is occurring through the expansion of the As-Samra wastewater treatment plant. In contrast, poorer countries in Latin America, Asia and Africa, such as Bolivia, Pakistan, and Senegal, will need more time to develop the guidelines for collecting and treating wastewater, with appropriate source controls. Therefore, to minimise the risks to public and farmer health, it is essential to increase awareness amongst affected groups, and with this added knowledge, to begin minimising human exposure, to treat infections, and to use safer irrigation methods.

In other words, countries can and should begin work on all recommendations concurrently, but it is acknowledged that in the least-developed countries, it will take time to develop and implement both guidelines and affordable treatment. However, many of the management options can be acted on immediately, with visible benefits to the most marginalised groups. In the poorer countries in particular, it is essential to practice what is in effect a multi-barrier approach, because it is unlikely that one measure alone will protect both farmer and public health. More details on each recommendation are discussed below.

Develop and apply holistic and appropriate health guidelines

It is essential for countries to develop guidelines that are adapted to their individual social, economic and environmental context. This means following the Stockholm Framework and the impending revised WHO guidelines, which recommend assessing the risks associated with wastewater use in agriculture within the context of the actual disease rates of the population from all sources, including water supply, sanitation, and contaminated food. Mexico is a case in point, where the WHO guidelines were adapted to reflect local conditions. As risk factors may vary from river basin to river basin within a country, so may the guidelines. Taking a holistic and flexible approach also means that the guidelines will change over time. As the relative risk factors change – for instance, when water supply and sanitation improve – the guidelines for wastewater should become accordingly more stringent. For greatest impact, the guidelines should be implemented with other health measures, such as health education, hygiene promotion, and the provision of adequate drinking water and sanitation. Positive health impacts arising from wastewater use, such as the resulting improved nutrition due to greater household income and food security, should also be duly considered.

Treat wastewater and control at source

Focusing as much as it is economically feasible at the start of the wastewater use chain will reduce downstream problems. This entails domestic treatment, but whether this requires higher levels of treatment for unrestricted use, or lower levels for restricted use, depends principally on whether vegetables are eaten

raw or not. In most cases, treatment will necessitate collecting and treating wastewater in decentralised plants that focus less on environmental pollutants, such as suspended solids and biochemical oxygen demand (BOD), and more on pathogens. The paper by Silva-Ochoa and Scott, Chapter 13, this volume, demonstrated that treatment plants are still being built without consideration of the benefits of use in UPA. Waste stabilisation ponds and chemically enhanced primary treatment with sand filters are two examples of methods that have proven efficient in protecting public health, while being less costly than traditional mechanical, secondary treatment plants. The oft-repeated refrain that treatment is too expensive is questionable – if the Stockholm Framework is properly applied, then in many countries the required standards will actually result in falling costs for the necessary treatment. Furthermore, as shown, farmers are increasingly prepared to pay for wastewater, so financing can be some mix of polluters and users pay principles. It is estimated that levying pollution taxes for only 10% of generated wastewater in Ghana, could bring in up to US$38 million annually (Agodzo, personal communication).

While treatment to meet appropriate guidelines may not yet be feasible in all cases, it should still be one of the desired end results. This however, does not preclude phasing in better treatment over time and progressively providing increased risk reduction, with the goal of eventually arriving at the ultimate target of full treatment. In Pakistan, where most irrigated vegetables are eaten cooked and the main health impact is hookworm in farmers, encouraging the use of footwear by farmers and gloves by crop handlers is more important at this stage than full treatment. Partial treatment would likely bring risk levels down to acceptable levels, and could be as simple as irrigation storage reservoirs, as outlined by Carr *et al.*, which have been proven to reduce risks to farmers and their families in Mexico to minimal levels. In this case, following a hypothetical strategy suggested by Carr *et al.*, Chapter 4, this volume, initial standards could be set at 10^5 FC/100 ml and 50 nematode eggs/l. This standard could be attained using irrigation storage reservoirs with sufficient retention time to allow the pathogens to die off. As resources become available to build additional treatment facilities, and as risks of disease from the water supply or contaminated foods fall, the standards could be tightened to 10^4 FC/100 ml and 10 nematode eggs/l, which could be met with natural primary treatment and storage reservoirs. Eventually, the standard could reach the current recommendation of 10^3 FC/100 ml and 1 nematode egg/l, which can be met by a waste stabilisation pond that provides secondary treatment, with sufficient retention time, disinfector, or polishing slow-sand filters. Inherent in this recommendation is the need to work with industries, institutions, and municipalities, in order to control industrial and toxic contaminants, such as heavy metals, at source. As Silva-Ochoa and Scott note in Chapter 13, it is also important to ensure that treatment does not shift sole access to the resource from poorer farmers, who currently depend on untreated wastewater, to more powerful farmers, or private organisations such as golf courses.

Apply other management options

Increase farmer and public knowledge and awareness

Education programmes for all stakeholders, including farmers, the public, and policy-makers, are essential complements to other risk-reduction tools. The findings in this volume can help stakeholders confront realities, and can form the basis for awareness-raising strategies, including discerning the extent of wastewater use, the extent to which farmers' livelihoods depend upon the practice, and both the positive and negative health impacts within the overall health context of the population. This should be followed by the application of mitigation strategies in line with the WHO guidelines, especially those under the control of the individual stakeholders, such as the wearing of shoes by farmers, and the adequate cooking of produce by consumers. In order to ensure that awareness strategies are relevant and sustainable, both secular tools such as schools and media campaigns, along

with culturally appropriate non-secular tools, need to be used for such strategies to be comprehensive and broad-based. A comprehensive public awareness programme would likely also bring actual and perceived risk levels closer in line, lessening the chance that unnecessarily strict guidelines would be adopted, which could drain a country's limited financial resources without resulting in greatly improved public health.

Minimise human exposure

The WHO has outlined preventive measures for groups potentially at risk from the use of wastewater in agriculture, including farmers and their families, crop handlers, consumers, and those living near the fields. The first two groups are especially susceptible to helminthic infections, so for protection, health authorities can encourage the use of shoes and gloves. Field workers need to be provided with potable water for drinking and hygiene. Similarly, produce vendors should use safe water for washing and rinsing produce – it is ineffectual to protect the crops in the fields if they are contaminated in the market. Finally, consumers should wash and cook vegetables and meats thoroughly, and maintain good hygiene practices. Consumers aware or suspecting that produce is contaminated should soak it in a disinfectant such as sodium hypochlorite or potassium permanganate. Of course these measures in themselves carry risks if the concentration of the disinfectant is excessive, so as always, it is essential for public health departments to underpin all of these measures with comprehensive health and hygiene education campaigns aimed at all stakeholders.

Treat infections

Infection with helminths is the most important health risk associated with wastewater use. In cases where even partial treatment is not possible, and where time is needed to implement other management options, effective health protection may be provided by regular mass treatment of exposed people with anthelmintic drugs. This is especially so if the communities of wastewater farmers are localised, and rather homogeneous. Of course the repeated treatment with safe, single-dose, affordable anthelmintic drugs is a short-term approach, but one that can provide immediate health benefits

Use safer irrigation methods

Irrigation methods can affect both the degree of plant contamination, and the types of precautions farmers can take. In Dakar, the principal method of irrigating with watering cans intensifies the risk of contamination, because droplets touch the plant leaves, while in Pakistan, over-irrigation in furrows without adequate drainage creates an ideal environment for hookworm infection. Localised irrigation techniques such as drip or trickle irrigation are the safest, because the wastewater is applied directly to the root zone of the plants. As an added benefit, this also reduces water consumption. Such techniques require treatment to reduce suspended solids that clog the openings, or the use of drip irrigators with fairly large holes. The treatment can be simple and inexpensive – storage reservoirs that allow suspended solids to settle out may be sufficient. Although drip irrigation is generally the most expensive to implement, some farmers in middle-income countries like Jordan (Faruqui and Al Jayyousi, 2002) are already using this method, and even some in lower-income countries such as Cape Verde and India (FAO, 2001) are doing so as well. Furthermore, low-cost drip irrigation systems such as the 'drum and bucket' that International Development Enterprises (IDE) has tested in Kenya and Zimbabwe have proven successful. Such schemes can be affordable if donors step forward with micro-credit projects to fund this small-scale infrastructure.

The timing of wastewater use can also reduce health impacts. Tunisian standards follow the WHO guideline recommendation that wastewater irrigation be stopped two weeks before harvest. However, this may not always be feasible for farmers without an alternate source of irrigation, as crops will literally wither in the field, particularly during hot and dry times of the year. In such cases, the waiting time period would have to be shortened.

Restrict crops

Crop restrictions can be used where water of sufficient quality is not available for unrestricted irrigation. While crop restrictions can protect consumers, they do not protect farmers and their families, so this measure cannot be applied on its own. Crops restrictions have proven most feasible (for example in Mexico, Peru, and Chile) (Blumenthal *et al.*, 2000), in situations when an irrigation project is centrally managed, strong law enforcement exists, and most importantly, when the crops allowed under the restrictions are profitable. For instance in Haroonabad and Faisalabad, Pakistan, farmers are happy to produce vegetables that are usually eaten cooked, because high demand makes these crops most profitable. In this case, crop restrictions are unnecessary, because there is no strong incentive to produce vegetables eaten raw. In cases when restrictions alone are impractical, such measures must be combined with a methodical public awareness and farmer education programme. In this way, if regulation fails, increased public awareness and market forces may succeed, as there may be reduced consumer demand to purchase vegetables eaten raw that are irrigated with wastewater.

Integrate guidelines and improve institutional coordination

The cases illustrate that health, agricultural, and environmental guidelines often overlap, and sometimes even conflict. Furthermore, there is a lack of collaboration between non-governmental organisations, for example, farmer groups, and those at different levels of government, from municipalities to national departments, including such entities as the Ministries of Agriculture, Health, and Urban Planning. It is essential that all stakeholders be brought together to find mutually satisfactory solutions – based on public input and the Stockholm Framework – policy-makers can then develop integrated health, agricultural and environmental quality guidelines, and implement them in partnership with communities. Although there are still some problems with Tunisia's organisational setup, as outlined by Shetty *et al.* (Chapter 15, this volume) the country has merged the Ministries of Agriculture, Environment, and Water Resources in a new super ministry that now manages water (including wastewater) in a more integrated manner.

Increase security of land tenure

To seriously confront the reality of wastewater use, and to have any lasting positive impact on the health of farmers, the issue of land reform needs to be included as an essential component of any integrated policy. At present, both farmers using wastewater and those using freshwater are already practicing UPA on thousands of hectares of undeveloped public land in and around cities. Often the issue is not the availability of the land, but rather the lack of an authoritative guarantee for its use for a specific period of time, without the threat of sudden expulsion. In exchange for this added security, farmers may even be willing to pay to lease the land, if they are not already doing so. It is unlikely that insecurity of tenure is preventing farmers from taking steps to minimise their exposure, such as buying shoes, gloves or medicine. However, secure tenure is more likely to increase the propensity of farmers to invest in land and irrigation improvements, and some such as localised irrigation systems – whether simple drum and bucket systems, or hoses, pumps, and drip irrigators – have additional protective health benefits. Land reform would also facilitate the building of storage reservoirs, a simple method of treatment that carries the additional benefit of helping balance irrigation water supply with demand. In many cases, these would have to be built on farmers' land, and neither the state nor farmers are likely to build decentralised treatment or storage facilities on land of uncertain status.

Increase donor/state funding

Ideally, polluters (both industry and households), governments, farmers, and consumers, would all pay a share of the costs needed for safe and sustainable UPA that protects the environment and public health, and that enhances food security and nutrition. Polluters

and governments alike should pay for the cost of treatment. Farmers should pay for access to the irrigation water, and for drip irrigators that protect their own and consumer health, recouping some of these costs from the consumers who pay for their produce. Farmers can also be reasonably expected to contribute to a portion of the cost for decentralised treatment, if it is close to or on their land.

Cost sharing may be a realistic medium-term scenario, but only if all stakeholders are convinced of the benefits stemming from policy measures such as wastewater treatment, or the implementation of safer irrigation systems. Farmers may be more willing to contribute if the benefits of such measures are first demonstrated to them. Governments may also be more willing to contribute to the cost of implementing the above recommendations after realising the economic and employment impacts arising from food markets, and the improved nutrition associated with UPA that uses wastewater. However, this requires investment before the fact, to bring services up to a standard to which all stakeholders are willing to contribute. During this transition period, it is crucial for foreign aid donors to step in to provide the initial funds, in order to prove to both farmers and policy-makers that the benefits of UPA can be realised without excessive health risks. Without additional funding, many of the recommended options cannot be meaningfully implemented.

Conduct research

Due to the informal and quasi-illegal nature of wastewater irrigation, and the cost and time required to do methodical research, many findings to date only probe the surface. More profound and methodical research will be necessary if the issues related to the realities of wastewater use are to be brought onto the global agenda. Chapter 8 by Ensink *et al.*, is a good model of comprehensive scientific, research on wastewater use in a particular case, while Buechler's Chapter 3 outlines useful suggestions to ensure that research is centred on the livelihoods of farmers, the principal actors in this play, while also capturing all social, economic, and political aspects. In fact, research needs to be participatory, and account for farmers' concerns, perceptions, and practices, if the research results are to be implemented in a sustainable fashion. Some key research gaps that must be addressed before the above recommendations can be meaningfully implemented include:

- testing the feasibility and cost-effectiveness of non-treatment management options;
- designing efficient, cost-effective, and sustainable natural wastewater treatment systems that conserve nutrients while effectively removing pathogens;
- identifying incentives for industrial effluent separation and treatment;
- developing appropriate standards and guidelines to protect public health in different contexts;
- finding the best institutional policies, frameworks, and implementation mechanisms to help municipal and national institutions work together to support urban farmers and protect public health; and
- investigating the political economy of wastewater use in UPA, including analysis of inequitable access to irrigation sources and land.

In addition, in order to attract increased donor and state funding, information on the following topic is required.

Value-addition of wastewater use

Better economic estimates of the value of UPA that uses wastewater will emphasise its importance for poverty alleviation to donors and policy-makers. Researchers have only been able to present vague economic estimates on the benefits and costs of UPA, and most donors and policy-makers are completely unaware of the degree of urban farming and its importance to the national economy. For instance, in Pakistan, 26% of the vegetables produced are grown using wastewater (Ensink *et al.*, Chapter 8, this volume). Decision-makers need hard estimates of the total area cropped, the annual production of different types of crops produced, and their monetary values. This could then be compared to the total amount produced in rural agriculture. Once its economic significance is realised, both donors

and policy-makers are likely to pay more attention.

One important missing area of research is a comprehensive guide to the economic impact of wastewater use that goes beyond the employment and nutritional benefits discussed above. Some attempts have been made to develop frameworks for such an analysis (Hussain *et al.,* 2001) but there is little information on the economic externalities associated with discharging wastewater into water bodies and wetland systems that have downstream beneficial uses. Little work has been made on savings in treatment costs associated with land application of wastewater, or income-generating opportunities derived from agricultural use. The results of such analysis could potentially impact the way in which wastewater agriculture is viewed. Research on household greywater reuse in Jordan has demonstrated that the benefit-cost ratio of reuse for agriculture is as high as 5 (Faruqui and Al Jayyousi, 2002). Also needed is a similar examination of semi-collective treatment systems, on which policy recommendations can be based. Ensink *et al.* (2004) provided an innovative way of estimating the value of land accessible to farmers, by identifying the higher rents for land having access to wastewater for irrigation, as compared to land that is irrigated with freshwater. However, more work is needed on this aspect of wastewater use.

Conclusions

The deepening integration of today's food markets makes the use of wastewater in agriculture a vital issue for all countries to address, and this recognition must start with the acknowledgement that the practice is already widespread, and contributes much more to farmers' livelihoods and to food security than is commonly understood. In some cases, farmers would be unable to earn a living without using wastewater, and for others, its use increases the income they would normally make, lifting them out of poverty. However the practice often threatens the health of the farmers, their families, the broader public, and the environment. Policy-makers must find a way to protect both farmers' incomes as well as public health, in a way that is economically sustainable. This volume was inspired by a workshop in Hyderabad, India, in November 2002, at which researchers, and policy-makers brainstormed potential options, and offered some suggestions, encapsulated in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume).

These realisations have changed the views of policy-makers, even among those involved in setting the initial 1989 WHO guidelines. The newly emerging ones recommend that guideline setting be a holistic risk-analysing exercise, adapted to each country's social, economic, and environmental circumstances. This would entail taking into account background levels of gastrointestinal illness, and allocating scarce health protection dollars to the highest priority. An integrated set of measures, that collectively form a multi-barrier approach to protect health is also suggested, including progressively phased-in treatment, and other management options. These encompass raising public awareness, using safer irrigation methods, minimising human exposure, restricting crops, disinfecting of produce by consumers, institutional coordination, increasing land tenure, and increasing funding. Finally, in order to achieve meaningful implementation, and to secure the necessary funding from donors, further research must be done to evaluate the feasibility and cost-effectiveness of the above suggestions, and to establish better estimates of the economic value of wastewater use in urban and peri-urban agriculture.

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