Wastewater Use in Irrigated Agriculture

Coordinating the Livelihood and Environmental Realities

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Foreword

Growing water scarcity threatens economic development, sustainable human livelihoods, environmental quality, and a host of other societal goals in countries and regions around the world. Urban population growth, particularly in developing countries, places immense pressure on water and land resources; it also results in the release of growing volumes of wastewater – most of it untreated. Wastewater is increasingly being used for irrigation in urban and peri-urban agriculture, and even in distant rural areas downstream of the very large cities. It drives significant economic activity, supports countless livelihoods particularly those of poor farmers, and very substantially changes the hydrology and water quality of natural water bodies. There are of course rather serious drawbacks for human health and the environment that result from using wastewater without adequate safeguards. The challenge is to identify practical, affordable safeguards that do not threaten the substantial livelihoods dependent on wastewater, or diminish the important role this resource plays in achieving household food security and supplying low-cost produce to growing cities.

The Millennium Development Goals aim to halve, by 2015, the number of people without access to water supplies or safe and affordable sanitation. Sustainable and safe wastewater use can support the achievement of these goals by preserving valuable fresh water for drinking. Furthermore, sanitation goals have always been difficult to achieve, as other priorities always seem to attract scarce resources. To ensure the efficient use of funds, the goal of improved sanitation should be pursued with the objective of wastewater use in mind, as the type of technology selected can either help or hinder the goal of reuse. Using wastewater for agriculture, i.e. valuing both the water resource and the nutrients for a new productive use, changes the thinking from having to deal with a costly nuisance to trying to harvest a potentially valuable resource.

The present volume addresses these issues head-on through a series of thematic chapters aiming to better understand wastewater use in agriculture in developing countries and detailed case study documentation of what works and what does not. The book is part of ongoing collaboration between the International Water Management Institute (IWMI) and the International Development Research Centre (IDRC). Both our institutions are committed to the sustainable use of natural resources in developing countries, and while we may approach the subject of wastewater from diverse perspectives, we agree that wastewater is a resource of growing global importance and that sustainably managed, it can greatly enhance livelihoods and improve environmental quality. This central tenet is recognized in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume), an important outcome of the joint IWMI-IDRC workshop held 11–14 November 2002 in Hyderabad, India.

The editors and contributing authors represent a wide spectrum of experience and perspectives on wastewater use in agriculture, and collectively form a growing 'community of practice' that will generate, exchange and broker knowledge. The volume should serve to change thinking on the part of decision makers in such international bodies as the World Health Organization, national and state governments (some of whom were present at the November 2002 workshop in Hyderabad), researchers and practitioners. Both IWMI and IDRC see this as an important boost to promoting safe and sustainable use of wastewater.

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Acknowledgements

Pulling together such a broad-based book as this has drawn on the considerable talents and efforts of many individuals and institutions. The editors would particularly like to thank those present at the November 2002 Hyderabad workshop (including a number of the contributing authors) for enriching and enlivening the debate around wastewater irrigation that was the genesis of this book. The fine quality of the 16 chapters would not have been possible without the excellent comments and inputs of the external reviewers. Additionally, we are indebted to the editorial, graphics and typesetting team – Sue Hainsworth, TNG Sharma, Deanna Hash and Shiraz Mehta – for their very substantial efforts that made this possible. Last but by no means least, the difficult logistical challenges of handling manuscript submissions, external reviews, rejections and approvals, author revisions, resubmissions and final turnover of the chapters to the editorial team was handled by Roja Rani with her usual aplomb and good nature. To all these and many others, thank you.

IWMI would like to thank IDRC for the generous grant that made this book possible. Finally, IWMI and IDRC gratefully acknowledge the role that CAB International and Tim Hardwick in particular have played in agreeing to publish the book; we count on their ongoing efforts to distribute this volume as widely as possible.

1 Wastewater Use in Irrigated Agriculture: Management Challenges in Developing Countries

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Abstract

Cities in developing countries are experiencing unparalleled growth and rapidly increasing water supply and sanitation coverage that will continue to release growing volumes of wastewater. In many developing countries, untreated or partially treated wastewater is used to irrigate the cities' own food, fodder, and green spaces. Farmers have been using untreated wastewater for centuries, but greater numbers now depend on it for their livelihoods and this demand has ushered in a range of new wastewater use practices. The diversity of conditions is perhaps matched only by the complexity of managing the risks to human health and the environment that are posed by this practice. An integrated stepwise management approach is called for, one that is pragmatic in the short- and medium terms, and that recognises the fundamental economic niche and users' perceptions of the comparative advantages of wastewater irrigation that drive its expansion in urban and peri-urban areas. Comprehensive management approaches in the longer term will need to encompass treatment, regulation, farmer user groups, forward market linkages that ensure food and consumer safety, and effective public awareness campaigns. In order to propose realistic, effective, and sustainable management approaches, it is crucial to understand the context-specific tradeoffs between the health of producers and consumers of wastewater-irrigated produce as well as the quality of soils and water, on the one hand, and wastewater irrigation benefits, farmers' perceptions, and institutional arrangements on the other. This introductory chapter to the current volume on wastewater use in agriculture highlights a series of tradeoffs associated with continued use of untreated wastewater in agriculture. Empirical results from the case studies presented in the volume shed light on devising workable solutions.

Rapid Expansion of Wastewater Irrigation in the Coming Decades

The use of urban wastewater in agriculture is a centuries-old practice that is receiving renewed attention with the increasing scarcity of freshwater resources in many arid and semi-arid regions. Driven by rapid urbanisation and growing wastewater volumes, wastewater is widely used as a low-cost alternative to conventional irrigation water; it supports livelihoods and generates considerable value in urban and peri-urban agriculture despite the health and environmental risks associated with this practice. Though pervasive, this practice is largely unregulated in low-income countries, and the costs and benefits are poorly understood.

This volume critically reviews worldwide experience in the use of wastewater for agriculture through a series of chapters defining and elaborating on the issues at the centre of the debate around wastewater use in agriculture. Particular emphasis is placed on untreated wastewater use through field-based case studies from Asia, Africa, the Middle East, and Latin America, which address the environmental and health impacts and risks of the practice. These chapters consider multiple aspects including the economic, social, health, agronomic, environmental, institutional, and policy dimensions and the research needs related to this growing practice. The editors conclude with a prognosis of future challenges and realities of wastewater use in agriculture.

Cities throughout the developing world are growing at unprecedented rates, yet there are no reliable data on the sewage volumes they generate or any comprehensive assessments of the fate or use of urban wastewater. However, because sewage collection and its disposal as wastewater are increasing in developing-country cities as a function of the growth in urban water supply, water supply coverage is a reasonable proxy for projecting increases in wastewater volumes. Increases in urban water supply depend on myriad factors and will likely be unable to keep pace with urban population growth, implying falling per capita water supply rates. In spite of the fact that trends show that rates of urbanisation are likely to slow down in developed countries, in many countries of the developing world urbanisation will continue rapidly. As a result, wastewater flows will increase in the future. In developing countries where investments in water supply far outpace those in sanitation and waste management, suffice it to say that treatment and disposal of wastewater are inadequate or non-existent and that raw sewage – full-strength or diluted – is used and even competed for in order to irrigate food, fodder, ornamental and other crops.

We suggest that raw wastewater use in agriculture is presently increasing at close to the rate of urban growth in developing countries subject to urban and peri-urban land being available. Consider the demographics that will drive expansion in the volumes of wastewater generated. It is projected that 88% of the one billion growth in global population by 2015 will take place in cities, essentially all of it in developing countries (UNDP, 1998). Developed countries' populations are expected to decline 6% by 2050, while the global rural population should plateau at approximately 3.2 billion. The result is that after 2015, all worldwide growth in population will take place in developing-country cities. Cities are home to political and economic power and will continue to ensure that their water supply needs are met on a priority basis subject to physical and economic scarcity constraints. The Millennium Development Goals call for halving the proportion of people without access to improved sanitation or water by 2015. As a result, an additional 1.6 billion people will require access to a water supply – 1.018 billion in urban areas and 581 million in rural areas (WHO and UNICEF, 2000).

Water supply ensures wastewater because the depleted fraction of domestic and residential water use is typically only 15–25% with the remainder returning as wastewater. Although the numbers of urban dwellers in developing countries that continue to rely on septic tanks, cesspits, etc. is unexpectedly high, growing numbers are connected to sewers that deliver wastewater – largely untreated – to downstream areas. Very often too in spite of onsite sanitation, substantial volumes of domestic wastewater including toilet wastes find their way into surface water networks within cities. Table 1.1 shows by region the percentages of sewerage coverage and the wastewater actually treated.

This volume covers wastewater management examples from Africa, the Middle East, Latin America, and Asia. Although the challenges are significant in all these regions, in terms of overall magnitude (volumes of wastewater, numbers of people affected, and land irrigated) Asia represents the largest challenge. Despite the relatively high sewerage and treatment figures reported for Asia in Table 1.1, most of the global growth in urban water supply will take place in this region as seen in Fig. 1.1. The total numbers of people in Asian cities will generate such large volumes of wastewater that

Table 1.1. Sewerage coverage and wastewater treatment by world region.

Region	Population (%) in large cities that is sewered	Sewered wastewater (%) that is treated to secondary level
Africa	18	0
Asia[a]	45	35
Latin America/ Caribbean (LAC)	35	14
Oceania	15	Not reported
Northern America	96	90
Europe	92	66

[a] The *Global Water Supply and Sanitation Assessment 2000 Report* figures for Asia include Japan, South Korea, Taiwan, and other developed countries (WHO and UNICEF, 2000).

downstream agriculture with highly polluted wastewater is well nigh unavoidable. In India for example, the major bulk of population growth is expected to occur in 40–45 cities each with population greater than 100,000, not just in the mega cities (Amitabh Kundu, urban demographer, personal communication). Based on Central Pollution Control Board data for 2001, the Infrastructure Development Finance Corporation estimates that 73% of urban wastewater in India is untreated, requiring an investment in treatment capacity of the order of US$65 billion or ten times greater than what the Government of India proposes to spend (Kumar, 2003). China is also experiencing rampant urban growth. In both countries, sewerage coverage and wastewater treatment lag behind water supply, which in turn lags behind population growth.

These demographic processes coupled with increasing purchasing power will create unprecedented demand in urban markets for vegetables, milk, ornamental plants, etc. that are readily – in fact, competitively – produced using the wastewater that urban consumers themselves generate. With water scarcity, land

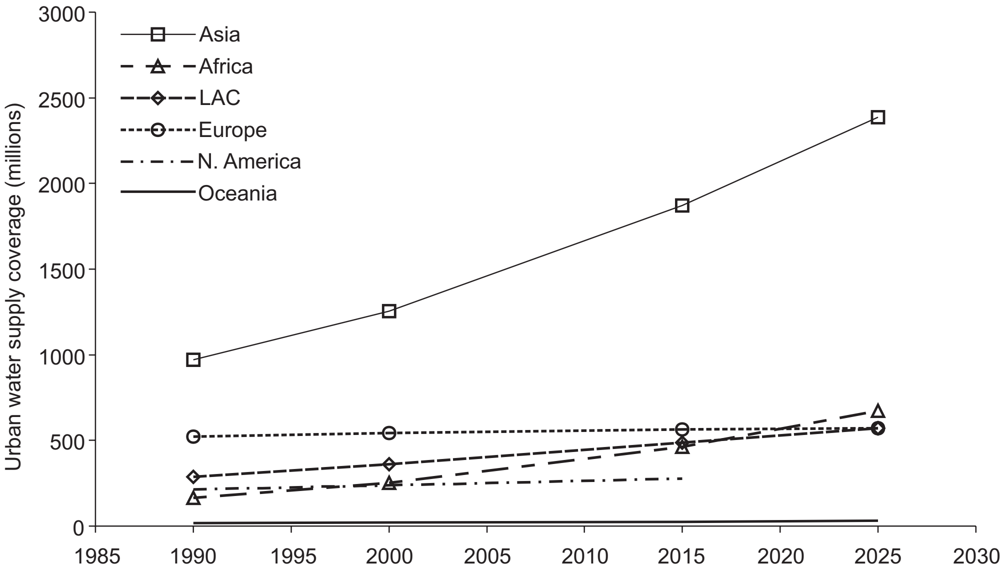

Fig. 1.1. Growth in urban water supply coverage by world region.

pressure, and little feasible budgetary alternative for effectively treating the growing wastewater volumes, the burgeoning of wastewater irrigation in developing country cities is already taking place.

Although it is impossible to devise effective management solutions from such global wastewater trends, our purpose at this juncture is to flag the immensity of the challenges of wastewater management in the urban and peri-urban fringe, where irrigation of a range of produce for urban markets is the most common use of wastewater. The challenges of wastewater management in the urban to peri-urban corridors will unavoidably grow more complex.

Both the pragmatists who see the difficulty in applying bans on wastewater irrigation and the detractors of wastewater use in agriculture find ample cause to bolster their positions. Numerous case studies on the dynamics of urban agriculture show that wastewater irrigation supports countless livelihoods of both marginal and better-established, or even commercial farmers and the labourers they employ, all of whom occupy production and marketing niches. These social and economic processes driving wastewater irrigation may often be overlooked from the regulatory perspective of urban, public health or environmental authorities who view the protection of public health and environmental quality as their primary objectives, despite the fact that regulators may be aware that urban farming using wastewater is a prevalent phenomenon. Furthermore, in many instances regulations are not applied with adequate rigour, entailing that purely regulatory approaches to manage wastewater irrigation tradeoffs are inevitably ineffective. For example, Accra, Ghana has passed regulations on the use of urban wastewater; but farmers largely ignore them and authorities are incapable of enforcement (Keraita and Drechsel, Chapter 9, this volume).

In water-scarce and even humid regions, farmers prize the water and nutrient value and supply reliability of the wastewater stream. And under the most common scenario in water-scare countries of a city expanding more rapidly than its water supply, sewage may water what little green space remains.

Irrigation with untreated wastewater can represent a major threat to public health (of both humans, and livestock), food safety, and environmental quality. The microbial quality of wastewater is usually measured by the concentration of the two primary sources of water-borne infection – faecal coliforms and nematode eggs. A range of viruses and protozoa pose additional health risks. Wastewater has been implicated as an important source of health risk for chronic, low-grade gastrointestinal disease as well as outbreaks of more acute diseases including cholera (e.g. Jerusalem and Dakar) and typhoid (Santiago). Disease agents are found in wastewater that drains from planned residential areas and slums alike. The health of the urban poor is particularly linked to inadequate management of wastewater. Chronic diarrhoeal and gastrointestinal diseases, which disproportionately affect urban slum dwellers who have inadequate sewerage and sanitation facilities, are clearly major negative outcomes of exposure to wastewater. A primary exposure route for the urban population in general is the consumption of raw vegetables that have been irrigated with wastewater (Fattal *et al.*, Chapter 5, this volume). Additional exposure routes for the urban poor, who are often migrants with little access to health services, include direct contact with solid waste and wastewater, as for instance through riverside open defecation grounds.

Additionally wastewater irrigation of vegetables and fodder may serve as the transmission route for heavy metals in the human food chain. Particularly in South Asia, where per capita milk consumption is the highest in the developing world and growing rapidly (Delgado *et al.*, 1999), wastewater is increasingly used to irrigate fodder that supplies an urban and peri-urban livestock-based production chain. Evidence of heavy metal transmission through milk is presented by Swarup *et al.* (1997). In the absence of chilling, storage and transport facilities, milk must be produced as close to market as possible; it represents an important urban and peri-urban agricultural product. Further, fodder cultivation is particularly well matched to wastewater; it requires continual irrigation application and is generally tolerant of the high salinity levels characteristic of urban wastewater.

Finally, the environmental quality of soils, groundwater and surface water, and to a lesser degree, stream channel biota and ecological conditions as indicated by the biodiversity of the wastewater-contaminated river or other receiving water body are often the second-order casualties if wastewater is disposed indiscriminately.

Cities in both arid and humid regions are witnessing unprecedented expansion of urban and peri-urban agriculture using poor-quality water. For example, in Bolivia, indirect use of wastewater takes place in almost all rural and peri-urban areas downstream of the urban centres (Huibers *et al.,* Chapter 12, this volume). Additionally, although wastewater irrigation has been thought to be limited to large cities, in regions such as Gujarat, India, it is common even downstream of small towns and villages (Bhamoriya, Chapter 11, this volume). As seen in the cases of Vietnam (Raschid-Sally *et al.,* Chapter 7, this volume), Jordan (McCornick *et al.,* Chapter 14, this volume), Senegal (Faruqui *et al.,* Chapter 10, this volume), or Bolivia (Huibers *et al.,* Chapter 12, this volume), the implications for public health and the environment are equally serious whether wastewater is intentionally used for irrigation or whether it is simply mixed with freshwater that is used for irrigation.

In sum, wastewater is a resource of growing global importance and its use in agriculture must be carefully managed in order to preserve the substantial benefits while minimising the serious risks. This reality was recognised and its implications deliberated in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume), one of the outcomes of a workshop held 11–14 November 2002 in Hyderabad, India and sponsored by the International Water Management Institute (IWMI, based in Colombo, Sri Lanka) and the International Development Research Centre (IDRC, based in Ottawa, Canada). The other outcome is this volume – most of the chapters were drawn from the workshop, which had the following objectives:

- To critically review experience worldwide in the use of wastewater for agriculture
- To present lessons learned from specific field-based case studies, including the environmental and health impacts and risks of wastewater use in agriculture
- To refine a methodology developed and applied by IWMI for selected countries that seeks to assess the global extent of wastewater use in agriculture
- To evaluate the institutional arrangements, constraints, and policy implications for sustained livelihoods based on wastewater use in agriculture
- To build a wastewater ‘community of practice’ integrating a variety of research, implementation and policy institutions and partners
- To offer some conclusions and recommendations for further research that help balance the need to protect public health and farmers’ incomes.

This introductory chapter sets the stage for the chapters that follow in this book. The initial chapters address key thematic issues for wastewater management: a wastewater use typology, an overview of a wastewater-based sustainable livelihoods framework, discussion of public health guidelines, and assessment of the cost-effectiveness of treatment required to meet guidelines. There follow a series of case studies detailing wastewater use practices around the world, focusing on the complex set of challenges and identifying potential solutions. The emerging view is that a realistic approach requires that tradeoffs are considered in both the short and long terms. Several factors drive wastewater irrigation: the lack of equally remunerative livelihood alternatives, the continued expansion of the wastewater resource base, and the ineffectiveness of regulatory control approaches that have characterised most attempts at management. The experiences of countries that are in the process or have completed the conversion from untreated to regulated, treated reuse can serve as important lessons. The cases of Tunisia, Jordan and Mexico are presented in this volume.

Treated wastewater currently represents approximately 5% of Tunisia’s total available water; this is planned to increase to 11% by 2030 (Shetty, Chapter 15, this volume). Salinity management remains a major objective of the Tunisian wastewater use programme. In Jordan, wastewater represents 10% of the current total water supply (McCornick *et al.,* Chapter 14, this volume). Groundwater recharge is one of the explicit uses of wastewater in Jordan, but not for aquifers that are used for drinking water supply. The previous (waste-) water quality standards required some revision in order to accommodate Jordan's plans to reuse water, particularly for sprinkler irrigation, which was prohibited for wastewater. In order to meet strict export phytosanitary controls, the irrigation of vegetables eaten raw with reclaimed water, no matter how well treated, remains prohibited in Jordan. In Mexico, implementation of wastewater treatment (but not necessarily its use) has been mandated by federal environmental quality regulations (Silva-Ochoa and Scott, Chapter 13, this volume). While wastewater use in agriculture is a common practice, particularly in Mexico's vast arid and semi-arid areas, it is mostly practised informally with the result that planned treatment for use in agriculture is not common. Instead, municipal water boards that bear the cost of treatment prefer to seek paying customers for treated wastewater, particularly golf courses, urban green spaces, etc.

Estimating the Magnitude of Wastewater Use in Irrigated Agriculture

Just how prevalent wastewater irrigation is today is a matter of conjecture; no sound, verifiable data exist. Earlier approximations by Scott (in Future Harvest, 2001, that were intended to stir the debate), based on figures for sewage generated, treatment capacity installed, assumptions of the proportion of peri-urban areas without wastewater demand for agriculture (e.g. coastal cities, etc.), freshwater mixing ratio, and annual irrigation depths, placed the area at 20 million ha of irrigation using raw or partially diluted wastewater. Since the release of this first-cut estimate, the reactions have been multiple that:

1. The 20 million ha figure is an overestimation of 'raw sewage irrigation' given that it includes areas irrigated with partially diluted wastewater
2. Wastewater irrigation is not important enough a phenomenon to warrant resources for research and management
3. The magnitude of the problem is significantly greater than that implied by the 20 million ha estimate
4. Isolated case studies barely scratch the surface and indeed irrigation using wastewater or seriously polluted water is pervasive and represents a major concern.

Clearly there is a need to establish and apply a verifiable method for determining the prevalence of wastewater irrigation. As an important first step in this direction, van der Hoek (Chapter 2, this volume) presents a typology. Raschid-Sally *et al.* (Chapter 7, this volume) and Cornish and Kielen (Chapter 6, this volume) present assessments at the country level with estimates of 9,000 ha for Vietnam and 11,900 ha for Ghana. Ensink *et al.* (2004) estimate that 32,500 ha are irrigated with wastewater in Pakistan. These results are based on a typological definition of undiluted wastewater, i.e. 'end-of-pipe' sewage irrigation, which does not account for irrigation using water polluted with wastewater, that poses many of the same risks and management challenges. Van der Hoek's typology includes marginal quality water, i.e. polluted surface water; however, country estimates have tended to focus on undiluted wastewater irrigation, suggesting that 20 million ha is an overestimation of the global extent of the practice. It is important to recognise, however, that improved estimates of global wastewater irrigation would need to account for a number of countries with rapidly growing cities and large national irrigation sectors including particularly China, Egypt, India, Indonesia, Iran, Mexico, and Pakistan.

This does not detract from the importance of wastewater irrigation or the difficulty of the management challenges in other countries or regions. Further, getting a precise fix on the global extent of wastewater irrigation should not deflect attention or resources from the far more substantive management issues that are invariably context-specific as demonstrated in the case studies presented in this volume.

Multiple complementary factors drive the increased use of wastewater in agriculture. Water scarcity, reliability of wastewater supply, lack of alternative water sources, livelihood and economic dependence, proximity to markets, and nutrient value all play an important role. Water scarcity and reliability of wastewater supply are crucial. The case studies in this volume of Dakar in Senegal, Cochabamba in Bolivia, and Vadodara in India all demonstrate this. That farmers have few alternative water sources may be true where wastewater is mixed with freshwater; however, in water-scarce regions, wastewater is invariably the only source. Interestingly in some cases, as in Pakistan where canal irrigation water is available, although with reliability and supply constraints particularly in the tail-end reaches of the irrigation systems, many farmers convert to wastewater by choice. Livelihood dependence for poor farmers remains the single most important socioeconomic driver of the practice, yet it is misleading to assume that all wastewater farmers are poor (Buechler, Chapter 3, this volume). Indeed, larger, commercial-scale farmers have made inroads and may compete with small-scale farmers for wastewater as well as for markets. Additionally, because of the market orientation of much wastewater agriculture in urban and peri-urban contexts, it absorbs significant labour, much of it female (Keraita and Drechsel, Chapter 9, this volume, and Faruqui *et al.*, Chapter 10, this volume). Finally, while most farmers acknowledge the nutrient value of wastewater this appears to be a secondary driver, i.e. the scarcity or poor quality (usually salinity) of alternative sources is generally more important.

Wastewater irrigation will remain consigned to informal practice and as a result management approaches must start at the informal or semi-formal level. Two important characteristics of wastewater irrigation in the case studies on Asian cities presented in this volume (Bhamoriya and Buechler from India; Ensink *et al.* from Pakistan) are semi-formal institutional arrangements and prominent, yet farmer-initiated, infrastructure for irrigation using untreated wastewater. Both suggest a degree of institutionalisation that is not evident in untreated wastewater use in other regions. While the use and livelihood dependence on wastewater in African cities is not entirely dissimilar, it is hypothesised that social relations and land tenure issues related to state or communal ownership of land may not result in the same formalisation of wastewater irrigation in urban and peri-urban agriculture as seen in Asian cities. By contrast, many countries in North Africa (Shetty, Chapter 15, this volume), the Middle East (McCornick *et al.*, Chapter 14, this volume), and Latin America (Silva-Ochoa and Scott, Chapter 13, this volume) have embarked on formal *treated* water reuse programmes. These provide important lessons, discussed in the conclusions, for the design of programmes to make the transition from informal to formal wastewater use.

Uni-dimensional management solutions for wastewater irrigation that employ exclusively technical (treatment) or regulatory (bans, crop restrictions, etc.) approaches have generally been inadequate. In isolation neither fully takes account of the multiple drivers of the process, nor the need for integrated management solutions. Realistic and effective management approaches rarely hold up technical or regulatory approaches as the complete solution, but instead seek to apply these in an integrated way. The more difficult question, particularly in the context of weak regulatory implementation, lies in the multiple – often competing – needs to secure livelihoods based on wastewater irrigation on the one hand, and public health and environmental protection imperatives on the other. Should the economic realities of a few override the need to protect broader societal goals? Clearly not, yet a more pragmatic approach is required than has been implemented in most developing country contexts. As discussed in the concluding chapter of this volume, we advocate a graduated approach to meeting targets [termed 'stepwise' in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume)], specifically that all aspects of the solution must be realistic. The concluding chapter elaborates the essential recommendations from this volume, i.e. 1. develop and apply appropriate guidelines for wastewater use, 2. treat wastewater and control pollution at source, 3. apply a range of non-treatment management options, and 4. conduct research to improve understanding of the practice as well as opportunities and constraints to adoption of these recommendations.

Guidelines for Health and Environmental Quality

The single most important rationale for more stringent control over wastewater use in agriculture is the risk posed to human health (of irrigators, consumers of produce, and the general public) and to the environment. Guidelines for wastewater use and standards for water quality matched to particular end uses have been developed and applied with varying degrees of success. Two sets of guidelines that aim to protect human health under conditions of planned reuse of treated wastewater – those set out by the World Health Organization (see Carr *et al.*, Chapter 4, this volume) and the United States Environmental Protection Agency (USEPA) – have raised considerable controversy in particular with respect to their feasibility and applicability in different developing country contexts. Fattal *et al.* (Chapter 5, this volume) estimate that the cost of treating raw sewage used for direct irrigation to meet the current WHO microbial guideline of 10^3 faecal coliforms/100 ml is approximately US$125 per case of infection (of hepatitis, rotavirus, cholera, or typhoid) prevented. By comparison, the incremental cost of further treating wastewater from the WHO to the USEPA microbial guideline is estimated to be US$450,000 per case of infection prevented.

It is not our purpose here to join the guidelines debate, except to insist that cost-effective risk mitigation be the primary goal of any programme that includes guidelines for wastewater use in agriculture. Developing and applying pragmatic guidelines based on *managed risk* or *acceptable risk* instead of *'no risk'* criteria must be the approach adopted. As detailed by Carr *et al.* (Chapter 4, this volume), the Stockholm Framework encourages flexibility in the adoption of wastewater use guidelines to facilitate progressive implementation of guidelines and to account for local conditions, particularly other risk factors that may be more acute than microbial diseases linked to wastewater. Additionally, Carr *et al.* identify a number of beneficial outcomes of wastewater use that tend to be overlooked in the guidelines debate. A key factor that needs to be integrated in any future approach is the livelihoods dimension of such unplanned use and the associated benefits (Buechler, Chapter 3, this volume; Drechsel *et al.*, 2002).

There are two primary constraints to the adoption of any set of guidelines: firstly infrastructure, operation and maintenance, and the associated investment and recurring costs that are required to handle or treat wastewater to the quality levels stipulated in the guidelines, and secondly regulatory enforcement to ensure compliance with required practice on the part of water authorities, those discharging wastewater, and those handling and using wastewater. Invariably the infrastructure issue is seen as the principal challenge, so that much of the debate is centred on wastewater treatment plants, their design, cost of operation, maintenance, etc. The assumption appears to be that with adequate technical control, the need to limit wastewater discharge and subsequent use is sufficiently minimised. This places ultimate responsibility for guidelines compliance on urban development authorities who control the finance of wastewater infrastructure and on wastewater treatment plant operators. Yet in the case of planned reuse there are larger institutional issues that permit (or impede) the implementation of wastewater use programmes, of which guidelines may be an important component. As seen in the Tunisian and Jordanian cases, the other 'software' components of such programmes including inter-agency coordination, public awareness campaigns, and emergency response (to disease outbreaks, etc.) are critical to risk mitigation.

In developing-country contexts, however, use of wastewater is an unplanned activity, and authorities tend to view the responsibility of regulating its use as a burden. In the absence of resources for treatment infrastructure and regulatory control, the guidelines proposed by the WHO, while relevant in a planned reuse context, are relegated to the status of targets (usually unachievable) instead of norms for practice. The distinction between norms and targets is an important one. Norms require compliance with a minimum acceptable level of practice, e.g. wastewater discharge for unrestricted irrigation must have less than 10^3 faecal coliforms per 100 ml. Targets are feasible but invariably unachieved levels, e.g. wastewater treatment plant X discharges effluent with 10^4 faecal coliforms/100 ml, almost meeting the 10^3 target.

Short-term and Long-term Scenarios and Tradeoffs

Based on projected increases in urban water supply coupled with improved sewage collection resulting from sanitation programmes, the volumes of wastewater released from developing-country cities will certainly increase in the short (next 5 years) and long (next 25 years) terms. At least three factors relevant to the subject of this volume make long-term future projections of the global extent of wastewater irrigation problematic:

1. The poor reliability of water supply goals as a proxy for increases in the volumes of wastewater generated over the long term
2. Uncertainty in the degree and effectiveness of treatment that is implemented and sustained for those volumes of sewage that are collected
3. Changing societal demands for health and environmental protection that necessarily must be the driving force behind compliance and enforcement of wastewater irrigation guidelines and related regulatory frameworks.

In the short term, wastewater use will continue to grow and the immediate priority challenges are posed by the need to mitigate both chronic and acute risks while simultaneously addressing medium- and long-term constraints to integrated wastewater management. A priority short-term objective is to control wastewater exposure (through crop selection to minimise exposure of both consumers and producers, providing extension support for affordable but safer irrigation practices including piped distribution, field application using broad furrows that minimise crop and irrigators' exposure, protective equipment supported by public awareness, etc.). Second order, but potentially effective measures include therapeutic medical care for irrigators, e.g. anti-helminthic drugs, and provision of safe water in markets to protect consumers of vegetables eaten raw by ensuring that market produce is not washed or 'freshened' using wastewater.

In the medium term (10–15 years), wastewater treatment capacity is unlikely to keep pace even with water supply increases much less to make up the current gap between wastewater generated and collected and that actually treated. To find workable interim solutions, it is essential to table a dialogue among wastewater managers, urban authorities and existing irrigation users of untreated wastewater. For example, farmers should make known their interest in nutrients and organic matter. Urban authorities responsible for watering green spaces should share information with farmers to best allocate dry-season wastewater flows. Finally, downstream users should demonstrate to upstream producers of wastewater and to sanitation planning authorities that downstream agriculture is providing *de facto* treatment, but should insist on effective upstream contaminant source control and efforts to prevent particularly the more toxic constituents from entering the waste stream. Industrial sources of heavy metals, organics, and pharmaceutical waste need to be recovered in on-site or industrial park common effluent treatment plants before the liquid discharge is mixed with wastewater of primarily residential and commercial origin. End-of-pipe regulations for industries are much more enforceable from a purely logistical perspective – though perhaps more difficult institutionally when corruption and associated 'insider deals' are at play – than will be efforts to sewer, collect and treat wastewater from millions of dispersed urban residents in growing urban centres.

In the long term, wastewater treatment to at least primary level using settling basins or facultative lagoons must be the norm. Lowering the cost is essential if efforts to treat wastewater are to be effective. Although the costs of technology and even operation and maintenance of primary treatment are low, land value or the opportunity cost of urban or peri-urban land is often a formidable barrier to effective treatment in the long term. Urban authorities need to recognise the growth requirements now and set aside land for future treatment facilities in order to offset high future land acquisition costs. They must also plan for integrated wastewater management that includes downstream beneficial uses of the wastewater.

At all stages, public awareness for farmers, authorities, and the public at large is essential, not just of the risks and benefits, but more importantly of several of the tradeoffs discussed here.

Conclusions

We have shown, based on our own experience and collaborations spanning multiple countries, continents, and contexts that irrigation using untreated wastewater is a prevalent phenomenon with multiple tradeoffs – between livelihoods and the need to protect health and the environment, between water demand under conditions of scarcity and the need for waste (water) disposal, and finally between informal practice led by farmers and formal institutional initiatives involving health, urban, water and agricultural authorities. A supreme degree of pragmatism and commitment is required under the realisation that effective solutions must be incremental and will take time to implement.

Planned reuse that seeks to maintain the benefits and minimise the risks will require an integrated approach. Key to the success of endeavours to make the transition to planned strategic reuse programmes are a coherent legal and institutional framework with formal mechanisms to coordinate the actions of multiple government authorities, sound application of the 'polluter pays' principle, conversion of farmers towards more appropriate practices for wastewater use, public awareness campaigns to establish social acceptability for reuse, and consistent government and civil society commitment over the long term with the realisation that there are no immediate solutions.

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