RESEARCH REPORT

127

Drivers and Characteristics of Wastewater Agriculture in Developing Countries:

Results from a Global Assessment

Liqa Raschid-Sally and Priyantha Jayakody

International Water Management Institute

COMPREHENSIVE Assessment of water management in agriculture

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Cover photograph shows a view of the Niger River flowing through Bamako, the capital city of Mali. The water is polluted from urban wastewater discharges and is used for urban agriculture on its banks.

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Contents

Acronyms and Abbreviations

AF	Africa
AS	Asia
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GNI	Gross National Income
LA	Latin America
LDC	Less developed countries
l/c/d	liters per capita per day
ME	Middle East
PPP	Purchasing Power Parity
UPA	Urban and Peri-urban Agriculture
WW	Wastewater
WWA	Wastewater Agriculture

Summary

In many cities of developing countries untreated wastewater and polluted water are used for agriculture in urban and peri-urban areas. Though such practices are a threat to the health of users and consumers, they do provide important livelihood benefits and perishable food to cities. This paper through a cross country analysis of 53 cities in the developing world, contributes to an understanding of the factors that drive wastewater use. The 53 cities represent a range of settings in arid and humid areas, in rich and poor countries, and coastal as well as inland cities to provide a picture of wastewater use globally. It relates the wastewater collection and disposal practices to the increasing impact of poor water quality on agriculture.

The study shows that the main drivers of wastewater use in irrigated agriculture are in most cases a combination of three factors:

- Increasing urban water demand and related return flow of used but seldom treated wastewater into the environment and its water bodies, causing pollution of traditional irrigation water sources.
- Urban food demand and market incentives favoring food production in city proximity where water sources are usually polluted.
- Lack of alternative (cheaper, similarly reliable or safer) water sources.

The key underlying factor is in most cases poverty which limits the “coping capacity” of cities to respond to the infrastructure needs of urbanization, e.g., with comprehensive wastewater treatment.

However, the use of untreated wastewater is not limited to the countries and cities with the lowest GDP, and is prevalent in many mid-income countries as well. In four out of every five cities surveyed wastewater is used (treated, raw or diluted) in urban and peri-urban agriculture even if areas cultivated in each of the cities may sometimes be small. Across 53 cities we conclude that just for these cities alone, approximately 0.4 million hectares (Mha) are cultivated with wastewater by a farmer population of 1.1 million with about 4.5 million family dependants. Compiling information from various sources, the total number of farmers irrigating worldwide with treated, partially treated and untreated wastewater is estimated at 200 million; farming on at least 20 Mha. These figures include areas where irrigation water is heavily polluted.

Though the actual physical areas under cultivation may be small, some vegetables are grown up to 10 times a year on the same plot. Data from a detailed city study in Accra showed that about 200,000 urban dwellers benefit everyday from vegetables grown on just 100 ha of land. Strict irrigation water quality guidelines can hardly be imposed where traditional irrigation water sources are polluted, and thousands of farmers depend on it, unless alternative sources of water are provided. Farmers are aware of the potential risks to themselves and to consumers but a clear understanding of cause and effect are missing. The fact that consumers in most cities habitually wash vegetables supports the idea that where treatment is still rudimentary, a feasible method of minimizing health risks for consumers in the short term would be to encourage effective washing of vegetables.

Some key policy recommendations are made:

1. Urban and peri-urban agriculture can enhance food supplies to cities and is an effective source of nutrition which can be improved at very little marginal cost.
2. The WHO (2006) guidelines for the safe use of wastewater should be extensively applied as it allows for incremental and adaptive risk

reduction which is more realistic and cost-effective than stressing the need to achieve certain water quality values.

3. Implementation of the Millennium Development Goals should more closely link policies and investments for improvements in the water supply sector with those in the sanitation and waste disposal sector, to achieve maximum impact.

4. In addressing health risks; on the one hand, state authorities have a role to play in planning, financing and maintaining sanitation and waste disposal infrastructure that is commensurate with their capacities and responds to agricultural reuse requirements. On the other hand, as comprehensive wastewater treatment will remain unlikely in the near future, outsourcing water quality improvements and health risk reduction to the user level and supporting such initiatives through farm tenure security, economic incentives like easy access to credit for safer farming, and social marketing for improving farmer knowledge and responsibility, can lead more effectively to reduced public health risks while maintaining the benefits of urban and peri-urban agriculture.

5. Finally, countries must address the need to develop policies and locally viable practices for safer wastewater use to maintain its benefits for food supply and livelihoods while reducing health and environmental risks.

Drivers and Characteristics of Wastewater Agriculture in Developing Countries: Results from a Global Assessment

Liqa Raschid-Sally and Priyantha Jayakody

Background and Scope

Contrary to most developed countries where wastewater is treated before reuse, in many developing countries, wastewater is used for agriculture both with and without treatment; in the latter instance it may be in undiluted or diluted form (Box 1). While wastewater treatment and recycling for various purposes has been well documented, the agricultural use of raw and diluted wastewater has only recently been brought to the foreground as a phenomenon that needs attention (Scott et al. 2004; Qadir et al. 2007; Keraita et al. 2008).

Box 1. Definitions

The term wastewater as used in this report can have different qualities from raw to diluted:

- **Urban wastewater** is usually a combination of one or more of the following:
  - Domestic effluent consisting of *blackwater* (excreta, urine and associated sludge) and *grey water* (kitchen and bathroom wastewater)
  - Water from commercial establishments and institutions, including hospitals
  - *Industrial* effluent where present
  - *Storm water* and other urban runoff
- **Treated wastewater** is wastewater that has been processed through a wastewater treatment plant and been subjected to one or more physical, chemical, and biological processes to reduce its pollution or health hazard.
- **Reclaimed (waste)water or recycled water** is treated wastewater that can officially be used under controlled conditions for beneficial purposes such as irrigation.
- **Use of wastewater:**
  - ***Direct*** *use* of ***untreated*** *urban wastewater* from a sewage outlet is when it is directly disposed of on land where it is used for cultivation.
  - ***Indirect*** *use* of ***untreated*** urban wastewater: when water from a river receiving urban wastewater is abstracted by farmers downstream of the urban center for agriculture. This happens when cities do not have any comprehensive sewage collection network and drainage systems are discharging collected wastewater into rivers
  - ***Direct use*** of ***treated*** wastewater: When wastewater has undergone treatment before it is used for agriculture or other irrigation or recycling purposes.

Concurrently, wastewater use is viewed both as a *benefit* providing livelihoods and perishable food to cities, and as a *threat* affecting the health of users and consumers of the said produce, and the environment. The secondary benefits are said to be:

1. Better nutrition and education to farming families and traders as the income generated from this practice (which usually involves cash crops) raises living standards;
2. Recycling of nutrients and, therefore, eventual savings in fertilizer, which on the one hand is a direct saving to the farmer and on the other provides an environmental benefit; and
3. Agricultural wastewater application is seen as a form of land treatment where other means are not viable, thus providing some reduction of surface water pollution.

The primary health risk is diarrheal disease for consumers and farmers as well as skin and worm infections for all those in contact with wastewater. Other related concerns are (Hamilton et al. 2007):

1. accumulation of bio-available forms of heavy metals and fate of organics in soil,
2. impact from extensive use on catchment hydrology and salt transport,
3. microbiological contamination risks for surface water and groundwater, and
4. transfer of chemical and biological contaminants to crops.

Importance of Treated Wastewater Use for Agriculture

Agriculture is the largest consumer of freshwater resources currently accounting for about 70% of global water diversions (but sometimes even up to 80-95% in developing countries) (Seckler et al. 1998). With increasing demand from municipal and industrial sectors, competition for water will increase and it is expected that water now used for agriculture will be diverted to the urban and industrial sectors. A number of examples from Asia, North Africa, and Latin America, are witness to this fact (Molle and Berkoff 2006). One observed response to this squeeze on agricultural water supply is to promote greater use of treated urban wastewater for irrigation. Discounting the significance of this practice as a partial solution to the freshwater squeeze in agriculture, it is argued that the total volume of *treated* wastewater available (even if all of it is treated), is insignificant in many countries in terms of the overall freshwater balance and the volumes that will need to be transferred from agriculture to municipal use. While this may be true in most parts of the developing world, in the water-short arid and semi-arid zones of the Middle Eastern, Southern and Northern African regions, the Mediterranean, parts of China, Australia and the USA, domestic water use can represent between 30 to 70% of irrigation water use (or between 10-40% of total water use) in the extreme cases (Abu-Zeid et al. 2004; Angelakis et al. 1999; Crook 2000; FAO 1997a,b; Lallana et al. 2001; Peasey et al. 2000; WRI 2001; UNEP 2002; WHO 2006; AATSE 2004). Substitution of freshwater by treated wastewater is already seen as an important water conservation and environmental protection strategy, which is simultaneously contributing to the maintenance of agricultural production. In Australia where the share of domestic water use (20% of total water use) is the second highest in the world, after the USA, the limited total water supply in the country, has necessitated careful use of water and recycling (in 2000 up to 11% of wastewater was being recycled in major cities, Vigneswaran 2004). Tunisia, a middle income country with an arid climate, is a typical example of good practice in this regard where over the past 20 years water reuse has been integrated into the national water resources management strategy. Over 60 wastewater plants in Tunisia produce high quality reclaimed water for use in agriculture, and irrigation of parks and golf courses (Bahri 2000, 2002). Currently about 43% of the treated wastewater is being recycled for these purposes. A recent comprehensive compilation of data on water reuse (Jimenez and Asano 2008), provides an understanding of common practices around the world, particularly of treated wastewater for municipal and industrial uses, agriculture and groundwater recharge.

Genesis of Untreated Wastewater Use and Its Importance

While wastewater has the potential to serve as a hitherto untapped water and nutrient source for agriculture; where treatment is limited it also has the potential to affect human health and pollute large volumes of freshwater, rendering them unfit for human uses. This problem is substantial in the developing world where urbanization has outpaced urban infrastructure development. Not only will cities be growing at an unprecedented rate accommodating 50% of the world's population (United Nations Population Division 2002) but urban water demand per capita will also increase with increasing supply, coverage and overall urban economic growth. More than 80% of urban consumption returns as waste (Tchobanoglous and Schroeder 1985) and its disposal has already become a major issue, likely to worsen in the future, without centralized collection and disposal systems. Furthermore, densification of urban areas reduces the possibility for on-site disposal via septic tanks. Centralized treatment systems in developing countries are not always affordable anyway, and when they are in place, they have always been vulnerable to the vagaries of skills, and institutional and financial capacities found in these countries. The fact that present wastewater management practices in major cities of the less developed countries are much less than desirable, is an indication that future scenarios are likely to be worse. As part of the the Millennium Development Goals for Sanitation, many countries are attempting to address the challenges of water supply and improved sanitation facilities for all without necessarily paying attention to the disposal of the increasing volumes of wastewater that are being discharged, in many instances, into the natural drainage systems and streams of the cities.

Figuratively speaking (waste)water finds its own outlet, and either oceans or water bodies close to cities act as a sink for wastewater. Thus, freshwater bodies which are already being used for multiple domestic and agricultural purposes including informal irrigation, literally become wastewater as their capacity for dilution decreases. Therefore, the term wastewater as used in this report can refer to treated, raw or diluted wastewater or, simply, highly polluted streams (Box 1) used under official or informal conditions for irrigated farming.

A number of case studies of city and country assessments of varying detail conducted in middle and low-income countries of Africa, Asia and Latin America have recognized that the use of *untreated* wastewater for the irrigation of high-value cash crops in and close to urban centers is a widespread practice. Recent estimates indicate that 20 Mha under agriculture are using treated, partially treated, diluted and untreated wastewater (Scott et al. 2004; Marsalek et al. 2005; Hamilton et al. 2007;Keraita et al. 2008). Even in the absence of a more accurate overall estimate, the fact is that a large part of this area is farmed by millions of poor farm households for whom wastewater is a highly important productive resource. It is being used in profitable, but often informal, production systems that contribute significantly to the supply of perishable produce, notably fresh vegetables, to urban areas (Scott et al. 2004; Drechsel et al. 2006). Cities in developing countries have difficulty in sourcing perishable crops from more distant locations due to the lack of necessary infrastructure and cooled storage trucks for transport. Thus, they depend on agriculture in market proximity. Furthermore, it is recognized that for these poor urban farmers, wastewater irrigation is a substantial and sometimes even a primary source of cash income in addition to contributing towards urban food supply (UNDP 1996; Drechsel et al. 2006; Van Veenhuizen and Danso 2007).

Drivers of the Practice and Objectives of the Study

Although wastewater use is a global phenomenon, its extent and drivers are likely to vary between regions and climatic zones. Despite increasing efforts by the FAO and others, and a growing number of individual studies and reviews (Jimenez and Asano 2008; Keraita et al. 2008; Hamilton et al. 2007; Lazarova and Bahri 2005; Jimenez and Asano 2004; Van der Hoek 2004; Strauss and Blumenthal 1990; Shuval et al. 1986); to date there are no comprehensive datasets that provide an understanding of wastewater agriculture and related practices across countries and cultures.

It is understood that local opportunities and constraints should guide policies and decisions about wastewater irrigation or wastewater agriculture. However, a knowledge of the drivers can steer decisions better and provide, in addition, an understanding of the trade-offs and limitations associated with the practice. With this in view, a study of 53 selected cities across the developing world was commissioned on the state of wastewater use in developing countries.

The study, therefore, attempts:

- to identify the different factors that drive wastewater use in developing countries,
- to understand the potential role that wastewater plays in reducing the demand for freshwater resources, in contributing to urban food supplies and as a livelihood strategy, and
- to assess the consequences of poor sanitation and wastewater management for agriculture and the environment.

This global study was supported by the Comprehensive Assessment of Water Management in Agriculture with a more detailed study in West Africa (Drechsel et al. 2006) and linked to three country case studies earlier commissioned by IWMI in Vietnam, Ghana and Pakistan, respectively (Raschid-Sally et al. 2004; Obuobie et al. 2006; Ensink et al. 2004).

Methodology and Selection Criteria

The city assessment, in selected cities around the world, was intended to provide first estimates of the volumes of wastewater generated and the related treatment and disposal practices, extents of agriculture practiced with wastewater and its value to society, its significance as a livelihood strategy, and its health implications. The main source of information was an extensive survey across 53 cities using a specifically designed questionnaire. The surveys were conducted using local experts from the selected countries/cities identified by an independent panel. The questionnaire was completed by the experts using secondary data, and further expert consultation through key informant and stakeholder interviews.

City Selection

The cities were selected through a stratification process to include both regulated and non-regulated (informal) use of wastewater. The regions targeted were Latin America, Middle East, Africa and Asia. The countries from these regions were categorized by the IWMI water scarcity index[1], annual rainfall and income[2], and the larger cities were identified for each country. Information on city area, city population, urban sprawl, and location (inland or coastal) was obtained for all the cities in order to get a basic understanding of the individual situation and to arrive at the final selection of cities representing the given diversity.

The city boundaries were based on the authors' understanding of the different definitions used in urban planning for city area boundaries (Box 2). Initially 45 cities were targeted. However, it turned out that some of the megacities selected comprised of more than one municipality (e.g., Kathmandu, La Paz, Sao Paolo, Mexico City and Manila); which expanded the final number of cities (which includes the urban and peri-urban areas) considered in this study to the odd number of 53.

[1] Seckler et al. (1997)

[2] Economies are divided according to the 2003 GNI per capita, calculated using the World Bank Atlas method. The groups are: low income - $765 or less; lower middle income - $766-3,035; upper middle income - $3,036-9,385; and high income - $9,386 or more (http://www.worldbank.org).

Box 2. Limitations of the study

Comparing city statistics in general, and looking at agricultural areas 'in' cities in particular, poses a significant challenge as the outer demarcations of the administrative city boundaries and areas vary significantly from city to city. Two examples might illustrate this:

The official administrative boundary of Accra, the capital city of Ghana, covers an area of about 230 square kilometers (km^2). The actual size of the urbanized area is, however, much larger (about 422 km^2) as the city boundaries are outdated. In both boundaries, there is little space for agriculture (about 10 km^2 in total with, depending on the season, 0.5-1.5 km^2 ha under wastewater irrigation) (Obuobie et al. 2006).

In Vietnam, on the other hand, the municipal boundaries of Hanoi and Ho Chi Minh City (HCMC) comprise much larger areas than the actual built "city" part, including several hundred square kilometers of agricultural lands, which form nearly 50% of the administrative area, while the residential area covers less than 15%. In these municipalities, agriculture is an essential part of municipal planning. In "suburban" HCMC there are more than 900 km^2 of cultivated land.

As water pollution does not stop at the administrative city boundary, an ideal dataset would actually have to go beyond these boundaries. This, however, was not possible to standardize. Having these limitations in mind, we consider this study as a first approximation.

Data for the respective countries was collected/collated by different consultants. Hence, in spite of detailed instructions and a well designed questionnaire, the quality of data varies from country to country. Wherever the need was felt, data cross-referencing was done.

The calculated regressions presented in some figures are only supposed to indicate tendencies irrespective of the level of significance.

The regional distribution of the countries selected is shown in Figure 1. The characteristics of cities selected are shown in Figure 2. Of the 53 cities 14 were coastal of which 5 had populations of over 5 million. Of the 39 inland cities 8 had populations of over 5 million.

Design of the Questionnaire

To identify the drivers of wastewater irrigation and extrapolate this data to other parts of the world, relationships with factors like city poverty levels, GDP per capita, sanitation coverage and the percentage of wastewater treatment were considered necessary. The questionnaire was, therefore, designed to seek several types of information: city statistics on development indicators, population, environmental condition, water supply, sanitation and waste disposal statistics, wastewater management and industrial development, environmental and irrigation legislation, and water quality. Urban agriculture was profiled to understand the context of wastewater agriculture if it existed. Data on wastewater agriculture, extents, practices and methods, farmer perceptions of risk and risk reduction methods, wastewater crop productivity, prices and marketing, and the livelihoods generated from wastewater agriculture through a profiling of labor, wages, income, and poverty levels was also requested where available. Gender differentiation questions were included.

As the data was to be obtained essentially from secondary data supplemented with key informant and stakeholder interviews, it was expected that some questions would be answered only for a few cities where studies were available. As it turned out, wages and income information was not available for many of the cities and these parameters were not included in the final analysis. The West Africa Survey (Drechsel et al. 2006) and some of the case studies in reference provide more details on some of these parameters for interested readers.

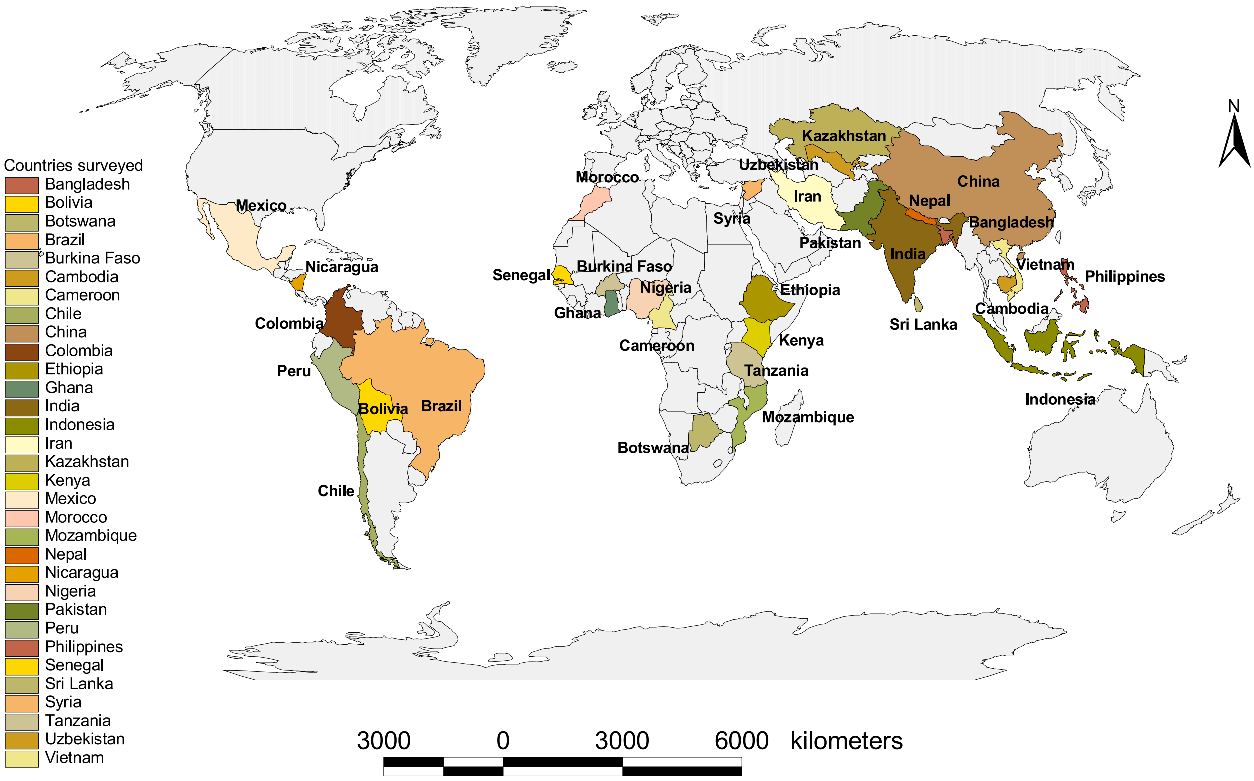

FIGURE 1. Regional distribution of 53 selected cities/countries for the global survey.

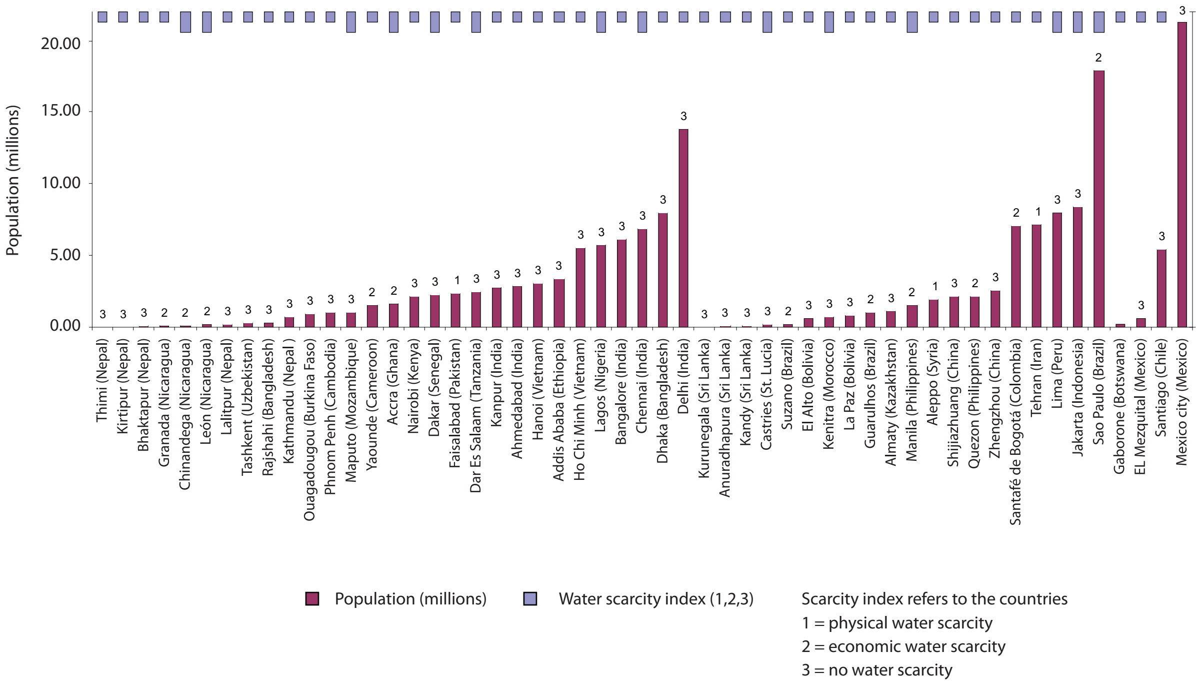

FIGURE 2. Characteristics of (53) selected cities.

Results and Discussion

In the following sections, the basic information derived from the analysis is presented.

Before analyzing data directly related to the use of wastewater for agriculture, the first sections will present a short analysis of water supply, sanitation and waste disposal settings as one of the identified drivers of wastewater agriculture, by looking at trends in urban water use, and its implications for sanitation and waste disposal in cities.

City Water Supply, Waste Disposal and Industrial Contamination

Urban water supply and its implications for wastewater generation

In 60% of the cities both surface water and groundwater are used for water supply, 23% used only surface water and 17% used only groundwater. Inland cities, which are closer to lakes or rivers, also used such surface water sources.

Only 50% of the cities have a pipe-borne water supply coverage of over 90%, indicating that in many cities service coverage is still largely inadequate. At least 25% of the cities have coverage of less than 25% (Figure 3).

The actual per capita water consumption[3] showed a very large variation from 34 to 350 l/c/d (Figure 4). Half the cities have a consumption of 100-250 l/c/d. This is quite high for LDCs but it must be remembered that non-domestic supply (smaller and larger industries, etc.) is included, and that system losses can be high – 50% of the countries indicated losses between 25 and 55%. There is a significant increase in water consumption with the GDP/capita.

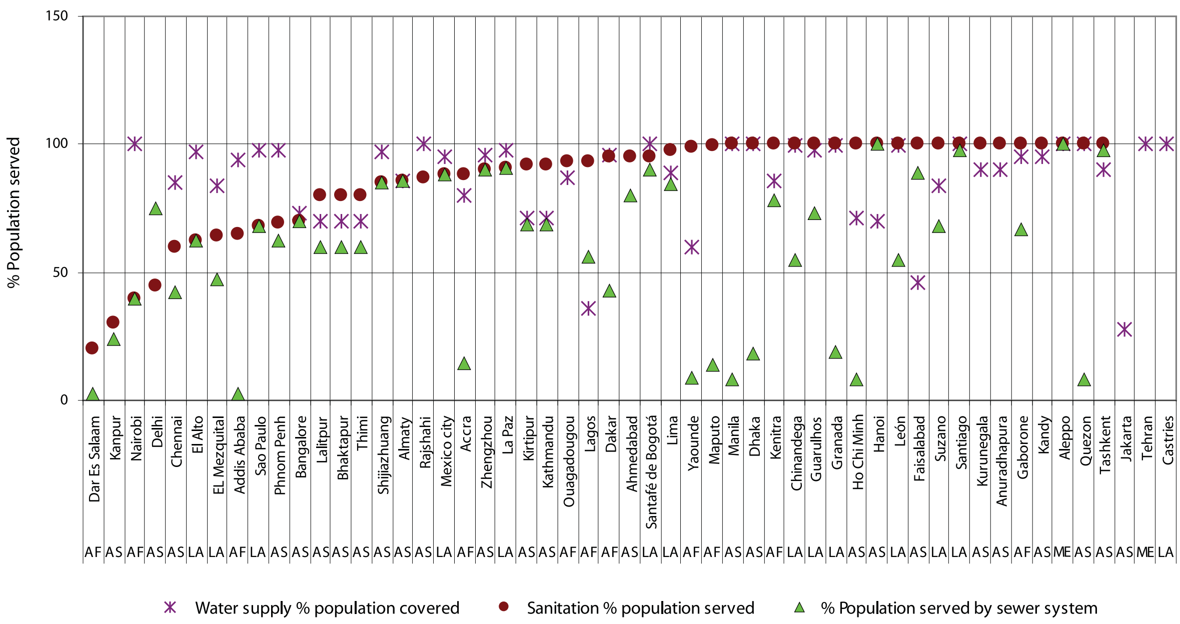

FIGURE 3. Water supply, sanitation, and sewer coverage by city.

[3] Calculated as “actual volume of water supplied by a water utility, divided by the population served, expressed in liters per capita per day.”

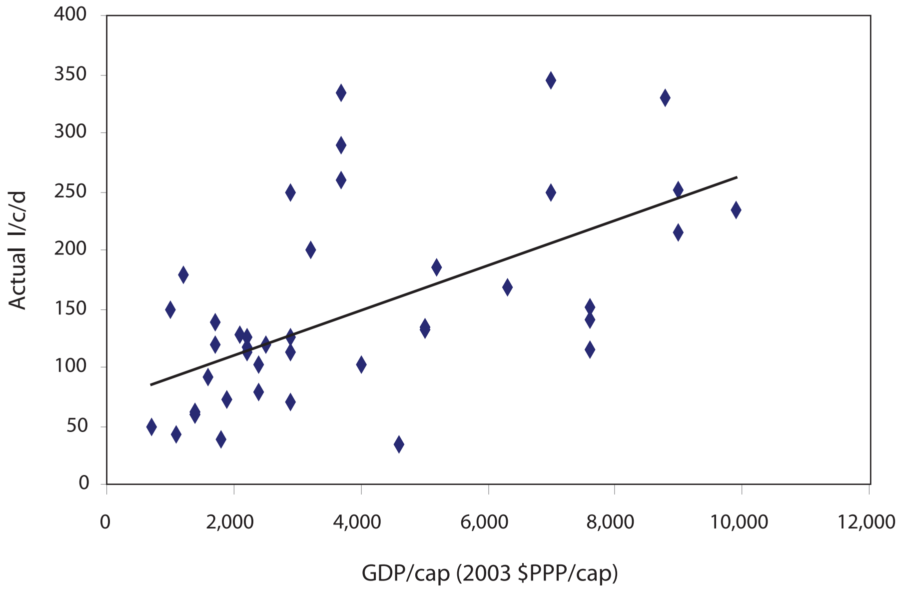

FIGURE 4. Actual per capita water consumption (in l/c/d).

Sanitation coverage and type

Knowing sanitation coverage[4] and the manner in which wastewater is collected and disposed of in a city, are essential to gain an understanding of the drivers of wastewater agriculture. About 80% of the cities had at least a small sewer system (sometimes various small areas of cities were sewered), but only one third of the cities reached a household coverage of 80%. Half of the responding cities had only closed sewers, whereas 33% had both open and closed sewers. Relating GDP/capita to sewer coverage shows a large and non-significant variation (Figure 5) which implies (in comparison with Figure 4) that investments in water supply are not accompanied with similar investments in wastewater collection.

From Figures 3 and 6, it is evident that 82% (39 of 47) of the cities had sanitation coverage of over 75% showing that most cities are well served with some form of sanitation.

In at least 60% of the cities, a large percentage of the urban population (between 30-100%) is still served by on-site sanitation systems (septic tanks/water flush pit latrines/ dry pit latrines) (Figure 6). Nearly half these cities have populations of over one million. Under conditions of urban densification, on-site systems which require space cannot function efficiently leading to septage disposal problems.

Treatment and disposal of septage and sewage

Disposal of household septage is by tankers in 80% of the cities and is handled by both the public and private sectors. Despite guidelines/regulations in many countries for safe disposal, the collected septage is disposed of in whatever convenient location that is available, sometimes into the sewers serving other parts of the cities, in other instances in rivers and other surface water bodies. In a few cases municipalities regulate the disposal when it is a private service and the septage is treated/dried before disposal.

In spite of relatively good sewer coverage in some cities, this does not imply that all the wastewater collected is also treated. While 74% of

[4] Sanitation coverage does not include solid waste disposal.

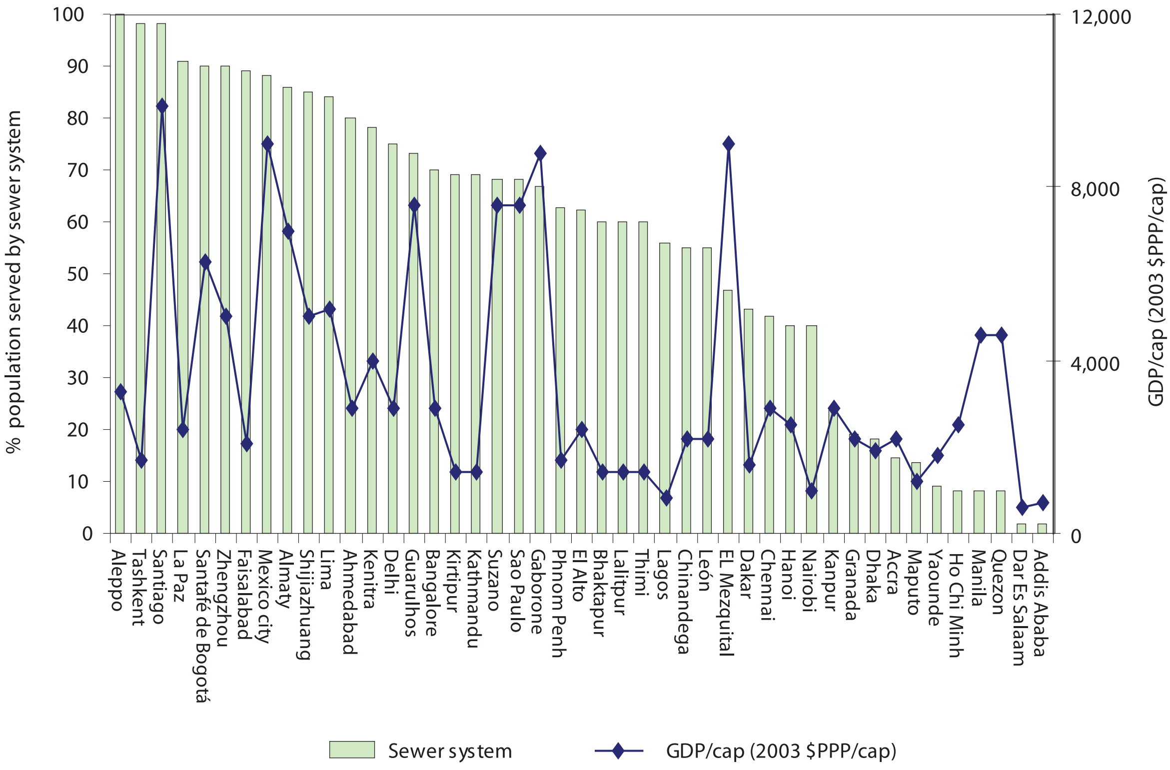

FIGURE 5. Sewer coverage and GDP/capita.

cities with sewers treat their wastewater, the type and degree of treatment varies widely. Responses from 27 cities indicated that only 30% treated all the wastewater collected. More than half of the cities treated less than 50% of the wastewater collected (Figure 7) at least to primary and in part secondary level with stabilization ponds or other biological processes. Only two cities carried out tertiary treatment on some of the wastewater for a specific use.

However, in 56% of the cities the treatment plants were reported as only partially functioning or not functioning at all. Overloading and poor maintenance were given as key reasons for ineffective treatment leading to water pollution of receiving water bodies.

This does not only concern surface water bodies. Many cities mentioned groundwater contamination from point sources (leachate from garbage dumps) and non-point sources (overflows from septic tanks).

"Quality" of wastewater and industrial contamination

Two thirds of the cities studied had a common sewer system for the disposal of both domestic and industrial wastewater. Only 28% had separate sewers, showing that in many cities industrial contaminants will find their way into municipal systems. Even in cities where wastewater is largely of domestic origin (90% of cities), the "better quality" kitchen, laundry and bath waters are not disposed of separately but sent to the sewer system with the toilet wastes. There was no formal grey water collection in any of the cities.

Even in cities categorized as largely residential (14 of the cities studied), there was a certain degree of mixing of industrial wastewater. However, in the majority of cities (70%), inflow of industrial wastewater was minimal due to limited industrialization and even in the worst cases did not exceed an estimated 40-50%. With a few exceptions, most industrial

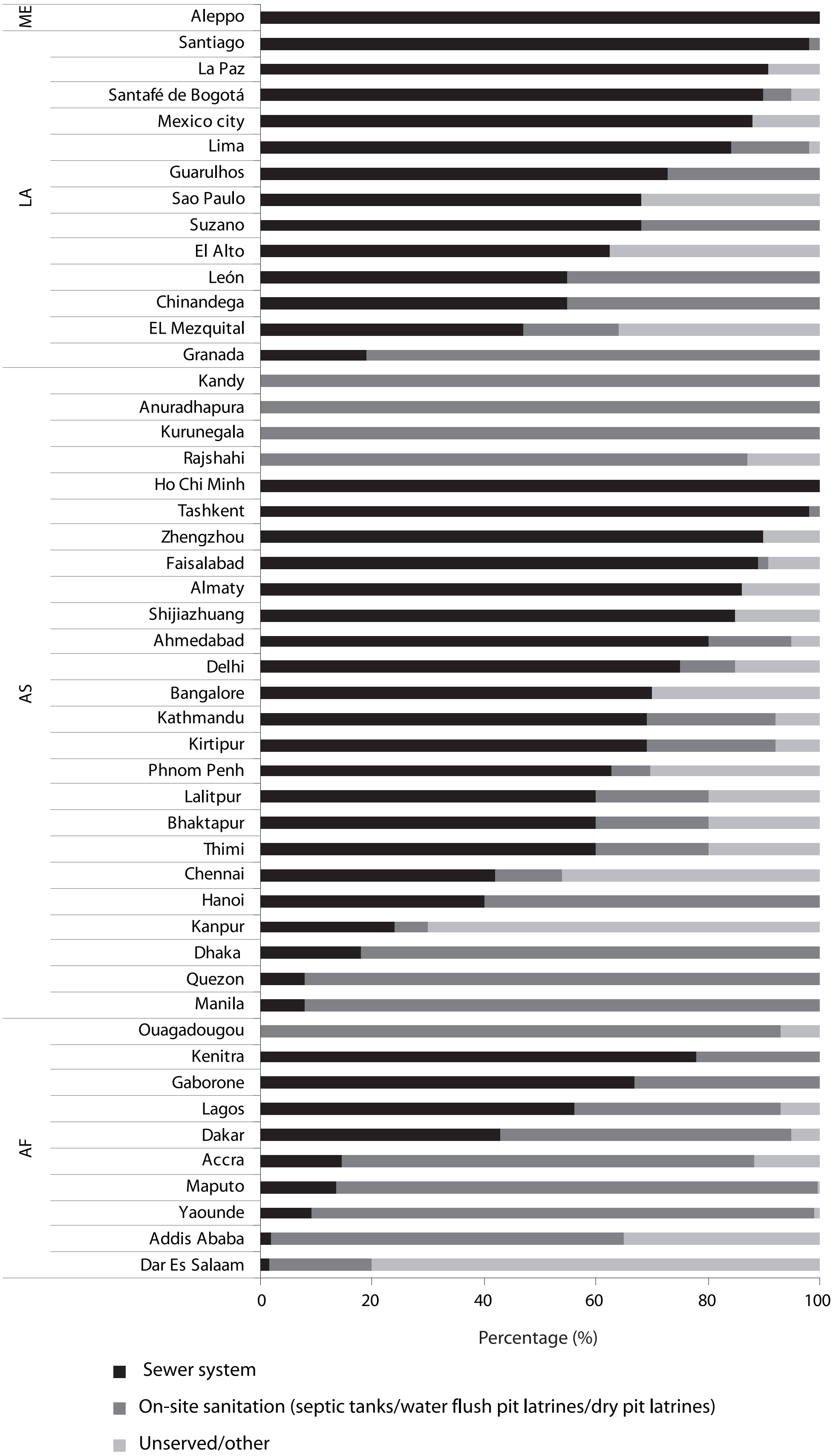

FIGURE 6. Type of sanitation coverage in the cities.

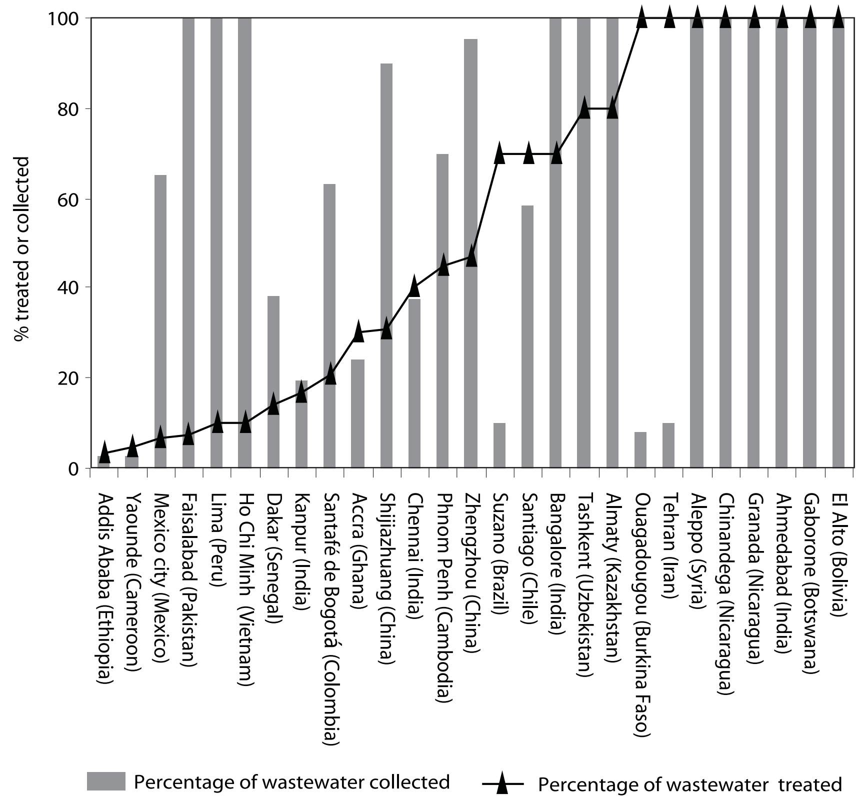

FIGURE 7. Wastewater collected as a percentage of wastewater generated and wastewater treated as a percentage of wastewater collected.

development was on a small-scale within cities. Contamination, of course, depends on the type of industry, but related information was scarce. About 60% of the responses confirmed that industrial wastewater was treated to some degree before being discharged, but with poor enforcement of regulations it is unlikely that treatment is very effective in removing chemical contaminants that are potentially harmful to human health.

However, in most developing countries with poor road infrastructure, heavy industry, if present, is located close to harbors where wastewater is discharged into the ocean without further use. Of the 14 coastal cities, 10 had rivers running through them which collected the waste before discharging into the sea. The others discharged directly into the ocean.

Wastewater in Urban Farming - Extents and Impact on Poverty and Water Scarcity

Nature and extent of wastewater irrigation

The presence of irrigated urban and peri-urban agriculture (UPA) was considered as a necessary condition for the occurrence of wastewater agriculture, where wastewater treatment was limited. Out of the 53 cities studied, only 8 cities reported to have little or no irrigated UPA. Seventy-four percent of the cities studied had wastewater agriculture though data on extents was not available for some of them. Where data was available (31 cities in this case), cumulative figures show that there are about 1.1 million farmers around these cities making a living from cultivating

0.4 Mha of land irrigated with wastewater (raw or diluted wastewater and includes all those areas that use polluted rivers as the irrigation water source). The regional breakdown of wastewater agriculture by area or by the number of farmers, the distribution of extents across cities, and the cities with the largest extents, are shown in Tables 1, 2 and 3, respectively. The large standard deviation for each group and the lack of correlation with the GDP/capita shows that wastewater agriculture has wide variations and occurs under a wide variety of socioeconomic situations. Other factors that may explain this variation across groups, are the location of the cities (e.g., no downstream agricultural areas), and the often outdated and comparatively narrow city boundaries in some cases (see Box 2). This was seen to be especially so for many West African cities.

In the majority of cities in Asia landholding sizes were seen to be small (less than 1 ha) in contrast to the Latin American situation where farmers owned larger farms in the range of 4-5 ha. In Africa, on the other hand, urban farm sizes are usually less than 0.05 ha, while peri-urban farms are about 1 ha on average (Drechsel et al. 2006).

Links to poverty, migration and water scarcity

It was interesting to see that as the poverty level in the city increases, i.e., the number of poor living within the city, the share of wastewater agriculture to urban agriculture increases, suggesting a close relationship (Figure 8). It seems plausible to infer from this that farmers in 'poorer' cities tend to face increasingly polluted water sources. This appears to be particularly so in Asia.

Rural-urban migration is a general factor of urbanization and was reported from 89% of the cities. It appeared, in general, higher in the selected African (2.5% percent on average) and Asian (4.2% on average) cities compared to Latin America (1.0% on average). Many cities with low GDP/capita (less than USD 2,000) had higher levels of rural to urban migration (Figure 9). As national income levels increase, the incentives for migration appear to decrease. This is also reflected in variations in the city poverty index[5] which, on average, decreased as we move from Africa to Asia to Latin America.

Under lower GDP/capita conditions (<USD 2,000/year), and where alternative urban employment is not available, the high levels of rural-

TABLE 1. Extents and numbers of farmers by region.

Region	No. of cities with data	Total farmers WW informal and formal	Total WW area (ha) informal and formal
Subtotal Africa (AF)	9	3,550	5,100
Subtotal Asia (AS)	19	992,880	214,560
Subtotal Latin America (LA)	8	88,300	142,160
Subtotal Middle East (ME)	3	3,320	34,920
Total	39	1,088,050	396,740

TABLE 2. Distribution of extents of wastewater agriculture.

Extents (ha)		No. of cities	GDP/capita range ($)
Range	Mean (SD)		
10-1,000	321 (272)	11	1,100-8,800
1,000-10,000	3,506 (2,589)	9	1,000-5,000
10,000-45,000	22,505 (12,917)	9	1,700-9,900
>75,000	-	2	2,500-9,000

[5]Percentage of the population below the poverty line. In most cases the poverty line was about USD1/day.

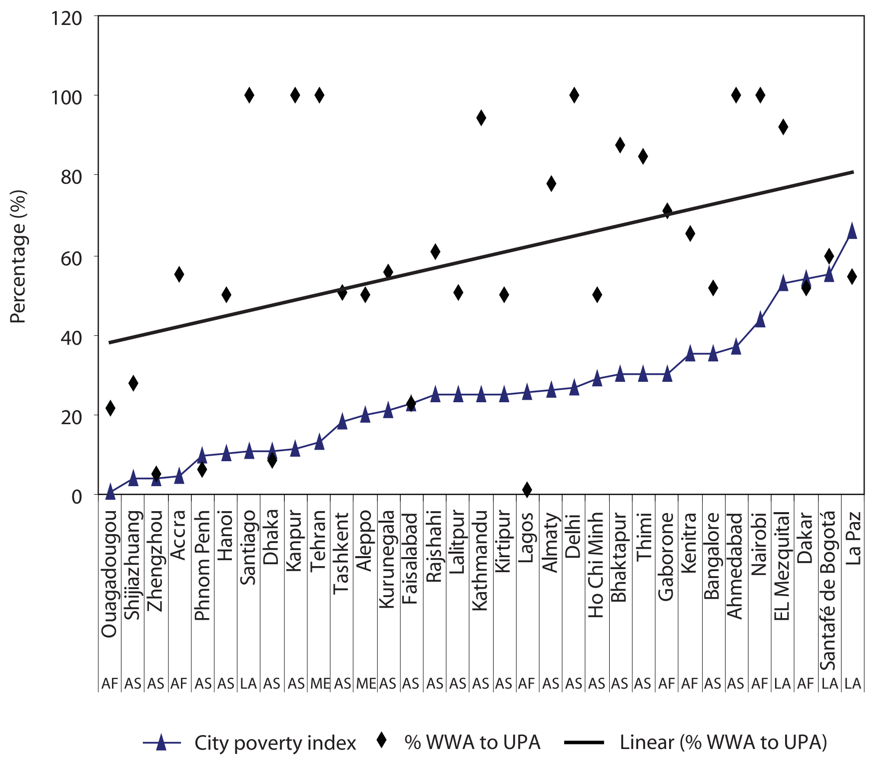

FIGURE 8. Wastewater agriculture variations with city poverty.

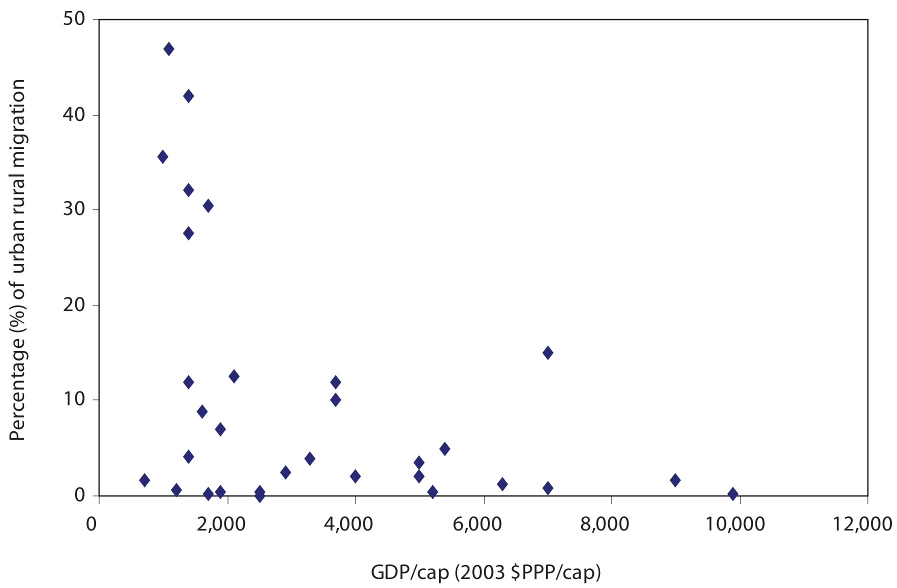

FIGURE 9. Urban-rural migration versus GDP per capita.

urban migration, particularly in the African and Asian cities studied, may be a factor that drives the migrant population towards market-oriented urban agriculture (in cities where land is available for this). An added reason is that these migrants are from an agricultural background which attracts them to use their skills where they are not competitive in other employment sectors. A survey of 12 cities in West Africa also showed that in many cities the majority of urban farmers engaged in irrigated agriculture are migrants (Drechsel et al. 2006).

Among the cities falling in the lower range of GDP/capita, irrigated UPA in many of them has small plot sizes (varies between 0.07 and 1.2 ha, but could sometimes be as small as 0.01 ha), low overall extents of land under urban and peri-urban agriculture (<15,000 ha) (Figure 10), and, consequently, lower total extents of wastewater agriculture. The lower plot sizes in many low-income cities in Africa is explained by the fact that plot sizes depend not only on access to land and water, but also on security of tenure and farmers' financial means to hire labor, all of which are limited in low-income countries (Drechsel et al. 2006).

Close to three-fourths of the sample cities studied had over 50% of their urban and peri-urban agricultural land under wastewater. Notably, such a dominance of wastewater irrigation in UPA is independent of the level of economic growth of the country in which the cities are located (Figure 11). This means that wastewater agriculture is not necessarily a phenomenon associated with the poorest of countries, but is also a significant phenomenon in high and middle income countries, where wastewater collection and treatment might gain momentum but is still far from providing full coverage or being comprehensive. This was also clearly seen in the sample of cities across Latin America and Asia (Table 3).

One aspect that is common across all the cities is that wastewater irrigation takes place under dry and wet climates, as it allows to crop in the dry season even in humid climates. However, it is noteworthy when comparing across cities with rainfall below 900 millimeters (mm) that wastewater irrigation definitely occurs in all but two of these cities[6], clearly showing that scarcity of water is also a driving factor (Figure 12).

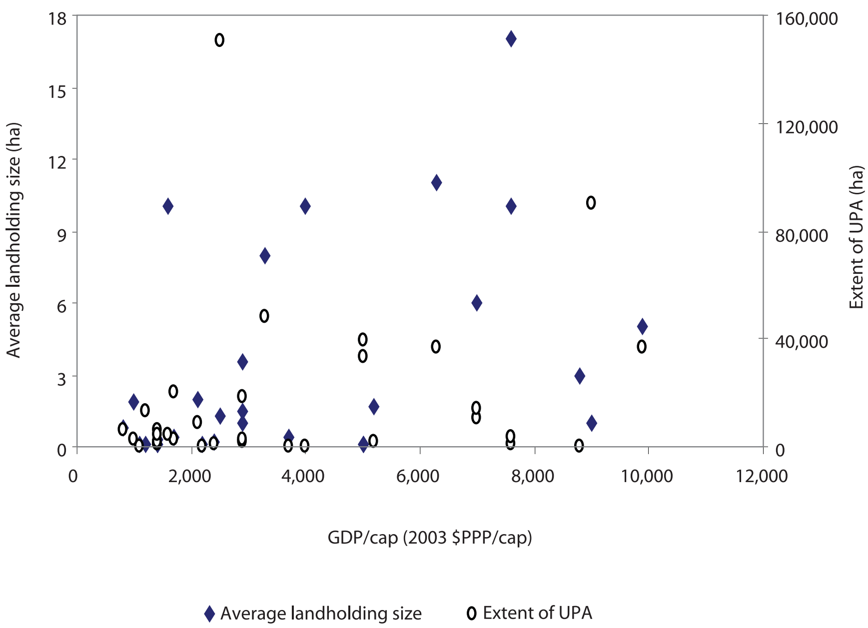

FIGURE 10. Landholding size and overall extents of urban agriculture with GDP/capita.

[6] In Chennai, India, where wastewater agriculture was not reported in the study; and in Mexico City where the wastewater is transported to the adjoining valley for agriculture.

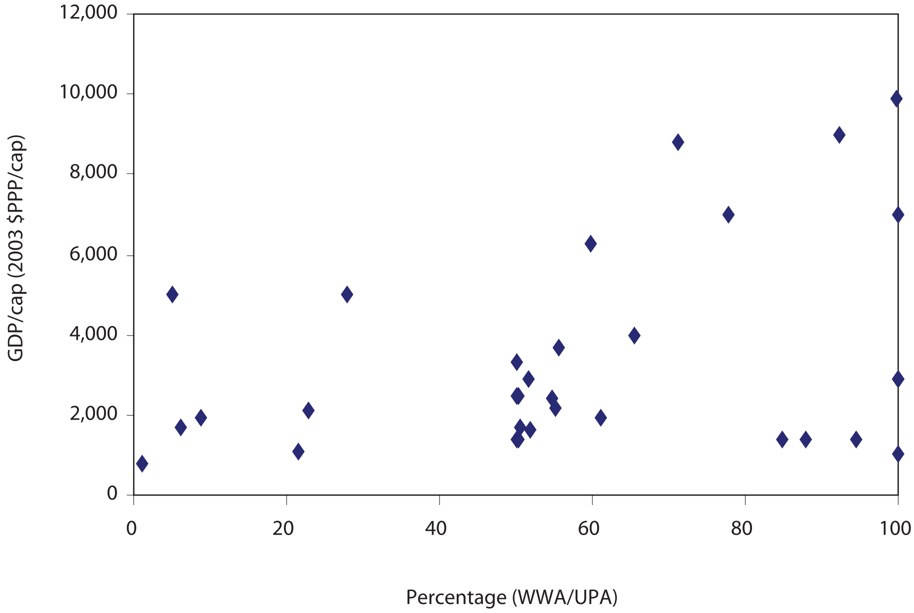

FIGURE 11. Variation of percentage of wastewater agriculture with GDP/capita.

Table 3. Cities with largest extents of wastewater agriculture.

Region	City	Country	City population (millions)	Total WW area (ha) informal and formal	Total farmers WW informal and formal
AS	Ahmedabad	India	2.88	33,600	No data
AS	Hanoi	Vietnam[1]	3.09	43,778	658,300
AS	Ho Chi Minh	Vietnam[1]	5.55	75,906[2]	135,000
AS	Kathmandu	Nepal	0.67	5,466	19,524
AS	Shijiazhuang	China	2.11	11,000	107,000
AS	Zhengzhou	China	2.51	1,650	25,000
LA	Mexico city/El Mezquital[3]	Mexico	21.3	83,060	73,632
LA	Santafé de Bogotá	Colombia	7.03	22,000	3,000
LA	Santiago	Chile	5.39	36,500	7,300

[1]Hanoi and Ho Chi Minh have very large extents of urban and particularly peri-urban agricultural land where irrigation water is often from polluted rivers running through the cities. The farmer numbers are large because of the importance of urban and peri-urban agriculture as a livelihood activity.

[2]Cropped area

[3]The large volume of wastewater from Mexico City is used to cultivate land in the El Mezquital Valley.

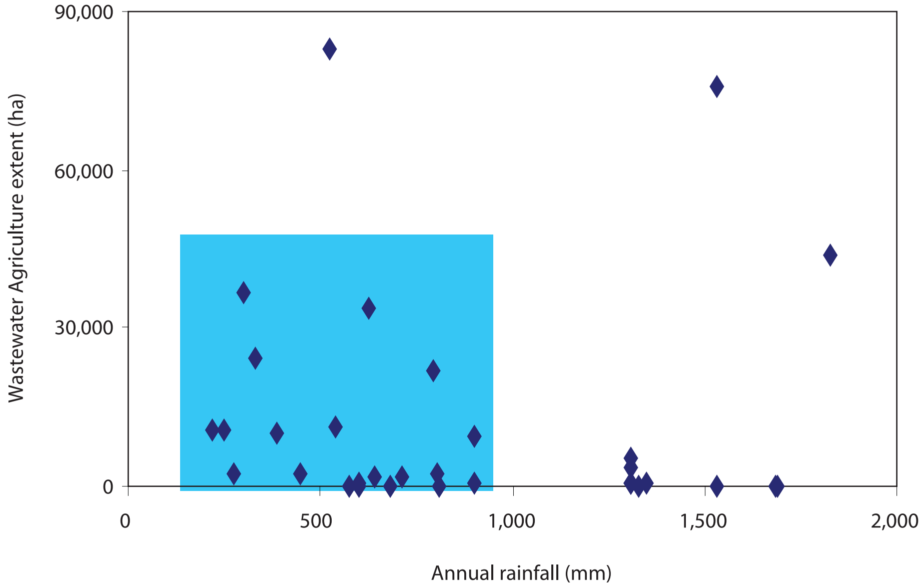

FIGURE 12. Extent of wastewater agriculture versus annual rainfall.

Water Sources, Crops Grown and Irrigation Methods

Water sources and quality as it affects decisions on wastewater use

Water sources used for irrigated UPA (Figure 13) were seen to vary between surface water, rainwater and groundwater. Rainwater, and with reservation groundwater, were assumed in many cases to be "clean" compared to surface water sources. In 31 out of 41 cities that responded on the reasons for wastewater use, there was a clear indication that farmers have generally little or no alternative (safer) water source than diluted wastewater/polluted river water or untreated wastewater. Preferential use of wastewater for its nutrient value and for its abundance (15 of 41) and regularity (16 of 41) were also cited as key reasons. The fact that wastewater is often available at no charge, was, however, seldom mentioned as an incentive for its use (5 out of 41 cities). From the data it was clear that if farmers have access to other water sources they will not seek to use wastewater. Avoiding wastewater use due to cultural constraints or due to awareness of risk was not cited as valid reasons for non-use, although some feel public pressure as reported from Ghana (Obuobie et al. 2006). However, a remarkable 41% of the farmers complained about industrial water contamination.

Crops grown and irrigation methods

Across the cities, vegetables and cereals (especially rice) were the two most common crop farmers cultivated with wastewater (Table 4). The popularity of vegetables as a crop is easily explained by their cash crop status, the lack of suitable transport for perishable produce, and the ready market proximity for such produce. Cereals, on the other hand, are equally popular, partly for sale as a cash source but mostly for consumption by the farming families themselves. There was a clear bias to more rice/cereal based systems in Asia.

For the type of irrigation method used, furrow, flood and watering cans appeared to be the most popular (Figure 13). In Africa, as irrigation with polluted stream water or wastewater only occurs in the informal smallholder irrigation sector, most of

TABLE 4. Distribution of crop types grown with wastewater.

Type of crop	Number of cities*			
	Africa	Asia	Latin America	Middle East
Vegetables	8	16	7	1
Cereals	5	15	5	2
Fodder	1	5	3	0
Other	1	5	3	2

* multiple responses were possible

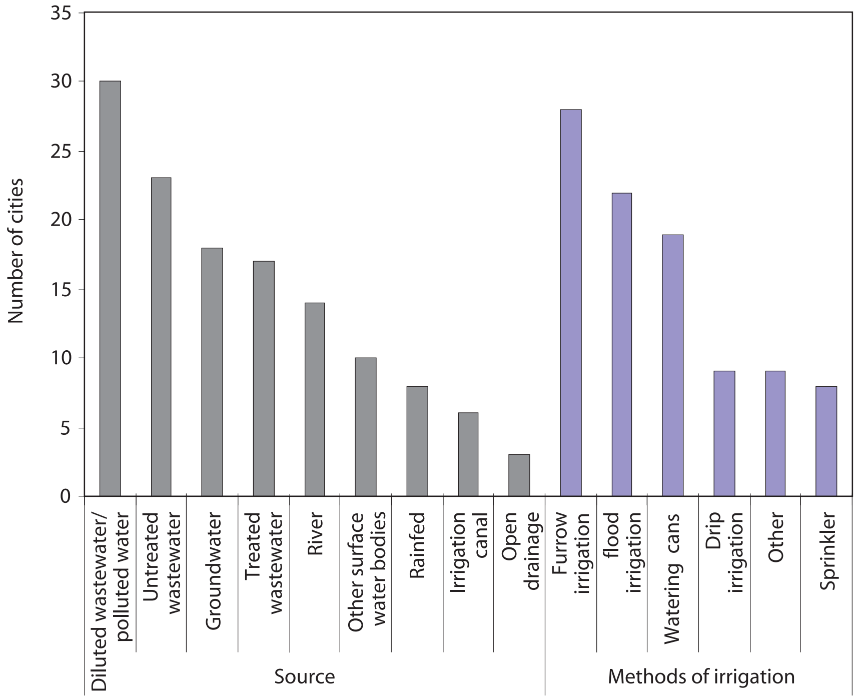

FIGURE 13. Water sources, quality and methods used in wastewater agriculture.

the African cities use mainly watering cans and furrow methods or flooding for wastewater irrigation (see also Drechsel et al. 2006) while Asian cities use a larger variety of methods. In the Latin American countries farmers rely on methods suitable for larger landholdings (furrow and flood predominate, with some sprinkler).

The lack of popularity of drip systems and sprinkler methods was confirmed in this survey as well, with farmers citing the commonly evoked reasons of costs and maintenance in the light of poor water quality.

Farmer Perceptions of Health Risks

Water quality and occupational risks

Table 5 shows that in 19 cases no protection was taken against wastewater exposure. An almost equal number protected their feet, but it was seen that in many instances this was not so much to protect against pathogens or other contaminants found in wastewater, but more as a protection against rough surfaces, snakes and other field dangers. The majority of farmers across the cities washed their hands after fieldwork. Washing of hands seemed an instinctive reaction towards general cleanliness and was not necessarily associated with particular risks related to the irrigation water.

Produce washing and consumption pattern

Only in 9 cases, was produce washed with the explicit objective of reducing contamination. Mostly, the produce was washed to clean off dirt and soil and to keep it fresh (looking) (Table 5). For this purpose, farmers or sellers often used the source of water locally available on farms and in markets, be it pipe-borne water, well water, or (polluted) stream water.

Farmers in 60% of the cities were reported to consume their own produce but the amounts were very variable depending on farm size and type of crop (cash crop versus subsistence crop, and exotic vegetables versus indigenous varieties). The consumption indicated ranged from 10-40% with a couple of exceptions where most of the produce was consumed by the family. Typical crops also consumed at home are rice and traditional vegetables while exotic vegetables are usually produced only for the urban market.

Perceptions on health

As reported, farmer perceptions on possible health problems associated with exposure to wastewater are also shown in Table 5. The majority of farmers associate wastewater with skin infections. Gastro-intestinal infections and diarrhea were also commonly cited but a large number of other general illnesses as well as respiratory problems were associated with wastewater agriculture. This association, of various types of unconnected illnesses, with exposure to wastewater may imply that farmers have little knowledge on general health.

However, farmers in 20 cities indicated that they were aware that health risks are associated with wastewater use. In 9 out of 20 cities between 90-100% of farmers were aware of this. The other cities had awareness levels ranging from 20-70%.

Twelve farmers out of 28 confirmed that they made no attempt to improve water quality or reduce risks either because they just did not see the need to do so or, in some cases, particularly because the wastewater contained useful nutrients. Other examples showed, however, that where farmers are more aware of their situation, they introduce interesting and effective ways of

TABLE 5. Reported health risk reduction methods and perceived health problems.

Description	Number of cities responding positively out of 53
Type of protection	
Protect feet	20
Protect hands	8
Wash hands	34
No protection	19
Reasons for washing produce	
Reduce contamination	9
Keep produce fresh	23
Clean dirt off produce	23
Farmer attributed perceptions of health problems	
Skin irritation	21
Gastro-intestinal/diarrhea	14
Respiratory	6
Other	15

Box 3. Indigenous practices to minimize risk at farm level.

Ouagadougou, BURKINA FASO: Farmers using industrial wastewater sources (brewery) make storage basins where they store untreated wastewater to settle out suspended matter. Some farmers time the collection and diversion to fields to avoid periods when industrial wastewater with high pollution loads are discharged. They use their sensory perceptions - appearance, odor and taste – to evaluate the quality of the wastewater. When the water appears not to be acidic and of "good quality" they fill the storage basins, and as soon as the quality of the water changes they stop the watering and close the inlet to the basins.

Phnom Penh, CAMBODIA: Farmers apply two methods to minimize the risk. The first is to clear away the solid wastes and settle the suspended matter (carried mostly in industrial effluents), and the second is to dilute with clean water to improve the water quality.

Shijiazhuang and Zhengzhou, CHINA: Farmers alternate irrigation between clean water and wastewater. Also, during the early and sensitive stage of crop growth, the farmers would not irrigate with wastewater.

INDONESIA, NEPAL, VIETNAM: Farmers use settling ponds which eliminate suspended solids and also iron.

Santiago, CHILE: Farmers either switch to groundwater sources when available to cultivate consumable produce, or change the crop to fruit trees and other crops whose produce will not be contaminated by poor water quality.

Santafé de Bogotá, COLOMBIA: Some farmers have settling ponds but this is not a common practice. However, one farmer explained how one of the supermarket chains rinsed produce with Chlorox (a chlorine based product) diluted in water, for cleaning leafy vegetables in particular.

In Guarulhos and Suzano, BRAZIL: When farmers realize that the water source used for irrigation is contaminated by wastewater, they begin to sell or lease out their lands and move on to other places with better water quality.

reducing risks to themselves and their crops (Box 3), e.g., by observing the quality of their water source using simple sensory perceptions like color, smell and taste (!) to regulate use.

Institutional Aspects Influencing Wastewater Use

Ownership of land

Legal status and tenure issues for land (Table 6) are complex and vary greatly from country to country requiring an in-depth analysis for a true picture to emerge, which the questionnaire was not able to provide. In the West African context, wastewater irrigated urban land was mainly of state/government ownership and its use was often without any security of tenure (Drechsel et al. 2006; Obuobie et al. 2006), while peri-urban land was under communal or chieftaincy ownership and leased or given to the farmers. In the case of Asia, private ownership was predominant with some state/government/municipality ownership of some lands. In Latin America too, private ownership of land (sometimes after land distribution processes and agrarian reforms) was common but some communal ownership was also seen here. Privately owned lands were then either cultivated directly by the owner or rented out to tenants.

Regulations and restrictions on wastewater use

Fourteen of the 26 countries that provided responses said they had no guidelines pertaining to irrigation with wastewater. Eight countries had their own guidelines while four used either FAO or WHO guidelines. Even where guidelines existed, the majority of responses indicated that water quality monitoring and enforcement did not always

TABLE 6. Ownership of land in wastewater agriculture areas.

Description	Number of cities responding positively out of 53
Legal status of land	
Only state owned*	17
Only privately owned	18
Both state and private	10
Tenure status of farmers	
Rent	10
Squatters	5
Lease	12
Privately owned	26

*this category includes public and community owned land

happen. This is further confirmed in West Africa where the use of wastewater or polluted stream water for irrigation is often forbidden but the enforcement of regulations is limited, resulting in an unofficially tolerated practice (Drechsel et al. 2006).

The act of regulating has to be interpreted in the light of whether wastewater use has been formalized or whether it happens informally. In the former case it is expected that treatment is required prior to use, and a state authority is then empowered to regulate it within the means available to them. In the latter, the state does not always feel responsible, and the informal nature of its use makes regulation even more difficult.

Out of 47 respondent cities 75% indicated that no explicit crop restrictions were imposed by the authorities. In 25% of the cities there were explicit restrictions, essentially those imposing bans on cultivation of food eaten uncooked, but in these instances too, the authorities are constrained in the enforcement of the regulation.

The majority of cities sampled did not pay for irrigation water. In the 17 countries that paid for irrigation water, payments were not linked to the quality of irrigation water. It should be understood that payment for irrigation water occurs in the formal sector/schemes and is not applicable to the informal sector.

Official attitudes towards the practice show some interesting situations (Box 4). Scarcity creates situations where even irrigation authorities sometimes fall back on supplying wastewater to farmers periodically. In other instances, the irrigation authorities are aware that the water they supply is mixed with sewage discharges from cities, but have no way of regulating the offending municipalities. The environmental protection authorities cannot do anything either, especially where the waste management utilities are public sector entities.

Attitudes and preferences of consumers

The groups at risk from consumption of vegetables grown with wastewater were of particular interest. The natural preference of consumers was to avoid wastewater produce. However, in about 90% of the cases consumers have no information on the source of the produce, and thus buy according to price and appearance of the crops. Price differences between clean and wastewater produce were, however, not reported.

Data available from six African, seven Asian, and two Latin American cities showed the following:

Box 4. Institutional attitudes influencing the application of wastewater.

Three interesting cases cited in Asia are Faisalabad, Pakistan, Bangalore, India, and Nam Dinh, Vietnam. In Faisalabad, which represents a typical situation in Pakistan, where there is an acute shortage of water for agriculture, the official stance is that whilst treated wastewater can be used, untreated wastewater is banned. However, the enforcement is ambiguous in that in times of seasonal scarcity, the authorities themselves auction untreated wastewater to the highest bidder. Users then have to informally share the water. In Bangalore, wastewater is an important commodity that the irrigation department officially distributes, in spite of the fact that some of it is distributed untreated. Similarly in Nam Dinh, the irrigation authorities periodically pump in wastewater from the city drainage system into a section of an irrigation scheme when water is scarce in the dry season. Another scenario presented, occurring frequently due to urbanization, was the discharge of wastewater into the irrigation or drainage systems untreated, where the irrigation authority has no way of regulating its use.

Wastewater as an environmental resource was cited in one of the cities with reference to the case of the Yamuna River in India, where wastewater maintains the environmental flow requirement of the river. What is interesting here is that the quality of the water for this purpose does not seem to be an issue. Though it does take place, the use of wastewater for agriculture is not encouraged in spite of water scarcity.

Amongst authorities, two sets of attitudes prevail - those who see wastewater agriculture as a health risk (particularly current untreated wastewater practices), and those who consider it as a potential resource to be used after treatment but lack the knowledge and skills to handle the treatment issues appropriately. They see, for example, the value of the nutrients but simultaneously suggest comprehensive treatment which would reduce the amount of valuable plant nutrients drastically.

- The consumption of wastewater produce concerns first of all (60%) those areas where wastewater is produced, i.e., urban and peri-urban areas. Only two cities indicated that consumers in rural areas were also affected.
- Eighty percent of the cities indicated that the urban poor were definitely affected, perhaps because they did not have access to the better class supermarkets which may be sourcing vegetables from safe sources, or because they eat cheap street food containing raw salads that are contaminated.
- However, in general, all income groups buying vegetables from markets were affected, but mainly the richer classes through the consumption of exotic vegetables since these are usually grown with wastewater.
- Depending on the level of awareness, consumers have different ways of avoiding suspect produce: They buy from trusted vendors (with no prior bad experience) and wash, sterilize or cook the produce.

Profiling Farmers by Diversity and Gender

There was no overriding social or ethnic factor characterizing the wastewater user group, but many distinctive examples peculiar to local circumstances. In Kenitra, Morocco, and Almaty, Kazakhastan, the users were of rural origin or outsiders settled under insalubrious urban conditions or in difficult locations with no other water source. Examples of ethnicity were from Bolivia (the Aymaras) and from Mexico. In Brazil, the leaseholders were poor immigrants who had obtained leases because landholders wanted to move out due to pollution of their water sources. In many cities in urban West Africa, farmers that engaged in open-space vegetable production were (poor) rural migrants of different ethnic and religious origins, to the local people. They use whatever water source that is available, without any particular affinity to wastewater (Drechsel et al. 2006).

Women's involvement in urban agriculture was manifested in all farming activities via land

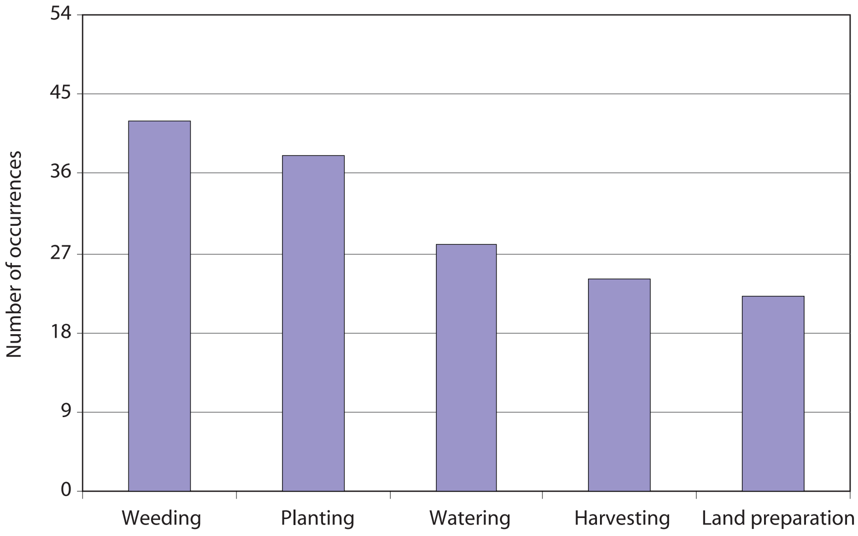

FIGURE 14. Degree of involvement of women in different types of farm activities.

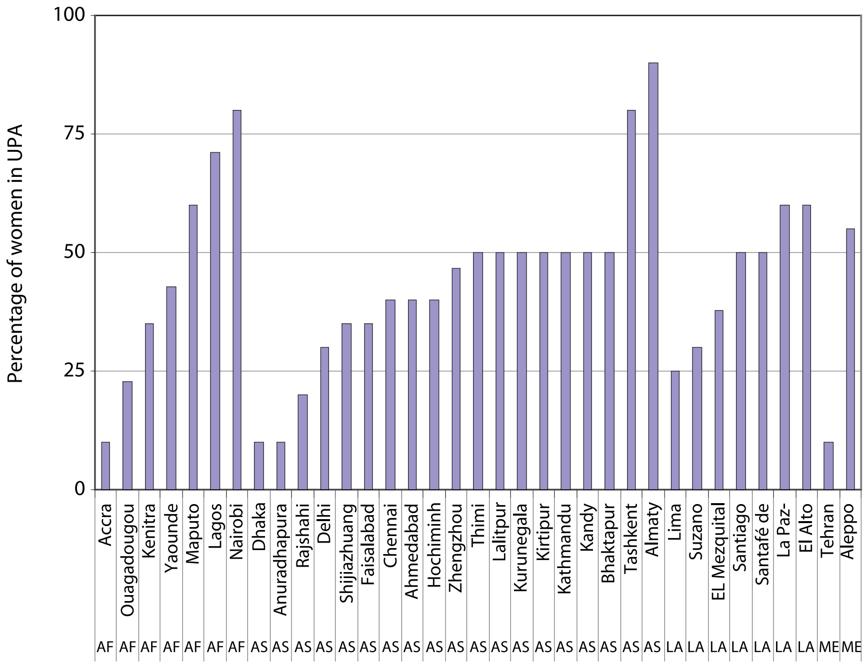

FIGURE 15. Involvement of women in irrigated UPA.

preparation, planting, weeding, watering and harvesting (Figure 14); and was substantial across the regions. Only 20% of the cities studied had less than 25% involvement of women. A predominance of women (over 70%) was seen in a few cities of Africa, Central Asia and Latin America (Figure 15). The reasons for this were the predominance of female headed farm households, which was usually due to the migration of men to more profitable employment abroad leaving women in charge, or due to tradition, because men had other occupations and women farmed.

Women's involvement in wastewater farming was only the result of their involvement in urban farming in general, and the survey showed that no general distinction can be made between male and female involvement in different types of urban agricultural farm activities across countries (with clean water or wastewater). In many African countries, however, water carrying activities (usually on the head) are traditionally done by women; so where irrigation using a bucket is common, this task is undertaken by women and not men. Also, in Hanoi, women traditionally have to carry blackwater, i.e., fecal matter to the field. It appears though that there is a general tendency to involve women more in planting and weeding which are considered "lighter" tasks (see Figure 14). Also, culture and tradition do influence the way women are involved in agriculture. Women are, for example, very involved in the selling of produce at the market. In West Africa, women dominate over 90% of the vegetable retail sector, including those crops produced with wastewater (Drechsel et al. 2006). The gender ratio amongst farmers differed in the subregion from country to country.

The response most often heard (in 75% of the cases) from women, regarding utilization of earnings from urban agriculture, was that their total earnings went for family use. Twenty percent of the time women said they made only a partial contribution to the family, and the rest was for their own use.

Conclusions

This study shows trends as well as clear gaps in our understanding of wastewater use in agriculture, backing findings from case studies commissioned by the Comprehensive Assessment of Water Management in Agriculture, past studies conducted by the International Water Management Institute and other institutions, and current literature. The study shows that the main drivers of wastewater use in irrigated agriculture are a combination of three factors in most cases:

- Increasing urban water demand and related return flow of used but seldom treated wastewater into the environment and its water bodies, causing pollution of traditional irrigation water sources.
- Urban food demand and market incentives favoring food production in city proximity where water sources are usually polluted.
- Lack of alternative (cheaper, similarly reliable or safer) water sources.

The key underlying factor in most cases is poverty which limits the "coping capacity" of cities to respond to the infrastructure needs of urbanization, e.g., with comprehensive wastewater treatment.

The study also establishes the following characteristics of wastewater use.

Pertaining to Wastewater Agriculture Extents, Associated Poverty, Livelihoods and Diversity

In four out of every five cities surveyed, wastewater is used (treated, raw or diluted) in urban and peri-urban agriculture, even if areas cultivated in each of the cities may sometimes be small. From data gathered across 53 cities we can conclude that just for these cities alone, approximately 0.4 Mha are cultivated with wastewater by a farmer population of 1.1 million with at least 4.5 million family dependants.

Wastewater agriculture was most prevalent in Asian cities with Vietnam, China and India being the most important. Although the data indicate that African cities have smaller areas under wastewater irrigation and smaller number of farmers, the reasons for this can be outdated administrative city boundaries (see Box 2). With limited wastewater treatment, there is hardly any stream flowing through an African city, that remains unpolluted; implying that downstream irrigated agriculture is definitely affected, which this study may not have captured.

Irrigation with treated recycled (waste)water is a phenomenon of higher income and often water scarce countries, where it is systematically planned, monitored, and regulated for effective and safe utilization. However, even in these economies, systems are sometimes dysfunctional resulting in poor quality water being used for agricultural purposes.

While controlled recycling of treated wastewater is well documented, the true extents of irrigation with partially or untreated wastewater are underreported or underestimated. This does not only concern Africa, but also Asia (with India and China taking the lead), Latin America and the Caribbean. However, several estimates point at a total area around 20 Mha.

This information gap also affects the quantification of the number of beneficiaries from wastewater agriculture including farmers, traders and consumers. The numbers can be significant as the country studies show. In Accra, for example, about 200,000 urban dwellers benefit everyday from vegetables produced in irrigated urban agriculture (Obuobie et al. 2006). From a livelihoods perspective, therefore, it must be remembered that extreme responses to minimizing risks from irrigated agriculture, like banning the use of polluted water, could have important adverse effects not only on farmers but also on other sectors of the economy and society, and on urban food supply, unless alternatives are made available.

Wastewater agriculture is not necessarily a phenomenon associated with the poorest of countries and cities, and many cities in middle income countries studied also had large extents of wastewater agriculture particularly those subject to water scarcity or where only part of the wastewater generated was collected and treated. However, in poorer cities with a higher city poverty index, where there is urban agriculture, the proportion of it under wastewater appeared to be higher. There was also a tendency towards a higher frequency of use of wastewater irrigation in drier regions, although in humid climates too, it is used in the dry seasons when water scarcity occurs.

Globally, there was diversity in the types of farmers, with many of them being rural migrants. Women’s involvement in wastewater farming and marketing was influenced by local or regional culture and tradition and was substantial.

“Exotic” vegetables were a popular wastewater crop in three out of five cities with the emergence of particular urban diets.

Pertaining to Water Supply and Sanitation Infrastructure

It is clear that to meet the growing urban demand, *water demand management* is necessary and that reallocation of water from agriculture to the growing domestic sector will be inevitable in many of these countries. Simultaneously, return flows have to be carefully managed to prevent contamination of large volumes of agricultural water and related environmental impacts. Considering the limited proportions of wastewater collected and treated, and the disposal points of effluents, it is not surprising that water bodies are getting increasingly polluted and that agriculture has to cope with this change.

Cities relying on on-site systems instead of sewerage are, in particular, facing a critical septage disposal problem. But even where sewer coverage is high, the study points at largely inadequate treatment facilities. Overall, data indicated that 85% of the cities studied discharged wastewater untreated or at best partially treated, and only 15% of the cities could be said to be adequately treating their wastewater. The bright side is that in arid areas, even untreated wastewater can be seen as a resource that creates a functioning “agro-ecosystem”, where the combination of water and nutrients encourages the growth of vegetation where otherwise little would grow. Streams are known to become perennial with discharges from cities, which then continue to serve agriculture downstream, especially in the dry seasons. The return flows from these agriculture systems undergo inherent natural purification, if, for example, filtered through the soil. The question then is, how can these systems be utilized safely to extract the maximum of benefits?

Where significant improvements in wastewater disposal are unlikely, the separation of industrial and domestic wastewater could result in less negative impacts on agricultural systems using wastewater. There is a risk of industrial contamination of water sources used in irrigated UPA (and further downstream of cities as well), because 70% of cities do not separate domestic from industrial wastewater in their evacuation systems. However, because of low levels of industrialization, this problem is not critical yet for wastewater agriculture in most low-income countries, but becomes an issue in emerging economies when regulations for industrial pollution control are not applied.

Pertaining to Regulation, Risk Reduction and Safe Use of Wastewater

Though extents of wastewater agriculture in and around cities may not be very large, the beneficial as well as potentially negative impact on consumers could be considerable. Extrapolating from the detailed studies in Accra, where vegetables produced on about 100 ha reach 200,000 urban dwellers everyday, these show the potential benefits of urban farming but also the risks of epidemics spread through wastewater. Not only will this affect the health of consumers locally, but it can also have an impact on the economy of countries exporting vegetables or depending on the tourist sector.

Strict irrigation water quality guidelines serve no purpose in the present context where means and capacities for treatment are lacking and farmers do not have much choice in the selection of the irrigation water source. It is clear that in the absence of the ability to enforce pollution control measures, and discharge standards and/or surface water quality standards, alternative ways for risk reduction are required. The “multiple barrier” approach to risk reduction recommended by the revised WHO guidelines (WHO 2006) offers a solution in this context. Additional factors of success to be considered are:

- At farm level, both the legal status of the land and the type of farming tenancy are essential to an understanding of how farmers will react to suggestions for adopting risk minimization methods which involve infrastructure development. These have implications for labor input and farm profit as well.
- At the market level, risk management is difficult as there is usually no incentive to differentiate between clean and contaminated produce. But, the willingness of consumers to pay more for clean-water produce could provide such incentives. However, care must be taken to introduce parallel measures of risk reduction to avoid poor sections of society being adversely affected.
- At a household level and with food vendors, taking preventive risk reduction measures via washing of produce and other food hygiene measures, may be an effective component of any larger risk reduction strategy (IWMI 2006) but might require social marketing as is done in other hygiene promotion campaigns.
- A clear understanding amongst consumers and farmers of the types of infections and risks associated with the use of wastewater in agriculture is lacking. Improving their knowledge via public awareness and extension services could increase levels of attention. On the other hand, recognizing and improving on farmers’ own innovations for risk reduction can result in cost-effective methods for immediate application. Farmers are the best judges of what can work under their conditions, and thus any on-farm trial should be of a participatory

nature incorporating feedback from the farmers.

- In addressing the issue of risk from consuming wastewater irrigated crops in poor developing country contexts, it must be remembered that for the average consumer, this may not be the only source of risk or even the highest. Other sources of risk such as overall poor sanitation and hygiene, or unsafe food preparation practices, to name a few, must be factored into risk assessment and mitigation strategies.

Recommendations for Implementation

Policies and decisions on wastewater use in agriculture should generally be motivated locally, as the socioeconomic, health, and environmental conditions which vary across countries will dictate how far common recommendations are applicable. The following general recommendations are nevertheless made to guide decisions, based on the findings of this study.

1. The gaps in knowledge of the true extents of the often informal use of wastewater at a country level must be addressed by governments through detailed assessments, which will allow them to evaluate trade-offs and decide on the hot spots that need immediate attention. For such assessments, the wastewater typology as outlined in Box 1 is recommended for use.

2. Urban and peri-urban agriculture can enhance food supplies to cities, especially where it has already made its mark, as a cheap and effective source of nutrition which can be improved at very little marginal cost if officially recognized.

3. The WHO (2006) guidelines for the safe use of wastewater should be extensively applied as it allows for incremental and adaptive risk reduction in contrast to strict water quality thresholds. This is a cost-effective and realistic approach for reducing health and environmental risks in low income countries.

4. Implementation of the Millennium Development Goals should more closely link policies and investments for improvements in the water supply sector, with those in the sanitation and waste disposal sector, to achieve maximum impact.

5. To improve the safety of irrigation water sources used for agriculture, and enhance the direct use of wastewater, it is imperative to separate domestic and industrial discharges in cities, and improve the sewage and septage disposal methods by moving away from ineffective conventional systems.

6. A research gap clearly exists on quantitative risk assessment studies which include multiple sources of risk, and such studies must be commissioned at a city or country level before decisions are made on water and sanitation sector investments.

7. Acknowledging that off-farm handling practices like washing of vegetables can be very effective as a means of reducing/eliminating contamination, and supporting widespread use of good practices, can facilitate trade exchanges for developing countries exporting vegetables.

8. In addressing health risks; on the one hand, state authorities have a role to play in planning, financing and maintaining sanitation and waste disposal infrastructure that is

commensurate with their capacities, and which responds to agricultural reuse requirements. On the other, as a comprehensive treatment will remain unlikely in the near future, outsourcing water quality improvements and health risk reduction to the user level and supporting such initiatives through farm tenure security, economic incentives like easy access to credit for safer farming, and social marketing for improving farmer knowledge and responsibility, can lead to reducing public health risks more effectively while maintaining the benefits of urban and peri-urban agriculture.

9. Finally, countries must address the need to develop policies and locally viable practices for safer wastewater use to maintain its benefits for food supply and livelihoods while reducing health and environmental risks.

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