Research Report

Drivers and characteristics of wastewater agriculture in developing countries – results from a global assessment

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Definitions and Acronyms

UPA	:	Urban and Peri-urban Agriculture
WWA	:	Wastewater Agriculture
WW	:	Wastewater
AF	:	Africa
AS	:	Asia
LA	:	Latin America
ME	:	Middle East
City poverty index	:	percentage of city poor living below the poverty line (1 USD/day)
LPCD	:	Actual per capita water consumption ie Actual volume of water supplied /population served in liters per capita per day
LDC	:	Less developed countries
GDP	:	Gross Domestic Product
PPP	:	Purchasing Power Parity
l/c/d	:	litres per capita per day

Abstract

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 livelihoods benefits and perishable food to cities. This paper through a cross country analysis of 53 cities in the developing world, provides an understanding of the factors that drive wastewater use. The 53 cities represent a range of settings in arid and wet 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 water, either treated or untreated, into the environment and its water bodies, causing pollution of traditional irrigation water sources.
- Urban food demand and market incentives favouring production in city proximity where water sources are usually polluted.
- Lack of alternative (cheaper or safer) water sources.

Additionally, poverty and migration play a secondary role; where cities are unable to treat wastewater due to lack of resources, where poor farmers use available water sources whatever the quality; and where migration results in urban and peri-urban agriculture as a means of livelihood support.

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, approx 0.4 million ha are cultivated with wastewater by a farmer population of 1.1 million with 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 million hectares. These figures include areas where irrigation water is heavily polluted.

Though the actual physical areas under cultivation may be small, some crops are grown at least 10 times a year. 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 cannot be imposed where traditional irrigation water sources are polluted, unless alternative sources of water are provided. Farmers are aware of potential risks to themselves and to consumers but a clear understanding of cause and effect are missing. The fact that consumers in cities habitually wash vegetables supports the idea that the best method of minimizing risk in the short term would be to encourage effective washing of vegetables.

Some key policy recommendations made are:

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 guidelines (2006) for safe use of wastewater should be extensively applied as it allows for incremental and adaptive change which is cost-effective in reducing health and environmental risks.
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 risks; on the one hand state authorities have a role to play in planning, financing and maintaining sanitation and waste disposal infrastructure that supports re-use of wastewater and is designed with agricultural end-use in view. On the other, 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 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 practices for safer wastewater use to maintain the livelihood benefits, but reduce health and environmental risks.

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Background and Scope

Contrary to most developed countries where wastewater is treated before re-use, 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 appearances from raw to diluted:

- **Urban wastewater** is usually a combination of one or more of the following:
    - Domestic effluent consisting of *black water* (excreta, urine and associated sludge) and *grey water* (kitchen and bathroom wastewater)
    - Water from commercial establishments and institutions, including hospitals
    - *Industrial* effluent.
    - *Storm water* and other urban run-off
- **Treated wastewater** is wastewater that has been processed through a wastewater treatment plant and that has been subjected to one or more physical, chemical, and biological processes to reduce its pollution of 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*** *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 (polluted) river receiving urban wastewater is abstracted by many users at many points downstream of the urban center for agriculture. This happens when cities do not have an operational sewage collection network and drainage systems collecting wastewater discharge into rivers
    - ***Direct*** *use* of ***treated*** wastewater: When wastewater has undergone treatment before it is used for agriculture or other irrigation or recycling purposes.

- **Legal regime**
    - **Regulated** use of wastewater refers to planned wastewater use with systems in place for collection and treatment of wastewater before use, and legislation for enforcement of standards.

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. Secondary benefits are said to be:

1. Better nutrition and education to farming families as the income generated from this practice 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
3. Agricultural wastewater application is seen as a form of land treatment where other means are not viable, thus providing some measure of protection against surface water pollution

Health risks include skin and worm infections for farmers and exposure to a variety of pathogens found in infected faeces; for all those in contact with wastewater or consuming the produce. In addition, 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 and ground waters 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 percent of global water diversions (but even up to 80-95 percent sometimes 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 in many countries insignificant 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 and Southern and Northern African regions, the Mediterranean, parts of China, Australia and the USA, domestic water use can represent between 30 to 70 percent of the irrigation water use (or between 10-40 percent of total water use) in the extreme cases (Abu Zeid *et al,* 2004; Angelakis *et al,* 1999; Crook, 2000; FAO 1997 a, 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 percent 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 percent 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 re-use 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 percent of the treated wastewater is being recycled for these purposes. A recent very comprehensive compilation of data on water re-use (Jimenez and Asano, 2008), provides an understanding of re-use 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 percent of the world population (UNPD, 2002) but urban water demand per capita will also increase with increasing supply, coverage and overall urban economic growth. More than 80 percent 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, because of densification of urban areas which reduces the possibility for onsite sanitation as it requires centralized collection and disposal systems. Centralized treatment systems in developing countries are not always affordable, and when they are in place, they have always been vulnerable to the vagaries of skills, and institutional 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. The Millenium Development Goals for Sanitation, in many countries are attempting to address the challenges of improved sanitation facilities for all without necessarily paying attention to the disposal of the increasing volumes of wastewater that are being discharged into the drainage systems of cities.

Figuratively speaking (waste) water finds its own outlet, and either oceans or water bodies close to cities act as a sink for wastewater. In the case of freshwater bodies receiving wastewater, they are used for multiple domestic and agricultural purposes including informal irrigation. Thus the term wastewater as used in this report can refer to treated, raw or diluted wastewater (Box 1) used under official or informal conditions.

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 close to urban centres is a widespread practice. Recent estimates indicate 20 million hectares under agriculture using treated, partially treated, diluted and untreated wastewater (Scott *et al*, 2004; Marsalek *et al,* 2005(Hamilton *et al.,*Keraita *et al.,* 2008). Even in the absence of an accurate overall estimate, the fact is that for millions of poor households wastewater is a highly important productive resource 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 such items, from more distant locations due to lack of necessary infrastructure and cooled storage trucks for transport, thus supporting agriculture in market proximity. Furthermore it is recognized that for these poor urban farmers, wastewater irrigation is a substantial and sometimes even primary source of cash income in addition to contributing towards urban food supply (UNDP, 1996; Drechsel *et al.,* 2006; Van Veenhuizen and Danso, 2008).

Drivers of the Practice and Objectives of the Study

Although wastewater use is a global phenomenon, its extent and drivers very between regions and climatic zones.Despite increasing efforts by 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 however there are no comprehensive data sets that provide an understanding of wastewater agriculture and related practices across countries and cultures; and little attempt has been made:

- to identify the factors that drive wastewater use in developing countries,
- to understand the potential role that wastewater plays in reducing 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.

It is understood that local opportunities and constraints should motivate policies and decisions about wastewater irrigation or wastewater agriculture. However, a knowledge of the drivers can steer decisions better and provide an understanding of the trade-offs. . associated with the practice. With this in view, a study of 53 selected cities across the developing world, was commissioned to carry out an analysis that would propel wastewater agriculture to the policy agenda of developing countries and justify research into the management or improvement of current practices. This global study was supported by the Comprehensive Assessment 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 was intended to provide first estimates of the volumes of wastewater generated, treatment and disposal practices, extents of agriculture, its value to society and its significance as a livelihood strategy, and its health implications, in selected cities around the world. The main source of information was an extensive survey across 53 cities using a purpose designed questionnaire. The surveys were conducted using experts from the selected countries/cities identified by an independent panel. The questionnaire was completed by local 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 use of wastewater. The target regions were: Latin America, Middle East and most parts of Africa and Asia. The countries from these regions were categorized by the IWMI water scarcity index[1], annual rainfall, and income[2] and the two largest cities were identified

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[1] Seckler *et al* Reference for IWMI water scarcity index

[2] Economies are divided according to 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; high income, $9,386 or more.

for each country. Information on city area, city population, urban sprawl, location (inland or coastal) was obtained for all the cities in order to get a basic understanding of the individual situation and to select 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). Consequently it turned out that some of the cities selected were comprised of more than one municipality (Kathmandu, La Paz, Sao Paolo, and Mexico City); which expanded the final number of urban areas considered in this study to the odd number of 53.

Box 2.
Limitations of the study

Comparing city statistics in general, and looking at agricultural areas 'in' cities in particular, poses 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 km^2. The actual size of the urbanised 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 km^2 ha under wastewater irrigation) (Obuobie *et al*., 2006).

In Vietnam, on the other hand, the municipal boundaries of Hanoi and HCM City comprise much larger areas than the actual built "city" part, including several hundred km^2 of agricultural lands, which forms 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 cultivated land.

As water pollution does not stop at the administrative city boundary, an ideal data set would have to ignore these boundaries. Having these limitations in mind, we consider this study as a first approximation.

Data for the respective countries was collected/collated by different consultants, so in spite of detailed instructions and a well designed questionnaire, the quality of data varied from country to country. Thus for some data cross referencing was necessary to interpret the data.

The regressions coefficients in the figures are presented only to indicate a trend and the values have a standard five percent significance.

The regional distribution of the countries selected is seen 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 over 5 million.

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

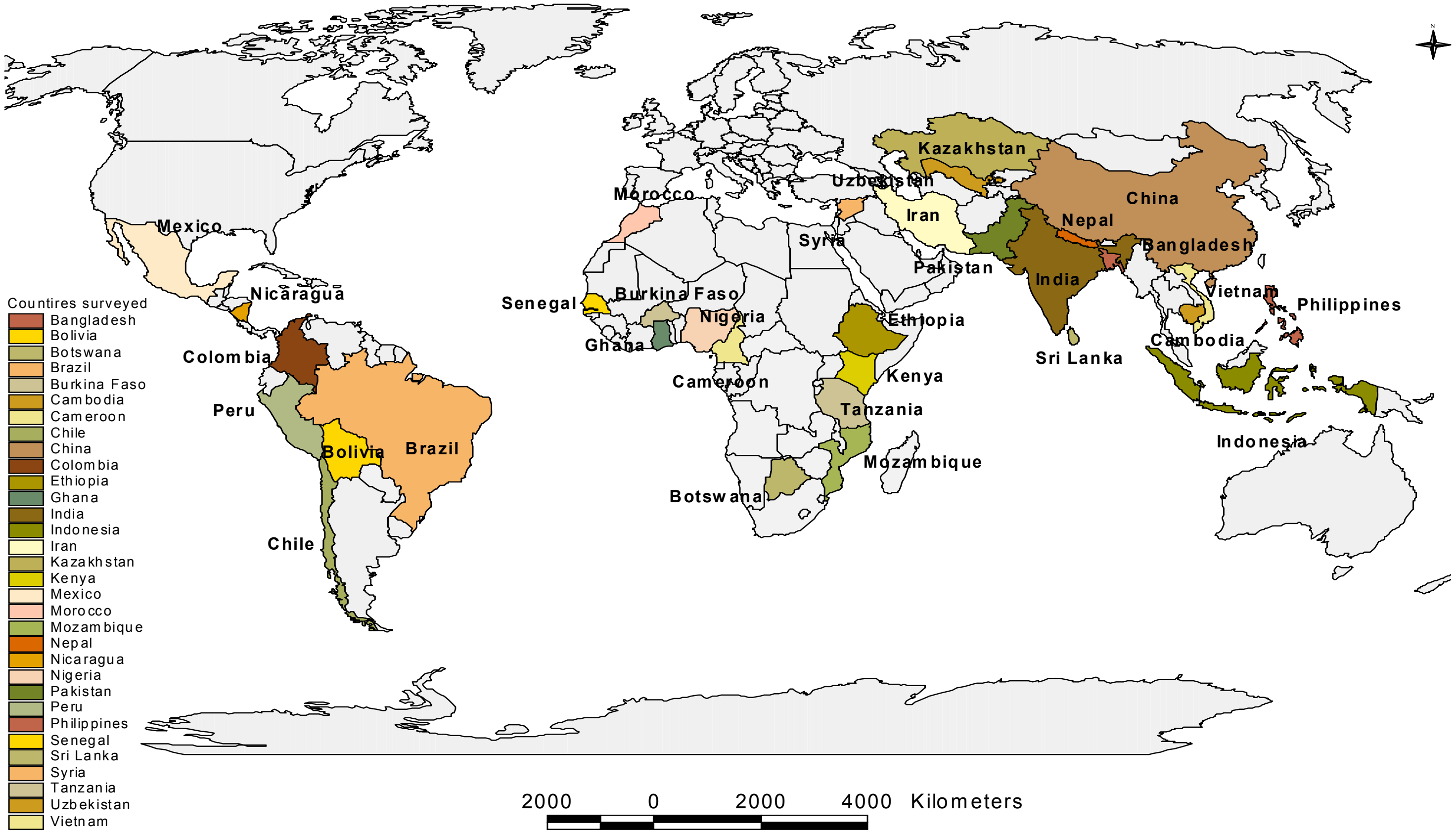
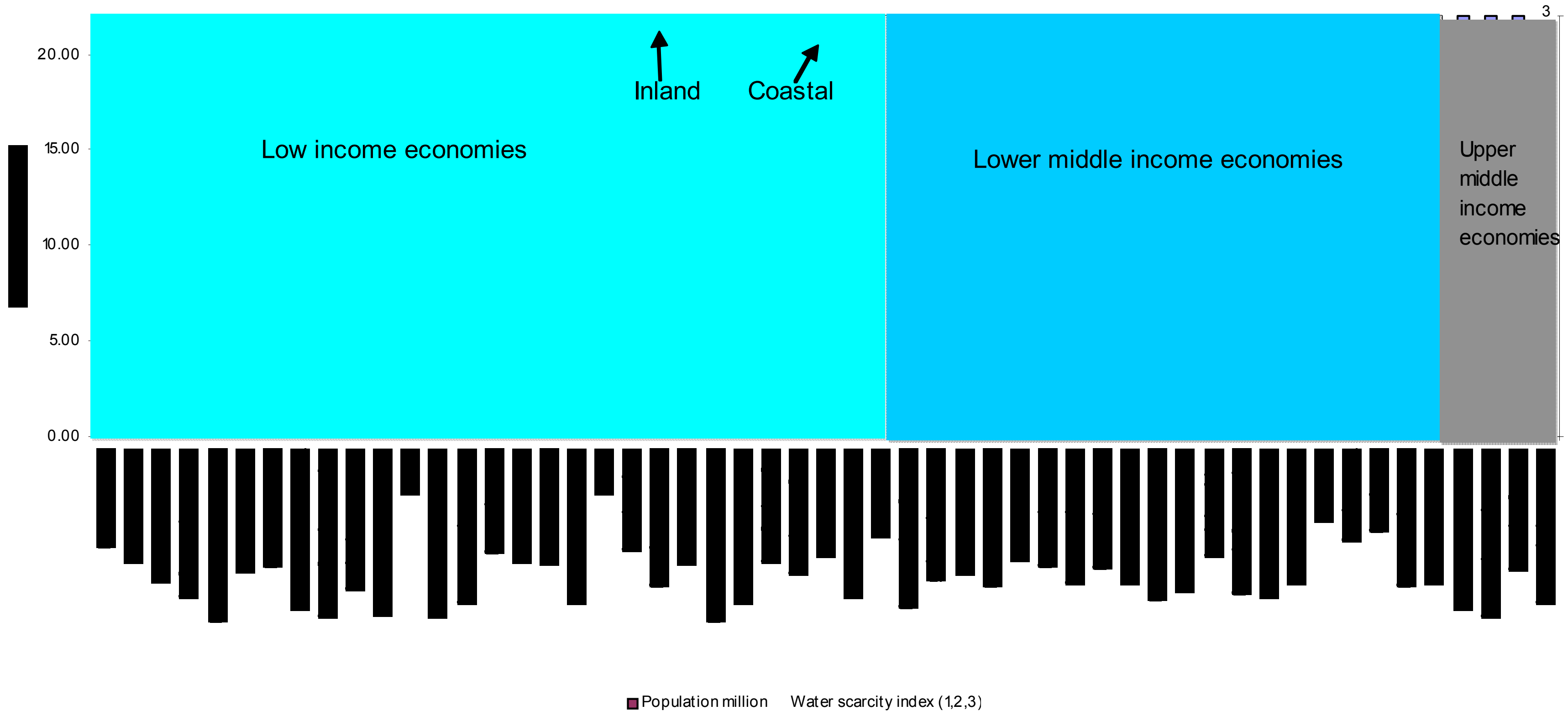


Figure 2.
Characteristics of (53) selected cities



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 percent wastewater treatment would be necessary. The analysis was done accordingly using the following 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 labour, 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 these parameters for interested readers.

Results and Discussion

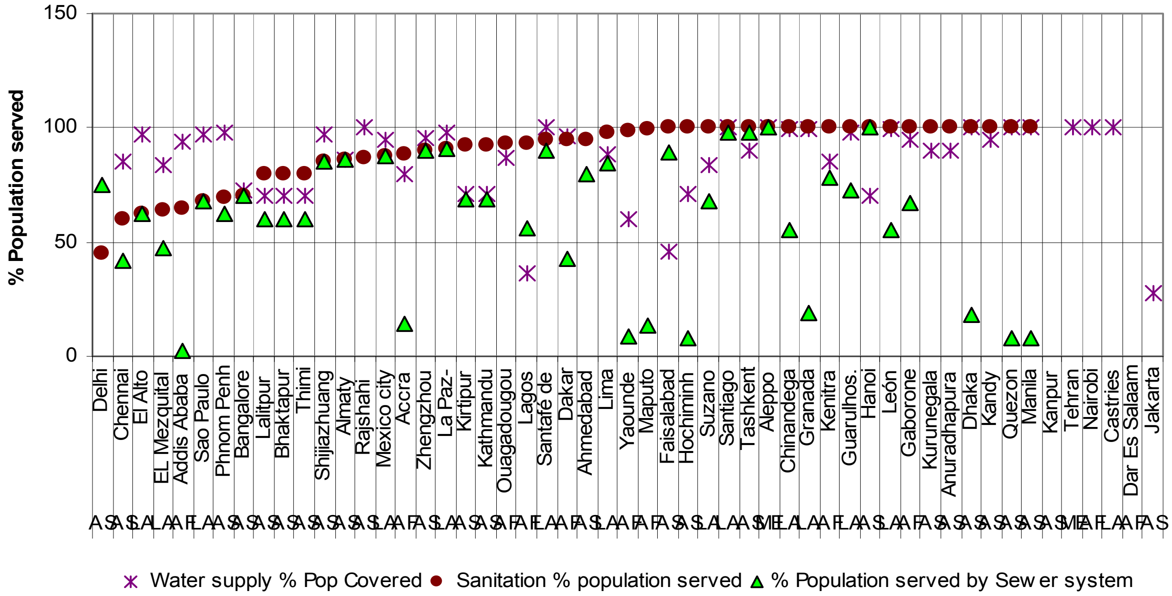
In the following sections, the basic information derived from the analysis is presented. Before analyzing data directly related to the use of wastewater, the first sections will present a short analysis of water supply, sanitation and waste disposal settings as one of the drivers of wastewater agriculture, 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

<u>Urban water supply and its implications for wastewater generation</u>
In 60 percent of the cities both surface and ground water are used for water supply, 23 percent used only surface water and 17 percent only ground water. Inland cities which are closer to lakes or rivers also used such surface water sources.

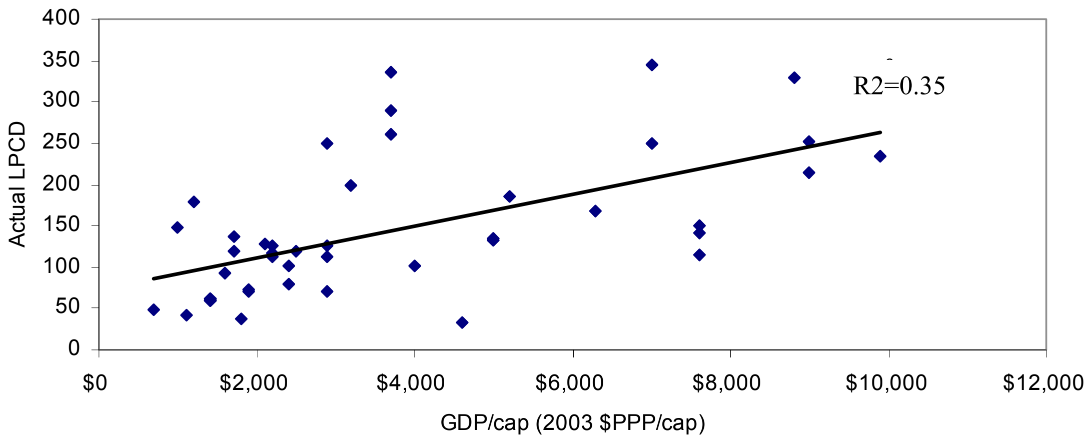
Only 50 percent of the cities have a pipe-borne water supply coverage of over 90 percent indicating that in many cities service coverage is still largely in adequate. At least 25 percent of the cities have a coverage of less than 25 percent (Figure 3).

Figure 3.
Water supply sanitation and sewer coverage by city



The actual per capita water consumption[3] showed a very large variation from 34 liters per capita per day to 350 liters per capita per day (Figure 4). Half the cities have a consumption of 100-250 liters/capita/day. This is quite high for LDC's but it must be remembered that urban industrial supply is included, and that system losses can be high – 50 percent of the countries indicated losses between 25 and 55 percent. There is a significant increase in water consumption with the GDP/capita implying that if disposal infrastructure does not keep pace with water consumption in cities, the positive health outcomes of improved water supply will be negated.

Figure 4.
Per capita water consumption (in Liters/day)

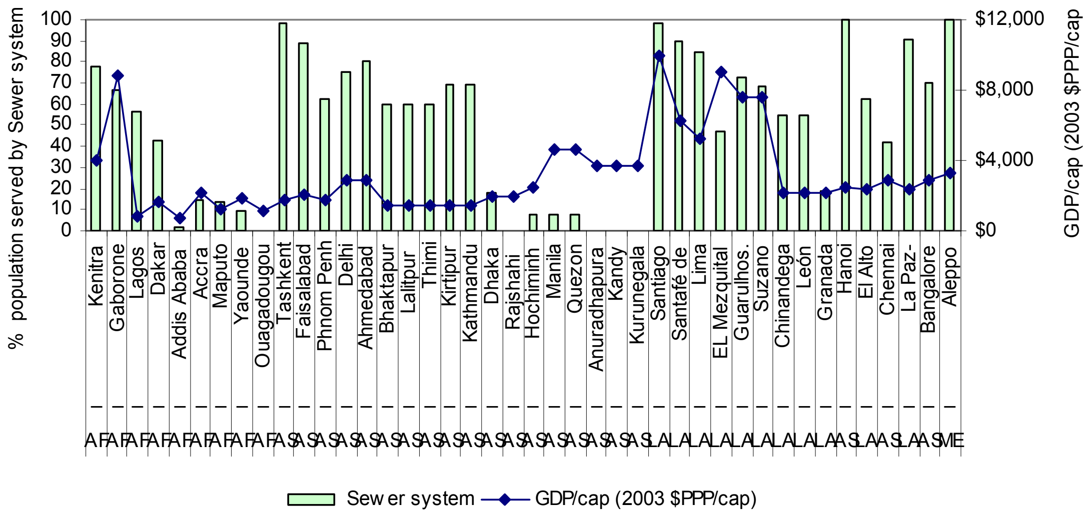


[3] Calculated as "actual volume supplied by a water utility, divided by the population served"

Sanitation coverage and type

Sanitation coverage and the manner in which wastewater is collected and disposed of in a city are essential to an understanding of the drivers of wastewater agriculture. About 80 percent 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 percent . Half of the responding cities had closed sewers only whereas 33 percent had both open and closed. Relating GDP/capita to sewer coverage in cities with over 50 percent coverage (many of these are in Asia and Latin America with Africa lagging behind) a large variation is seen (Figure 5).

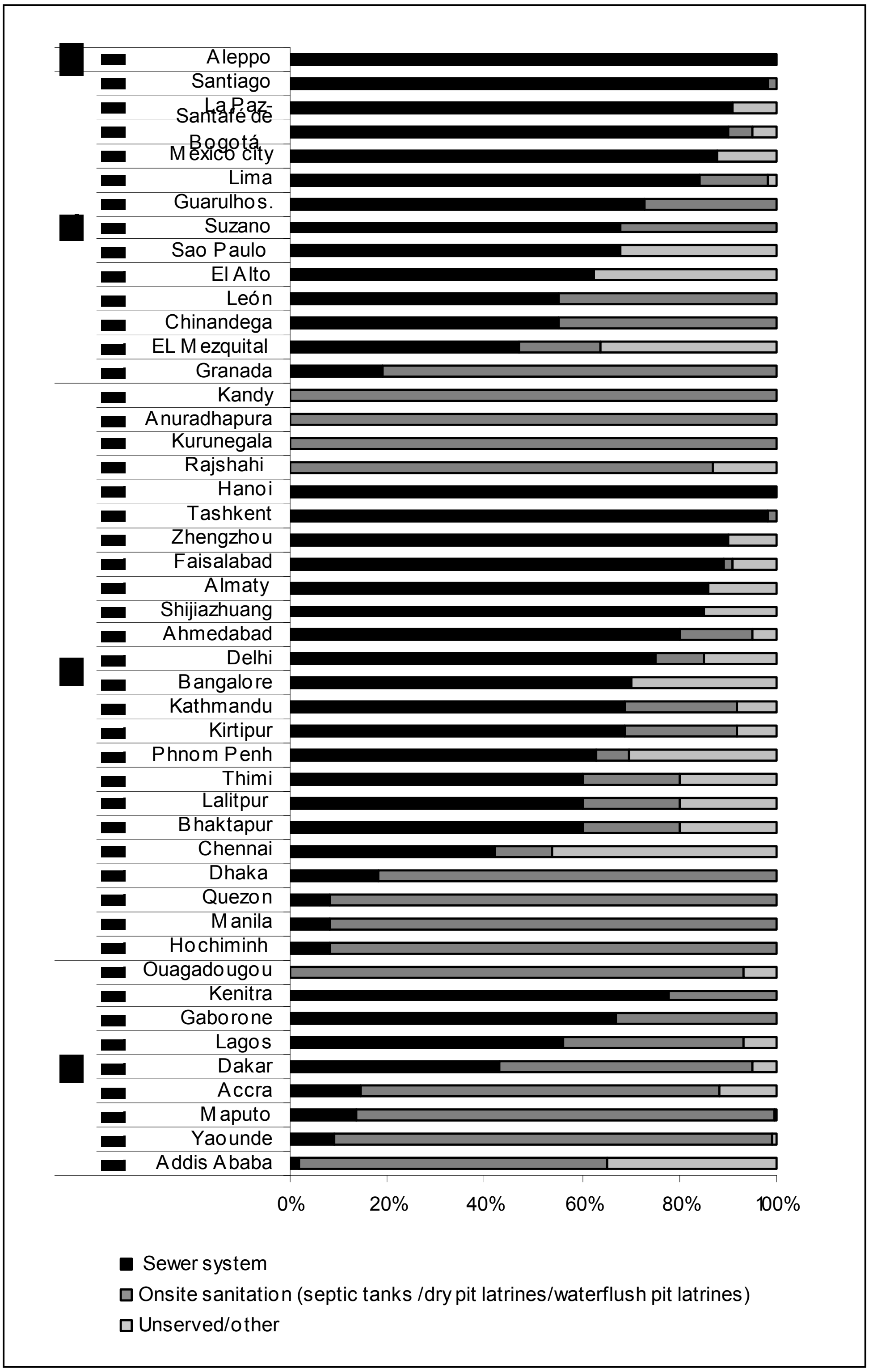
Figure 5.
Sewer coverage and GDP/capita



From Figure 3 it is also evident that 82 percent (39/47) of the cities had sanitation coverage (this is not synonymous with sewer coverage!) of over 75 percent showing that most cities are well served with some form of sanitation.

In at least 60 percent of the cities a large percentage of the urban population (between 30-100 percent) 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, onsite systems which require space, cannot function efficiently leading to septage disposal problems.

Figure 6.
Type of sanitation coverage in the cities



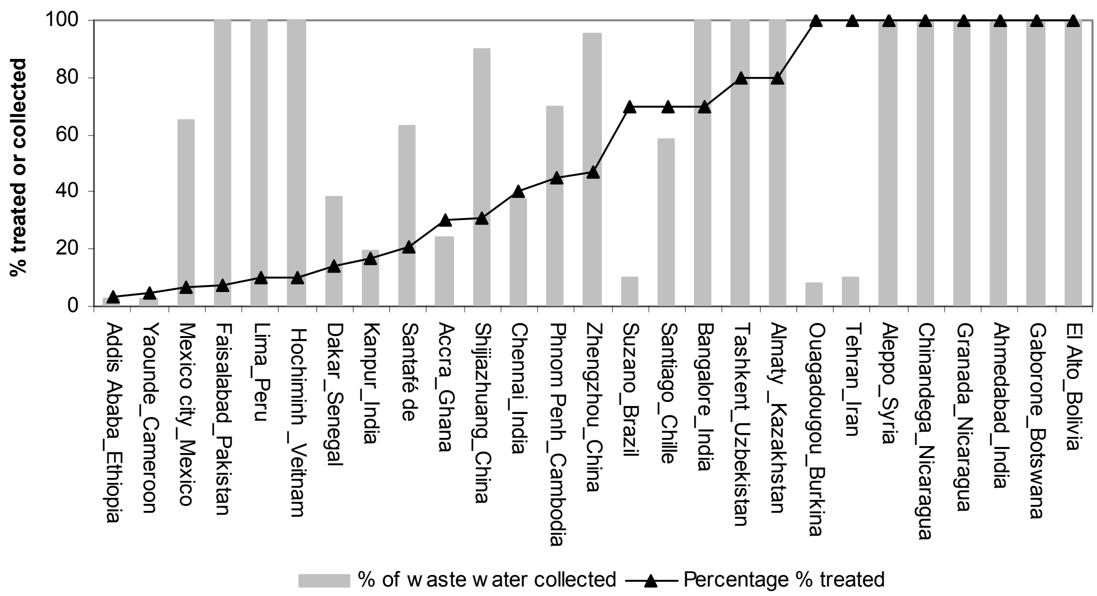
Treatment and disposal of septage and sewage

Disposal of household septage is by tankers in 80 percent 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 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 collected wastewater is also treated. While 74 percent of cities with sewers treat their wastewater, the type and degree of treatment varies. Responses from 21 countries indicated that only 30 percent treated all the collected wastewater. More than half of them treated less that 50 percent of the collected wastewater (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.

Figure 7.

Waste water collected as % of generated and Waste water treated as % of collected



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

This does not only concern surface water bodies. The majority of cities mentioned ground water contamination in some locations where leachate from garbage dumps, and overflows from septic tanks infiltrate groundwater.

“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 percent 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 percent 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 greywater 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 percent) mixing of industrial wastewater was minimal, and even in the worst cases did not exceed 40-50 percent. With a few exceptions, most industrial development was of small scale within cities. Contamination depends of course on the type of industry, but related information was scarce. About 60 percent of the responses confirmed that industrial wastewater was treated to some degree before discharge but with poor enforcement of regulations, it is unlikely that treatment is very effective in removing chemical contaminants harmful to human health.

Moreover, heavy industry is often located close to harbours where wastewater enters 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

<u>Nature and extent of wastewater irrigation</u>

The presence of irrigated urban and peri-urban agriculture (UPA) was considered as a likely indicator or necessary condition for the occurrence of wastewater use (for agriculture) where wastewater treatment was limited. Out of the 53 cities studied, only 8 cities reported to have little or no irrigated UPA. 74 percent of the cities studied had wastewater agriculture though data on extents was not available for all 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 million ha 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, and the range of its extents across cities, by area or by number of farmers is 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 socio-economic situations.

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
Sub total Africa (AF)	9	3,550	5,100
Sub total Asia (AS)	19	992,880	214,560
Sub total Latin America (LA)	8	88,300	142,160
Sub total Middle-East (ME)	3	3,320	34,920
Total	39	1,088,050	396,740

Table 1.
Distribution of extents of wastewater agriculture

Extents (Ha)		No of cities	GDP/capita
Range	Mean (SD)		Range
10-1000	321 (272)	11	1100-8800$
1000-10000	3506 (2589)	9	1000-5000$
10000-45000	22505 (12917)	9	1700-9900$
>75000	-	2	2500-9000$
No extents data	-	8	NA

Table 2.
Cities with largest extents of wastewater agriculture

Region	City	Country	Total farmers WW informal and Formal	Total WW area (ha) informal and formal	Population million
AS	Ahmedabad	India	No data	33600	2.88
AS	Hanoi	Vietnam*	658300	43778	3.09
AS	Hochiminh	Vietnam*	135000	75906	5.55
AS	Kathmandu	Nepal	19524	5466	0.67
AS	Shijiazhuang	China	107000	11000	2.11
AS	Zhengzhou	China	25000	1650	2.51
LA	EL Mezquital	Mexico	73632	83060	0.65
LA	Santafé de Bogotá	Colombia	3000	22000	7.03
LA	Santiago	Chile	7300	36500	5.39

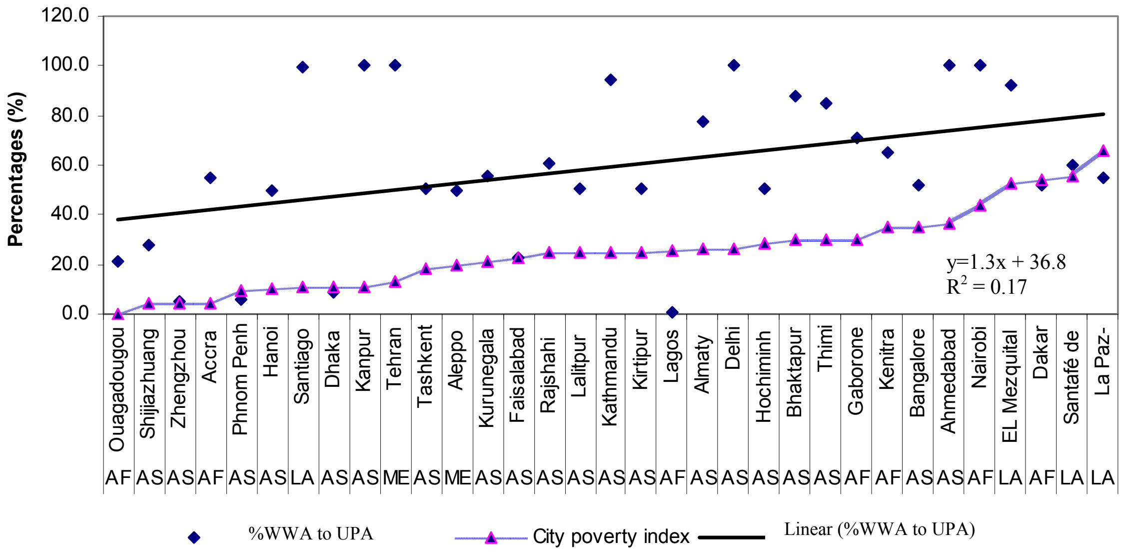
* Hanoi and Ho Chi Minh have very large extents of urban and particularly peri-urban agricultural land where irrigation water is from polluted rivers running through the cities

In the majority of cities in Asia landholding sizes were seen to be small (less than 1ha) 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 and water scarcity

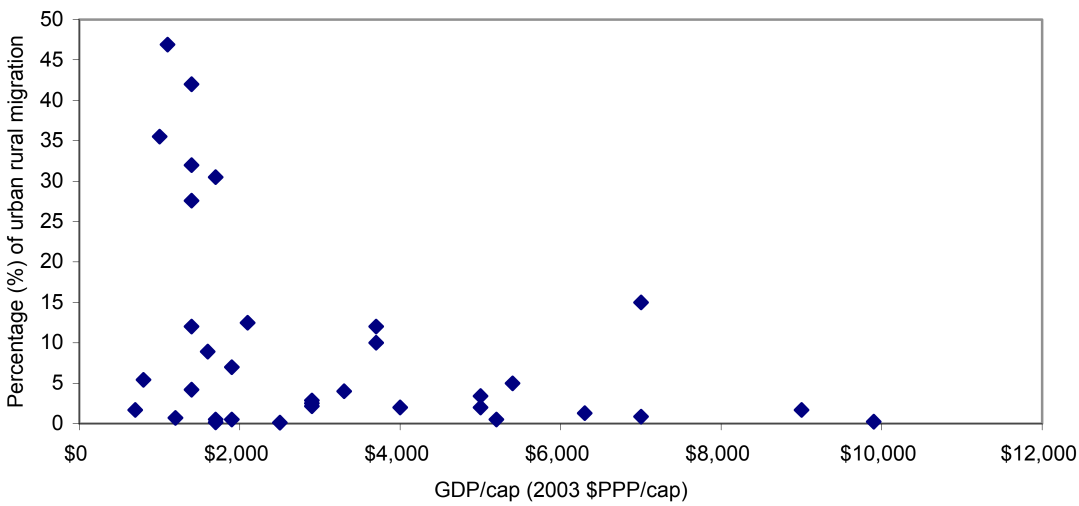
It was interesting to see that as the poverty level in the city increases in the sense of more poor living within the city, the share of wastewater agriculture to urban agriculture increases, almost displaying a linear relationship (Figure 8), indicating that farmers in poorer cities tend to use the available water sources, usually wastewater for irrigation. This appears to be particularly so in Asia. There as also some notable trends in terms of other socio-economic factors such as migration. Migration is intimately related to both poverty and wastewater. For instance a more detailed 12 city survey in West Africa showed, these migrants form in many cities the majority of urban farmers engaged in irrigated agriculture (Drechsel *et al.,* 2006).

Figure 8.
Wastewater agriculture variations with city poverty



As expected, rural urban migration was reported from 89 percent of the cities and appeared in general higher in African (2.5 percent on average) and Asian cities (4.2 percent on average) studied compared to Latin America (1.0 percent on average). Many cities with low GDP/capita (less than 2000 USD) 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 poverty index[4] which on an average decreased as we move from Africa to Asia to Latin America.

Figure 9.
Urban-rural migration Vs GDP per capita

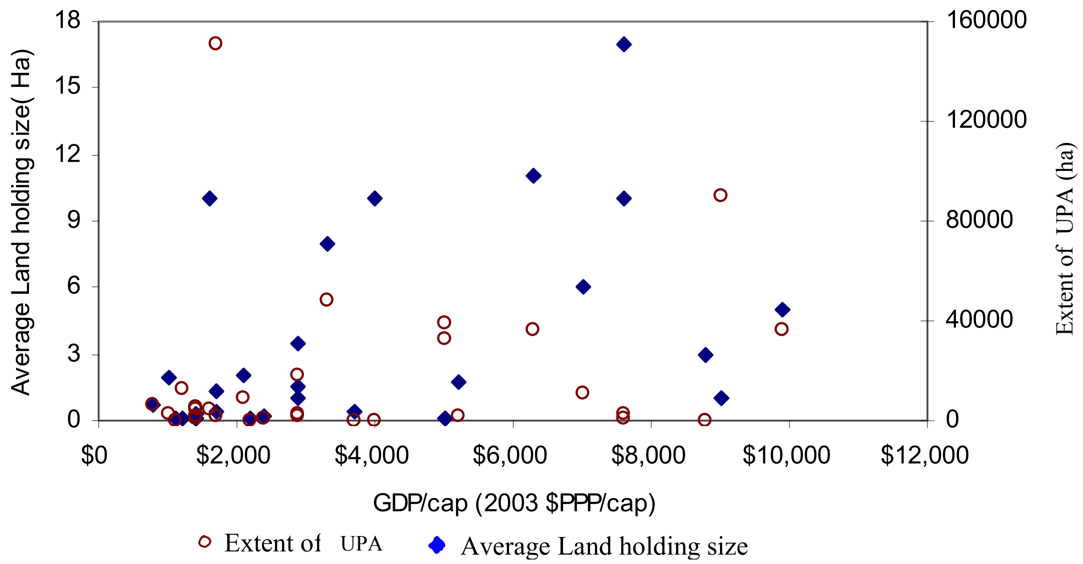


[4] Percentage of the population below the poverty line. In most cases this was 1USD/day

Under lower GDP/capita conditions (<2000 USD/year), and where alternative urban employment is not available, the high levels of rural 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.

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 be sometimes as small as 0.01 ha), low overall extents of land under peri-urban agriculture (<15,000ha), and lower total extents of wastewater agriculture (Figure 10). In many cities in Africa this is explained by the fact that, plot sizes depend on land and water access, tenure security and farmers' financial means to hire labour, all of which are poor or minimal (Drechsel *et al.,* 2006).

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



Close to three fourths of the sample cities studied had over 50 percent of their 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, associated with the pollution of water sources traditionally used for agriculture. This was also clearly seen in the sample of cities across Latin America and Asia (Table 3). But one aspect that is common across all cities is the close relation between wastewater use and physical water scarcity. For instance the use of wastewater in agriculture takes place in all but two study cities, with rainfall less than 800 mm, a level that is prone to create physical water scarcity (Figure 12).

Figure 11.
Variation of Percent wastewater agriculture with GDP / capita

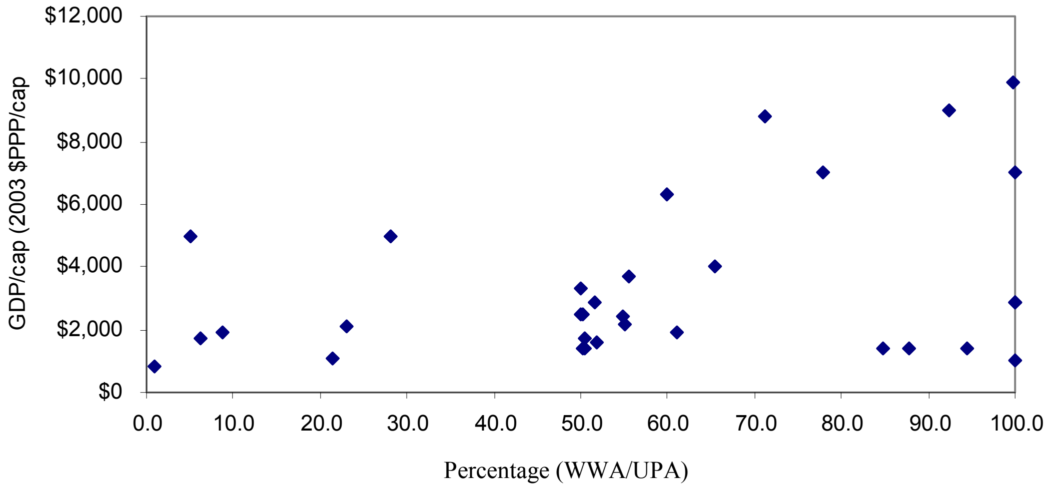
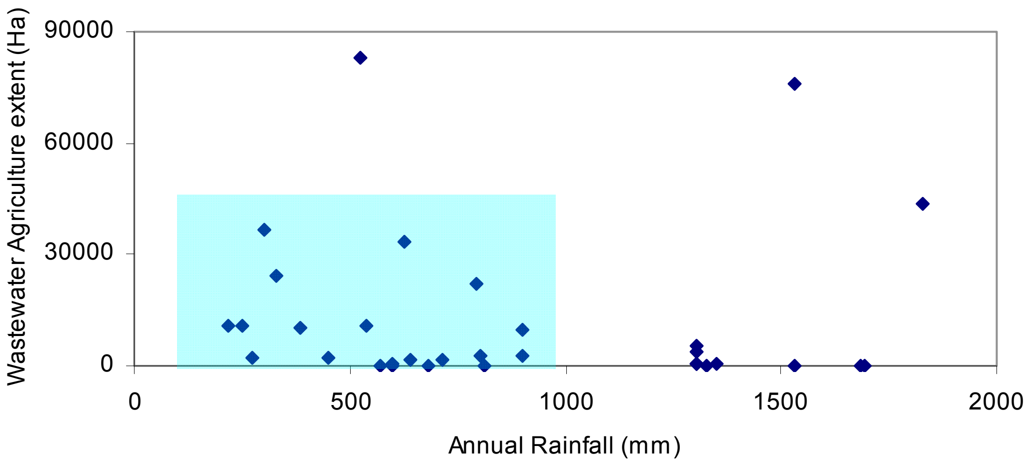


Figure 12.
Extent of wastewater agriculture Vs annual rainfall

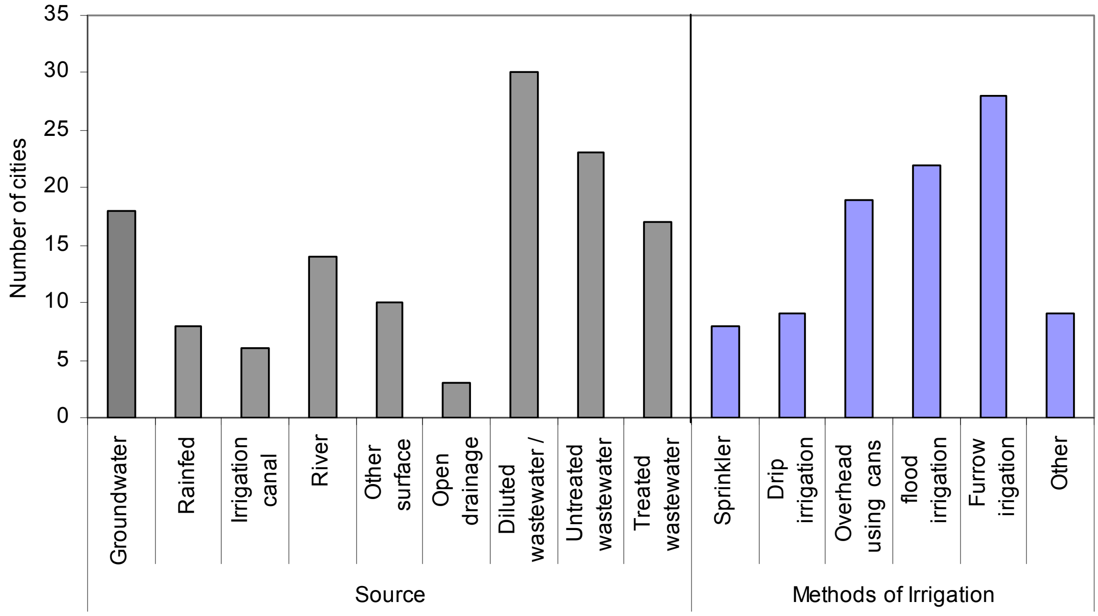


Water Sources, Crops Grown, and Irrigation Methods

Water sources and quality as it affects decisions on wastewater use

Water sources used for irrigated UPA (Figure 13) were seen to be various surface waters, rainwater and groundwater. While rainwater and groundwater are assumed to be comparatively "clean", the quality of surface water sources is questionable in the vicinity of cities as all case studies show. In these cases (31 out of 41 cities that responded), farmers have often 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 and regularity were also cited as key reasons (15 and 16 cities respectively out of 41). 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. Only 41 percent of the farmers complained about industrial water contamination.

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



Crops grown and irrigation methods
Across the cities, vegetables and cereals (especially rice) were the two most common crop families 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.

Table 3.
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

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 the African cities use mainly watering cans and furrow methods for waste water 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 predominates with some sprinkler.

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.

Farmer Perceptions of Health Risks

<u>Water quality and occupational risks</u>

Table 5 shows that in 19 cases no protection was taken against wastewater exposure. An equal number used foot protection, 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 hand s seemed an instinctive reaction towards general cleanliness and not necessarily associated with particular risks related to the irrigation water.

Table 4.
Health problems and reducing health risks

Description	Number of cities responding positively out of 53
Farmer attributed perceptions of health problems	
Skin irritation	21
Gastro-intestinal/Diarrhea	14
Respiratory	6
Other	15
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

<u>Food washing and consumption pattern</u>

Only in 9 cases, produce was 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). Farmers or sellers often used the source of water locally available on farm and on markets, be it pipe borne water, well water, or (polluted) stream water.

Farmers in 60 percent of the cities confirmed that they consume their own produce but the amounts were very variable depending on farm size and type of crop (cash crop vs. subsistence crop, and exotic vegetables vs indigenous varieties). Farmers in most cities indicated consumption ranging from 10-40 percent 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

Farmer perceptions as reported, on possible health problems associated with exposure to wastewater are 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. The association of various types of unconnected illnesses with exposure to wastewater may imply that farmers have little general health knowledge.

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 percent farmers were aware of this. The other cities had awareness levels ranging from 20-70 percent.

Twelve farmers out of 28 confirmed that they made no attempt to improve water quality either because they just did not see the need to, 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 reducing risks to themselves and their crops (Box 3), e.g. by observing the quality of their water source using for example simple sensory perceptions like color and smell and taste (!) to regulate use.

Box 3.
Indigenous practices to minimize risk at farm level

Ouagadougou BURKINA FASO: Farmers using industrial wastewater sources make storage basins where they store raw waste water to settle out material in suspension. Some farmers avoid periods when industrial waste water with high pollution loads are discharged, and time the collection and diversion to fields according to quality. They use their sensory perceptions, appearance, odour, taste assert to evaluate quality of the wastewater. When the water seems to be not acid and of "good quality "they fill storage basins and as soon as the quality of the water changes they stop the watering and close the basins.

Phnom Penh, CAMBODIA: There are two methods to minimize the risk. The first is take away the solid waste (contained mostly in industrial effluents loads), and the second is to dilute with clean water to improve the water quality.

Shijiazhuang and Zhengzhou, CHINA: they use alternative irrigation with clean and wastewater. Also during the early and sensitive stage of crop growth, the farmers would not irrigate with wastewater

INDONESIA NEPAL VIETNAM: use of settling ponds which eliminate suspended solids and also Iron.

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

Santafé de Bogotá: Some people have settling ponds but this is not a common practice. But one farmer explained how one of the supermarket chains rinsed produce with Clorox diluted in water, leafy vegetables in particular.

In Guarulhos and Suzano, Brazil when farmers realize that the water source used for irrigation is contaminated by wastewater, they start to sell or lease out their lands and move on to other place with better quality water.

Institutional Aspects Influencing Wastewater Use

Ownership of land

Legal status and tenure issues for land are complex and vary greatly from country to country (Table 6) requiring an in depth analysis for a true picture 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 tenure security (Drechsel *et al*., 2006), while peri-urban land was of communal or tribal 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.

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

<u>Regulations and restrictions on wastewater use</u>
14 of the 26 countries that provided responses said they had no guidelines pertaining to irrigation with wastewater. 8 countries had their own guidelines while 4 used either FAO or WHO guidelines. Even where guidelines existed, the majority of responses indicated that water quality monitoring and enforcement do not always 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 and attempts to do so within means available to them, not always successfully. 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 percent indicated that no explicit crop restrictions were imposed by the authorities. In 25 percent of the cities there were explicit restrictions, essentially those imposing bans on cultivation of food eaten uncooked but even in these instances 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 which paid for irrigation water, payments were not linked to the irrigation water quality. 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 irrigation authorities are aware that the water they supply is mixed with sewage discharges from cities, but have no way of regulating the municipalities which do this. Neither can the environmental protection authorities, when the waste management utilities are also state run.

Box 4.
Institutional attitudes influencing application of wastewater

Two interesting cases cited in Asia are Faisalabad, Pakistan and Bangalore, India. In Faisalabad, which represents a typical situation in Pakistan, where there is acute water shortage for agriculture, the official stance is that whilst treated wastewater can be used, untreated is banned. However the enforcement is ambiguous in that in times of scarcity seasonally, 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, Vietnam 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 river Yamuna 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, 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 the skills to handle the issues. They also see the value of the nutrients but simultaneously feel that tertiary treatment is necessary possibly due to ignorance about treatment processes.

Attitudes and preferences of consumers

The groups at risk from consumption of vegetables grown with wastewater, was of particular interest. Across the cities a natural preference of consumers was to avoid wastewater produce but since in 90 percent of the cases the origins were not known to the consumers, they could not avoid it. Indeed vendors have reason to hide the origin suspecting that they will be penalized. The general trend in cities was for consumers to go for the cheapest produce. There was no reported price difference between clean and wastewater produce.

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

- The consumption of wastewater produce concerns first of all those areas where wastewater is produced, i.e. urban and peri-urban ones. 60 percent of the cities responded positively. Only two cities indicated that consumers in rural areas were also affected.
- 80 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 ate cheap street food containing raw salads that are contaminated.

- However, in general all income groups buying vegetables from markets were affected, the richer classes mainly through consuming the exotic vegetables 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 examples of particular local conditions. 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 urban West Africa, farmers engaged in open-space vegetable production were in many cities (poor) rural migrants of different ethnic and religious groups to the local people. They use whatever water source is available, without any particular affinity to wastewater (Drechsel *et al.,* 2006).

Women's involvement in urban agriculture was manifested in all farming activities viz: land preparation, planting, weeding watering and harvesting Figure 14; and was substantial across the regions. Only 20 percent of the cities studied had less than 25 percent involvement of women. A predominance of women (over 70 percent) was seen in a few cities of Africa, Central Asia and Latin America (Figure 15) the reasons for this were varied – predominance of female headed farm households usually due migration of men to more profitable employment abroad leaving women in charge, or tradition, because men had other occupations and women farmed.

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

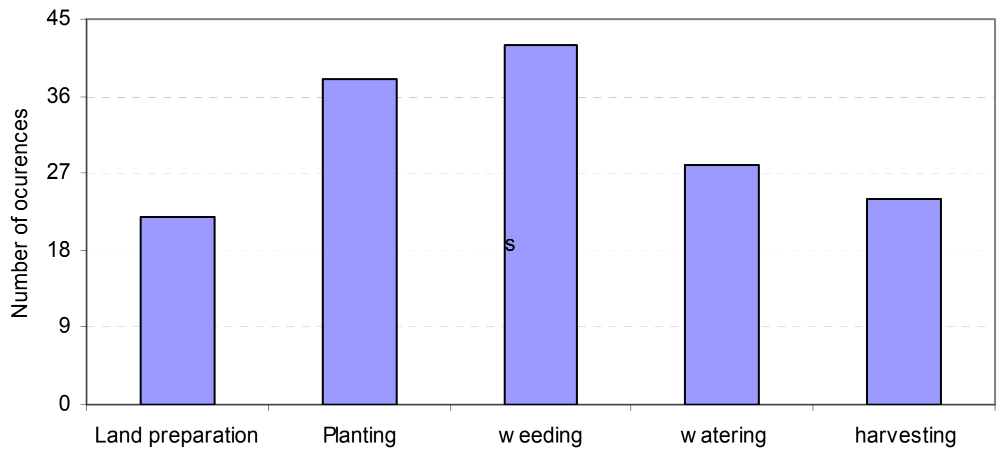
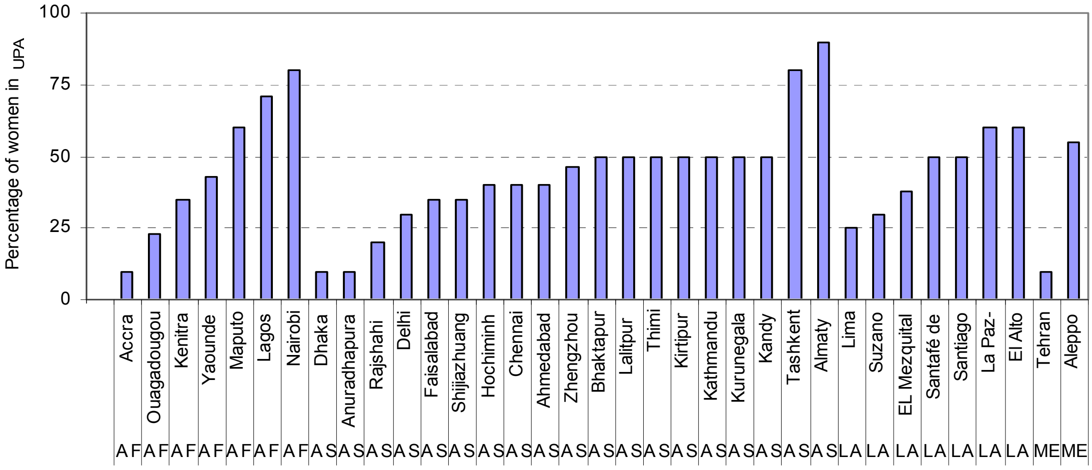


Figure 15.
Involvement of women in irrigated UPA



Women's involvement in wastewater farming was only the result of their involvement in urban farming in general and the survey showed that no distinction was made between male and female involvement in different types of urban agriculture 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 bucket irrigation is common, this task is undertaken by women and not men. Also in Hanoi, women traditionally have to carry black water i.e. fecal matter to the field. It appears though that there is a general tendency to involve women more in planting and weeding jobs which are considered "lighter" tasks (see Figure 14). Culture and tradition do influence the way women are involved in agriculture. Women are also very much involved in selling of produce at the market. In West Africa, women dominate to over 90% the vegetable retail sector, including those crops produced with wastewater (Drechsel *et al.,* 2006). The gender ratio amongst farmers differs from country to country.

The response most often heard (in 75 percent of 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, past studies conducted by the International Water Management Institute, and other literature. 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 water, either treated or untreated, into the environment and its water bodies, causing pollution of traditional irrigation water sources.

- Urban food demand and market incentives favouring production in city proximity where water sources are usually polluted.
- Lack of alternative (cheaper or safer) water sources.

Additionally, poverty and migration play a secondary role; where cities are unable to treat wastewater due to lack of resources, where poor farmers use available water sources whatever the quality; and where migration results in urban and peri-urban agriculture as a means of livelihood support.

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, approx 0.4 million ha are cultivated with wastewater by a farmer population of 1.1 million with 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 numbers of farmers, the reasons can be differences in city boundaries (see Box 2). With limited wastewater treatment, there is hardly any unpolluted stream leaving an African city implying that downstream irrigated agriculture is definitely affected.

Irrigation with treated recycled (waste) water is a phenomenon of higher income 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 poorer 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 under-reported or underestimated. This does not only concern Africa, but also Asia (with India and China taking the lead), Latin America and the Caribbean.

This gap also affects the quantification of numbers 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 every day 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 other sectors of the economy and society and 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. However, in poorer cities with higher city poverty index, where there is urban agriculture, the proportion of it under wastewater is higher.

Globally there was diversity in the types of farmers, with many of them being migrants. Women's involvement in wastewater farming and marketing was influenced by 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 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 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 percent of the cities studied discharged wastewater untreated or at best partially treated, and only 15 percent 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 nothing would grow. Streams are known to become perennial with discharges from cities, which then continue to serve agriculture even in the dry seasons. The return flows from this agriculture systems, undergo inherent natural slow purification. 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 impact 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 percent of cities do not separate domestic from industrial wastewater in their evacuation systems. However, because of low levels of industrialization, the problem is not yet critical for wastewater agriculture.

Pertaining to Regulation, Risk Reduction and Safe Use of Wastewater

Though extents of wastewater agriculture around cities may not be very large, the beneficial as well as potentially negative impact on consumers could be considerable. Extrapolating the detailed studies in Accra, where vegetables produced on 100 ha reach 200,000 urban dwellers every day, shows the potential risks for other cities, 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.

Strict irrigation water quality guidelines serve no purpose in the present context of water use where individuals and irrigation authorities do not have much choice in the selection of the irrigation water source. It is clear that without enforcement of pollution control measures, discharge standards and/or surface water quality standards, even if available, will be of no avail. Other regulations, including crop restrictions are done within the measures available in countries, but not always very effectively. Under these conditions "multiple barrier" approaches to risk reduction following on the recommendations of the revised WHO guidelines, 2006) are a solution. 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.
- At the market level, risk management is difficult as there is usually no incentive to differentiate between clean and contaminated produce. But willingness of consumers to pay more for clean-water produce could provide such incentives but 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).
- A clear understanding amongst consumers and farmers of the types of infections and risks associated with wastewater is lacking. Improving their knowledge via public awareness and extension services could increase levels of attention. On the other hand, recognizing and improving on farmer 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, thus any on-farm trial should be of a participatory nature incorporating farmers' feedback.
- 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 nor even the highest. Other sources of risk such as overall poor sanitation and personal hygiene, unhygienic 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 socio-economic, 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 wastewater at a country level must be addressed by governments through detailed country assessments, which will allow them to evaluate tradeoffs and decide on the hotspots 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 through, 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.

3. The WHO guidelines (2006) for safe use of wastewater should be extensively applied as it allows for incremental and adaptive change in contrast to 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. Finally, addressing risks from wastewater agriculture must adopt a two pronged approach. On the one hand state authorities should consider the advantages to be gained in planning, financing and maintaining sanitation and waste disposal infrastructure designed with agricultural end-use in view, instead of aiming at more sophisticated but vulnerable systems. On the other, outsourcing water quality improvements to the user level and supporting such initiatives through tenure security, economic incentives like easy access to credit for safer farming, and social marketing for improving farmer and consumer knowledge and responsibility, can be an immediate measure to improve the quality of wastewater produce, and reduce public health risk

9. Finally countries must address the need to develop policies and practices for safer wastewater use to maintain the livelihood benefits, but reduce health and environmental risks.

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