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Urban growth, wastewater production and use in irrigated agriculture: a comparative study of Accra, Addis Ababa and Hyderabad

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Abstract The relationships between urban development, water resources management and wastewater use for irrigation have been studied in the cities of Accra in Ghana, Addis Ababa in Ethiopia and Hyderabad in India. Large volumes of water are extracted from water sources often increasingly far away from the city, while investments in wastewater management are often lagging behind. The resulting environmental degradation within and downstream of cities has multiple consequences for public health, in particular through the use of untreated wastewater in irrigated agriculture. Despite significant efforts to increase wastewater treatment, options for safeguarding public health via conventional wastewater treatment alone remain limited to smaller inner-urban watersheds. The new WHO guidelines for wastewater irrigation recognize this situation and emphasize the potential of post- or non-treatment options. Controlling potential health risks will allow urban water managers in all three cities to build on the benefits from the already existing (but largely informal) wastewater reuse, those being the contribution to food security and reduction of fresh water demands.

Keywords Urban growth · Wastewater irrigation · Water scarcity · Urban water balance · Developing countries · Cities · Urban agriculture

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Introduction

Cities are large ‘organisms’ which consume and transform huge amounts of energy, water, food and materials into goods and waste products. Water is a particularly vital resource needed for the survival of humans and cities. In places where, in response to rapid urbanization, water supply has outpaced sanitation coverage and wastewater management, pollution of natural water bodies and the use of wastewater in irrigated agriculture have become common realities (Raschid-Sally and Jayakody 2008).

This paper attempts to investigate this nexus and options to safeguard public health, taking the example of three growing cities in the developing world. The findings presented here are part of ongoing research into the impact of growth and development of large cities on water demand and wastewater use across the urban-rural gradient in low-income countries. The main research questions are: how has wastewater generation and treatment changed over time; how will it develop in the future; and what are the practical implications for irrigated farming in the vicinity of cities? Results of this research will be useful for urban planners and policy makers in cities that are likely to follow a similar development path towards achievement of the water supply and sanitation related Millennium Development Goal (MDG).

Upstream and downstream implications of urban water use

This research evolved largely from conceptual thinking on the interactions between cities and their evironments, as a result of upstream water withdrawal and downstream wastewater disposal (Fig. 1). Developments within the city, such as population growth, infrastructural development of water supply and distribution, household-level water and sanitation facilities and drainage infrastructure, have inescapable consequences for water resources management across the rural-urban divide and sometimes between basins, often with significant impacts, both positive and negative, on public health and wellbeing. The case of wastewater irrigation shows the risks of such a nexus, where city effluents might re-enter the urban food chain. The assessment of some of the underlying causal relations and possible future developments helps to explain why urban water management is becoming more challenging at the institutional, organisational, technical and political level, and in which way the challenges could be addressed.

Introduction to Accra, Addis Ababa and Hyderabad

The three cities included in this study are engines of economic growth and the political centres of the country or State. Accra, located on the West African coastline, in the Gulf of Guinea, is the capital of Ghana and, together with its close neighbour Tema is today home to around 3.3 million inhabitants in the Accra-Tema Metropolitan Area (ATMA). This is slightly less than the number of urban dwellers (3.5 million) living currently in Addis Ababa, the capital city of Ethiopia and the second largest city in the East African region after Khartoum. However, as ATMA has a higher average growth rate of 4.4%, compared to 3% in Addis Ababa, Accra will soon catch up. Hyderabad, on the other hand, is the capital of the State of Andhra Pradesh in India and shows already today an urban population which is as large as both African cities together (6.8 million) (UN-Habitat 2008).

All three cities have in common the fact that heavily polluted water is used for irrigation, not as a planned means to address water scarcity but due to widespread pollution of existing

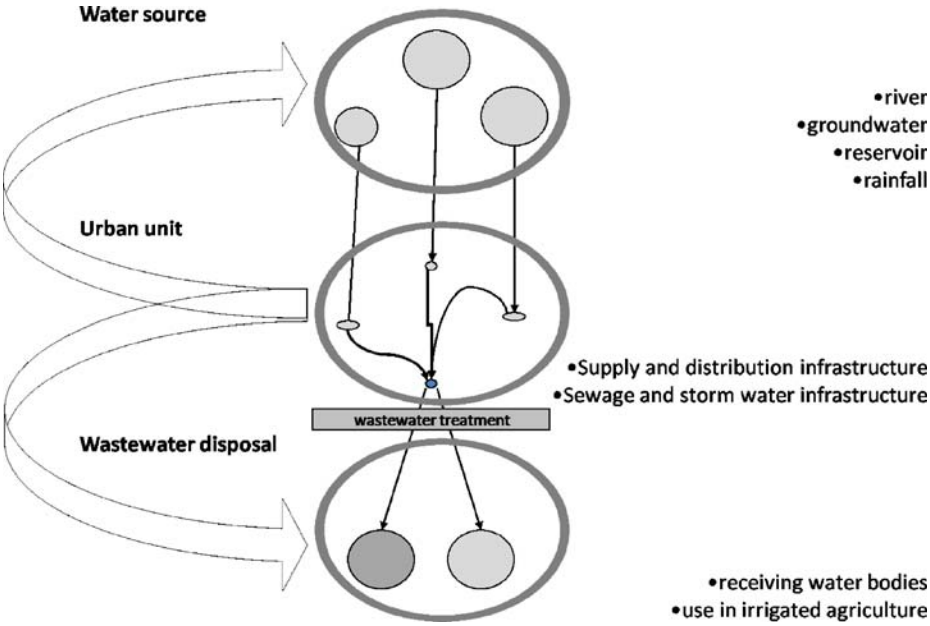

Fig. 1 Schematisation of the impact of urban growth on water supply and wastewater generation

irrigation sources. Irrigation in Accra and Addis Ababa can be classified as informal smallholder irrigation, but in Hyderabad farming is supported by public irrigation infrastructure, initially intended to convey freshwater. The background conditions in each city are summarized to provide the context for the analysis.

Accra[1]

Accra is facing significant challenges in both water supply and sanitation. With a population growth rate of as high as 6–9% in its administrative fringe, unregulated urban sprawl has outpaced planning of infrastructure and public services by more than a decade. To improve service provision and private sector participation, urban water supply in Ghana was separated from sanitation and rural water supply in 1999 with the creation of the Ghana Water Company Limited. Further changes to the administrative structure mean that since 2006, the operation of urban water supply has been the responsibility of an international consortium that has set targets aiming to improve efficiency and delivery. It currently supplies water to the city from two basins. The management of wastewater is under the control of the Waste Management Department of the Metropolitan and Municipal Assemblies but the existing wastewater and sludge treatment facilities are almost all in a state of disrepair, and nearly all excreta are dumped into the ocean. Most of the household greywater drains into natural streams, including the Odaw River, which has a catchment covering about 60% of Accra (without Tema) and is heavily polluted (Boadi and Kuitunen 2002).

[1] Most data used in the paper refer to the complex of the Accra-Tema Municipality, which is in short referred to as Accra.

Along the tributaries of the Odaw River and other streams, extensive urban farming takes place on any unoccupied open spaces. About 680 ha are under maize cultivation (which is not irrigated), 47 ha are exclusively under vegetables and 251 ha are under mixed cereal-vegetable systems, resulting in an average area of 100 ha of irrigated urban vegetable production (Table 1). Some of the sites have been in use for more than 50 years. There are about 800–1,000 market-oriented vegetable farmers of whom 60% produce exotic and 40% indigenous local or traditional vegetables, with only the latter using parts of their production for home consumption. Farming areas in the city range between 1 and 30 ha; with plots around 0.05 ha per farmer. Although the total area appears to be small, farmers crop up to 8 times per year and supply 60–90% of the perishable vegetables consumed in the city (Obuobie et al. 2006). Most sites belong to government institutions or private developers who have not yet started constructing. Most farmers have only informal land use agreements with the landowner or his caretaker.

Vegetable farming is done on raised beds each of which covers an average area of 3–8 m^2. Water fetching and irrigation are manual, usually with watering cans. In some cases motor pumps are used to fill small intermediate ponds. Where the topography allows it, gravity is used to support furrow irrigation. Compared to Addis Ababa the climate is much hotter and the irrigation frequency higher. For example, lettuce is irrigated trice a week in Addis Ababa but twice a day in Accra.

Addis Ababa

The management of water supply and sewage disposal is the responsibility of the Addis Ababa Water Supply and Sewerage Authority (AAWSSA), set up in 1972 and formerly known as the Water Services Section under the Addis Ababa Municipality. The authority currently supplies water from three dams (75% of the total supply) and a well field system (25%).

Table 1 Characteristics of irrigated urban agriculture with wastewater in Accra, Addis Ababa and Hyderabad (IWMI, *unpublished*)

Wastewater irrigation characteristics	Accra	Addis Ababa	Hyderabad
Crop types cultivated with wastewater	Vegetables	Vegetables	Paragrass, rice, vegetables
Common irrigation method	Watering can, seldom furrow irrigation	Furrow and flood irrigation	Flood irrigation, furrow irrigation
Average plot size (ha)	0.05	1.0	1.5
Irrigation schemes	None (hand-made high beds)	Hand made channels and furrows	Partly; pumping stations, channels, tanks
Water storage facilities	Dug-outs, sand-bag dams	Small ponds, self-made dams	Check dams in river, large ponds (*tanks*)
Sources of water	Drains, streams, river	River, streams and drains	River, tanks
Number of irrigating farm households in city	800–1,000	1,300	Not determined
Irrigated area (ha)	100 (in the city)	1,240	100-500 (in the city), 8,000 (downstream)
Vegetables from these areas on city markets	60–90% of easily perishable ones	90% of easily perishable, 60 of others	<5% of all

Due to the combination of poor sanitation and undulating topography almost all wastewater generated in the city finds its way through a dense network of streams into the Akaki River, which originates in the North and flows via two branches (Little and Great Akaki) to the South of the city. Several factories also dump their untreated effluents into the Akaki River. Wastewater collection and treatment are so far limited and treated wastewater is discharged into the same river.

Since the 1940s, a variety of vegetables have been produced within and around the city, mainly using water from the Akaki River. The irrigation is carried out informally by smallholders without conventional irrigation infrastructure (Table 1). In most cases farmers take advantage of gravity by blocking waterways upstream and allowing a proportion of the water to flow through temporary channels into a larger system of furrows. Further downstream pumps are also used to flood fields. Farmers are organized into 11 vegetable producers and marketing cooperatives but there are also many independent vegetable farmers, bringing the total to around 1,300. There is no legislation that prohibits or permits the use of stream water for crop production in the study area, although campaigns try to alert people to the related risks. Urban farmers do not pay for the water but there is an annual tax on their farmland. They produce vegetables for both market and home consumption, in a ratio of approximately three to one. They provide about 60% of the vegetables on the cities' vegetable markets, which provides their main source of household income (Weldesilassie 2008).

Hyderabad

Hyderabad is the largest city in the analysis; it had more than 1 million inhabitants by 1950 when Addis Ababa and Accra each had about half a million. Annual growth rates since then have ranged between 2 and 6% (Fig. 2).

In Hyderabad, water supply and sewage disposal are managed by the Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB). In contrast to the institutional separation of water and sewerage in Ghana, the HMWSSB came into being in 1989 with the merger of the previously separate State-level agencies in charge of water supply and municipal sewerage services. This re-organisation was encouraged by the World Bank as a means to achieve greater financial and operational authority as well as increasing accountability to consumers (Davis 2006). One of the HMWSSBs key goals is to reduce the quantity of water that is unaccounted for, which currently stands at 40–55% of supply. Consumption was estimated at 80 l cap^{-1} d^{-1} and intermittent water supply has become the norm in Hyderabad, like in all major cities in India and Africa.

In Hyderabad, the Musi River collects the majority of all wastewater from both domestic and industrial sources. In the dry season it is this contribution which allows the river to flow downstream of Hyderabad because the entire upstream flow is utilized in the city. Within the city itself, irrigated farming involves only a few households growing predominantly paragrass (*Brachiaria mutica*), a water buffalo fodder crop, as well as banana, coconut and some green vegetables. These are grown on a variety of small plots on about 100 ha in total (Buechler et al. 2002). Large scale irrigation takes place along the Musi just downstream of the city. In contrast to both other cities, irrigation infrastructure is available. River water is diverted into irrigation channels at weirs located every few kilometers along the river and there is an extensive network of irrigation canals and drainage channels on both sides of the river. These are interconnected with small reservoirs, locally known as tanks, forming a complex artificial flow, land application and storage network. An estimated 10,000 ha, primarily of rice (*Oryza sativa*) and paragrass are irrigated with water from the Musi River

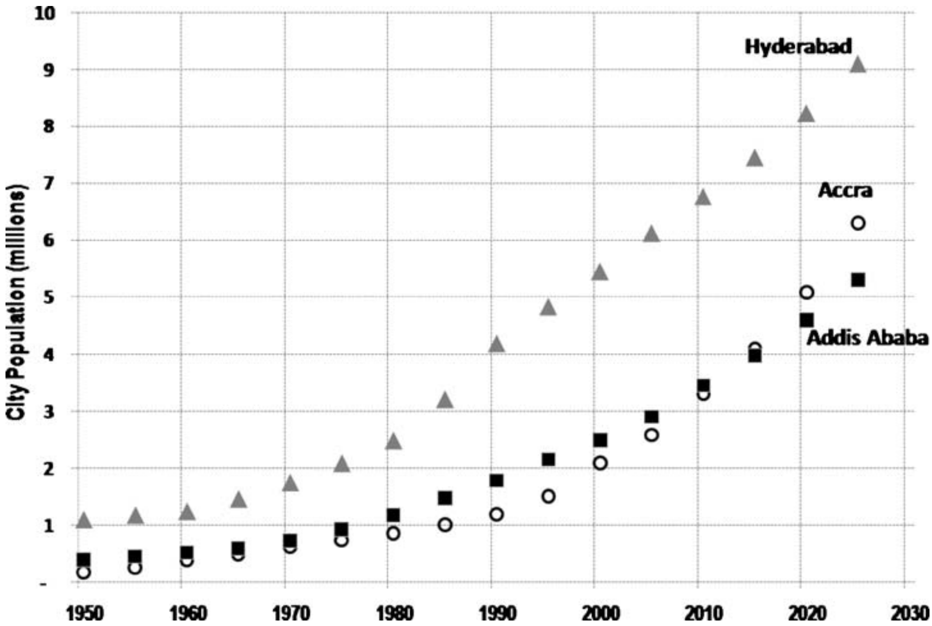

Fig. 2 City population of Accra-Tema, Addis Ababa and Hyderabad between 1950–2025 (Modified from UN-Habitat 2008)

(Ensink 2006). Irrigation enables farmers to harvest paragrass throughout the year or to produce two rice crops annually. Utilisation of this wastewater in the peri-urban and rural areas downstream of Hyderabad is estimated to support, directly and indirectly, the livelihoods of approximately 150,000 people (Buechler et al. 2002).

Methods

Data collection and semi-structured interviews were conducted with the respective water supply and sewerage authorities. Analysis was based on a time span from 1950 to 2030 considering population growth and (former, current and planned) infrastructure investments. Projections are based on city development plans and donor agreements (AfDB 2005; NEDECO 2002; GHMC 2005) with all related uncertainties.[2]

The water supply-demand gap was calculated by dividing the difference between city water supply and demand by city water demand. Calculations are based on data from the respective water utilities and do not account for informal water use. Data on populations, water flows, volumes, and disposal pathways of wastewater were derived from local sources and modelling. Net water supply is calculated from the gross supply (recorded and projected) minus physical losses. Physical water losses through the distribution system were derived from estimates of the respective water supply companies; 25% for Accra (AVRL

[2] Especially in the case of Addis Ababa, the funding and implementation of the Sanitation Master Plan has been delayed. The data and projection in this paper for 2008 ff will therefore probably only be realized over the next years. The accuracy and verifiability of data presented here should therefore be regarded with reservation, also due to difficulties in validating some of the original data.

2006), 33% for Addis Ababa (AAWSSA 2008) and 30% for Hyderabad (HMWSSB 2004). City wastewater production was estimated by multiplying net city water supply (estimated) with a standard return fraction[3] for all water use sectors (Tchobanoglous and Schroeder 1985), as follows;

$$WWG = WS \times (1 - WSLF) \times WRF$$

Where:

WWG	Wastewater Generation (volume)
WS	(gross) Water Supply (volume)
WSLF	(physical) Water Supply Loss Fraction (fraction)
WRF	Water Return Fraction (fraction)

The water return fraction is usually assumed to be 0.8 or 80% (Tchobanoglous and Schroeder 1985) although it is likely to vary to some extent from city to city. Per capita domestic wastewater generation was calculated by dividing net domestic water supply by city population, multiplied by the water return fraction. In the description of wastewater generation we distinguish between black (toilet water) and grey (kitchen and bathroom) water. The fraction of wastewater that is used for irrigation was based on expert consultation (Addis Ababa), literature (Hyderabad) and calculations (Accra). Data on industrial wastewater flows were based on water use figures from the water supply companies and an assumed water return fraction, as in the domestic sector, of 0.8 (Tchobanoglous and Schroeder 1985). Data on the quality of urban water bodies and water used in irrigated areas in the study cities were derived from accompanying International Water Management Institute (IWMI) projects unless other references are provided.

Results

Water supply and wastewater generation

In response to growing water demands, water supply agencies in all three cities have planned and carried out urban water supply expansion projects, and continue to do so. While Addis Ababa and Accra have significant freshwater resources within a radius of 35 and 60 km, respectively, Hyderabad is increasingly seeking water from new sources located up to 250 km from the city. In all three cases, current water supply lags behind population growth, resulting in irregular supply in time and space. The water supply-demand gap was 39, 69 and 56% for Accra, Addis and Hyderabad respectively, for 2005. However, data vary largely in time and space. For 2008, for example, a gap of 47% was reported for Accra even in the best of times (AVRL 2008). The real gap might however be smaller due to informal water supply such as private groundwater abstraction and vending.

Domestic wastewater generation in 2005 was calculated from water production records (134, 91 and 380 million cubic metres per year (MCM yr^{-1}) for Accra, Addis Ababa and Hyderabad respectively), which corresponds to a calculated total wastewater generation of 80, 49 and 213 MCM yr^{-1} (Table 2). The lower wastewater volume generated in Addis compared to Accra results from much lower average water consumption per capita in the Ethiopian capital.

[3] Although this is the accepted method of calculating wastewater generation, the reality is that the physical losses have to go somewhere so that the actual wastewater produced and available for irrigation may be higher.

Table 2 Wastewater production and use in Accra, Addis Ababa and Hyderabad for 2005

		Accra	Addis Ababa	Hyderabad
Total wastewater generation[a]	*MCM* yr^{-1}	80	49	213
Industrial wastewater[b]	*MCM* yr^{-1}	9	4	37
Wastewater use in agriculture[c]	*MCM* yr^{-1}	10	9	192
	% of tot generated	13	20	90

[a] Calculated, based on water production records and city specific loss factors. Includes domestic and industrial fraction

[b] Figures were derived from volumes of water used by industries from records from the respective water utility, using a water return fraction of 0.8 (Tchobanoglous and Schroeder 1985). Figures for water supply to industries; AVRL (2006) for Accra, Kebbede (2004) and Asfaw (2007) for Addis and Van Rooijen et al. (2009) for Hyderabad

[c] For Accra, Lydecker and Drechsel (2009), for Addis, Adebaw (2008), for Hyderabad, Van Rooijen et al. (2005)

The fraction of households that are connected to sewers is small (5–10% in the African cities and 41% in Hyderabad) while those with a septic tank or at least shared pit latrine range from 50 to 70% (AAWSSA 2008; GSS 2006; IIPS 2007; GHMC 2005). Unless the water is needed to support a sewer, greywater generated in kitchens and bathrooms is mostly disposed of into gutters and storm water drains where a part is lost through evaporation or infiltration unless it enters larger canals or streams.

Black water from toilets either flows away from the site (through sewerage or stormwater systems) or remains on site (in pits or septic tanks). Wastewater that remains on site infiltrates into the soil, evaporates or is eventually removed when septic tanks are emptied. In Addis and Hyderabad, septic sludge is disposed of in corresponding treatment plants, where most of the water evaporates while in Accra nearly all is officially dumped in the ocean.

Larger functional wastewater treatment plants were only found in Hyderabad (design capacity[4] 113,000 m^3d^{-1}). However, also in this case only ca. 23% of the total wastewater volume generated can potentially be treated (Table 3). Furthermore, only the smaller of Hyderabad's two treatment plants (treating less than 5% of the city's wastewater) has the capability to carry out more than primary level treatment (Gerwe 2004).

In all cities, water quality data obtained from urban surface water bodies show severe evidence of microbiological contamination (EEPA 2006; Ensink 2006; Karikari et al. 2006; Mensah et al. 2001). For the use of this water in irrigated agriculture, the presence of excreta related pathogens gives particular reason for caution especially where irrigated vegetables are grown and consumed uncooked as it is the case in particular in both African cities. Besides human health risks, environmental concerns have been raised. For example, the water quality of the Musi River only improves about 40 km downstream of the city, while the Aba Samuel Lake and Awash River south of Addis Ababa, and aquatic life in the Gulf of Guinea in the case of Accra, suffer severely from the urban pollution load (Boadi and Kuitunen 2002; Ensink 2006; Kebbede 2004). Special attention has to be given to wastewater generated by industries, which is less than 20% in the three cities (Table 2). However, recent studies have shown significant amounts of heavy metals at least in the Musi and Akaki Rivers (Chary et al. 2008; EEPA 2006; Gerwe 2004; Itanna 2002; Melaku et al. 2007; Tolla 2006).

[4] To date, no time series data were found on actual treatment volumes.

Wastewater use in irrigated farming

As all urban streams in and around the three cities are heavily polluted, farmers depending on them as the single source of water for irrigation have little alternative. The significance and potential risk of wastewater irrigation in a city or region can best be assessed via quantitative microbial risk assessment (QMRA) as promoted by WHO (2006). The case of Accra showed for example that a small area can produce, through year-round cropping, a significant share of what is consumed in the city. Here, about 200,000 people consume crops from irrigated farming in and around the city every day, but are also at risk from consuming lettuce produced with polluted water (Obuobie et al. 2006). The risk appears lower in Addis Ababa due to less frequent watering and lower faecal coliform counts, and lowest in the case of Hyderabad, not only due to the smaller percent of vegetables produced with Musi water, but also the more common cooking of vegetables. The risk also varies with wastewater dilution in the receiving streams. The percentage of wastewater that is eventually used for irrigation varies thus between seasons and could be estimated, especially in the dry season, to be as low as 20% in Addis (Adebaw *Pers Comm*) and around 90% in Hyderabad (Van Rooijen et al. 2005) (Table 2). The nearly complete re-use of wastewater in Hyderabad is linked to the drainage system, which is almost entirely discharging into the Musi River, and the extended irrigation network that recovers most of the water (except in the rainy season). Just like the Musi River, the Akaki River in Addis Ababa receives most of the wastewater, but the irrigation network along the river is more informal and smaller, thus only making use of a smaller portion of what the stream carries (although this has implications for agriculture and health risks further downstream). In Accra, an even smaller percentage of the water carried in the Odaw River finds its way to farms along tributaries of the river. Comparing farmers' water demands and wastewater discharged into the river, an equivalent of 10% is reused (Lydecker and Drechsel 2009). Due to the proximity of the ocean, there is no space for farming downstream of Accra.

Potential of wastewater treatment for risk reduction

Comparing current and planned wastewater treatment capacities in Accra with the current and expected wastewater volume, the treated fraction will only change slightly from 7 to 9% (Table 3). Given the problems with the existing plants, the probability that the new plants will operate at maximum design capacity is doubtful. There are a few other treatment

Table 3 Wastewater generation and treatment in Accra, Addis Ababa and Hyderabad for 2008 and in brackets 2020

		Accra	Addis Ababa	Hyderabad
Wastewater generation[a]	*1,000* $m^3\ d^{-1}$	225 (307)	130 (453)	585 (807)
Installed treatment capacity[b]	*1,000* $m^3\ d^{-1}$	16 (29)	39 (238)	133 (590)
Potential wastewater treated	*%*	7 (9)	30 (53)	23 (73)
Untreated wastewater volume	*1,000* $m^3\ d^{-1}$	209 (278)	91 (215)	452 (217)

[a] Wastewater generation is calculated on the basis of data for city water supply, physical water supply and distribution losses and a general water return fraction of 0.8, adapted from Tchobanoglous and Schroeder (1985)

[b] Key figures for current and future installed treatment capacity were derived from AfDB (2005) for Accra, NEDECO (2002) for Addis Ababa and GHMC (2005) for Hyderabad. The projected 2008 treatment capacity for Addis has not yet been achieved

plants scattered across Accra, most of them are not functional and those that do work are usually privately owned, by larger hotels for example.

Addis Ababa currently has two secondary treatment plants that are in operation. Following current treatment capacity expansion plans (NEDECO 2002) the wastewater treatment fraction will increase from the present 30% to 53% by 2020 (Table 3) if funding for the project can be secured.

Hyderabad has two sewage treatment plants in operation, and the water utility is currently constructing several additional treatment plants (HMWSSB 2002). Under these plans the total wastewater treatment capacity will reach about 590,000 m^3d^{-1} by 2020 (Mekala et al. 2009), which would account for 73% of the estimated wastewater volume by that year, including industrial wastewater but excluding most grey- and stormwater (Table 3).

The planned increases in wastewater treatment capacity of 50–70% of the wastewater flow in the cases of Addis Ababa and Hyderabad are definitely impressive and will cut down the general pollution load, but this will not be enough to reduce the risk for farmers or consumers given the high absolute pollution load. It is important to bear in mind that reducing an initial faecal coliform load of 1,000,000 or more counts per 100 ml (1×10^6) even by 73% will still result in 2.7×10^5 counts which remains far above any irrigation threshold. It can thus be argued that exposure to health risks for farmers and consumers will not reduce at the same rate as improvements sanitation coverage or wastewater treatment might imply, but at a much slower rate. The only exception would be if the treatment efforts could concentrate on a certain sub-basin or watershed in a city where farming could then be allowed. If only one stream or canal is draining the city, as it is in Hyderabad, the treatment level would have to increase to 99.9% to reduce an initial load of 1×10^6 coli counts in the wastewater by 3 log units to 1×10^3 per 100 ml, which is still the most often cited FAO and WHO threshold value for unrestricted irrigation (WHO 2006).

Conclusions

The urban centres discussed here, have seen considerable demographic growth and spatial expansion in the last seven decades and are expected to continue to do so. Urban population growth and rising living standards have caused water demand to grow which is supported by related investments to upgrade and extend existing water supply capacities. The incremental increase of water supply to the cities has created a similar growth in wastewater volume, which has however not been supported by similar investment in wastewater collection and treatment. The resulting gap has led to large-scale water pollution which, in addition to the three case study cities presented here, is the case in some 75% of all cities in the developing world (Raschid-Sally and Jayakody 2008). Under the prevailing conditions of urban growth and investment in the water and sanitation sector, irrigation with untreated wastewater is expected to remain a wide-spread practice.

The increasing efforts to close the gap between water supply and wastewater treatment in Hyderabad and Addis Ababa are positive examples, but while more sewer connections and treatment capacity might reduce water pollution in the near future, there is no relief yet in terms of health risk reduction for farmers and consumers affected by wastewater irrigation.

As significantly higher investments in wastewater collection and treatment appear unlikely in most developing countries, the WHO (2006) acknowledges that any normal scenarios of expansion of wastewater treatment alone will not be effective in reducing the health risks associated with irrigation with wastewater. WHO (2006) therefore points to various additional options for health risk reduction which can be implemented at farm level and during the preparation of food that is derived from wastewater irrigation. These options can complement conventional wastewater treatment and, even where treatment is marginal, still provide at least some level of risk reduction. The IWMI has worked extensively on such non-treatment or post-treatment options, such as adjusting irrigation practices and awareness creation to support public health from 'farm to fork' (Drechsel et al. 2008).

Where health risks are controlled or farmers find a market for alternative crops, such as fodder grass in Hyderabad, wastewater irrigation has a significant potential to contribute to urban food supply and reduce farmers' dependency on fresh water resources. The amount of water that can be saved in this way can easily be estimated from the urban water supply capacity.

A potential threat is the increase of industrialisation and the likelihood of chemical water contamination if industries are not obliged to have treatment facilities and if legislation is not adequately enforced. This is important as it is much more difficult to manage chemical threats taken up by plants than microbiological ones on their surface. To ensure the sustainability of wastewater irrigation, one of the common key recommendations is to keep industrial pollution streams minimal and separate from domestic wastewater flows.

Besides Accra, Addis Ababa and Hyderabad, there are many low-income cities that are confronted with very similar challenges in the face of urban expansion and a more intense interaction with up- and down-stream areas as a result of increasing urban water use. As shown in this paper, this is strongly affecting different sectors including agricultural production and public health. Findings from this research may be useful to support inter-disciplinary approaches to integrated urban water management and planning for cities in a similar context and development paths.

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