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# Urbanization, water demand and sanitation in large cities of the developing world: an introduction to studies carried out in Accra, Addis Ababa and Hyderabad

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## Abstract

Water managers in large cities in developing countries experience great difficulties in providing proper water supply and sanitation services in a context of rapidly growing population with changing water use patterns, structural lack of capacity and resources. There is a need for in-depth city-wise water assessments of fast growing large cities in developing countries to help gain insight into the implications of urban water and sanitation development scenarios on urban water demand, wastewater disposal and downstream water use. The generation of reliable data sets and modeling results for a selection of cities will help understand the present and future impact that water use has on water resources and flows that cross the urban-rural divide. Also, an easy-to use model can support decision making at the local urban water planning and policy level. This paper describes ongoing research on the urban water system in three fast growing cities in the South. The application of integrated urban water management in developing countries is needed for the sustainable management of water resources within the city and basin.

## Keywords

Urban water; sanitation; water resources; sustainable development; developing countries

## INTRODUCTION

Urban population numbers and water use patterns mainly determine the management of water supply and wastewater disposal and thereby contribute to the ecological footprint of a city. In many developing countries in Africa and Asia, urban water agencies have great difficulties to provide proper water supply access and sanitation due to rapid urbanization and insufficient capacity and resources (UN HABITAT 2001). A complex of technical, institutional, economic, social and environmental problems can be noted in many cases (STEPHENSON 2001). The challenges to meet water demand are much bigger, as compared to cities in the developing world, due to a much higher urban growth rate and lower average income (BISWAS 2006). Both low income and rapid urban growth are found in countries in Africa and Asia, justifying the narrowing of focus to these continents. Proper water management is often lacking, although allocation plans of water to a large city can be ambitious in terms of added water volumes and far reaching as they cross basins borders (VAN ROOIJEN *et al.*, 2005).

A sound assessment of the current watsan situation in cities is limited by unreliable governmental data (due to its political dimension) and their possible use of inappropriate criteria that define what is 'safe supply' and 'adequate sanitation'. The implications of (proposed) water

and sanitation development for urban water demand and wastewater generation is not sufficiently researched. It is important that the impact of cities on the rural environment should be researched and translated into useful tools for planners and policy makers.

Findings from urban hydrological studies based on collection of hydrological data, calculations and modeling constitute a necessary fundamental for meaningful water management not only in urban areas but also in entire river basins (NIEMCZYNOWICZ 1999). City case studies that assess the current water supply and sanitation situation and model scenarios of future water demand and wastewater disposal, contribute towards this end and support integrated water management in an urban watershed context. Based upon the above problem analysis, the following research question, objectives, hypotheses and goals were developed;

### **Research question**

What implications do different urban water and sanitation development scenarios have for the future characteristics of urban water demand and wastewater generation across the urban-rural gradient?

### **Overall objective**

To assess the impact of urban water and sanitation development scenarios on the future characteristics of urban water demand and wastewater generation across the urban-rural gradient.

### *Sub-objectives*

1. To assess the impact of urban water demand scenarios on existing agricultural uses.
2. To assess the current and future urban and industrial water demand in a closed basin, and its impact on future water availability for agriculture.
3. To assess the impact of urban water supply and sanitation investment scenarios on urban water demand, water flows and water resource availability.
4. To assess the potential of urban domestic wastewater re-use in agriculture for different urban water supply and sanitation scenarios.
5. To define a logical framework for future water demand scenarios for cities in developing countries in varying institutional and climatological settings.

### **Hypotheses**

1. Urban growth will lead to considerable changes in irrigated agriculture in the future, in terms of wastewater irrigated area and water resource availability of existing systems.
2. The share of non-agricultural water demand in basin water demand will become significant, with implications for water availability for agriculture.
3. Any likely investment scenario will cause a rise in average per capita water demand with likely stress on water resources and agricultural water demands.
4. Urban domestic wastewater will contribute significantly to water resource availability in (peri-) urban agriculture, given that wastewater irrigation is at least acknowledged and permitted by governmental authorities.
5. Future urban water availability can be modeled with current data on urban water and the institutional and physical environment. Cities in a similar development stage and with a similar institutional and physical setting are likely to follow a similar path of change in urban water demand.

### **Goals**

To contribute to useful research in the area of integrated urban water management in developing countries. To contribute to improvement of the management of water resources in developing countries. To stimulate further thinking on the increasing importance of large cities in integrated water management.

### *Objective*

To get insight into the implications of water and sanitation development scenarios for urban water demand and wastewater generation in fast growing cities across the urban-rural gradient in developing countries and develop an easy-to-use urban water model adapted to use by planners and policy makers.

## **MATERIAL & METHODS**

The research consists of four phases. Part of the analyses and writing will be done at the university. Most of the data analyses and modeling will be done at the International Water Management Institute in Accra. Data collection, consultation of local stakeholders and field visits will take place in the selected cities; Accra, Addis Ababa and Hyderabad. The proposed time frame will be two years of field work and one year of analyses and writing at either university or research institute (IWMI).

### **Phase 1: Selection of cities**

The analyses of two cities in Africa (Accra and Addis Ababa) and one in Asia (Hyderabad) is considered to be representative to some extent, for these continents and main characteristic of cities (coastal/inland, dry/wet climate). Criteria for selection were the present or potential severity of urban water issues, representation of a geographical context, local demand, donor preference and the advantage of present data from previous work. Also, synergy with other projects was a criterion. Selection of all cities was also influenced by the presence of office infrastructure and facilities.

### **Phase 2: Data collection**

On site (city) data collection was done during about 3 months after literature review and the setting up of professional connections. Local expertise from persons or institutes was sought and a local research assistant was used in some cases. The use of existing contacts was considered to be advantageous. In this period, discussion with stakeholders took place to make them aware of the research and to include their knowledge.

Quantitative data is still being collected from secondary sources for use with the model. For scenario development, projections will be made based on growth patterns and future city plans. Data are population data (census), time series of urban water flows (water supply, wastewater generation, treatment, re-use), rainfall and river flow patterns into and out of the city (if required). Maps of land cover and use within the urban boundaries are required. Also statistics on urban water use patterns, from information on water supply and sanitation facilities. If statistics on water and sanitation cover seem unreliable or incomplete, then surveys can serve to get similar information. Data for the model will be compared with and supported by literature review, estimations and assumptions.

### **Phase 3: Urban water balance and modeling**

Developing countries typically have poor existing data sets that limit the use of sophisticated hydrological models in any context. Easy-to-use software to model urban water flows provide

local water planners with an effective tool to get insight in interactions between urban water management and the environment outside the urban boundaries. This can imply withdrawal from upstream reservoir and use of wastewater in agriculture downstream. For the two reasons mentioned, a simple model is effective and appropriate both for use by researchers and local planners.

Hydrological data will be presented schematically as a water balance (for general impression of city). Data will then be processed in the model. The choice of scenarios may differ by city, but same scenarios should be there for comparative analyses. Potential scenarios can be; doubling of connections to supply system, stepwise increase in coverage of conventional wastewater treatment, and installation of flush toilet and septic tank at households. Spatial boundary of the model will be the official or 'real' (peri) urban area, depending on the difference between the two and data availability. Time frame of the model will be long term (*up to 30 years*).

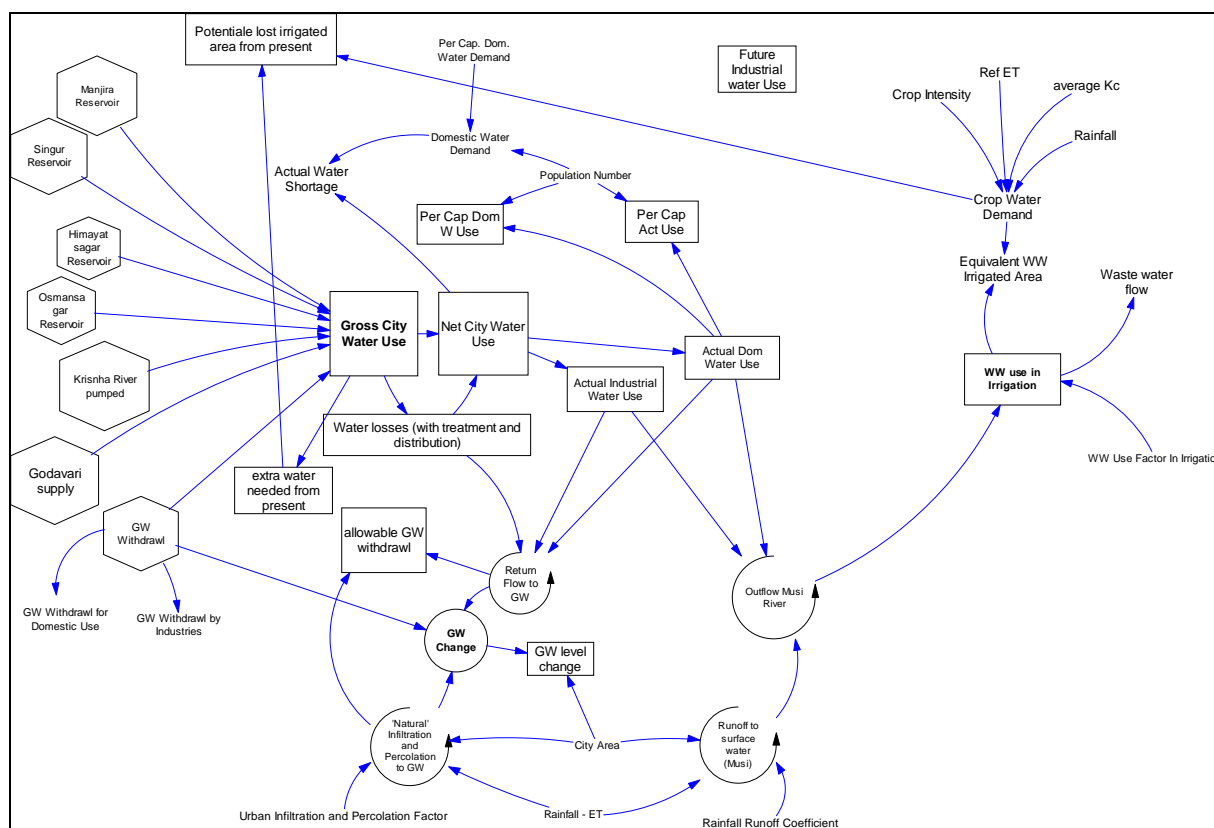


Figure 1. Copy of the VENSIM model as used for Hyderabad. Boxes display input or output components and arrows display mathematical relations.

An appropriate and easy-to-use model like VENSIM or UrbanCycle will be used (See VAN ROOIJEN et al., 2005, HARDY et al., 2005). The model can be built manually (like VENSIM for Hyderabad, see layout fig. 1), or an existing structure can be used and adopted to the specific environment (like UrbanCycle for Sydney). Model inputs are the data collected. In the absence of local data, assumptions will be made based on other comparable cities and information from literature. For example, the per capita water use is often unreliable because of poor measurements. A realistic value can be based upon a combination of municipality reports, corresponding literature, and assumptions. The model is based on a set of relatively simple calculations that provide numbers as output (see for example fig.2).

In a project following up on the PhD, the model will be adjusted and disseminated as a useable tool for local urban water planners and policy makers in any city in a comparable setting.

[1]	$I_{dom} = \sum N_i \omega_i$	with:	$I_{dom}$	= Domestic water use ( $\text{m}^3 \text{ year}^{-1}$ )
			$N_i$	= Population number of water use category $i$ (no.)
			$\omega_i$	= Per capita water use of water use category $i$ ( $\text{m}^3 \text{ day}^{-1}$ )
[2]	$P_{dom} = \sum N_v \delta_v$	with:	$I_{dom}$	= Domestic wastewater generation ( $\text{m}^3 \text{ year}^{-1}$ )
			$N_v$	= Population number of wastewater gen. category $v$ (no.)
			$\delta_v$	= Per capita wastewater generation category $v$ ( $\text{m}^3 \text{ day}^{-1}$ )

**Figure 2: Formulation of domestic water use [1] and wastewater generation [2].**

#### **Phase 4: Analyses and writing**

Model results of each city will be analyzed separately and compared eventually. Articles that focus on each city as well as all cities (comparative) will be published. Findings from cities and major similarities and differences between them will be compared with literature to confirm or challenge existing theories and approaches in this research domain. Research findings will be combined with research from a previous study, on the implications of city water use for water allocation and basin water management which was conducted in the Krishna Basin in India (see VAN ROOIJEN et al., 2008). This will also become part of the PhD thesis.

#### **PRELIMINARY RESULTS AND DISCUSSION**

This paper is describing ongoing PhD research. Therefore results are still in preparation and have not yet been published. An introduction to the water situation can be found in VAN ROOIJEN & DRECHSEL (2008) for Accra and VAN ROOIJEN & TADDESSE (*forthcoming*) for Addis and VAN ROOIJEN et al., (2005) for Hyderabad.

#### **CONCLUSIONS**

The aim of this research is to provide persons involved in urban water management or research with decision support and insight into urban water flows and its impact on water resources and wastewater disposal. Also, the importance of urban water management across the urban-rural gradient has not been studied much previously and this is a new research area being pioneered. Results expected from this research will therefore contribute to a better understanding of the dynamics of urban water systems and its management in developing countries.

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