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Assessment of the Integrated Urban Water Management Strategic Plan of Accra City

Using Aquacycle13 Model to Develop an Outline of the Strategic Directions for Dhaka City

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ABSTRACT: *Accra, the capital city of Ghana, is facing on major challenges in both water supply and sanitation. Urban sprawl has outpaced planning of infrastructure and public services by more than a decade due to rapid urbanization and a high population growth rate. As a result, providing water and sanitation services to all in a fast growing, largely unplanned city like Accra is a great challenge. In order to meet these challenges, the Integrated Urban Water Management (IUWM) is introduced and IUWM provides an outline for planning, designing, and managing urban water systems. Although, Accra and Dhaka city are geographically located in two different regions on the earth, but there are some similarities, which have been found between them. Similarly, many differences have also been observed. In addition, the IUWM strategic plans of Accra city have been assessed by the two different engineering tools in order to generate different scenarios before and after considering the strategic directions suggested by the SWITCH—Sustainable Water Improves Tomorrow's Cities' Health project. In this regard, Aquacycle13, a modern urban water balancing model has been used in this study where the developed scenarios have showed the future prediction on the basis of the different strategies that must be executed in future. Finally, this study makes an outline of IUWM strategic directions for the Dhaka city in Bangladesh, based on its future challenges and lesson learnt from the existing strategic plan of Accra, Ghana.*

KEYWORDS: *sanitation, stormwater, water supply, wastewater, water management*

Introduction

About Accra City

Accra, Ghana's capital city, is the country's largest and fastest growing metropolis (Figure 1). In addition, people come to the city to trade goods (from November to April), so there is a fluctuation of its residential population (Adank et al., 2011). The city has been struggling to keep up with its high population growth (6-9% annually). The main challenge for Accra is to ensure water and sanitation services to all city dwellers. Most people do not have connection to the central water supply network and only a very small part of the city is connected to the central sewerage system. Accra is in a flood-prone area, partially caused by storm water and a poor drainage system (Adank et al., 2011). Although there have been several plans for the better management of urban water and sanitation services within the city, none of them so far have resolved the city's water management problems.

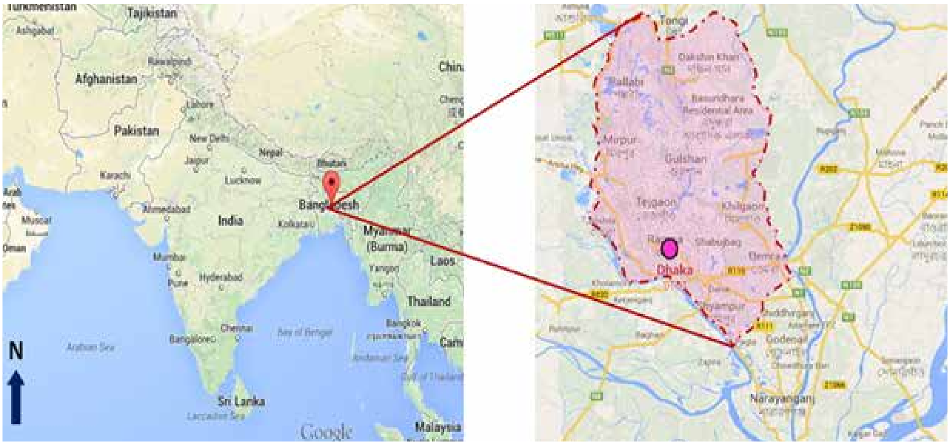
About Dhaka city

Dhaka, the capital city of Bangladesh, is experiencing similar water management problems to those in Accra (Figure 2). The Dhaka Water Supply and Sewerage Authority (DWASA) has estimated water demand as 150 litres per capita per day. But, presently one-third of city dwellers receive 40 l/p/d for their daily activities; the remaining two-thirds are not connected. Uddin and Baten (2011) found in their study that only 5 percent of the total population of Dhaka city receive more than 60 l/p/d; 43 percent of residents receive a basic requirement of 50 l/p/d. The rest of the city population (58 percent) suffer from water scarcity. Approximately 31 percent of Dhaka households have no access to piped

Figure 1: Location Map of Accra City

Source: https://www.googlemaps.com

Figure 2: Location Map of Dhaka City



Source: https://www.googlemaps.com

connection. They have to depend on NGOa or other sources, such as a standpipe. There is an obvious need of proper water management planning, to address Dhaka's future challenges without compromising the standard of living.

Assessment Tool and Modeling Concept

Engineering tools have been used to evaluate the strategic plans for the city of Accra. The Aquacycle modelling toolkit generates scenarios to measure the area's water balance and to model the study area in terms of its water resources and future options to meet the increasing demand. The scenario planning is used to forecast the future situation in terms of population, socio-economic growth and uncertainties.

About Aquacycle toolkit

Aquacycle is a daily urban water balance model, which simulates the total urban water cycle as an integrated whole and provides a tool for investigating water use efficiency and the use of locally generated storm-water and wastewater as a substitute for imported water. It has the capability of modelling a residential property through to an entire urban catchment. Land use in a cluster is separated into unit blocks (individual lots), road, and public open space. Road areas are assumed to be impervious to water and all public open space is assumed to be pervious. Unit blocks can be separated into roof, paved and pervious surfaces. Furthermore, the toolkit produces daily, monthly, and annual estimates of water demand, wastewater yield, storm-water yield, evaporation, imported water use, wastewater use and storm-water use. Finally, this model measures the impact of alternate water management strategies.

Input parameters for the model

Although the data available are not sufficient for a full analysis, we have attempted to understand the probable water balance situation in Accra. First, we use the daily recorded rainfall data of Accra city from 1970 to 2005. Annual variation in different years is quite high. Second, we use the 2010 population of Accra (about 3.5 million) in an area of 185 km2. The area has been divided into three different clusters on the basis of per capita income levels: a High Income Group (HIG), a Middle Income Group (MIG), and a Low Income Group (LIG) (World Bank, 2010). This division displays the expected positive correlation between water consumption and income levels (see Table 1). Per capita income is one of the important factors in water demand forecasting. Third, we assume an average household size of Accra of four per household as default value of the model. The existing treatment plant is designed to treat a total hydraulic flow of 16,080 m3/day (Adank et al., 2011). It will be necessary to undertake rainwater harvesting at the unit block level in order to meet the future water demand in Accra. Finally, the targeted amount of unaccounted for water (UFW) in the supply and distribution systems is presently very high, at 60%; the current strategic plans estimate it at only 25% (Adank et al., 2011).

Based on the parameters in Table 1, the average consumption per capita per day is 76 litres (120 * 0.10 + 90 * 0.32 + 60 * 0.58 = ≈76 litres). As the weighted average household size is 13[1], the water consumption is approximately 988 L/block (13 * 76 = 988).

As shown in Table 2, the total land area of Accra is about 185 km^2 including all occupancy types: residential, commercial, industrial, public open places and roads. Out of 185 km^2 total (Table 2), the area allocated among the three income groups are HIG 37 km^2 (20%), MIG 65 km^2 (35%) and LIG 83km^2 (45%). The table also shows the relative water allocation of each income group, in terms of garden, pavement and roof, as well as public space and roads. Table 3 shows more detailed area calculations under the different clusters.

In Table 3, the area of unit blocks is calculated by dividing the total area of the cluster by the number of blocks. And, the columns

Table 1: Water demand by different income groups in the Accra, Ghana

Income group	Per capita consumption (lpcd)	Average Household size	Percent of the population (%)
High income group (HIG)	120	8	10
Middle income group(MIG)	90	12	32
Low income group(LIG)	60	15	58

Source: Design parameters (Planning and Development Document for GWCL, Accra.) and (World Bank, 2010)

Table 2: Assumed area under each block (as it was not possible to collect original data)							
Group ID	Population	Area (km²)	Block			Public open space (%)	Road (%)
			Garden (%)	Pavement (%)	Roofs (%)		
HIG (10%)	350,000	37	40	15	25	10	20
MIG (32%)	1,120,000	65	25	10	20	05	20
LIG (58%)	2,030,000	83	15	05	15	05	15
Total	3,500,000	185					
Weighted average household size = (8*0.10+12*0.32+15*0.58) = 13.34, rounded at 13 persons							

Table 3: Calculated statistics for the model (according to the above proportion shown in Table 2)						
Cluster type	No of Block	Unit block (m²)	Garden + Pavement + Roof per Block (m²)	Public Open Space (m²)	Road(m²)	Total area (m²)
A	b	c = d + e + f	d	e	f	g = b x c
HIG	43,750	845	591.50	84.50	169.00	37,000,000
MIG	93,333	696	556.80	34.80	104.40	65,000,000
LIG	233,333	355	301.75	17.75	35.50	83,000,000
						Total = 185,000,000
No. of Blocks = Population in the cluster/Household size in the cluster						

d, e and f have been calculated based on the percentages estimated for garden, pavement and roof in Table 2. For example, for the HIG cluster, the area for the garden, pavement and roof is 70% (20 +10 +40 = 70%) of the unit block area, which is 591.50 m2 (845 * 0.70 = 591.50 m^2). Similarly, the calculated area for the public open space and roads are 10% (845 * 0.10 = 84.50 m^2) and 20% (845 * 0.20 = 169 m2), respectively.

Results and Discussions

Output of the model

The table below illustrates the output of the Aquacycle model. In Table 4, the result shows the average of the annual water balance (1970 to 2005) for the catchment of Accra for both before and after considering the strategic measures suggested by the SWITCH project. Without considering strategic measures, the average requirement of imported water is found 693 mm^2. The storm-water runoff and the wastewater discharge are 629 mm and 428 mm, respectively. After considering the strategic measures (such as introducing multiple alternative sources of water) the amount of imported water has been significantly reduced, from 693 mm to 249 mm. In particular, the unit block rainwater tank with a capacity of 1.4 m^3 (size of the rainwater tank as optimised by the model) generated a good result that minimized the demand for reticulated water in the whole catchment.

The six existing wastewater treatment plants have a total capacity 16,080 m^3/day, which has been taken into consideration in the analysis, though few of the plants are currently functional. The current volume of unaccounted for water (UFW) is 60%. Therefore, the result of the model with the existing system is quite vulnerable. The existing system can only supply between 71% and 81% of the total demand.

Table 4: Average of the Annual Water Balance for the Catchment, 1970 to 2005

Component	Averages	
	Without considering strategic measures	After considering strategic measures
	(water depth in mm)	
Precipitation	745	745
Imported water	693	249
Stormwater inflow	0	0
Wastewater inflow	0	0
Evaporation	375	369
Stormwater run-off	629	420
Wastewater discharge	428	8
Change in storage	5	195
Transfer of water (+ve means net input)	0	0

With the strategic measures the volume of estimated UFW declines from 60% to 25% of the total. With these strategic measures, the water balance in the city is much better than previously and now it has more renewable water sources. For example, grey water is used for irrigation and gardening; treated wastewater and rainwater are stored and used for toilet flushing. Finally, these actions contribute to a reduced use of reticulated water in the city. If these strategic measures are implemented, Accra will be much more resilient and sustainable in terms of its water balance.

Evaluation of the different scenarios developed for Accra

To identify robust strategies to achieve the vision, scenarios of possible future trends have been developed, taking into account unpredictable external factors that have a great impact on outcomes.

Worst-Case Scenario (Table 5):

The worst-case scenario assumes a high rate of population growth of Accra, which in turn has a high level of influence on water demand and sewerage. The projected future population is more than four times its present level, causing water demand seven times the current demand.

In addition, climate change adversely affects outcomes. This scenario addresses the decline of river flows in the coming years.

Medium Case Scenario (Table 6):

In this scenario, the economic growth rate is good, due to oil exports. Public awareness is better than in the worst-case scenario, resulting in improved solutions for water-related problems. Moreover, other factors have a medium level of influence, and there are fewer adverse uncertainties compared to the worst-case scenarios. For example, there are no more power shortages and there is a lower rate of population growth.

Table 5: The influence level of factors in the worst-case scenario

Sl No	Factors	Level of Influence		
		High	Medium	Low
1	City population	+		
2	Economic growth			+
3	Effect of climate change	+		
4	Power/energy supply			+
5	Political commitment and interference			+
6	Public awareness and attitude			+

Table 6: The influence level of factors in the medium-case scenario

Sl No	Factors	Level of Influence		
		High	Medium	Low
1	City population		+	
2	Economic growth	+		
3	Effect of climate change		+	
4	Power/energy supply		+	
5	Political commitment and interference		+	
6	Public awareness and attitude	+		

Table 7: The influence level of factors in the best case scenario				
Sl No	Factors	Level of Influence		
		High	Medium	Low
1	City population			+
2	Economic growth	+		
3	Effect of climate change			+
4	Power/energy supply	+		
5	Political commitment and interference	+		
6	Public awareness and attitude	+		

Best-Case Scenario (Table 7):

The base case should be the medium-case scenario, which could be realized by adopting the strategic directions implicit in the SWITCH project. The best-case scenario is the ideal for realizing a sustainable and resilient future for the city, but it is the least likely. The worst-case scenario is not the most likely but the outcomes of such a scenario should be analysed. By highlighting the problems arising under the worst-case scenario, people may be more willing to undertake the initiatives implicit in the medium-case scenario

Strategic Directions for Dhaka City

In analysing the water management problem for Dhaka, there are strategic lessons to draw from our analysis of Accra. Managing water demand requires education, incentives, and enforceable regulations, and possibly water tariff adjustments designed to reduce consumption. Improving the Dhaka water management and sewerage sysem requires the following elements:

- Decreasing groundwater extraction gradually, by banning illegal private pumping wells;
- Expanding capacity of surface water treatment plants of the DWASA;
- Exploring alternative sources of water, e.g. rainwater storage and water from Buriganga and Turag, the two most polluted rivers running through the city;
- Promoting rainwater harvesting in Dhaka, (the city has an annual average rainfall rate about 1,854 mm);
- Reducing the amount of UFW through rehabilitation of the distribution system, better operation and maintenance and active leakage detection, including bulk metering;
- Lowering water prices for slums, through special consideration in the water tariff for compound housing.

Strategic directions to meet future wastewater management challenges

- Ensuring access to sanitation facilities in the slum areas by constructing sufficient public latrines and through proper hygiene education;
- Increasing the existing treatment capacity by increasing the number of connections to the sewer system and by building the capacity of the sewerage unit staff.

Strategic directions to meet future stormwater challenges

- Improving storm water discharge by improving and maintaining the stormwater drainage system;
- Managing solid waste by installing sufficient number of dustbins all over the city and conducting awareness campaigns, so that drains are less likely to be clogged by solid waste;
- Reducing surface water run-off by applying sustainable urban drainage systems, paving footpaths and public open places with semi permeable tiles, developing and maintaining a green belt around the current built up area, where urban agriculture can be practiced and by promoting rainwater harvesting.

Conclusion

Water and waste management problems are similar among developing countrycities. Accra and Dhaka share many common issues:for instance, an ever-increasing demand for water, weak systems of urban sanitation, seasonal fluctuation in urban population, undeveloped infrastructure and a poor institutional set-up.

Some strategic directions from Accra have been considered indeveloping the Integrated Urban Water Management (IUWRM) strategic plans for Dhaka city.Some strategic plans have been introduced to reduce the groundwater extraction rate, which isan urgent priority for Dhaka city. Huge investments are proposedto restore the most polluted localrivers (the Buriganga and Turag). If these rivers are restored, they become alternate sources of water, which wouldsignificantly decrease reliance on ground water. Moreover, the average annual rainfall of Dhaka is higher than in Accra, which means rainwater could becomea major renewable source of water for DWASA.

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