International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 09, September-2015

Developing a Framework for Analyzing End-Use Water Demand Dynamics

Aradhana Hans
I/C HOD
Dept. of Architecture and Interior Design
Govt Women's Polytechnic College
Bhopal, India

Dr. Alka Bharat
Professor
Dept. of Architecture and Planning
Maulana Azad National Institute of Technology
Bhopal, India

Abstract **- Water resources of a country are one of its vital assets. The enormous increase in the population in urban areas, along with change in the pattern of water consumption has added to the complexity of scarcity of fresh water resources particularly in developing countries. Understanding of water resources in terms of trends of water consumption and demand is important in framing of sustainable water resources management strategy. Demand for water depends on several factors such as population; income; lifestyle as well as physical features of residential developments. In developing countries like India, urban development plans do not consider probable spatial variations in water consumption and demand in different areas of a city and per capita water consumption at city level as a benchmark is still being used in water related projects and plans. The present paper identifies the influence of several variables on the water consumption or demand based on literature review and thematic maps are then developed in Arc GIS software for the case of Bhopal, Madhya Pradesh, India. Expected uniform water consumption patches are identified with multiple intersection process. Fifteen such patches based on density of population and water source are identified spatially for the study area. The results have helped to address such variations in water consumption and demand within a city spatially and provide a framework to analyze urban household water consumption and demand in a systematic manner. Tremendous research opportunities are explored including analysis of water consumption in the delineated uniform water consumption patches and inter and intra correlation among several variable.**

Keywords — Population growth; urbanization; water scarcity; water demand; uniform water consumption patches

I. INTRODUCTION

In comparison with prediction of world population by UNESCO [1], which will grow from 6.8 billion in 2010 to 8.3 billion in 2030 and to 9.1 billion in 2050, an increase of 2.9 billion, from 3.4 billion in 2009 to 6.3 billion in 2050 is expected in urban populations This tremendous population growth is predicted to live in urban areas of the world, Furthermore, most of the population growth expected in urban areas will be concentrated in the cities and towns of less developed regions of the world [1].

Of all the planet's renewable resources, water has a unique place. Water is a basic and also economic resource. Nowadays, it is becoming a scarce resource with the ever-growing demand for household and industrial consumption [2]. With the rapid development of urbanization and population growth, water using appliances (such as bathing facilities, washing machines, and dishwashers) are increasingly contributing to the growth of domestic water consumption. With its building population, the scenario does not seem favorable for people and as predicted, that if a third world war occurs, it would center on the issue of supply of drinking water [3].

India has been always fortunate in having abundant fresh water reserves, however the increasing population and unsustainable exploitation of surface and ground water over the past few decades has resulted in water scarcity in some regions. The annual utilizable surface water and groundwater resources of India are estimated at 690 km3 and 396 km3 per year, respectively [3]. With rapid growing population and improving living standards the pressure on our water resources is increasing and per capita availability of water resources is reducing day by day. In India about 7 km3 of surface water and 18 km3 of groundwater are being used for community water supply in urban and rural areas. A clear understanding of urban household water consumption will ensure better water consumption trends, more efficient use of water as well as better forecasting of future water demand.

As per 2011 census figures, Madhya Pradesh is a fast growing state in India. A look at the decennial growth of towns, from 1901-2011, shows that the number of towns in Madhya Pradesh have grown more rapidly in comparison to the national average figures. Bhopal city, which is the 15th largest metropolitan city of India and also the capital of Madhya Pradesh state, has been selected as the study area for urban water consumption study.

The objective of the present study is to develop a framework for analysis of water consumption of a city. Present study is focused on identification of urban pockets where water consumption is likely to vary. The results would be useful in analyzing water consumption and other water services spatially in a systematic manner.

II. MATERIAL AND METHODS

Present study includes descriptive as well as empirical exercises. The descriptive part of the study covers identification of city and household level variables which are responsible for the difference in the quantum of the household water consumption. Later it tries to relate these variables spatially for the case of Bhopal. Studies were selected and referred for identification of variables based on the water consumption, requirement and demand preferences.

Spatial sprawl of household water consumers were identified taking urban area, habitable area and residential land use. Administrative boundary and land use maps were collected from T&CP, Bhopal. Habitable area was identified from satellite imagery provided by Google Earth. Thematic maps based on density and source of water are prepared in GIS and uniform patches of household water consumptions were identified through multiple intersections of maps. For urban water consumption or demand studies future research scope is also explored.

III. VARIABLES RESPONSIBLE FOR WATER DEMAND AND CONSUMPTION

Population, income level or lifestyle and industrialization are among many factors on which demand for water depends. Demand increases with the population as water is needed to sustain life, for sanitation, agriculture, generate energy, run industries, etc. People tend to use more water as income rises. City dwellers consume more water than those living in rural areas. The affluent section of the society consumes more water for different activities [4].At the broadest scale, the determinants of total water use are population, climate and price: more people use greater quantities of cheaper water on hotter days [5]. However, at smaller spatial scales, urban water use is driven by a complex combination of structural (property level), socio-demographic and psychological factors [6]. The determinants of outdoor water use are generally structural factors, such as lot size and water using equipment. On the other hand, determinants of indoor use are generally socio-demographic, and include household size, income and education.

The structural features of residential developments, such as neighborhood density, lot size, and outdoor area, have been closely tied with water consumption. In a comparative study of two neighborhoods in Sacramento [7] found that per capita water consumption was higher in a low-density development neighborhood than in a high-density neighborhood. Houses located in high density areas tend to use less water for outdoor use than those located in suburban areas due to smaller plot size and matured tree canopy [8].

At city level per capita water consumption rate is affected by many factors like, social and economic level of the community served; number, size and type of industries; weather, expressed in terms of air humidity and temperature; size, characteristics and topography of the town; water tariff; percentage of households with water metering; satisfactory pressure in the distribution network; water supply system management [9]. CEPT [10].has suggested that the consumption of water is depended on a number of factors including but not limited to size of city, characteristics of population and standard of living, type and number of different industries climatic conditions of area, provision of metering system etc.

Environmental awareness and water consumption behavior are also found correlated. Metering and the costs that incurred to the domestic consumer were shown to cut demand for water. Demographics, dwelling characteristics as well as household composition all influence water consumption. For instance, large lots increase water demand, due to increased outdoor use and longer lengths of pipe [11]. The most important components behind the empiric relations obtained are socio-demographic and indicate that consumption is higher for large families employed in the tertiary sector (higher incomes), families with adolescents and university graduates.

With the ever increasing population, the demand for potable water in urban areas has also increased, while the water sources began to decline over time [2]. Planning of a research study on perception based modeling based water needs was carried out in two income groups in India [12]. Water demand and its various components is one of the main forcing of the water supply subsystem. There are a number of end-use components that determine the overall water demand, including indoor uses (cooking, washing, bathroom) and outdoor use (gardening, car washing). These individual components of demand are often determined from household surveys or actual meter readings and then extrapolated at different spatial scales (precinct, development, and city) and various economic sectors (residential, commercial, amenities) [13]. Water-use equipment have different using priorities, depending on the type of water required [14].

Climate, temperature, quantity of water supply, supply pressure, sewerage network, population density and land use are city level attributes suggested in referred literature which determines quantum of water consumption. Thus household water consumption in areas having similar characteristics and level of services is expected very less variation. This could be developed as a hypothesis and tested for a case example.

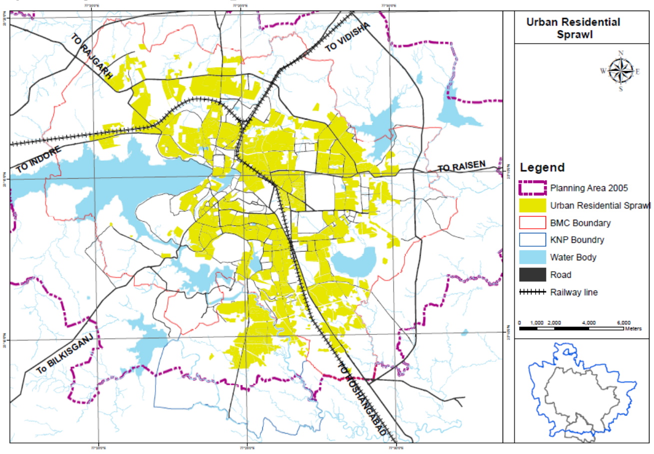
IV. IDENTIFICATION OF POSSIBLE UNIFORM WATER CONSUMPTION PATCHES IN BHOPAL

Bhopal being the state capital is growing relatively at a rapid pace and is likely to promote increasing urbanization in and around it. It may be necessary to channelize the city growth in terms of infrastructure and services to maintain the quality of life as a long-term measure. Bhopal city has been projected as a "Global Environment City" due to its rich natural tradition. Bhopal city needs major investments in Water Supply, Sewerage, Solid Waste Management and Drainage to reach the Specified Global Standard. Per capita water is the base for quantum of water services. Estimation for water consumption for a city like Bhopal having population almost 2 million is significant.

In spite of having seven lakes within the city, water for household use is an issue. City manages to produce only 240 MLD of water with a meager 20% of losses it should theoretically give 135LPCD supply but with lack of efficiency in the production at source, large amount (64%) of non-revenue water (NRW) and only 50% storage capacity available than demand has made the actual water supply of 88 LPCD. Only 67% of the population has access to piped water supply that too for short period of 2-3 hours in the day hence extension of the piped distribution system is a need. Rest of the population is dependent upon the community stand posts. There is extensive wastage of water in stand posts, supply set up and about 25,000 illegal connections. Water auditing is one of the major issue meters are not installed neither at the source to know the actual water production nor at the consumer end to evaluate the consumption. The Narmada Water Supply Scheme is under implementation to meet the future water demand [15].

Through literature review it is very well observed that there are many socio economic as well as structural and behavioral variables which determine household water consumption. Water consumption varies spatially depending upon density of the area for example in high density areas household consume less water on account of many structural features including smaller plot size, matured tree canopy and comparatively less pipe lengths. Thus density is identified as governing factor for spatial variation in water consumption within a settlement. However development plans consider population density as a measure of assessment of requirement of land and forecasting of water supply and sewerage disposal as well as amenities and other facilities, but probable spatial variations in water demand are not taken in to consideration. Per capita water consumption as a benchmark is still being used in water related projects and plans In view of above thematic maps of density pattern as city level variable for water demand and water sources are then developed in Arc GIS software for the case of Bhopal city. Later probable patches where variations in water consumption or demand, water service levels, are expected are identified through multiple intersection process in GIS.

Spatial sprawl of household water consumer were identified taking urban area, habitable area and residential land use. Administrative boundary and land use maps were collected from Directorate of town and country planning, Bhopal. Habitable area was identified from satellite imagery provided by Google Earth. Thematic maps of these were prepared and residential urban habitable areas were identified by using intersection process of GIS.



Map 1: Intersection Map of Municipal Boundary, Habitable Area and Residential Land Use

Looking to the water supply system in Bhopal, the city gets its piped water from three surface water sources namely, Upper Lake, Kolar dam, and exported water from Narmada River. Ground water is also used as a supplementary source and supplies about 22.5 MLD which supplement water requirement particularly in outskirts. Some growth areas particularly development along Kolar road lying outside municipal limits of city depend entirely on ground water.

Based on water services, Bhopal city area can be divided into four categories of Upper Lake, Narmada, Kolar dam and Kolar area which is entirely ground water dependent area. Water supply map was prepared according to this classification. This was overlaid on population density map. Urban population density map was developed based on census data 2011 for each ward. Ward density was classified into four category of density as suggested in Bhopal Development Plan. These overlay of density and water supply system divided city into 15 parts.

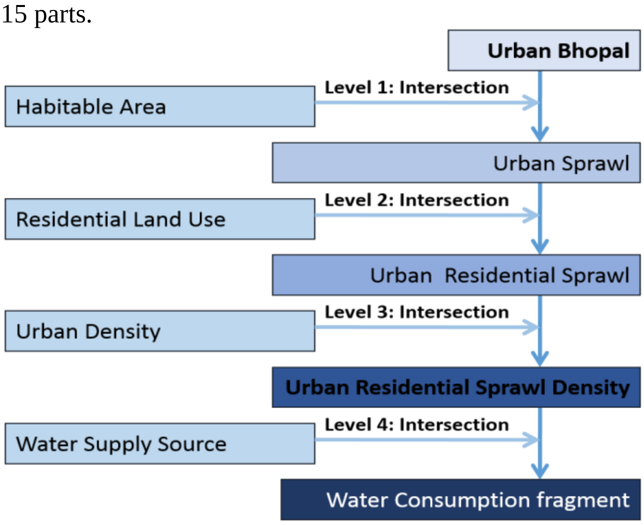


Figure 1: Identification of Uniform Water Consumption Patches

Following the procedure as per figure 1, water consumption fragments were identified. These fragments are expected to have different consumption pattern.

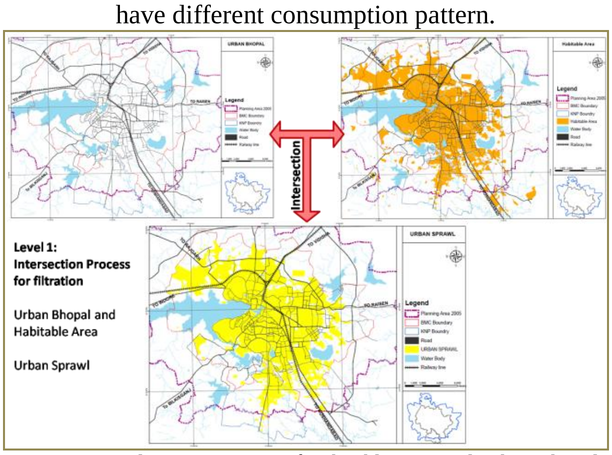


Figure 2: Level 1 - Intersection of Habitable Area and Urban Bhopal

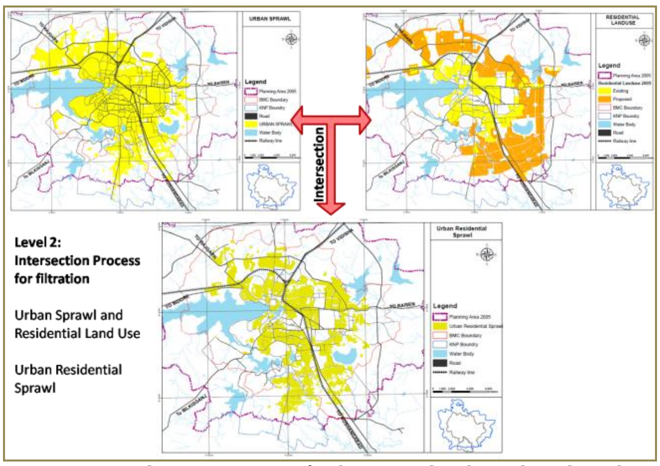


Figure 3: Level 2 - Intersection of Urban Sprawl and Residential Land use

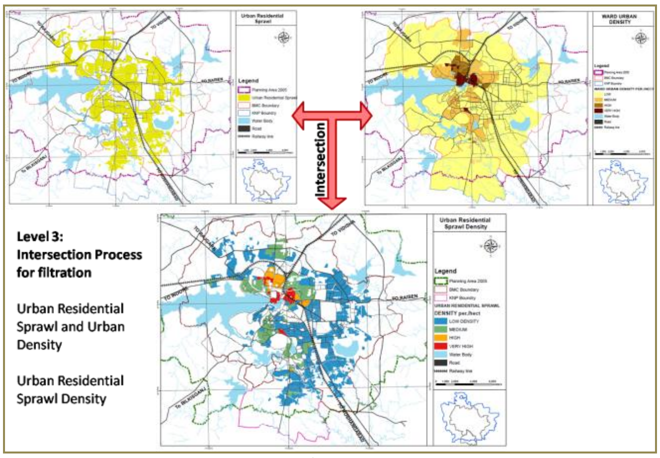


Figure 4: Level 3 - Intersection of Urban Residential Sprawl and Urban Density

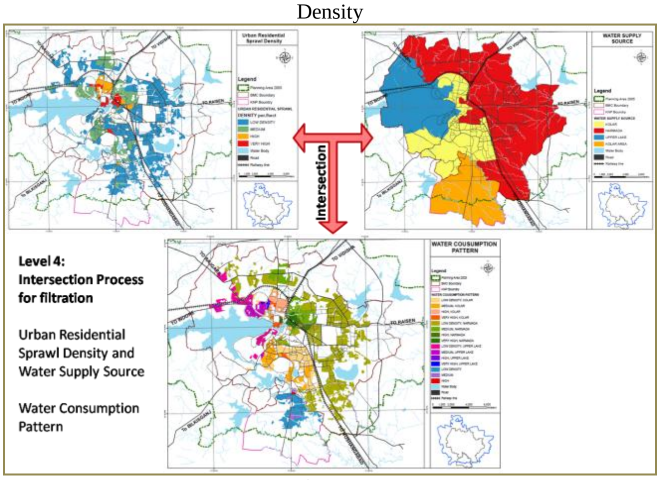
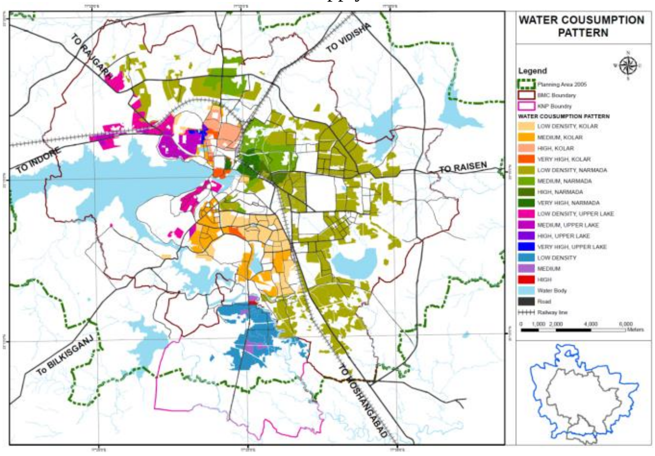


Figure 5: Level 4 – Intersection of Urban Residential Sprawl Density and Water Supply Source



Map 2: Different Uniform Water Consumption Patches of Bhopal City

V. Discussion and Conslusion

A major driver of freshwater demand is population pressure. Even in the absence of significant population pressure, the demand for freshwater in low and middle income countries is likely to increase with economic development and related processes, such as industrialization, energy production, health and sanitation developments, or changing food habits.

Water as a commodity is different from other commodities; it is a life sustaining product. Water is the main source of life and nourishment. Water resources of a country constitute one of its vital assets and always feature high on lists of scarce resources that may be worth fighting for. Water is traditionally considered a renewable resource however there is an increasing awareness that water resources exist in limited quantities, and available supply varies considerably during the course of a year. As a result, there is an urgent need to find ways of saving, reusing and recycling water and to develop methodologies to improve water resource management.

The accuracy of projection is based on the benchmark. Per capita water consumption as a benchmark is being used in water related projects and plans. This water consumption is parallel compared with water requirement and water demand. Water requirement is the basic need of water suggested by guidelines with logical justification and supporting evidence. Water consumption is the actual water quantity consumed. It varies cases to case and suggests updating water requirement base. Water demand is the perception of people expected for good living condition. A realistic assessment of regional water consumption is essential in understanding which can accommodate variations in time and type of use. Consumption patterns include a number of water use characteristics representative of the individual users in space and time. These characteristics include, but are not limited to: the number of inhabitants to be supplied with water and their demographics; the consumption habits of the population; the type of development, property size; and property landscape. Each of these and several other parameters play a role in explaining overall demand.

Based on socio-economic variation water demands fluctuate. The per capita water demand is the base for the city water demand accounting or even for country water demand. Literature has not shown same opinion for per capita water consumptions. Per capita water demand has also been divided into different activities. Composition of water in these activities is important to determine per capita water consumption. Household water use is more reliable base unit compared to per capita water as most of the consumption component of per capital water is shared among household members like cooking, washing etc.

Water consumption variables could also be classified into city level, neighborhood level and household level. Density, land use and water services in all terms are city level factors which determine the quantity of water consumption. Assuming the same water consumption for the area having same density, land use and level of water services in all terms, empirical exercise for the case of Bhopal was made. It identifies fifteen patches in urban area of Bhopal city which are expected to be uniform in terms of water use related issues like but not limited to quality, quantity, other service indicators and associated perceptions of residential water users.

Household water consumption variables and uniform water consumption areas for the Bhopal city are major finding of the study. It generates tremendous research scope. Study could be made to improve the list of the variables of household demand by experts or other stakeholders. Depending on data availability more urban patches could be identified through imposing more city level variables like sewer services; income groups; building typology etc. Correlation among household water related attributes could be established for identified patches. Study could be further extended to check the satisfaction level or public perception in these patches. More work could be done to improve the estimates of water demand. Improvements in record keeping and record availability by the public water providers would greatly aid periodic updates of the study. Classification based on density also divides a settlement in core, intermediate and suburban areas. This provides different criteria for study of end use water dynamics.

ACKNOWLEDGEMENT

The authors acknowledge the support given by the officials of Bhopal Municipal Corporation, and Directorate of Town and Country Planning Bhopal M P for providing relevant data and maps.

REFERENCES

[1] UNESCO, 2012. Facts and figures from the WWDR4, Paris: United Nations World Water Assessment Programme.
[2] Candelaria, A. P., 2010. Assessing the Potable Water Consumption in the Urban Barangays of Sto. Domingo, Albay Province, Philippines, Legazpi City: s.n.
[3] Jethoo, A. S., 2011. Consumer Behavior of Urban Residents of Jaipur City (India) for Water Supply. IACSIT Press, Singapur, pp. V1-453-V1-455.
[4] Jain, S. K., 2011. Population rise and growing water scarcity in India – revised estimates and required initiatives. Current Science, 101(3), pp. 217-276.
[5] Birrell, B., O. K. & R. V., 1999. Explaining spatial concentrations of the poor in metropolitan Melbourne. People and Place 7(1), pp. 53-64.
[6] UNICEF, FAO & SaciWATERs, 2013. Water in India: Situation and Prospects, New Delhi: UNICEF.
[7] Allen, E., 1999. Measuring the environmental footprint of the new urbanism. New Urban News, vol. 4, pp. 16-18.
[8] Chang, H., Parandvash, G. H. & Shandas, V., 2010. Spatial variations of single-family residential water consumption in Portland, Oregon. Urban Geography, 31(7), p. 953–972.
[9] Neto, M. d. L. F., Naghettini, M., Sperling, M. v. & Libânio, M., 2005. Assessing the relevance of intervening parameters on the per capita water consumption rates in Brazilian urban communities. Water Science and Technology: Water Supply, 5(1), pp. 9-15.
[10] CEPT, 2011. Module 2.2: Demand Assessment. [Online] Available at: http://jnnurm.nic.in/wp-content/uploads/2011/01/RTP_MOD-2.2.pdf [Accessed 2 August 2014].
[11] Dziedzic, R. & Karney, B., 2014. Integrating data for water demand management. Procedia Engineering, pp. 583-591.
[12] Sharma, A. et al., 2012. Fuzzy Logic Application in Water Supply System Management: A case study, s.l.: s.n.
[13] Malano, H., Arora, M. & Rathnayaka, K., 2014. Integrated Water Cycle Modelling of the Urban/Peri-urban Continuum, s.l.: Springer.
[14] Perez, P. et al., 2003. AtollScape: Simulating Freshwater Management in Pacific atolls. Spatial processes and time dependence. Volume 4, pp. 514-518.
[15] Mehta & Associates, 2007. Bhopal City Development Plan, Bhopal: Bhopal Municipal Corporation.