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Urban Hydrology, Need of India

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Abstract

Urban hydrology is the interdisciplinary science of water and its interrelationships with urban man. Human population increasing at an unprecedented rate in urbanized area which creates a scope of urban hydrological studies in India. Urban Hydrological Cycle changes with respect to time and space hence the networks of monitoring stations equipped with rain gauges capable of measuring short-term rainfall, runoff gauging as well as water quality monitoring stations in all urban areas should be established and it may be operated by local body. To avoid unplanned urban expansions and land-use pattern, urban planning should be carried out by using remote sensing and GIS technique. Fastest urban development putting great stress on the natural water cycle which can be minimize by promoting the reuse of wastewater for water-demanding activities, which consumed limited freshwater**.** Establishment of research and education institutions and awareness among the people by taking the help of media and Non-Government Organizations (NGO's) regarding hydrology so as to create better understanding of water resources and foster public understanding through water education.

Introduction

Urban hydrology is not a new field (Leopold, 1968; Johnson, 1971). Urban hydrology is defined as the interdisciplinary science of water and its interrelationships with urban man (Jones, 1971). Simply it means the investigation of hydrological cycle, water regime and quality of water in urbanized territory. Urban hydrology is a special case of hydrology applied for cities i.e., areas with very high level of human interference with natural processes (Janusz 1999). Urbanization influences the land use and interaction between land and water because as urbanization proceeds, an increasing proportion of the total land area becomes covered with impermeable surfaces such as roofs and pavement. Rainfall, which formerly trickled slowly through vegetated areas or soaked into the ground, now runs quickly over the surface to streams which create the crucial difference between urban hydrology and rural hydrology. Urban Hydrological Cycle changes with respect to time and space therefore all the hydrological processes in urban areas must be considered less than the macro scale is the today's major challenge for all developing countries**.** Human activity in an urban environment produces large quantities of wastes that can find their way into and degrade the quality of the natural waters of the area. Hence the hydrology of urbanized areas differs notably from that of the same land in its preceding rural condition. Data collected by the national meteorological services, water commissions are adequate for urban hydrological applications. Urban hydrologists must install their own data collection systems capable of delivering data on small spatial scale and short time resolution. These data are site specific i.e., must be collected locally.

Modelling for prediction of environmental impacts of urban areas on a river basin scale, and finding optimal means for mitigation is a new challenging area of activity within modern urban hydrology. However, performance of technical solutions used in the design of water-related structures in a city depends on climate as well as on social, economic and cultural conditions. Some solutions and technologies may be meaningful and function well in some countries but applied in different conditions can become a total failure (Janusz 1999).Several researchers have proposed and developed mathematical models for estimation of runoff from nonlinear reservoirs in an urban drainage basin such as RRL (Road Research Laboratory Method Illusion and Simulator) in 1962, SWMM (Storm Water Management Model) in 1971, and ILLUDAS (Illinios Urban Area Drainage Simulator) in 1974 etc.

Population Status in India

As per the United Nations report in the year 2025 more than three fifth of the world population will live in urban areas (United Nations 1993). India is urbanizing at an unprecedented rate. In 1901, only 10.8% of the population of the India lived in urbanized area, but in 1951, 17.3% of the population of the India lived in urbanized area and recently in 2011, 31.2% of the population of the India lived in urbanized area (Census India, 2011). In 1951 there were only 5 Indian cities with a population greater than 1 million and only 41 cities greater than 0.1 million population but in 2011 there are 3 cities with population greater than 10 million and 53 cities with population greater than 1 million. Over 833 million Indians live in 0.64 million villages but 377 million live in about 8000 urban centers. By 2031, it is projected that there will be 6 cities with a population greater than 10 million. Typically level of urbanization in India increased from 27.81% in 2001 to 31.16% in 2011 (Census India, 2011). Urban population growth is much faster compared to rural population growth; on the other hand, rural population growth is declining compared to urban population growth and the challenges of urbanization are increasing day by day. There are a number of factors such as natural growth, geographical expansion of urban centers, migration from rural to urban areas due to natural calamities, displacement and non-availability of gainful employment responsible for faster urban population growth. Urbanization shapes the environment, but the way in which it does so depends on where and how cities grow.

In Indian cities and towns, large habitations are coming up in the low-lying areas, often encroaching over drainage channels. In some cases, houses are constructed even on top of nallahs and drains. Encroachment in the immediate upper catchments of hilly urban area has also causes on hydrology.

In the absence of a proper sewerage system, most of the habitations discharge their sewage into the existing channels. The net result has been that the width of the natural drainage channels has become inadequate and the capacity for draining the rainwater has been greatly reduced.

Moreover, urbanization leads to increase in impervious an area which, in turn, significantly increases the rate of runoff, resulting in overwhelming of designed capacity of the storm water drainage system. As a result of all these happenings, even small amounts of rainfall can cause urban flooding.

Urban Hydrological Data

All planning and development of urban areas, design of man-made structures and all water management activities in cities should take into account local climatological and hydrological conditions and possible interactions with rural areas around the city. Thus, gathering of reliable and adequate hydrological data is an important task for urban hydrological studies. The rainfall is a driving force of all hydrological processes and it constitutes the most important input to any runoff calculations and modelling procedures.

Lack of spatial and temporal rainfall data over urban areas on a real-time basis is a very critical gap in India. Therefore, establishment of local networks for real-time rainfall data has to be accorded the highest priority. This will be immensely useful for much improved early warning, resulting in better response and management of urban flooding. Such rainfall data will also enable robust designing of urban drainage infrastructure in future. In UK, the recommended rain gauge density for urban areas is 1 ARG per 4 sq km while in Malaysia, it is 1 ARG per sq km. However, the area covered by all 2325 class I, II and III cities in India is about 54274.59 sq km and also total no. of rain gauge stations required to cover all these cities/towns on the basis of 1 per 4 sq km will be about 13569.

There are many reasons for measurement of discharge from rivers and streams like for irrigation. People wanted to know what variations in water availability can be expected, what magnitude and timing of flood and draft events may be expected. Such reasons for monitoring of river flow are still valid. To achieve these goals it is necessary to measure flow and its variations in time. Development of cities with their infrastructure brought additional needs and reasons for flow monitoring. In modern times, as cities grow, not only hydrological regime of river through the city but also magnitude and variation of smaller flows in man-made water-related infrastructure and on paved surfaces are of human interest. Moreover, it must be possible to predict these flows a priori, even before the new construction is built. As a matter of fact, any construction of urban water-related infrastructure, channels, pipes, conduits and even shaping of streets must be based on good knowledge of what will be the effect of these structures on water flows in the city and what is necessary to avoid damage on man-made constructions. Even more increasing imperviousness of the city area with generation of storm water flows may significantly influence the flow regime in the entire river downstream. All these influences must be quantified by analysis of hydrological data and calculations before any construction is built (Janusz 1999).

Several activities in urban areas generate pollution. Pollutants carried by water propagate downstream the city influencing not only the quality of water in a river itself but also polluting flooded land areas of downstream side. Therefore, in order to prevent downstream pollution it is necessary to know what kind, in which activities and where in the city pollution is generated. Thus, in order to plan measures against pollution water quality measurements constitute a necessary element which should be included in measurement program of any urban experimental basin. The collection of urban water quality data is costly and requires sizable investments in instrumentation, data processing, chemical and bacteriological analysis. Therefore a lot of planning effort is necessary in order to maximize the generalizability and applicability of such data (Geiger & Becker, 1997) thus, the set of water quality data to be collected should be chosen in relation to the type of receiving water and water quality-related problems downstream the city. Such data should concentrate on the quality and the environmental status of a river or other water bodies to be protected against pollution. Choice of the parameters to be measured depends also on type and size of a city and human activities bringing potential pollution. For example, if sewerage without treatment is released to the river, conducting bacteriological studies may be in place. If the city is highly industrialized, pollution with heavy metals and other industrial pollution should be monitored. Duration of the water quality sampling can be limited, often to one year in order to reveal seasonal water quality changes (Janusz 1999).

India Meteorological Department (IMD) established in 1875 which is National Meteorological Service provider of the country and Central Water Commission (CWC) established in 1945 which is the apex organization in the country in the field of Water Resources, these organizations dealing with all the matters relating to meteorology, and water resources sectors but the coverage of the IMD and CWC is on country scale therefore in order to get necessary data for urban applications, networks of monitoring stations equipped with rain gauges capable of measuring short-term rainfall as well as runoff gauging stations should be established in all cities.

Central Pollution Control Board (CPCB) which was established in 1974 in collaboration with concerned State Pollution Control Boards established a nationwide network of water quality monitoring comprising 2500 stations in 28 States and 6 Union Territories but the coverage of CPCB is quite small for urban hydrological studies. Therefore establishment of water quality monitoring stations in all urban areas of India is immense need.

Flooding

In recent decades increasing trend of urban flooding in India is also demonstrates the need of urban hydrological studies. There has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. The most notable amongst them are Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009 and Guwahati and Delhi in 2010 etc. Urban hydrology is concerned with the management of flood plains under urban conditions. Many urban areas have been built on flood plains because these areas are level, easily built on and usually dry but buildings and other objects on the flood plain tend to be submerged or swept away at times of high water. A measure to prevent or reduce the loss of life and property on urbanized parts of flood plains thus becomes an important part of urbanized territory which may be covered in urban hydrological studies. The choice of measures to accomplish this includes structural measures, such as levees, dikes, channel improvement and upstream storage, and non-structural measures such as zoning and building regulations. The best solution in any given situation depends on local circumstances, and a combination of structural and non-structural measures often produces the best results.

Coastal Cities: Coastal cities/towns, which are located on the coastline, experience flooding due to localized rainfall, storm surges caused by cyclones. They also get affected by high tides, coinciding with localized rains.

Cities near Dams/Reservoirs: There are cities/towns which are located along a river, either downstream or upstream of dams/ reservoirs. Those located downstream of reservoirs can get flooded by release of water in excess quantities. Sometimes cities/towns located upstream of a dam/reservoir also get affected by rising level of back waters when release of water is sometimes withheld during the flood season. There have been instances when water was released suddenly without appropriate notice, causing severe loss of life and property.

Inland Cities: Cities/towns located inland can experience floods largely because of localized heavy rainfall within the watershed due to overwhelming of the storm water drainage system capacity.

Cities in Hilly Areas: Cities/towns located in the hilly areas experience flash floods due to localized heavy rainfall which can also result in landslides. Sometimes, habitations in hilly areas comprisinga part of large cities/towns also get affected in a similar manner.

It is now well-documented that urbanization leads to an increase in rainfall (NDMG, 2010). As early as 1921, scientists noted thunderstorm formation over large cities while there were none over rural areas. This can be very well explained by the Urban Heat Island Effect – the rising heat induces cloud formation while the winds interact with urban induced convection to produce downwind rainfall. National Aeronautics and Space Administration (NASA) has indicated increased rainfall intensities over urban areas due to the Urban Heat Island Effect precipitation for an urban station showed an increase in the frequency of intense (>20 mm/h) rain showers and that the day time Heat Island Effect was associated with the intensification of rain showers. In India, urban heat islands over Pune and Chennai have been reported. There has been an increase in the average annual rainfall of Hyderabad from 806 mm in 1988 to 840 mm in 2002.

Stormwater Management

Storm water runoff is generated when precipitation from rain and snowmelt events flows over land or impervious surfaces and does not percolate into the ground. As the runoff flows over the land or impervious surfaces (paved streets, parking lots, and building rooftops), it accumulates debris, chemicals, sediment or other pollutants that could adversely affect water quality if the runoff is discharged untreated (EPA, 2014) .A variety of new storm water handling and treatment methods have been developed in the world but still water is heavily polluted with domestic sewage, industrial effluents and solid wastes in most of urban parts of India. Only 209 of India's 3119 towns and cities have even partial sewage systems and treatment facilities (NIH 2000).Consequently many urban rivers have steadily deteriorated in quality although on national scale ambitious projects have been started to reverse this trend. Wastewater management is a serious problem in major cities of India. The amount of water, which gets into an urban center's system, finally empties out as sewage and drainage water. These pollute both surface and subsurface water resources in the region. A very huge quantities of solid waste is generated by the Indian cities and it is estimated that only 60% of it is collected. The uncollected solid waste fills open space, drains and roads and it is major cause of the insanitary conditions and diseases (NIH, 2000) but still storm water may in the future constitute an important resource possible to re-use separately or together with "gray water" for toilet flushing, irrigation in urban small-scale urban agriculture or even for production of drinking water. Especially, rainwater that is captured on the roofs should be considered as a valuable resource and not mixed with various other residuals. Some of these ideas are already realized in ecological villages in many countries. The role of urban hydrology is to deliver scientific base for realization of new goals in urban water management. Stormwater may be a future great water resource for Indian continent because, if suppose volume of water that is delivered to the urban areas by nature in the form of rainfall: 100 mm rain on 1 km^2 impermeable area gives 100 000 m^3water *i.e.* enough for 1830 people during one year counting with water use 150 l/day. If dry toilets are used, water consumption of households may be reduced by 70%, i.e., 5500 people may gain all necessary water from 1 km^2 and rainfall 100 mm/year. In other words, theoretically, 182 m^2 impermeable area can deliver water that 1 person needs. This amount of water is considerable, and though in practice it cannot be easily utilized, it should be considered as an important resource. Utilization of this water requires basic change in applied technology of stormwater management. Urban hydrologists may work to develop technical methods of how to harvest stormwater and make it available for less demanding water uses or after purification, even for drinking purposes. Provision of proper sanitation should be coupled with development of methods and technologies capable of recycling nutrients from wastewater to near urban agricultural areas. Therefore urban hydrologist must be develop technologies for use wastewater for irrigation.

Water to Feed Depleted Aquifers

In many locations of Indian urban areas groundwater resources are endangered due to over exploitation and polluted aquifers, therefore urban hydrology may be act for integrated and lasting solution of groundwater depletion problems not only to satisfy running municipal water needs but also to restore depleted groundwater levels. In large cities stormwater is usually an "untapped"' resource conveyed to the nearest surface water body. Instead, it can be used for restoration of groundwater levels. Wastewater can be, after adequate treatment, also used for this purpose.

Education and Transfer of Technology

Water is one of the most essential natural resources required for survival of the human beings. It is becoming scarce in quantity and quality throughout the world. Without effective capacity building in the water sector, it is very difficult to solve water related problems. The hydrological education should be one of the important aspects of the national policy of any country for capacity building in the water sector. Realization of this view point led to the establishment of research and education institutions and awareness among the people by taking the help of media and NGO's regarding hydrology is the immense need.

Conclusions

Planner and the decision makers should create opportunities like quality of education, health, employment in the rural areas in order to prevent the migration of people. Effective measure should be taken to minimize the population growth rate in urban as well as rural areas.Networks of monitoring stations equipped with rain gauges capable of measuring short-term rainfall and runoff gauging as well as water quality monitoring stations in all urban areas should be established and it may be operated by local body.One of the biggest problems of most of the urban areas of India is the unplanned urban expansions and land use patterns, which have triggered conflicts between urban and peri-urban interest. By using remote sensing and Geographical Information System (GIS) techniques, urban planning of the cities should be carried out. Emphasis should be given on the use of open and abandoned areas for the plantation and formation of water recharge structures. Areas with natural vegetation covers are the most important part of the urban planning with higher infiltration and reduced runoff rates. Therefore as much as possible these areas are protected for any construction to maintain the groundwater level and improve the water quality (Misra, 2010) also structural measures such as levees, dikes, channel improvement and upstream storage, and non-structural measures such as zoning and building regulations for avoid of flooding disasters.

Almost every city of India required up gradation of drainage and sewerage network. In majority of the cities there is a complete mismatch between drains inside a colony and their outfalls. Further almost all the drainage and sewerage systems in the cities are faulty and there is no chance for the rainwater and domestic water of findings its way to their designed outfalls. It causes stagnation of water and chokingof drainage and sewerage systems especially during rainy seasons and become a potential health hazard leading to many epidemic diseases and pollutes surface and groundwater resources. Now it is urgently required to upgrade the existing systems along with creating new facilities for the sewerage waste treatment so that without primary treatment it is not allowed to dump in the rivers (Misra, 2010). Fastest urban development is putting great stress on the natural water cycle. This can be minimize by promoting the reuse of wastewater for water-demanding activities, which consumed limited freshwater resources. Many developed and developing countries have adopted the option of recycling and reuse of wastewater for agricultural and non-potable purposes. Same practices must be encouraged and facilities for recycling of wastewater should be built to minimize the pressure on groundwater resources.

The hydrological education should be one of the important aspects of the national policy of any country for capacity building in the water sector. Realization of this view point led to the establishment of research and education institutions and awareness among the people by taking the help of media and NGO's regarding hydrology so as to create better understanding of water resources and foster public understanding through water education.

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