URBAN HYDROLOGY

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Summary

Urban hydrology is a science, part of land hydrology investigating the hydrological cycle, water regime and quality in urbanized territory. Urban hydrology is a link in a number of sciences dealing with the problems of ecology, environmental protection, conservation and rational use of the Earth’s water resources. The population growth and

concentration of its increasing portion in cities is a natural historical process. By the end of 2000, half of the Earth's population lived in cities.

Local water resources cannot provide the ever-increasing communal and industrial water use in many urbanized territories, and water is transferred from other basins or non-renewable groundwater supplies are used. The changes of the natural landscape components – relief, soil-ground, vegetation and water objects in urbanized territories, determine the climatic features of cities and zones of their influence. The runoff regime is disturbed and new conditions of surface/ground water interaction are created. Structures and road pavement increase the water drainage decreasing its infiltration. The aim of urban hydrology is to make an assessment of the current changes and reveal possible adverse phenomena in the system of water consumption and diversion of used water.

1. Introduction

Urban hydrology is a science investigating the hydrological cycle and its change, water regime and quality within the urbanized landscape and zones of its impact.
Urban hydrology is a link in a number of sciences dealing with the problems of ecology, environmental protection, conservation and rational use of the water resources of the Earth.

The problems of studying the influence of urbanization on the hydrological cycle present an issue of international cooperation of scientists that has been especially fruitful for the last 40 years.

The International Hydrological Program of UNESCO, including a comprehensive Project 'Influence of Urbanization on Water Quality and Regime,' was adopted in 1974, and had great importance for the establishment and development of urban hydrology. The Project covered a wide range of issues related to studying the impact of urbanization on the water balance and water resources. In the 1980s–1990s, there were many publications on the results of the Project, reflecting the state of knowledge in the area of urban hydrology based on information received from many countries. In particular, in 1987, UNESCO published two volumes of the basic guidance on urban hydrology, containing information on data acquisition, analysis and processing, observations of hydrological cycles and calculations of drainage systems in cities.

The results of international cooperation over the last decades allow us to define a range of objectives addressed by urban hydrology and the level of our knowledge.

2. Urbanized Landscape

Urban landscape presents a territory transformed by human activity, which is occupied by a city with suburbs, and industrial and economic facilities and communication lines. The landscape formation and evolution result from a natural historical process of development of the human society with its larger portion concentrating in cities.

2.1. Growth of Urban Population and Urbanized Territories

In 1880 only 3% of the Earth's population lived in cities with 5 thousand inhabitants and more, 30% in 1950 and about half of the population by the end of the second millenium.

If we consider the urban population in continents, from 1970 to 2000 it has increased 1.5-fold in Europe, 3-fold in Asia and 4-fold in Africa. In North and Central America, 80% of the population lives in cities. In Australia, urban population comprises 85% of the total number of 19 million inhabitants.

An important fact of the development of urbanization governing the anthropogenic landscape and its water regime features is the increasing population concentration in large cities. In 1820, the population comprised 1 million people only in London, however within 50 years, the number of cities with more than 1 million inhabitants was 75 with, 24 of them in underdeveloped countries. There are many cities with the number of inhabitants more than 10 millions, such as Mexico City, Tokyo, Shanghai, London, New York and Paris with suburbs and some others. The areas occupied by some cities can be several thousand square kilometers.
In general, on a global scale, the urbanized landscape occupies a small area – about 5% of the Earth's surface. However, in some countries such as Germany, Netherlands, Denmark and others, the areas of urbanized landscapes reach near-critical values – 10% of lands suitable for economic use.

The formation and peculiarities of the hydrological cycle of urbanized landscapes are determined by the:

- involvement of a large quantity of water frequently greater than the local water resources in moisture turnover to cover the population demands in industry.
- transformation of landscape, natural regime and water balance formed.

2.4. Water Use

One of the main characteristics as a result of urbanization is involvement of large water volumes in moisture turnover to cover the domestic and economic needs of the population. Modern cities with industrial and economic facilities cannot in many cases meet their requirements for water due to local water resources. For water supply, water is transferred frequently from the other basins and secular supplies of non-renewable groundwater are used.

In general on earth, the current gross annual communal water use by urban population comprises about 385 km^3. To meet the industry demands, about 780 km^3 is withdrawn annually from the water objects.

2.2.1. Communal Water Use

The communal water use is directly related to water consumption by the population of cities and urban settlements and enterprises of domestic, communal and servicing spheres. The communal consumption also includes water consumption by industry directly providing for the needs of urban population and consuming high quality water from the city water pipelines. In many cities, a significant quantity of water is used for irrigation of vegetable gardens and farmlands and garden-plots. In many large developed cities in the world, modern water use comprises 300-600 l/day per capita. In the industrially developed countries of Europe and North America, the specific water use per capita in the cities comprises 500-1000 l/day. On the other hand, in the developing agrarian countries of Asia, Africa and Latin America, the communal water use comprises 50-100 l/day being not greater than 10-40 l/day of fresh water per capita for some areas with insufficient water resources.

The greatest portion of the water intake in the urban water supply with the efficient sewer system is returned after the use (after treatment or without it) to the hydrographic network as sewage water. The main portion of water withdrawal is comprised of the water losses due to evaporation at leaks from the water pipeline or sewer networks, watering of green plantations, streets, recreation zones, farmlands, etc. Thus, it depends to a large extent on the climatic conditions (in dry hot areas, the losses are naturally much greater than in cold and moist ones). Water use directly for personal human needs is small compared to the water losses due to evaporation. Relative values of water consumption typically expressed in percentage of the water intake depend to a great extent on the volume of full specific water use for communal needs. In modern developed cities with a centralized water pipeline network and efficient sewer system characterized by the specific water withdrawal of 400-600 l/day, water consumption is not usually greater than 5-10% of the total water intake. For small cities with a large fund of individual buildings not fully provided by the centralized system where the specific water withdrawal is 100-150 l/day, water consumption significantly increases and can achieve 40-60% of the water intake. The least values at this refer to more northern areas and the highest to dry southern areas.

The current tendency for the development of communal water use in all countries of the world is to construct in large and small cities the efficient centralized water pipeline and sewer systems and connect with these systems the increasingly greater number of buildings and human settlements. In this respect, it should be anticipated in the perspective that the specific water use per capita will increase whereas the water consumption values expressed in percentage of the water intake will significantly decrease.

2.2.2. Industrial Water Use

Water in industry is used for cooling, transport and washing. It is used as a solvent and it is present in the composition of finished products. Thermal energy (including nuclear energy) that requires a large quantity of water to cool units is the main water user in industry. The industrial water use facilities are different for different industrial branches depending on the production process characteristics, application of recycling technologies and climatic conditions. As a rule, the water use in industry in the northern areas is much less than in the dry southern areas with high air temperatures.

The dynamics of increasing costs for domestic water use and the demands of industry are different. If the domestic water use constantly increases in relation to the population growth and its increased requirements until a maximum is achieved (600 liters per individual per day according to UNESCO data), the changes in the volume of industrial water use will be a more complicated process. The water discharge to meet the requirements of industry does not have an unambiguous relation to the volume of products made. It is determined to a greater extent by the constantly improving production technology towards using a smaller water quantity by introducing the recycling and waterless technologies. Water withdrawal due to increased evaporation in the water use system in different countries can differ significantly depending on the natural peculiarities and social-economic conditions.

2.5. Transformation of the Surface and Water Bodies

In city planning, there are drastic transformations in the soil-ground layer. Roofs of buildings, asphalted streets and roads create large areas of water impermeable or little impermeable surfaces occupying half and more of urban territories. With the formation and development of urbanized landscape, the hydrographic network is transformed. During reclamation of the build-on territory, channeling, filling up or creation of new water bodies and water courses and bog reclamation is undertaken resulting in the disturbance of the natural relation between surface and underground waters.

Filling up of the natural drainage courses can lead to the rise of the groundwater table and the adverse consequences related to partial submerging of the underground parts of structures and communication lines. The character of the hydrographic network change in spite of its diversity and peculiarities of urbanized landscapes has common features in different natural zones. In the excessive moistening zones, urbanization is accompanied with reclamation of lands from built-on territory, which is carried out by deepening river channels, receiving water reservoirs and arrangement of network drainage. Simultaneously, small rivers, water streams and water bodies are filled in. As a rule, natural hydrographic network during urbanization in the excessive moistening zone decreases, although in some cases, an increase might occur connected with the creation of artificial water bodies for the purpose of runoff regulation and solution of water use objectives. A reverse phenomenon occurs in the cities of the insufficient moistening zone where artificial water bodies and watercourses are created alleviating the heat and making the built-on territory more picturesque. The changes introduced by urbanization to the landscape and hydrography of tundra and permafrost zone where transformations cover vast territories appear to be quite peculiar.

In the process of urban construction, drastic relief changes occur, namely, the depressions and runoff bands are covered up. Simultaneously with the locality rise, an inverse process of ground subsidence occurs in some cases due to melting of multiyear frozen rocks, melting of peat bogs, plateau of slopes and other phenomena related to a thermal regime change of soils and load on their surface. Disappearance of a large number of bogs and runoff bands typical of the natural tundra landscape characterizes the urbanized tundra landscape. A new anthropogenic hydrographic network appears near the fill motor roads. In the head of embankments, water accumulations form at the aquiclude of multiyear frozen ground preventing infiltration. Water concentrations form a series of small water bodies with a length between several to tens of meters. Artificial water bodies formed due to the discharge of technical water at the industrial sites are also widespread.

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Biographical Sketch

V.V. Kupriyanov was born in 1915. From 1933 until his retirement in 1988, he worked at the State Hydrological Institute as a specialist in land water research. In 1948, he has taken an external degree at the Leningrad State University in the field of physical geography. From 1970 to 1979, he was Deputy Director of Science, in 1979 he was made Head of the Global Hydrology Department. V.V. Kupriyanov believed in participation and international cooperation on hydrology, being IAHS Vice-president for 12 years and a permanent participant of the Working Group under the Urban Hydrology Project, phases II and III of the International hydrological Program of UNESCO.

V.V. Kupriyanov has more than 100 publications on urban hydrology and applications of satellite information on hydrology, hydrography and water studies with three monographs among them – one on urban hydrology and two – on application of satellite information in hydrology. More than 20 works were published in English in several foreign countries.

After retirement in 1988, V.V. Kupriyanov is a consultant in the area of the effect of urbanization on the hydrological cycle.