Analyzing the causes of urban waterlogging and sponge city technology in China

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Abstract. With the rapid development of social economy in China, increased urban population, and rapid urbanization cause serious problems, for example, a heavy rain in the city inevitably leads to waterlogging, which poses a great threat to the livelihood and property security. Disaster due to urban flood is a key problem that restricts the development of urban ecology in China. The reason is the sharp increase of impermeable surface ratio in urban areas, leading to a decrease in rainfall infiltration and increase in surface runoff. To effectively solve the urban waterlogging, China proposed the construction of sponge city. This paper analyzes and summarizes the reasons for the formation of urban waterlogging, and introduces the concept of the sponge city technology to prevent waterlogging.

1. Introduction

China experiences several disasters including flooding, storm, and drought due to its geographical location and monsoon climate. Climate change in China has modified the frequency of storm and flood, resulting in an annual summer waterlogging multiple times. Meanwhile, due to a high volume during peak flooding, majority of the flood are unused and infiltrated, leading to increased risk of intermittent and alternate river flooding.*[1]* In 2010, it was found in a survey of 351 cities that urban waterlogging in China has been increasing nationally*[2, 3]*.

It is important to note that building a "gray" infrastructure through a single-objective engineering approach has been widely used to solve complex and systemic water problems until today. However, the problem has not been solved, instead it goes into a vicious circle. Combined with the domestic and international theoretical achievements and practical experience in urban rainwater management, the "sponge city" theory encompassing the natural infiltration, and natural purification has been proposed and developed. *[4, 5]*

2. Causes of urban waterlogging

2.1 Geological and meteorological factors

With global warming, extreme weather events are more frequent than before. Urbanization has led to an increase in precipitation and heavy rainfall events in large cities. Urban heat island effect makes the atmosphere over the city unstable. In certain weather conditions, the development of convection is conducive to the formation of convective clouds and convective precipitation, and heavy rainfall events. Urban waterlogging caused by short duration of heavy rainfalls or long time precipitation of high rainfalls is influenced by direct meteorological factors.*[6, 7]*

2.2 Urbanization factor

2.2.1 Change in underlying surface condition. Urban development and construction led to the expansion of impervious area, reduced surface infiltration and reduced recharged groundwater, increased runoff, and increased peak flow, and increased peak flow in advance. With urbanization, the impervious surface area of the city increases continuously, while the storage facilities such as large paddy fields and fishponds decrease, leading to increased runoff coefficient. Permeability of the ground is conducive to guide the rainfall infiltration, and to form underground runoff, thereby resulting in the reduction of urban rainfall caused by the water accumulation. However, urbanization decreases the natural vegetation, changes the surface material, and hardens the bedding surface, and reduces the amount of surface runoff. The rainfall could not be well drained, leading to an increased runoff and peak discharge.*[8, 9]*

2.2.2 Artificial occupancy of the river section, and reduction in water storage capacity. River network as an important component of regional water cycle is formed by the interaction of natural factors and human activities. Since the reform and opening, the process of urbanization by leaps and bounds, a highly-urbanized region of the river network structure is simple, non-trunk river to reduce. The development and construction has changed the natural geographical environment. Large number of illegal buildings along the part of the river occupy the river flood section, aggravating the river water atrophy, and restricting the river tributaries.

2.3 Urban heat and rain island effect

Urban population, factories, and automobiles consume significant amount of energy. In addition to causing air pollution, they also release waste heat into the atmosphere. This man-made release of heat increases the average annual temperature of the city above 0.5 to 3 ^{o}C in comparison to the temperature in the suburbs. In terms of the spatial distribution of temperature, the city becomes similar to a warm island, known as the "heat island effect".

"Heat island effect" exacerbates the convection of air movement, leading to the formation of the easy showers over the city. Moreover, the dust in the city is far more than that in the suburbs. Thus, the atmosphere of the city can condense into the rain condensate nuclei compared to that of the suburbs. Therefore, it is more likely to rain in the city, which is known as the "rain island effect".*[10, 11]*

2.4 Drainage engineering construction lag

According to the information survey, the total length of urban drainage pipes in Germany in 2002 was 446,000 km, with an average density of more than 10 km/km^2. The length of urban drainage pipes in Japan was 350,000 km in 2004, and had the average density of 20 ~ 30 km/km^2, with the maximum of 50 km/km^2. The US urban sewer length in 2002 was about 1.5 million km, while the average density of urban drainage pipe network was more than 15km/km^2. However, the total length of urban drainage pipes in China reached 370,000 km by the end of 2010, and the density of urban drainage pipes was 9.0 km/km^2. The urban per capita drainage pipe was found to be only 0.57 m in 2010, for an urbanization rate of 46.6%. Before the release of the 2014 edition of the "Specification for Design of Outdoor Drainage Systems", the domestic urban waterlogging control could not be in accordance with the situation, suggesting that the city does not provide its due importance to the planning and construction of drainage works.*[12]*

2.5 Low terrain

Urban construction in low-lying areas often become waterlogging areas after rainfall, since the rain water cannot be discharged in time due to the terrain.

2.6 Lag-management

Drainage facilities are unevenly managed. Most urban villages and old villages have problems such as inadequate drainage facilities, lack of pipeline clogging and rain water collection facilities. More than half of the waterlogging points are caused by this problem. During a rain event, these facilities cannot play its due role in the drainage.

Most communities, and villages in the city do not have the information about the pipe network. The disorder section of the pipeline in these places is widespread, such that some areas do not have adequate rainwater pipe network or collection facilities leading to inadequate drainage network capacity.

In some drainage facilities such as small village drainage pumping stations, and tidal gates, improper management leads to aging equipment and other problems such as rain cannot open the pump, shut the gate used to retain water, resulting in waterlogging.

Development of the city results in increased constructions, leading to difficulties during water law enforcement. There are some problems in the soil and water conservation and construction drainage in some subways, important transport facilities construction and area development and construction. The drainage problems are not given importance during the actual construction. Mud and silt from construction site block drainage culvert, resulting in waterlogging. In particular, stealing emission of mud can have a direct adverse impact on the municipal drainage system.

3. Sponge city technology

"Sponge City" is the integration of a series of specific rainwater management technology, and is the result of extensive practical experience. It covers concepts and technologies such as Low Impact Development (LID) in the United States, Sustainable Urban Drainage Systems (SUDS) in France, and Water-sensitive Urban Design (WSUD) in Australia. *[13]*

LID refers to a rainwater management method based on the principle of simulating natural hydrological conditions, and using source control concept to realize rainwater control and utilization. The main objective is to maintain or restore the previous hydrological characteristics of a development area, after the construction. Such measures include protection of water quality, replenishment of groundwater, reduction of flood peak, conservation of land, reduction of runoff accumulation time, prevention of river pollution, and reduction of pressure on municipal pipe network facilities. SUDS has evolved from a simple "emission" based drainage system to a sustainable and benign water cycle drainage system. It focuses on water quality, landscape value, entertainment and rest value of the urban environment.*[14, 15]*

4. Conclusions

This paper analyzes and summarizes the reasons for the formation of urban waterlogging in detail and introduces the concept of the sponge city technology for the prevention of waterlogging. Conventional urban drainage to prevent waterlogging can only deal with extreme storm waterlogging problems. The project focuses on the construction of large-scale storage tank, additional pumping stations, improving the drainage pipe network standards and other measures, but does not investigate the corresponding conditions conducive to waterlogging. In the construction of the sponge city, the generalized LID and green rainwater infrastructures can reduce the pressure on the traditional pipe network system to a certain extent in the control target, facility type and application scale. Further, it can replace the traditional gray drainage facilities under certain conditions.

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