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Analysis on Problems of Sponge Cities in China

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Abstract. Nowadays, as the development of urbanization, it is necessary to put forward solutions to solve urban waterlogging problems. In this paper, the author makes an introduction of the backgrounds of sponge cities as well as the ultimate solution from Chinese government, and analyzes the effects of the solution. The fatal flaws of stormwater management systems will be focused, which stand in the way of upgrading the sponge cities, In addition, this paper reviews historical practices that are targeting similar problems and gives proposals for current management to solve water problems.

1. Introduction

Urban planning has always been an important measurement to evaluate the overall condition of a country. China, striving to grow into a developed country, is working on providing solvencies for its urban waterlogging problems. This paper would introduce the backgrounds of sponge cities, the ultimate solution from Chinese government, and analyze the effects of the solution on urban waterlogging. Taking the current stormwater management system into account, it's not easy to evaluate the efficiency of sponge cities simply by studying the existing systems in other developed countries. This paper will be focusing on the fatal flaws of these systems standing in the way of upgrading the sponge cities, and review historical practices targeting similar problems to bring up proposals for current management of water problems.

2. Overview of Sponge Cities

Considering the reason why Chinese government introduced sponge cities, sponge cities have a different focus compared with previous practices. Instead of simply decreasing stormwater runoffs inside urban areas, sponge cities are built to prevent urban flooding. Besides, the stormwater would be collected to compensate for urban water consumption. Thus, sponge cities should be defined as cities installed with integral systems that can drastically decrease surface runoffs, prevent urban waterlogging, and utilize collected water[11].

2.1 The origin and development of sponge cities

Sudden and strong precipitation is not a problem unique to China. The concept of sponge cities dates back to the ancient time. One of the most important properties of sponge cities is a decrease in surface runoffs. The first practice of the concept took place in the late 20 centuries.

2.1.1 Best Management Control System (BMPs)

Traditionally, sewage systems are mainly responsible for draining stormwater. The traditional system, a branch of the best management control system (BMPs), typically utilizes engineering systems (e.g. filers, clarifiers) for pollution control. It resembles a two-dimensional net-like structure. Under this system, stormwater in a certain area is transported in the form of streams and drained through each node. The old system failed from time to time to protect urban cities against waterlogging.

On the one hand, the old system allowed surface runoffs to go beyond city planners' control. Moreover, the malfunctioning of one "node" would burden all other nodes `as it went out of work. The drainage could such a level that paralyzed other nodes. With the breakdown of nodes, the presence of waterlogging would just be a matter of time[2].

2.1.2 Green Infrastructure (GI)

To cope with the increasingly challenging stormwater management, many western countries introduced the concept of green infrastructure (GI), or green stormwater infrastructure (GSI) to be specific. Just as its name suggested, GI tried to manage stormwater by integrating applications that were widely utilized in the natural world to solve similar problems confronting cities.

GI could be traced back to mid-19th centuries when city parks started to emerge. Global advocations for ecology that started around 1960s draws attentions from many researchers to this topic, contributing to its development. In the twentieth centuries, this concept has already widely accepted and implemented in fields apart from urban planning[4,6].

2.1.3 Low-impact Development (LID)—A Comparison with Traditional Systems

Low-impact development (LID) is the first systematic technical measure of GI is. It was brought up in Prince George's Country, Maryland in 1990 as an alternative solution to traditional best management practices (BMPs), a system that typically utilized engineering systems (e.g. filers, clarifiers) for pollution control. In the case of Prince George's Country, LID was used as a substitution for GI or was integrated with the original draining system that consisted mostly of runoffs and concentrated discharges by sewers[7].

The technique contributing to the significance of LID was that instead of building sewage systems to direct stormwater to streams, LID set up multiple barriers to separate parts of the precipitation and store stormwater elsewhere, or collected stormwater via countless smaller paths. Interventions in city precipitation significantly improved the functions of the former BMPs system. LID barriers were mainly made up of biologic materials. That's why LID was categorized under GI. Green roofs, green walls, and bioswales were common examples of these barriers.

The trace of LID could be found in many other developed countries. In the United Kingdom, a system that shares the same function as LID is named sustainable drainage system, for example, in Australia, the system is titled water-sensitive urban design[9]. However, LID is still the most widely accepted term for these systems. Before being introduced to urban planning in China, this term was used as substitution for LID in countries in northern Europe like Dutch.

2.1.4 Low-impact Development (LID)—an innovative water-supporting system

In addition to solving problems created by its predecessor, LID is also involved in water consumption management.

Stormwater, in most cases, could be considered as slightly polluted water. Compared with water from water treatment plants, stormwater is more unpredictable in terms of composition and it even varies over a short time period. Just like other water sources, stormwater is affected by the surrounding environment, but it is also heavily affected by the collecting process. Runoffs collected from rooftops are slightly polluted in the beginning, but the follow-ups are relatively clean while road runoffs suffer from different pollutants. Metals, oil, and rubber are relatively unusual pollutants.

3. Current situation and potential problems associated with sponge cities

As a major developing country that encourage a transformation to sponge cities, China is facing a series of problems that developed countries don't have to worry about. The high density of population of China and pollution is threatening sponge cities. One of the most significant difference between existing GI cities and the examinees inside China is the quality of the water collected. Thus, this paper will discuss traditional techniques in China, and propose corresponding solutions.

Flooding, especially waterlogging, is considered one of the most common and most devastating natural disaster in the many parts of China. China loses hundreds of lives and millions of dollars as a direct impact of flooding. The driving forces behind this phenomenon could be divided into controllable and non-controllable factors for the Chinese government. The Chinese government is trying to develop sponge cities to alleviate urban waterlogging. The policy is heavily affected by the following three factors.

3.1 Insufficiency of original gray infrastructures

Sponge-like structures could not achieve the full target of preventing urban-waterlogging—they have to be constructed alongside gray infrastructures[3]. Most cities in China are still utilizing traditional BMPs. In the process of rapid urbanization, city-planners often ignore the possible outcomes of heavy precipitation. Many cities have seen an increase of impervious lands in the past few decades. With asphalt roads covering most of the lands, it has become extremely hard for stormwater to penetrate the originally filterable lands. When peak flow accumulates at a speed faster than the drainage system and runoffs from different sources encounter, urban waterlogging takes place[8].

In addition, China's stormwater management systems are much less efficient compared with those of the developed countries. The draining ability and the stormwater capacity of these systems are much worse than that of their forebears. This is partly because China has always been prioritizing GPD over investment of massive urban hydrology infrastructures. The integration of gray infrastructures and green infrastructures would be much harder in China.

In addition, confluent sewages are still in practice in most cities of China. The sewages were designed for transporting daily waste water rather than managing sudden bursts of stormwater. New pathways are necessary to decrease water consumption for urban landscape projects. Rain and sewage division is a prerequisite of developing sponge cities.

3.2 Geological and meteorological factors

Compared with human-related factors, geological and meteorological factors are much harder to control or predict. These factors, as main sources of precipitation, are still unlikely to be controlled by the government in the future. As many parts of China are covered by monsoon climates, storms could still pose a series of threats associated with flood to cities in southern China despite a low average level of monthly precipitation across the country[5].

Terrain factors also contribute to the form of urban waterlogging. There are two main landforms in the southern China, including the Southeast Hills and the middle and lower sections of Yangtze Plain. As these cities were mostly located in lowlands and plains, there is no alternative to ease the logged water when surface runoffs accumulate to a certain level above the surface.

3.3 Environmental impacts from sponge cities

Another factor sponge cities need to consider would be the impact on the environment. Sponge cities usually "reuse" the water collected. Different from the developed countries that make a full use of stormwater, China uses the water exclusively for landscape projects while the remaining water would be discharged to the natural water system. Currently, most cities discharge stormwater along with polluted water for purification. If the cities want to use the water collected, additional waterways must be created. This means that either a massive number of new pipes are required to direct the stormwater directly to the system at the risk of pollution.

Rainwater itself is slightly polluted when it just starts to rain, but the latter part could be considered clean. Once the collected stormwater could be stored, they could be easily purified. Heavy metals are common pollutants from areas like roads or machines. Point pollution is much harder to classify and control. Residential areas could produce dissolvable harmful wastes in many kinds.

4. Solvency

However, there are ways to solve these problems. Most problems, if listed separately, are not unique to China. What distinguishes these problems is the differences in background. Thus, the most effective and feasible solution should be concluded through massive comparisons with similar problems in other countries.

4.1 Upgrading sewage system

Green infrastructures and gray infrastructures are complementary. As mentioned before, Chinese government didn't pay enough attention to building sewage systems. The problem is also not about the number of sewage systems storing stormwater, but rather the internal capacity of the system.

Many cities are not equipped with enough stormwater pump stations that are efficient and reliable. These stations are often malfunctioning during heavy storms due to reasons like blackouts.

Underground water reservoirs are also parts of the gray infrastructures. Different from many other countries that have their underground water reservoirs built prior to other underground systems like subways or electricity cables, it should be easier to organize the systems in China. These reservoirs could also function as the junctions that connects tunnels, which could serve as pathways that facilitate maintenance. These reservoirs are useful structures against unpredicted heavy storms[1].

4.2 Coping with polluted water

The amount of pollutants is nothing compared with the amount of rainfall in planned sponge cities. These pollutants also have almost no damage to the environment and can be considered the same as running water in urban areas. Thus, they could be safely discharged to the water cycle directly. Moreover, each stormwater colleting system should have its own path so as to avoid burdens on purifying the stored water.

For stormwater collected via rooftop runoffs or greenbelts, it is safe to transfer them to the water cycle. Dusts and dissolvable harmful substances from the air are common pollutants in this form of stormwater.

For the portion of water that is hard to determine the contaminant, it is recommended to follow the procedures applied in other sewages. As there is no huge demand for water consumption in the existing sponge cities, the water collected via roads and rooftops could already fulfill the need for water[10].

5. Conclusion

Introducing sponge cities to cities in southern China would help ease up the urban waterlogging problem. However, without the improvement in the infrastructure and existing sewage systems, the effect would be largely limited. There is no reserved capacity and the level of rainfall varies greatly from seasons to seasons. Only when a balanced combination between gray infrastructure and green infrastructure is maintained could the problems be solved.

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