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Commentary

Understanding China's Urban Rainstorm Waterlogging and Its Potential Governance

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Abstract: Urban rainstorm waterlogging is one of the most important problems in urban development and a comprehensive embodiment of urban diseases. China is facing a severe risk of rainstorm waterlogging disasters, which is affecting sustainable development. Urban rainstorm waterlogging in China is caused by many factors, including natural factors and human factors, such as climate warming, unreasonable urban construction, inadequate upgrading of urban fortification standards, etc. Based on the analysis of the current strategies to deal with urban waterlogging around the world, including an increase in surface infiltration, and a reduction in runoff (and its various impacts), this paper holds that the connotation and goal of these measures are highly consistent with the construction of a sponge city in China. Based on the analysis of the problems, including construction of an urban rainwater recovery system, construction of urban rainwater storage facilities, and construction of data platforms faced by China's sponge city, this paper puts forward the guiding principles of promoting the construction of a sponge city. The guiding principles are to cooperate to deal with climate change and ecological civilization construction, to study the foreign experience, and to unite multiple subjects, integrate multiple elements, design multiple processes, form a joint force, and create an all-round response system to deal with urban rainstorm waterlogging. Then, this paper gives policy recommendations on how to deal with the urban rainstorm waterlogging disasters, which include improving the defense standards, encouraging social participation, popularizing the construction of sponge cities, perfecting the monitoring and early warning system, strengthening the scientific planning of cities, strengthening the ability of dealing with catastrophes in metropolitan areas, the overall planning of cross-regional responses, and enhancing the awareness of decision makers. Finally, this paper expounds the reference significance of urban rainstorm waterlogging control in China to the global audience. This paper explores the significance of comprehensively and scientifically understanding urban rainstorm waterlogging disasters, and provides support for long-term planning and high-quality construction of future safe cities.

Keywords: urban rainstorm waterlogging; urbanization; climate change risk; drainage system; urban governance; urban catastrophe risk prevention; China

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1. Introduction

Due to the effects of global warming and rapid urbanization in recent years, urban rainstorm events are becoming more frequent [1–3], and are occurring at the same time across the world, resulting in a high risk of urban rainstorms and flood disasters [4–6].

China is a high-risk, flood-prone area when it comes to the frequency of global flood-causing factors [7]. It is estimated that the global economic exposure to rainstorms and floods will increase to USD $158 billion by 2050 [7]. "Waterlogging every rainstorm" has become a significant problem in the sustainable development of large- and medium-sized cities in China [8–11]. It has led to serious economic losses, casualties, and various kinds of urban operation risks, arousing strong concern from society [12]. Global warming, rapid economic growth, poor infrastructure, lack of urban planning and design concepts, insufficient comprehensive regulations and control ability of river basin systems, paralytic thinking and fluke mentality in urban disaster prevention and, finally, heavy rain, can destroy the defense capabilities of a city, and lead to large-scale urban waterlogging [13–16]. For safe and healthy development of a city, urban rainstorm waterlogging needs to be improved and solved by comprehensive measures [17].

Two-thirds of China's land area is presently at risk of flooding [18]. About 62% of more than 500 cities in China have experienced urban rainstorm waterlogging disasters in recent years [19]. Among them, 137 cities have suffered from rainstorm waterlogging more than three times, and 57 cities have accumulated water for more than 12 h [20]. Moreover, there were 184 cities in China experienced waterlogging in 2012; 234 in 2013; 127 in 2014; 154 in 2015; 183 in 2016 [21]. In general, rainstorm waterlogging disasters in China are more serious in the south than in the north, more serious in the mid-east, especially in the eastern urban agglomerations, and light in the west [22–24]. The rainstorm waterlogging disaster in China is becoming more serious [25–31], and the situation is not optimistic.

Considering the background of severe rainstorm waterlogging, how to better understand the natural and human causes of rainstorm waterlogging in China is not only the focus of academic circles [32–37], but also the basic work of the government (i.e., to carry out rainstorm waterlogging control). It is also one of the important aspects of this paper. Regarding natural, man-made factors, this paper first analyzes the potential factors causing rainstorm waterlogging in China. Then, based on the international model of urban rainstorm waterlogging management, their advantages and typical characteristics are analyzed. Combined with the sponge city construction policy proposed by China, to solve the problem of urban rainstorm waterlogging, this paper analyzes the main problems faced by China in promoting the construction of a sponge city. On the basis of the above analysis, this paper finally provides policy suggestions for the Chinese government to control urban rainstorm waterlogging, and expounds China's experiences in controlling urban rainstorm waterlogging, which may be of reference value to other countries and regions in the world (Figure 1).

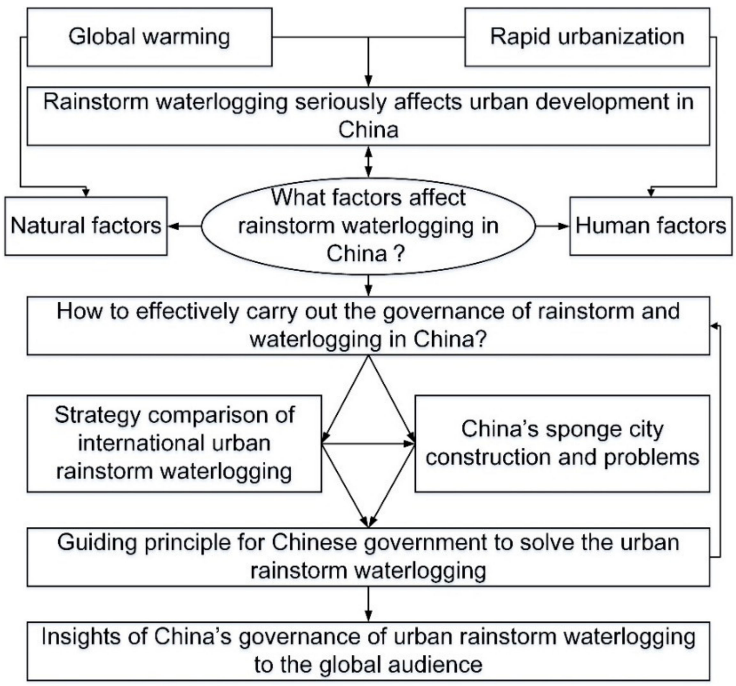

Figure 1. The logical framework of this paper.

2. Diversified Potential Causes of Urban Rainstorm Waterlogging in China

2.1. Internal Logic between the Causes of Urban Rainstorm Waterlogging

The formation of urban rainstorm waterlogging in China is the result of a variety of natural and human factors [21,23,37]. The increase of urban rainstorms caused by global warming is an objective natural factor [1,2,7], but it is worth noting that global warming causes the increase of carbon dioxide emissions from human society, so it implies the role of human factors [21]. In the process of China's urbanization, due to the lack of foresight in urban planning, urban construction has destroyed the original natural geographical landscape pattern on a large scale, resulting in many unreasonable factors to expand urban rainstorm waterlogging [7,27]. China's urbanization construction constantly erodes the limited space of absorbing rainstorm in cities, which makes it difficult for cities to absorb a large amount of rainwater resources in a short-time in case of rainstorms [35]. Rainstorms often affect the normal operation of the whole city through the weak links in the city [27]. The existing urban drainage pipe network is old, the management is chaotic, and it has not been improved with global warming and regional environment changes, which leads to a low level of urban storm waterlogging protection compared with the increasing number of rainstorm [29,32]. At the top level of urban development, emergency planners and urban development planners do not pay enough attention to urban rainstorm waterlogging (a basic security issue), leading to the frequent occurrence of urban rainstorm waterlogging in China at an institutional level [21,23]. Based on the logical analysis of the above factors, and combined with the characteristics of climate change and urban development in China, this paper analyzes the potential causes from the following eight aspects (Figure 2).

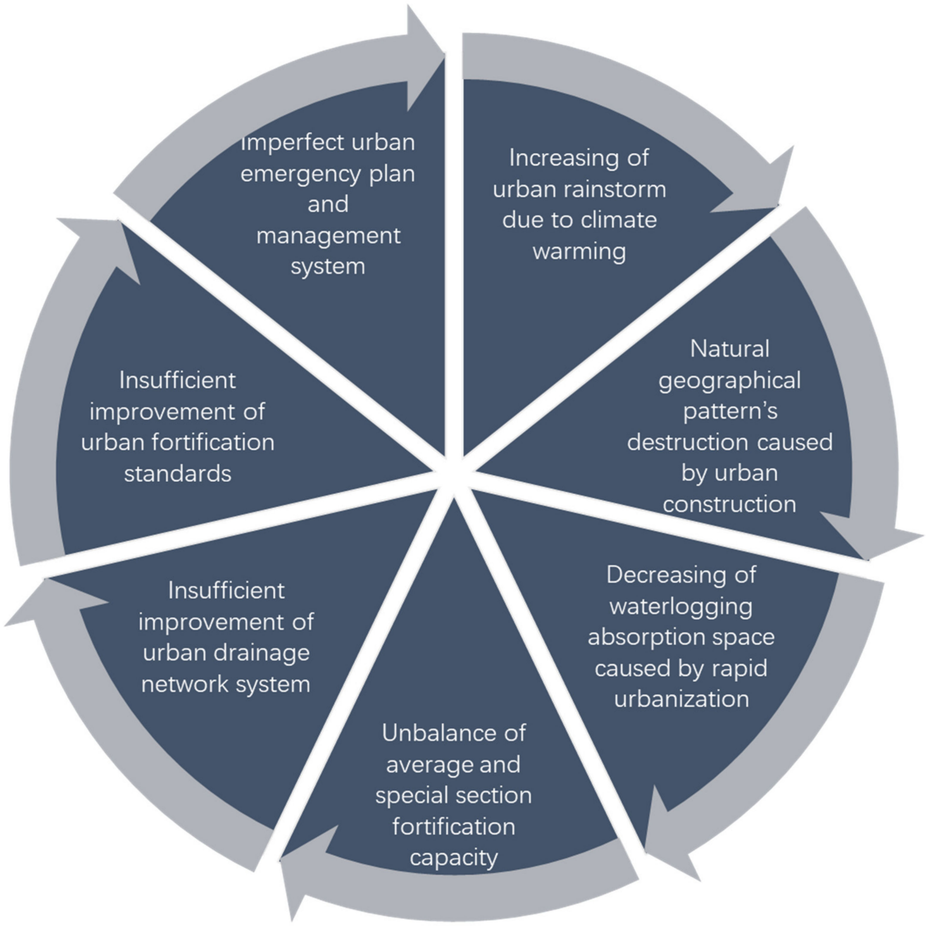

Figure 2. Diversified potential causes of urban rainstorm waterlogging in China.

2.2. Increase of Urban Rainstorms Due to Climate Warming

The frequency and intensity of urban rainstorms tend to increase due to climate warming (Figure 2) [1,2]. Due to global warming, the amount of water vapor in the atmosphere has increased by about 5% compared to the 1960s (Barros and Stocker, 2012). With an increase in the atmospheric average temperature, the energy storage in the atmosphere tends to increase due to the increase of water vapor content. Atmospheric energy storage is released due to the phase change of water vapor, accompanied by a rainstorm [13]. A special report from the Intergovernmental Panel on Climate Change on extreme events and disaster risk management for climate change adaptation estimates the return periods of the daily maximum precipitation in 26 land regions of the world. It was found that the recurrence periods of the two adjacent times exceeding the daily maximum precipitation are becoming shorter, indicating that the frequency of daily maximum precipitation is increasing in the same period of time [1].The short duration of super standard rainstorms occurred frequently in China in recent years and showed an increasing trend year-by-year. The occurrence probability of extreme heavy rainfall events in China was about 10–15% in the 1960s, but the occurrence probability of extreme precipitation events has exceeded 20% in the recent 20 years period [26]. In particular, in the economically developed urban agglomerations in eastern China, due to the influences of "heat island effect" and "Rain Island Effect", local heavy rain events with sudden, short durations, and high intensity, occur frequently in urban areas [23].

2.3. Natural Geographical Pattern Destruction Caused by Urban Construction

China's urban construction and planning focuses on the beauty of geometric symmetry, and the planning concept is an aesthetic coordination rather than landscape coordination. Therefore, the ring pattern of urban construction becomes larger, destroying the original ancient river network and other water systems, which is not conducive to the internal digestion of urban waterlogging. Once encountering high-intensity short-term sudden rainstorm events, it often causes serious urban waterlogging disaster (Figure 2) [34]. Taking the rainstorm waterlogging disaster in Beijing (on 21 July 2012) as an example, 63 waterlogging points (with serious ponding) have changed the original water network patterns in urban construction, and have been built into sunken overpasses and key transportation hubs, with dense traffic and personnel. In particular, many sunken overpasses in Beijing are located in low-lying negative terrain areas [36]. Most of these areas are ancient river channels and ancient river networks. The low-lying areas formed by human factors in urban construction are vulnerable areas of rainstorm waterlogging disasters, which are often "flooded in case of rain". In addition, as a transportation hub, the traffic is blocked slightly, which affects the area, thus greatly aggravating the rainstorm waterlogging disaster. Based on the investigation of the second, third, and fourth ring overpasses in Beijing, it is found that there are 34 overpasses in the second ring road, of which 16 are sinking types, accounting for 47.06%. There are 49 overpasses in the third ring road, of which 12 are sunken, accounting for 27.27%. There are 65 overpasses in the fourth ring road, of which 14 are sunken, accounting for 21.54% [21]. Moreover, the signs under the overpasses are not only chaotic, they are poorly visible (many signs are relatively hidden). Furthermore, under the overpass holes, the light in these places is often too poor to be detected, especially on cloudy days. The most important thing is that there is no warning light. When it rains at night, it cannot give a good–danger signal to passers-by. If the water level is too high, it is extremely easy to cause accidents.

2.4. Decreasing of Waterlogging Absorption Space Caused by Rapid Urbanization

China's urbanization process is presently in a stage of rapid development. In the process of urbanization, a large number of the population, wealth, and industries are concentrated in urban areas [23,37]. The city scale is expanding continuously, impervious surface layers are greatly increasing, urban forest land and garden land are reduced, and the urban rivers and lakes are shrinking, which greatly reduces the storage space of urban rainstorm waterlogging (Figure 2) [17]. For example, the continuous development of urban construction from the inner ring to the outer ring in Beijing has not only changed the original water system, but also affected the existing urban water system pattern; thus, affecting its flood control and drainage function [35]. There were 127 lakes in Wuhan city in 1949. With rapid and extensive urban construction, people scrambled for construction space and resources from lakes. There are only 38 lakes currently left [21]. Urban construction has changed the urban hydrological process, reducing surface infiltration and speeding up runoff; urban flood hydrograph has become higher, sharper, and thinner, with flood peak occurring ahead of time. The rainwater generated by short-time confluence causes great pressure on the underground drainage network, leading to the sharp increase of urban flood discharge channel flow, which is bound to cause severe challenges to the adjacent regional waterlogging. In addition, the development of urban underground space is becoming more sufficient. With the intensive distribution of underground garages, subways, underpass tunnels, underground power, heat, and telecommunication pipelines, underground space for storing rainwater is becoming less and less. Rainwater also has a severe impact on underground construction—even the phenomenon of ground subsidence appears. At present, the situation of underground space utilization in most cities in China is simple and the utilization type is single [37].

2.5. Unbalance of Average and Special Section Fortification Capacity

The average fortification capacity and the fortification capacity of special sections are not properly dealt with in urban construction. Urban operation is a network system extended in all directions, and interconnection is a typical feature of urban systems. Due to the different levels of disaster prevention and resistance in different areas of urban systems, the impacts of urban rainstorms and waterlogging are leading to the whole bodies (Figure 2). Areas with higher fortification levels will be affected by surrounding areas with lower fortification levels. The fortification levels of special sections will affect the overall urban operation through the network system, extending in all directions, forming a typical barrel effect. At the same time, rapid urban construction has occupied a lot of land, and there is no space for the installation of a pumping station for the sunken overpass in these areas [21]. Therefore, average fortification capacity cannot be used to replace the fortification capacity of special sections. High average fortification capacity does not mean that the overall fortification capacity is high. When encountering severe rainstorm events, special areas with high vulnerability often become key factors affecting the overall situation.

2.6. Insufficient Improvement of Urban Drainage Network System

Due to the poor planning and management of urban flood drainage pipelines in China, there are some problems, such as low popularization rates of drainage pipelines, aging, lagging, unsound facilities, blockage of pollutants, insufficient water carrying capacity, overload operation, and urban construction, which cannot meet the drainage demand in flood season (Figure 2). Taking Beijing as an example, there are four rivers for flood discharge in urban areas: Liangshui River, Qinghe River, Bahe River, and Tonghui River. However, due to the blockage of pollutants discharged in daily life and production, the effectiveness of urban rainstorm flood discharge is seriously affected [21]. At present, the drainage pipelines of most cities in China lack conventional and effective management. Problems in urban construction include paying attention to the ground construction, ignoring the underground construction, and not matching the development of the ground construction and underground construction [27]. Ground waterlogging is often affected by the poor development of underground supporting facilities, which has become a common feature of rainstorm waterlogging in Chinese cities [34]. It is worth noting that the urban drainage pipelines in China include sewage pipes, rainwater pipes, and rainwater sewage combined pipes. The density of drainage pipes in most provinces of China is less than 15 km/km^2. The proportional length of the rainwater pipes in the total length of the above three pipes is less than 40% [21]. The vast majority of underground pipelines are used for sewage rather than drainage. Therefore, once encountering severe rainstorms, urban drainage networks will face severe challenges.

2.7. Insufficient Improvement of Urban Fortification Standards

Under the background of climate change, there are more severe rainstorm events, but most cities in China have not improved the urban fortification standards (Figure 2). In recent years, the intensity of rainstorm events that cause urban rainstorm waterlogging in China have more than 50-year return periods. The old drainage standard cannot cope with the increasingly frequent urban rainstorm waterlogging. Among the 640 cities undertaking flood control tasks in China, 80% of the cities have rainstorm and waterlogging standards of less than 50-year return periods, no more than 10 cities reach 100 year-return periods, 18% have more than 50-year return periods, and about 21% of cities have not reached 10-year return periods [7]. Using Beijing as an example, the hourly drainage standard in most areas can withstand the rainstorm with a return period of 1–3 years, and some important areas have a return period of 3–5 years. Only areas as important as Tiananmen Square have reached a 10-year return period. The standard of rainstorm and flood prevention in important regions of China is far lower than that of developed countries, such as the United Kingdom, the United States, and Japan [21].

2.8. Imperfect Urban Emergency Plan and Management System

China's emergency plans are strategic, not tactical. China's major cities have contingency plans, but public perception has not improved significantly in the face of sudden floods (Figure 2). This is mainly because there are too many theoretical, procedural, and universal operation modes in urban emergency plans, which are difficult to meet the personalized challenges of each disaster and cannot adapt to the circumstances, leading to local deterioration and no fundamental improvement. Urban management mechanisms are not perfect, and there is a lack of coordination concerning urban rainstorm and flood procedures. Drainage, waterlogging removal, and flood control belong to different departments. The division of authority and the responsibilities of departments are unclear. Therefore, the ability and level of emergency management need to be further improved. Although most of the key flood control areas in China have prepared flood risk maps, which have not been released to the public, and legislation lags behind, the flood risk maps do not have legal status and are not binding. The users of flood risk maps are limited to flood control command agencies (their application scopes and fields are very limited) [34,35,37].

2.9. Urban Development Planning with Prominent Problems

In the urban development process, primary problems that need to be solved include employment, housing, transportation, and other aspects related to human survival. Due to huge investments, long construction periods, and slow construction benefits, flood control and waterlogging drainage is often ignored by Chinese urban decision makers. Urban development planning is greatly influenced by decision makers, especially urban flood control and drainage projects, which cost a lot and last for many years. The planning made by a former decision maker is often shelved or changed when a new decision maker is in power, which leads to the stagnation of flood control planning in many cities in China. However, due to the lack of planning in most cities in China, the construction of ground cities is advancing rapidly [7]. In some old urban areas, there are new buildings planned on the drainage pipe network that cannot be demolished. Once complete, it is very difficult to repair or rebuild the underground flood control facilities. Even if problems are discovered, they can only be patched, and the cost is even higher. In addition, the urban drainage network reconstruction project is facing approval form of the government water department and housing construction department, and the construction cannot keep up with the government approval, leading to the lag of urban drainage system construction. At present, the economic cost of rebuilding the drainage system is very high. The average cost of an underground pipe gallery, per kilometer, is about 100 million renminbi (RMB) yuan. If the construction is carried out (according to high standards), it will cost at least 130 million RMB yuan per kilometer, which has not been included in the huge maintenance and renewal costs after the operation of the pipe gallery [21].

3. Strategy Comparison of International Urban Rainstorm Waterlogging

The key to dealing with urban rainstorm waterlogging is to develop adaptive technologies for urban storm water management. The core of the different technologies is to increase surface infiltration, as well as reduce runoff and its various impacts. Internationally, many developed countries have proposed (and developed) urban storm water management measures and systems with regional characteristics. Although the system names and key directions of regions are different, the core concept is basically the same—that is, rainwater source control, recycling, and multi-functional storage [38–42]. Among them, rainwater source control involves the use of green space, vegetation, and buildings in the rain source area to absorb and reduce rainwater runoff. The typical technologies include house roof greening, permeable green space construction, rainwater absorbing garden, permeable road construction, permeable ditch construction, etc. Compared with the concept of rainwater source control, urban rainwater recovery has a long history [38]. Its core concept is to effectively utilize rainwater and reduce groundwater intake. This concept cannot only effectively conserve regional water resources, solve the problem of urban water shortage, and effectively avoid urban land subsidence caused by excessive groundwater intake, but also reduce the pressure of urban drainage network systems and the possible effects of waterlogging [39]. The core idea of urban rainwater regulation and storage is to use specific regional measures to control the flood in case of rainstorm waterlogging disasters, on the basis of protecting the existing functions of a city [40,41].

The concept of a sponge city has been put forward with the aggravation of urban rainstorm and waterlogging in China [17]. Based on this concept, the Ministry of Housing and Urban Rural Development launched the "Sponge City Construction Technical Guide". Its core is to build a new city that can adapt to environmental changes and effectively respond to natural disasters, to increase urban resilience, and effectively alleviate urban rainstorms and floods [27]. The concept of a sponge city coincides with the rainwater management measures of foreign cities. How to absorb foreign experience and serve the construction of a local sponge city has become one of the key problems in solving urban waterlogging in China [29].

4. Main Problems of Sponge City Construction in China

The first problem of a sponge city construction in China is the construction of an urban rainwater recovery system (Figure 3). An urban rainwater recovery system is an important part of sponge city construction. In 2006, the Ministry of Housing and Urban Rural Development issued the "Technical Code for Rainwater Utilization in Buildings and Residential Quarters", which aims to promote the scientific development and construction of an urban rainwater recovery system in China, so as to obtain comprehensive economic, social, and environmental benefits [21]. However, at present, the scale (and construction) of an urban rainwater recovery system is affected by many aspects of urban construction and development in China; the urban rainwater recovery system has not really been built or played its role in China [37]. Moreover, the urban rainwater recovery must deal with pollutants. At present, the construction of an urban rainwater recovery system in China has not been mentioned in the national policy [27].

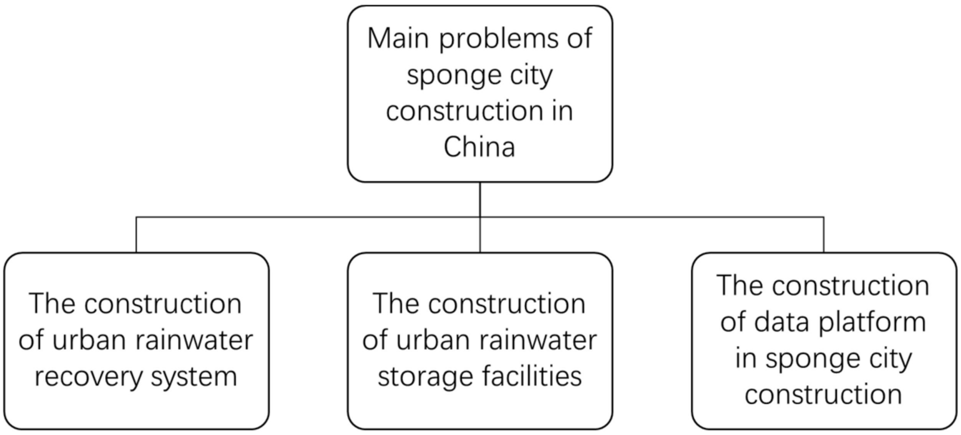

Figure 3. Main problems surrounding a sponge city construction in China.

The second problem of a sponge city construction in China is the construction of urban rainwater storage facilities (Figure 3). In China, urban land is precious and scarce [30]; thus, how to scientifically plan and effectively use urban rainwater storage facilities is key. The core issue is that the type, scale, and quantity of urban rainwater regulation and storage facilities have not been reasonably demonstrated. Therefore, the implementation of urban rainwater regulation and storage facilities is affected. In addition, the lack of awareness of the natural geographical pattern in the existing urban construction in China has led to the continuous emergence of facilities, such as a sunken overpass, which also has a negative impact on the construction of a sponge city [43].

The third problem of a sponge city construction in China is the construction of a data platform (Figure 3). Sponge city construction involves information data sharing and integrating data across departments. In China, this generally includes a transportation department, urban construction department, hydrological department, meteorological department, civil affairs department, emergency management department, public finance department, etc. [44]. Although the concept of a sponge city has been put forward—for many years—in China, an official website that integrates data across departments, has not been built. How to cooperate with multiple departments in sponge city construction is not only a policy level matter, but also concerns determining internal functions and responsibilities, which need to be considered as a whole.

5. Key Points, Guiding Principles, and Policy Suggestions for the Chinese Government to Solve Urban Rainstorm Waterlogging

It is necessary to abide by the principle of urban sustainable development to deal with urban rainstorm waterlogging. Based on the above diversified causes of urban rainstorm waterlogging in China, international governance experience and problems faced by sponge cities in China, the effective governance of urban rainstorm waterlogging in China not only requires changing the concept of urban rainstorm waterlogging governance from the height of top-level design, and upgrading it to the height of national construction and governance, but also requires learning and absorbing the advanced ideas and practices of urban rainstorm waterlogging governance in the world [43,44]. At the same time, in practice, the Chinese government should cooperate with various forces of urban governance, gather consensus, and create a joint force, to effectively control urban rainstorm waterlogging (Figure 4).

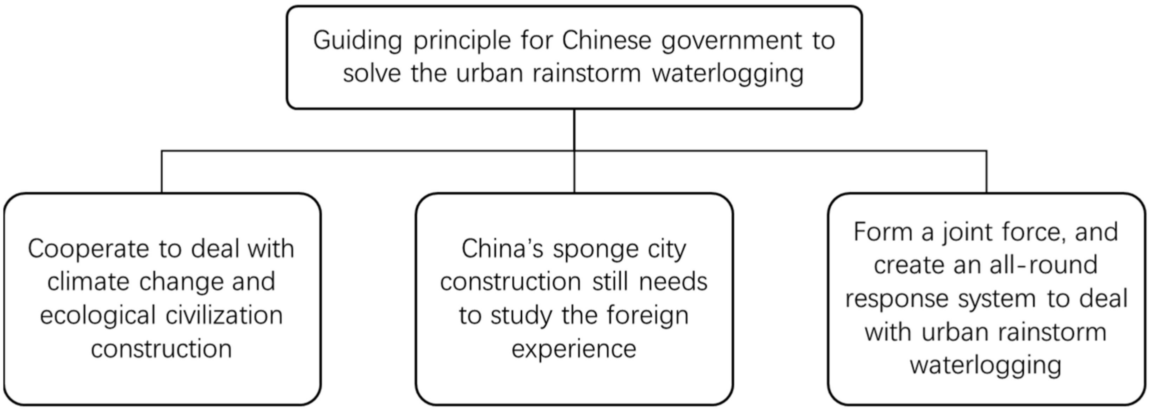

Figure 4. Guiding principles for the Chinese government to solve urban rainstorm waterlogging.

First, to deal with urban rainstorm and waterlogging, the Chinese government should coordinate the coping with climate change and ecological civilization construction (Figure 4). Simply dealing with climate change cannot meet the needs of urban system operations. Urban areas should promote the control of waterlogging to the height of ecological civilization construction, take climate change as the starting point, pursue advantages, avoid disadvantages, and follow scientific planning, to ensure the long-term stability of a city. China's ecological civilization construction policy essentially requires efforts to promote green development, circular development, and low-carbon development; adhere to the basic national policy of saving resources and protecting the environment, and adhere to the policy of giving priority to conservation, protection, and natural recovery [44]. China's ecological civilization construction policy should not only involve its own ecological construction, environmental protection, and resource conservation well, but also include it in a prominent position, in national development, and integrate it into all aspects (i.e., the whole process of economic construction, political construction, cultural construction, and social construction), which means that the construction of ecological civilization is not only parallel with economic construction, political construction, cultural construction, and social construction, but also in a comprehensive way, in order to form the five major constructions, The Chinese government should integrate the concept, viewpoint, and method of ecological civilization into the process of economic construction, political construction, cultural construction, and social construction. The above objectives of China's ecological civilization construction policy provide a solid theoretical basis, top-level design, and policy support for coping with the risk of climate change, especially urban rainstorm and waterlogging. Therefore, the first problem to be solved in China's current urban rainstorm waterlogging is the change of governance concept—that is, to coordinate the response to climate change and ecological civilization construction [43].

Second, in regards to China's sponge city construction, foreign experience needs to be studied (Figure 4). Foreign urban storm water management technology has advantages of conforming to local policies and environments. It is necessary to study foreign governance paradigms of urban rainstorm waterlogging, develop sponge city construction technologies and schemes suitable for different regions, establish a perfect rainstorm waterlogging management system, and effectively improve urban resilience.

Third, the Chinese government should unite multiple subjects, integrate multiple elements, design multiple processes, form a joint force, and create an all-around response system to deal with urban rainstorm waterlogging (Figure 4). Through construction, communication, coordination, and cooperation, a top-level design is carried out. From the response concept of urban rainstorm waterlogging, scientific fortification, multi-participation, and sponge city construction, multiple elements are integrated to achieve advantages and avoid disadvantages. At the defense level, we should cooperate with governments, institutions, enterprises, and individuals at all levels to actively participate in the construction of a sponge city, and effectively deal with urban rainstorm and waterlogging.

Based on the above guiding principles, the government needs to take specific policy recommendations as follows in China:

Firstly, the government needs to establish the idea of "fighting a protracted war" of urban rainstorm and waterlogging (Figure 5). The current urban waterlogging problem in China cannot be solved in a short-time. With the process of climate change and urbanization, the problem of urban rainstorms and floods in China will become more prominent. Therefore, it is necessary to do a good job in top-level design, system formulation, long-term construction, maintenance, and operation preparation for urban waterlogging control. At present, it is critical to establish a basic rainwater and sewage diversion system, and reconstruct the rainwater pipe network and drainage pump station in key areas. The government should pay back historical debts as soon as possible, treat the symptoms and root causes, get rid of the state of "waterlogging every rain", and gradually achieve the goal of no-ponding in light rain, no waterlogging in heavy rain, no black and smelly water bodies, and relief of urban heat islands.

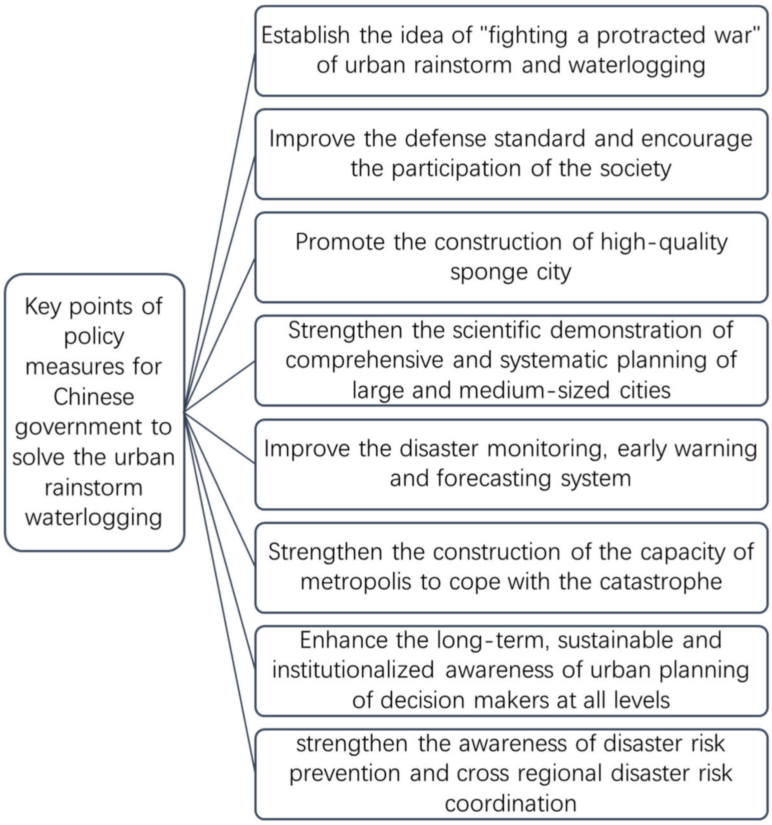

Figure 5. Key points of policy measures for the Chinese government to solve urban rainstorm waterlogging.

Secondly, the city should improve the defense standard and encourage society to participate in the management of urban rainstorm waterlogging disaster risk (Figure 5). Combining the experience and technology of urban rainstorm flood control construction from foreign countries with the actual situations of urban rainstorms and floods in China would involve reasonably improving the drainage design standard, scientifically planning the construction of an underground corridor, and avoiding the old development road of "above ground first and then underground". In addition, relying solely on government funding to construct a drainage pipe network places great pressure on China's economic development. Therefore, it is suggested that, while the central, provincial, and municipal governments finance the construction of an urban underground pipe network, various financial means, such as insurance, funds, and bonds, should be used to promote the construction of the project, and social capital should be encouraged to participate in the construction of a sponge city.

Thirdly, the government should promote the construction of a high-quality sponge city (Figure 5). The concept of a sponge city is put forward to solve the problem of urban waterlogging. According to its concept, urban planners should start the construction of roof rainwater collection systems as soon as possible, promote sponge type buildings and communities, sponge roads, and squares, and promote the construction of green space parks and natural ecological restoration. It would not only absorb and utilize more rainwater on site, and reduce rainwater discharge in the drainage network, but also save thousands of cubic meters of tap water for toilet flushing, reduce waterlogging, and save water—effectively achieving a win–win situation.

Fourthly, the government should strengthen the scientific demonstration of comprehensive and systematic planning of large- and medium-sized cities (Figure 5). On the one hand, the original natural river network survey is carried out, on the other hand, the urban micro topography and geomorphic fluctuation changes are investigated. The impact of large-scale road and bridge construction on local disasters is evaluated, and the harmonious coexistence of urban development and natural geographical patterns are emphasized. At the same time, new technologies and new materials should be used in urban construction to promote industrial upgrading and transformation, effectively improve the fortification level of infrastructure, promote the transformation and relocation of villages in cities with prominent security problems, and enhance the comprehensive disaster prevention capacity of vulnerable areas.

Fifthly, the government should improve disaster monitoring, early warning, and forecasting system (Figure 5). The first is to carry out large-scale investigations of natural disaster risks, and compile a large-scale comprehensive natural disaster risk assessment and zoning map of the whole city. The government should carry out the general survey and detailed investigation on the hidden danger points of urban waterlogging, plain flood discharge areas, ancient river channel areas, mountain torrents, collapses, landslides, debris flows, and earthquake hazard sources in mountainous areas, and compile account books. It is critical to establish and improve the comprehensive natural disaster monitoring and forecasting early warning network systems by using the modern internet of things, high-precision remote sensing, a geographic information system, and communication technology, as well as a group survey. It is urgent to establish and regulate a unified reporting channel of natural disaster information by provinces, cities, districts, streets, and communities, and acknowledge the important role of grassroots community organizations in regards to disaster information early warnings, disaster statistics, and verification, to ensure timely and accurate reporting of disaster information.

Sixthly, it is critical to strengthen the construction of the metropolis's capacity to cope with a catastrophe (Figure 5). It is crucial to improve the construction system of an urban lifeline access capacity and warning system under catastrophic disaster conditions. At the same time, it is necessary to establish the risk assessment system (of a lifeline system) under catastrophe conditions, and formulate a catastrophe response plan for the metropolitan area. In urban planning and construction, it is necessary to integrate the two major constructions—of lifeline accessibility and warning—to promote urban development and the construction of a comprehensive disaster prevention plan. Focus on the case study of heavy and special natural disasters, use scenarios and simulation technology to formulate emergency plans for serious and special natural disasters, and objectively evaluate the ability and effect of an urban lifeline system to cope with catastrophic disasters.

Seventhly, it is imperative to enhance the long-term, sustainable, and institutionalized awareness of urban planning of decision makers at all levels (Figure 5). On the one hand, once scientific urban planning is approved, it must be stipulated in the form of legislation. If there is no major accident, it cannot be changed at will to ensure the continuity of urban construction; even if it must be changed, it needs to be evaluated by a third party appointed by higher authorities. At the same time, urban decision makers should improve their understanding of urban construction, and incorporate it into the national strategy of ecological civilization construction. On the other hand, the relevant business management departments should scientifically prepare flood risk maps, formulate risk assessment and emergency plans for catastrophic floods, including reservoir optimal operation plans, reservoir dam break risk identification, emergency plan management of engineering and non-engineering measures, personnel risk avoidance, transfer methods, etc., which is an insurmountable task for urban development. At the same time, the government should make full use of modern information technology and model means to improve the intelligence and credibility of decision-making.

Eighthly, it is urgent to strengthen the awareness of disaster risk prevention and cross regional disaster risk coordination (Figure 5). First, strengthen education. In schools, we should strengthen disaster prevention and mitigation education, compile teaching materials, train teachers, increase disaster prevention, and reduce education hours. In communities, we should popularize disaster knowledge, improve risk prevention awareness, be familiar with disaster risks in the jurisdiction, master escape skills, and understand the setting and use of surrounding shelters and related disaster prevention and mitigation facilities. Secondly, to use traditional and new media, such as television, radio, and microblogging to carry out regular disaster prevention and mitigation publicity activities, so that the public cannot only understand the level of various disasters in the forecast information, but also understand how to deal with such disasters, and understand the meaning of various disaster warning signs. Thirdly, to establish the concept of urban safety development, which is to be prepared for danger in times of safety, to improve the public's psychological ability to bear and deal with natural disasters, to minimize the loss of disasters. We should strengthen the coordination of cross regional disaster relief/risk prevention efforts, strengthen the construction of natural disaster rescue command systems and disaster relief material (regarding emergency support capacity), and improve and strengthen the construction of grassroots disaster relief teams and disaster relief emergency equipment.

6. Insights of China's Governance of Urban Rainstorm Waterlogging to the Global Audience

Urban rainstorm waterlogging is the result of the interactions among climate change and rainstorms, urban development planning and concepts, and waterlogging prevention facilities and human activities. China's urban rainstorm waterlogging control has some aspects that are worthy of reference and learning (from a global audience)—from a governance concept to specific practice.

First, China implements more comprehensive and scientific ecological civilization construction (regarding urban rainstorm waterlogging control). Human beings need "self-revolution" to accelerate the formation of the green development mode and lifestyle, to build an ecological civilization and a beautiful earth [45,46]. One of the key directions in the construction of an ecological civilization is to actively deal with the integration of climate change and green city development. It focuses on system planning to promote the integration of strategic planning, to highlight synergy (to promote the integration of policies and regulations), and to lay a solid foundation to promote the integration of the system. The construction of an ecological civilization requires that, in the face of resource constraints, serious environmental pollution, and ecosystem degradation, we must establish the concept of an ecological civilization that respects, conforms to, and protects nature, following the path of sustainable development. Therefore, the construction of an ecological civilization has become China's national strategy to deal with the climate change risk, including urban rainstorm waterlogging, and it is also one of China's plans to deal with the risk of global climate change [43].

Second, a sponge city construction concept proposed by China involves a new generation of urban stormwater management, which aims to make cities as flexible as sponges in adapting to environmental changes and natural disasters brought by rainstorms. Starting from ecosystem services, the core of a sponge city is to build water ecological infrastructure through cross-scale construction, combined with various specific technologies. A sponge city is an innovative performance of promoting green building construction, low-carbon city development, and smart city formation. It is an organic combination of modern green new technology and social, environmental, cultural, and other factors under the background of global change. The construction of a sponge city follows the principle of ecological priority, which combines natural ways with artificial measures [44]. On the premise of ensuring the safety of urban drainage and waterlogging prevention, it can maximize the accumulation, infiltration, and purification of rainwater in urban areas, and promote the utilization of rainwater resources and ecological environment protection. The construction of a sponge city is not to replace the traditional drainage system, but to "reduce the burden" and supplement the traditional drainage system, to maximize the role of the city itself. In the construction of a sponge city, the systematicness of natural precipitation, surface water, and groundwater, the coordination of water supply, drainage, and other aspects of water recycling, and the consideration of its complexity and long-term nature are coordinated [27]. Therefore, sponge city construction is a concrete plan for China to promote green urbanization, providing a reference for the construction and development of cities across the world, especially in developing countries [43,46].

7. Discussion

Dealing with urban rainstorm and waterlogging has become one of the prominent problems faced by urban security development, and its governance involves different levels of problems. From a global perspective, effective response to climate change and its disastrous impact is related to human well-being and sustainable development. How to gather the consensus of all countries in the world and form an effective mechanism to deal with global climate change is still a difficult problem for policymakers in all countries. Because climate change itself has the characteristics of space–time difference, the adverse impact on some areas may be small or favorable in a short-time. However, in the long run, climate change is not conducive to the well-being of human beings. Human society should form a consensus to deal with climate change and cooperate to implement countermeasures as soon as possible. From the regional level, under the background of global climate change, how to give consideration to the scientificity, long-term, and predictability of urban development, and how to formulate a strategic plan in line with regional sustainable development, is a development problem that policymakers of all countries must face. Urban rainstorm waterlogging, as a product of natural and human factors, needs top-level design at the institutional level. At the local level, how to systematically promote the construction of a sponge city, systematically solve the problem of urban rainstorm waterlogging, and promote the development of a local economy, requires multi-disciplinary system thinking.

Based on the above analysis, we think that we can carry out relevant research and practices from management concepts, legal policies, applications in planning, and technical levels. In terms of management concept, we should adhere to the basic principles of sustainable development, close to the natural state and multi-functional urban stormwater management concept, change the separate flood discharge and waterlogging storage mode, and form a multi-functional management mode of flood control and disaster reduction, pollution control and prevention, water ecosystem restoration and protection, and urban environmental beautification and comprehensive utilization of water resources. In terms of laws and policies, we should build an efficient urban rainwater management system, formulate laws and regulations on urban rainwater utilization and management, adjust the coordinated management mode of urban rainwater and flood, change the chaotic management situation of water control, implement the integrated construction of water affairs, and ensure the implementation and promotion of sustainable urban rainwater and flood management technical scheme. In terms of application and planning, according to the comprehensive urban planning, the development of population, economy, resources, and ecological environment shall be coordinated. Considering factors, such as natural conditions, land use, infrastructure construction, and economic development level, the appropriate technical scheme for urban rainwater and flood management shall be established to deal with the urban rain and flood problems under the changing environment. In terms of the technical level, the government should strengthen the research and practice of source control technology and prevention measures, establish long-term monitoring and evaluation technology, combined with engineering measures and non-engineering measures, to ensure the effectiveness and adaptability of urban rainwater and flood management technology to improve the level of urban rainwater and flood management.

8. Conclusions

This paper mainly introduces the situation, causes, experiences, problems, and suggestions of urban rainstorm waterlogging disaster risk management in China under the background of climate change. The main conclusions are as follows. First, due to global warming and rapid urbanization, urban rainstorm waterlogging in China is becoming more serious, and the situation is not optimistic. Second, The main causes of urban rainstorm waterlogging in China are caused by the joint action of many aspects—that is, climate warming leads to the increase of urban rainstorm frequency and intensity; urban construction planning does not follow the original natural geographical pattern; rapid urbanization construction processes bring many adverse aspects; urban construction ignores the relationship between the average fortification capacity and the fortification capacity of special sections; the old problems regarding drainage network system facilities are prominent; China's urban fortification standards under the changing environment have not kept pace with the times; the urban emergency plan and management system are not perfect; the long-term planning and evaluation index guidance of urban development are prominent; and the upper design system of urban safety risk management is unreasonable. Third, the strategies of urban rainstorm waterlogging control at home and abroad are different. Although the systems, names, and emphases vary in different regions, the core concepts are mainly rainwater source control, rainwater recycling, and rainwater multi-functional storage. China's sponge city construction is similar to it, but it still needs to learn from foreign experience to serve local urban waterlogging control. Fourth, the policy suggestions for urban rainstorm waterlogging control in China are mainly manifested in eight aspects: establishing the idea of fighting a protracted war for urban rainstorm waterlogging; improving the fortification standards and encouraging social participation in the control; promoting the construction of a high-quality sponge city; strengthening the scientific demonstration of comprehensive system planning for large- and medium-sized cities; improve disaster monitoring, early warning, and forecasting systems; and vigorously strengthening the response of the metropolis. Concerning the construction of a catastrophe capacity plan, the awareness of long-term, sustainable, and institutionalized urban planning of decision makers at all levels should be enhanced, and the awareness of disaster risk prevention and cross regional disaster risk coordination of all people—the whole region (at all times)—should be strengthened. This paper is of great significance for comprehensive and scientific understanding of urban rainstorm waterlogging disasters in China, and provides crucial information for long-term planning and high-quality construction of safe cities in the future.

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