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Sustainable Water Management in Cities under Climate Changes

Zrównoważone zarządzanie wodą w miastach w warunkach zmian klimatycznych

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Abstract
Increasing global change pressures like urbanisation, climate change, deterioration of urban water infrastructure, cities have difficulties in efficiently managing water resources. To manage these challenges cities have to improve the efficiency of urban water systems by rethinking old paradigms and developing more sustainable solutions.. Between 1.8 and 2.5 % of the annual global GDP is needed for implementation of water-related sustainable development goals. Currently the main challenge is to ensure public health and satisfy water needs while protecting the quality and quantity of water resources for future generations by efficient production and use of water, energy and materials. The paper presents principles to develop water-sensitive cities that ensure access to safe water and sanitation and also to increase resiliency to floods and droughts.

Key words: climate change, population growth, sustainable development, water management, water resources

Streszczenie
Zarządzanie zasobami wodnymi w obszarach miejskich jest coraz bardziej problematyczne z uwagi na intensywną urbanizację, zmiany klimatu oraz starzenie się miejskiej infrastruktury wodnej. Aby sprostać tym wyzwaniom, miasta muszą poprawić efektywność miejskich systemów wodnych poprzez odejście od dotychczasowych paradygmatów i opracowanie bardziej zrównoważonych rozwiązań. Obecnie około 1,8 ÷ 2,5% rocznego światowego PKB potrzebne jest do realizacji celów w zakresie zrównoważonego rozwoju gospodarki wodnej. Głównym wyzwaniem jest zapewnienie zdrowia publicznego i zaspokojenie potrzeb w zakresie dystrybucji wody, przy jednoczesnej ochronie jakości i ilości zasobów wodnych dla przyszłych pokoleń dzięki wydajnej produkcji i wykorzystaniu wody, energii i surowców. W artykule przedstawiono główne wytyczne dla rozwoju miast zapewniających bezpieczne źródła i systemy dystrybucji wody, odprowadzenie i oczyszczenie ścieków, a także zwiększenie odporności miast na występowanie zjawisk powodziowych oraz okresów suszy.

Słowa kluczowe: zmiany klimatyczne, wzrost zaludnienia, zrównoważony rozwój, gospodarka wodna, zasoby wodne

Introduction

With increasing numbers of people living in metropolitan areas, water, energy and materials need to be used carefully, reused and renewed. By 2030, over 6 billion people are expected to live in cities. More populated, denser cities will be required to provide more efficient services. Water is essential for the well-being of citizens, their safety and social inclusion in cities (IWA, 2016). Historical development pathways are often not appropriate to plan future water systems. Two uncertain factors are forcing the changes in water, wastewater and stormwater management: climate changes and population growth.
The Intergovernmental Panel on Climate Change (IPCC) coordinates the activities of scientists and

other researchers around the world to prepare projections of future climate changes and associated impacts. Climate change projections presented in assessment report are based on the outputs of computer simulations that project how the climate might evolve given different assumptions about greenhouse gas concentrations in the atmosphere. The observed historical record and future simulations indicate that it is certain that temperatures have increased and are likely to continue increasing – even the most optimistic scenario assumes a temperature increase to average value 4°C (fig.1). Increased atmospheric moisture storage is likely to lead to increased precipitation and more frequent and intense precipitation events, although it is less certain that this outcome has already been observed in the historical record (Paludan et al., 2016).

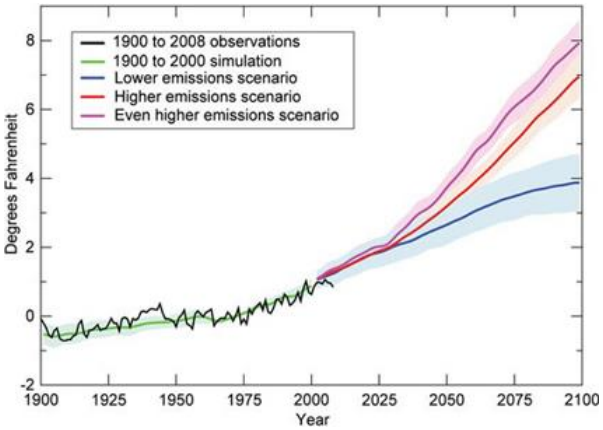

Figure 1. Prediction of world's average temperature growth by 2100 year (IPCC, 2014).

Climate changes may lead increase of the intensity, frequency, and duration of extreme rainfall events, with impacts on urban drainage systems. It is also possible that climate change will affect average sea levels and extreme sea level rise events. Because of computational limitations, global climate models use a grid size that is too large to simulate physical processes that are important for rainfall and other variables at local scales. Therefore, regional climate models are required to project changes in the characteristics of local weather.

In 2013 European Commisssion published *The European Union strategy on adaptation to climate chang*e. Urbanized areas were defined as special category in the structure of geographical space, characterized by a high density of the human population, and thus are very sensitive due to the negative impact of anthropopression. Cities are directly threatened by three phenomena:

- intensification of urban heat island,
- intensive rainfalls causing floodings,
- drought periods (water deficit in cities).

The abovementioned phenomena must be disturbing if we take into account the prediction of population growth. In its most recent forecast, the United Nations predicted that the world's population would keep rising throughout this century, reaching 10.9 billion people by 2100. The urban population in 2014 accounted for 54% of the total global population, up from 34% in 1960, and continues to grow. The urban population growth, in absolute numbers, is concentrated in the less developed regions of the world. It is estimated that by 2017, even in less developed countries, a majority of people will be living in urban areas. The global urban population is expected to grow approximately 1.84% per year between 2015 and 2020, 1.5 % per year between 2020 and 2030. According to United Nation's predictions, the world population is expected to be 67 % urban in 2050. It should be noted that there are major differences in the rate of population growth and urbanization in different parts of the world. Thus, urban areas of the world are expected to absorb all the population growth over the next decades. Deterioration of the water management is expected to be worse, while already in many cities this is a serious problem.

Due to bad economics or poor infrastructure, every year millions of people, most of them children, die from diseases associated with inadequate water supply, sanitation and hygiene. In 2013, 783 million people globally did not have access to potable water – it is nearly 10% of the world's population.

It is certainly not possible to precisely provide either population or temperature, as it depends on many factors, but both values will increase. Cities are major contributors to climate change with estimates suggesting that cities are responsible for more than 75% of global carbon emissions. To safeguard public goods and services, such as water, cities must develop and implement innovative and sustainable solutions to protect their residents.

2. Present situation and future challenges in water management

It is now well established that population and economic growth are placing water resources under increasing pressure. Major regions of the world will face a massive water challenge the coming decades if current trends continue – with potentially devastating consequences for human life and health, business and agriculture, international relations, and the environment if they do not adapt. Today's situation in water management in cities is varied and depends on the location and development of a given country. Globally at least 1,8 billion people use a source of drinking water that is fecally contaminated. Between 1990 and 2015, the proportion of the global population using an improved drinking water source has increased from 76 % to 91 %, but water scarcity affects more than 40 % of the global population and is projected to rise. Over 1,7 billion people are currently living in river basins where water use exceeds recharge. When assessing the situation in water supply it should be emphasized the wastewater management is even more problematic. Near 2,5 billion people

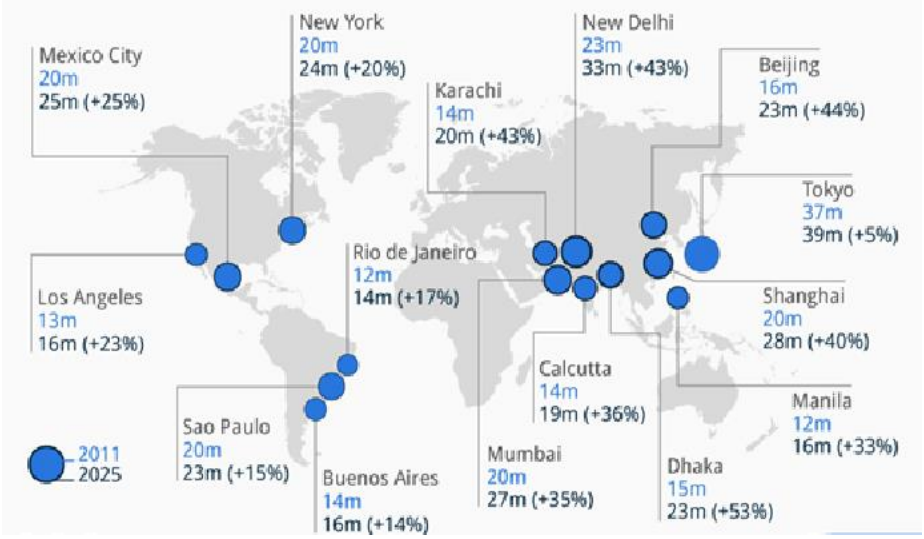

Figure 2. Population growth of the world's top fifteen cities, including metropolitan areas (millions, 2011-2025).

lack access to basic sanitation services, such as toilets or latrines. More than 80 percent of wastewater resulting from human activities is discharged into rivers or sea without any pollution removal. This threatens the quality of water supply sources.Approximately70 % of all water uptaken from rivers and aquifers is used for irrigation. Higher temperatures and increased variability of precipitation would lead to increased irrigation water demand, even if the total precipitation during the growing season remains the same.

By 2030, under an average economic growth scenario and if no efficiency gains are assumed, global water requirements would grow from 4,500 billion m^3 today to 6 900 billion m^3 – this is 40 percent above current accessible, reliable supply (including return flows, and taking into account that a portion of supply should be reserved for environmental requirements (WRG, 2009).

In global scale floods and other water-related disasters account for 70 per cent of all deaths related to natural disasters. In Europe floods are the most prevalent natural hazard – it was estimated that floods cost € 4.9 billion a year on average from 2000 to 2012, a figure that could increase to 23.5 billion euros by 2050 (Jongman et al. 2014). In addition, large events such as the European floods in 2013 are likely to increase in frequency from an average of once every16 years to a probability of every ten years by 2050 (Koop and Leeven).The impacts of floods and droughts could be tempered by appropriate infrastructure investments and by changes in water and land-use management, but the implementation of such measures will entail costs (US Global Change Research Program, 2000). Conventional drainage systems remain the most common, method to manage stormwater in cities throughout the world. This is despite a number of issues that question the sustainability of such systems in the long-term, particularly their increasing inability to prevent flooding, pollution and environmental damage.

3. Sustainable water management

The three pillars of sustainable development - economic, environmental and social – are integral to the development agenda worldwide. The idea of *sustainable cities* is closely aligned with this understanding, according to definition: *A sustainable city enables all its citizens to meet their own needs and to enhance their well-being, without degrading the natural world or the lives of other people, now or in the future*. Climate change and urban population growth are urgent imperative to move toward sustainable cities – the foundation of sustainable development. On September 2015, countries adopted a set of goals to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved until 2030 year. Water related goals call upon countries to: *Ensure access to water and sanitation for all (*goal 6), *Make cities inclusive, safe, resilient and sustainable (*goal 11) and *Take urgent action to combat climate change and its impacts* (goal 13).

Sustainable water management is a major challenge. This is probably also the reason why the World Economic Forum (2014) ranked the water crisis and water-related risks as major global risks in terms of both probability and impact. Cities need to protect their citizens against water-related disasters (e.g. droughts and floods), to guarantee water availability and high-quality groundwater, surface water and drinking water. Cities need to have adequate infrastructure in response to climate, demographic and economic trends (OECD, 2015). The cost of water and wastewater infrastructure estimated by UNEP (2013) for period 2005÷2030 is about 22 trillion

USD, more than that for energy, roads, rail, air and sea ports put together.

There is a significant distinction between climate change mitigation and adaptation. Mitigation efforts aim to prevent further climate change. Adaptation involves readjusting life to the reality that a certain amount of climate change will inevitably occur. An effective climate change policy for cities however needs to include both, and they need to be approached in an integrated manner.

Adaptation will have impacts primarily on a local scale: actions are based on specific needs of the affected regions. Costs might be very high, especially in large-scale infrastructure such as flood protection works.

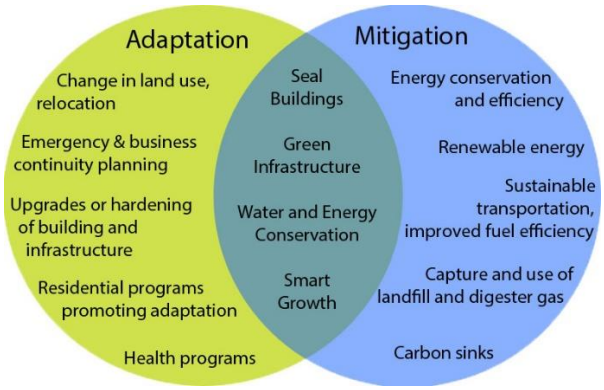

Figure 3. Adaptation and mitigation action.

Mitigation is a global effort requiring broad changes of behavior and technological advancements. Mitigation strategies are usually expensive in the short term, because they are capital intensive and require fundamental changes to urban systems. Over time, the cost of mitigation is generally self-financed through cost savings. Wastewater, stormwater and water supply are each managed separately without being aware and taking advantage of the numerous links that exist between them. Examples:

- stormwater can be used for non-potable water supply such as irrigation, car washing, toilet flushing etc. and also to recharge aquifers for supply purposes,
- wastewater and stormwater is linked through combined sewer overflows, releasing untreated sewage into rivers during rainfalls; combining stormwater with wastewater increases the volume and cost of wastewater treatment,
- reuse of grey water and treated wastewater is an alternative water supply source that can supplement non potable water demand needs;
- poorly treated wastewater discharges due to leakages, overflows and inadequate treatment can pollute water supply sources such as rivers and lakes.

Understanding and use of mutual connections in urban water cycles makes possible to implement integrated water management in cities. An integrated approach to urban water management makes it easier to identify and exploit these positive links while minimising the negative implications throughout the system.

4. Water-wise cities

In 2016 the International Water Association developed principles to help city leaders ensure that everyone in their cities has access to safe water and sanitation, that their cities are resilient to floods, droughts and the challenges of growing water scarcity, and that water is integrated in city planning to provide increased livability, efficiencies, and a sense of place for urban communities (IWA, 2016). The main goal is to ensure public health and satisfy all current needs while protecting the quality and quantity of water resources for future generations by efficient production and use of water, energy and materials. Increasing demand of potable water will be difficult maintain without negative consequences for water resources, so consumption per capita of water will need to fall. Reduce water intakes to match quantities that the natural environment is able to renew, and protect the quality of water sources from wastewater and urban runoff so that it is fit for ecosystems and for use with minimal treatment requirements. To obtain these goals cities need to reduce the amount of water used and also the energy used in transporting and treating urban waters and use diverse sources of water with treatment that matches the user needs. Urban water system should be flexible and ensure there are multiple resource, treatment, storage and conveyance options for ensuring appropriate service and resilience of the systems in the face of predicted climate changes.

Water sensitive urban design seeks the integration of urban planning with the management, protection and conservation of the total urban water cycle to produce urban environments that are *sensitive* to water sustainability, resilience and live ability co-benefits. Plan and implement urban design enabling regenerative water services to reduce the water, energy and carbon footprint of housing, benefiting ecosystems and people, while also improving social and urban amenities. Urban spaces should be designed to reduce flood risks by developing urban drainage solutions, integrated with urban infrastructure design (limiting local floods and treating rainwater as a resource). Natural water bodies should be visible –and create opportunities for recreation, inclusive public space, economic development and transportation, providing shade and mitigation of heat islands phenomenon. Next important issue is selection of urban materials of roofs, walls, surfaces, roads etc. to minimise their impact on water pollution.

It is important paradigm to plan and design in the basin scale. Secure the water resource and plan for drought mitigation strategies by sharing the water resource with agriculture, industry and energy sectors, and other cities who all contribute to the basin's. This applies not only to quantitative aspects but also

to protection of the quality of the water resource together with the other basin stakeholders to ensure high quality drinking water achieved with minimal treatment and energy requirements. Prepare for extreme events, such as storms and heavy rains, by investing in flood warning system and managing flow regimes in rivers, by maintaining adequate vegetation cover in the basin to reduce flash floods phenomenon.

The implementation of the previous sets of principles requires a holistic approach and strong partnerships – people are probably the most important ingredient during implementation of sustainable concepts. Following groups can be distinguished (IWA, 2014):

- Citizens involved in the sustainable urban water vision, can drive urban planning and design with their understanding of the risks (i.e. flooding) and opportunities (i.e. resource recovery).Trust and engagement of the local community is the foundation of successful implementation of waster sensitive city concept.
- Professionals who understand the co-benefits (finance, technical, social) across urban sectors so that they may plan and implement the best solutions for inhabitants and businesses. Professionals, realising the market and non-market value of the co-benefits associated to an integrated urban agenda, will enable innovative sustainable solutions. Interdisciplinary teams should integrate all kind of waters (freshwater supply, stormwater, rivers, seas and wastewaters) in city planning. Additionally all waters are connected with other urban systems(parks, roads, energy, transport and waste) and urban planning so that efficiencies and synergies arise from a coordinated approach.
- Policy makers establish policies and financing mechanisms to drive and enable sustainable urban water; they monitor, evaluate and adjust the policies based on future needs as they change over time.

Key factor is collaborative action, underpinned by a shared vision, so that local governments, urban professionals, and individuals actively engage in addressing and finding solutions for managing all waters of the city.

Conclusions

Climate change poses serious threats to urban infrastructure, quality of life, and entire urban systems. Not only poor countries, but also rich ones will increasingly be affected by anomalous climate events (World Bank, 2010). As rapid urbanization continues, cities will be confronted with ensuring that water resources are effectively managed (Policy summary). With more than half of humanity now living in urban agglomerations, so cities around the world are playing a leading role in building resiliency against climate change impacts. Whereas storm events may become stronger, at the same time it is expected that dry periods will become longer, it may lead to increased water scarcity. To manage these challenges cities have to improve the efficiency of urban water systems by rethinking old paradigms and developing more sustainable solutions. City densification is both an opportunity for economic growth and a threat to liveability. By managing water sustainably, we are able to better manage the production of food and energy and contribute to economic growth.

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