European cities facing climate change: water management issue

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The article provides an overview of spatial and legal solutions related to the issue of water management in cities in the context of climate change. The aim of the research is to identify the main differences between the traditional and integrated approaches to water-related infrastructure based on case studies of European Cities at different scales.

Climate change threatens European cities. The shift in climate zones is causing cities to suffer from droughts and heat on the one hand and storms with subsequent flooding on the other. Their intensity is causing increasing amount freshwater to flow into the oceans. Coastal cities, including those in Europe, are in danger of being permanently flooded (e.g. The Hague or Venice), while others are already facing permanent problems of access to drinking water.

Nevertheless, we know that the management of cities has contributed to the emergence of these negative phenomena. The problems are also embedded in spatial issues (e.g.: excessive urbanisation and construction, large-scale river regulation, hardening of the biologically active surface and resulting surface runoff of rainwater, excessive use of materials that accumulate heat or cutting down trees) and social issues (lifestyle and consumer choices). To adapt cities to climate change, we need to redefine development goals. The demand for urban flexibility, resilience and adaptability forces measures that firstly adapt cities to the new conditions and prepare them for further processes, and secondly reduce the negative impacts on the whole ecosystem.

Maciej Zalewski describes the widespread traditional approach to water management in cities as "mechanistic", focused on a specific goal without taking into account the interactions between environment and infrastructure. The reason for this, according to him, is the sectoral approach, the lack of technical knowledge exchange between different sectors and the poor communication between decision-makers, institutions and users [1].

The main effect of a wrong approach to water management in cities is that the focus is on diverting water as quickly as possible from the place where it is generated. An inefficient wastewater system that is not adapted to current, dynamically changing weather conditions and too much grey infrastructure that reduces natural water retention are serious problems for modern urban centres. Their main component – excessive surface runoff – is the main cause of flooding and inundation in urban areas and is responsible for increased transport of pollutants into natural reservoirs (see fig. 2.). This accelerated water runoff in urban areas subsequently also lowers groundwater levels and leads to soil degradation, disappearance of biotic components of the natural environment and undesirable changes in the urban microclimate, such as the urban heat island effect.

Other activities that significantly affect the likelihood of occurrence and magnitude of floods include large-scale changes in the management of natural river basins in the form of deforestation and draining of floodplains, and the common regulation of river beds through their narrowing and sealing. Such activities negatively affect the self-purification potential of rivers and reduce the positive impact of water on surrounding areas, thus impairing their biological functions [2].

Poorly functioning water management in the city is not neutral for the inhabitants. Reduced humidity and air quality, poor biodiversity and excess of grey infrastructure lead to a serious problem of modern cities, namely respiratory diseases. Data from Central Statistical Office how that the biggest health problems of the 21st century in Poland among children and adults up to 30 years of age are allergies and asthma, which specifically affect residents of large urban areas [3, 22]. Accordingly, dealing with water issues

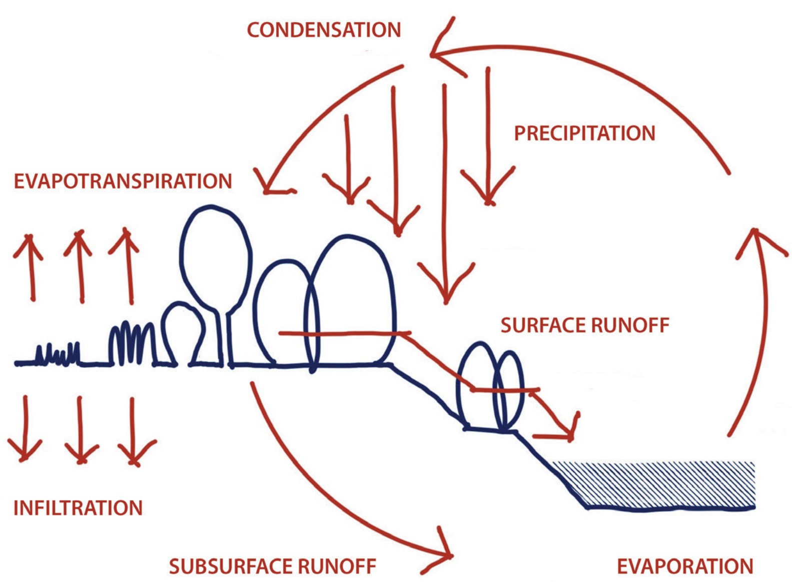

Fig. 1. Circulation of water in natural environment. The authors' own work

is crucial. The new approach must be implemented in an integrated way at all levels of planning: from supra-regional to local.

Aim and scope

The main objective of this research is to identify the main differences between the traditional and the integrated approach to water-related infrastructure, especially at urban and local levels.

The authors of the paper have posed two research questions:

– Do the new water-related urban flagship projects meet the main theoretical assumptions of the integrated approach to blue infrastructure?
– Do they bring the effect of synergy between environmental, social and economic conditions?

The methods used in the research are literature review, critical examination of best practises and comparative study.

The main Polish authors referring to integrated blue infrastructure, whose work served as a basis for this research, are Anna Januchta-Szostak [4–5], Ewa Kozłowska [6], Jakub Kronenberg and Tomasz Bergier [7], Joanna Rayss [8], Krystyna Solarek, Elżbiera D. Ryńska and Małgorzata Mirecka [9]. Among the international authors it is worth mentioning: (1) specialists in SuDS: Geiger i Dreiseitl [10], Hasse with team [11], Hurley [12] and White [13], (2) authors from the field of WSUD: Brown, Keath and Wong [14], Djukic, Vukmirovic and Stankovic [15], Novotny [16].

Contemporary methods of water treatment

Building a sustainable, water-sensitive city requires a shift in perspective from a traditional (mechanistic) approach to an integrated (systemic and evolutionary) one. According to Zalewski, this new perspective is "a comprehensive approach that starts from the achievement of more than one goal and is based on the understanding of long-term environmental processes and interactions between different elements of the environment, society and infrastructure" [1].

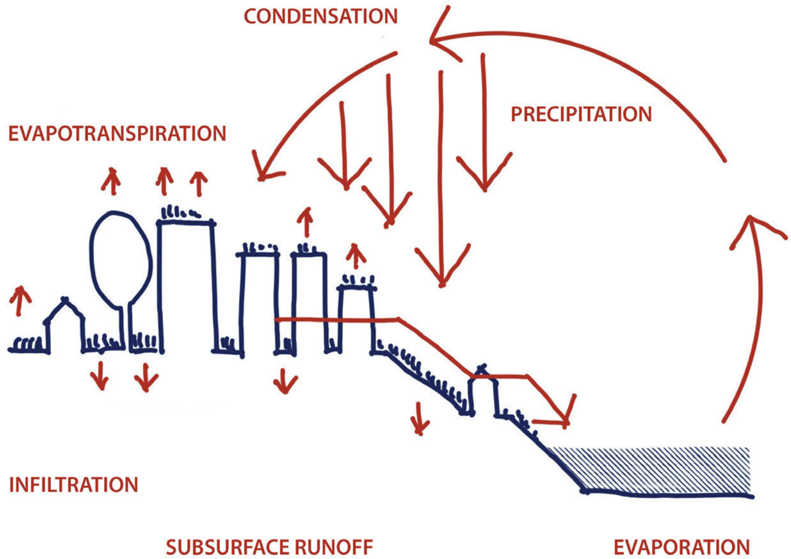

Fig. 3. Circulation of water in sustainable environment. The authors' own work

The basis of the new approach is the recognition of stormwater as an important element of an efficiently functioning system of urban infrastructure and as a prerequisite for creating a high quality of life in the city (see fig. 3.). Stormwater retained on the surface is no longer treated as a threat, but as an important element of the urban landscape. We notice its social, spatial and environmental benefits. Meanwhile, urban policy is changing from top-down planning based on statistics and focusing on temporary problem solving to long-term planning that involves many groups of stakeholders and meets their needs. Integrated water management in the city is based on three pillars [17]:

1. social equality – understood as the right to access resources that guarantee a decent life for all citizens, regardless of their economic situation;

2. economic efficiency – provision of water benefits to the largest possible group of users, as far as reasonably feasible;

3. ecological balance – treating ecosystems as water users, which means that we must ensure their access to the resource to the same extent as that of humans and support the process of regeneration of the natural system.

The integration of these three pillars brings about a synergistic effect that causes the total value of the investment to be greater than the value measured separately in each of the areas. Such an approach became the basis for creating a three-level water management system that includes both strategic programmes and planning tools:

– at a planning level (supra-regional) – such strategies as Delta Urbanism (an international programme combining flood control and spatial planning of river delta areas);
– at an urban level – Water Sensitive Urban Design (WSUD) – interdisciplinary urban systems that require the collaboration of professionals from different fields dealing with the water cycle in the city, combining eco-hydrology and spatial planning approaches;
– at the architectural level (local) – Sustainable Drainage System SuDS (Polish: System Powierzchniowej Retencji Miejskiej SPRiM) [18] and the concept of Low Impact Development (LID) – includes solutions for environmentally friendly micromanagement of ▶

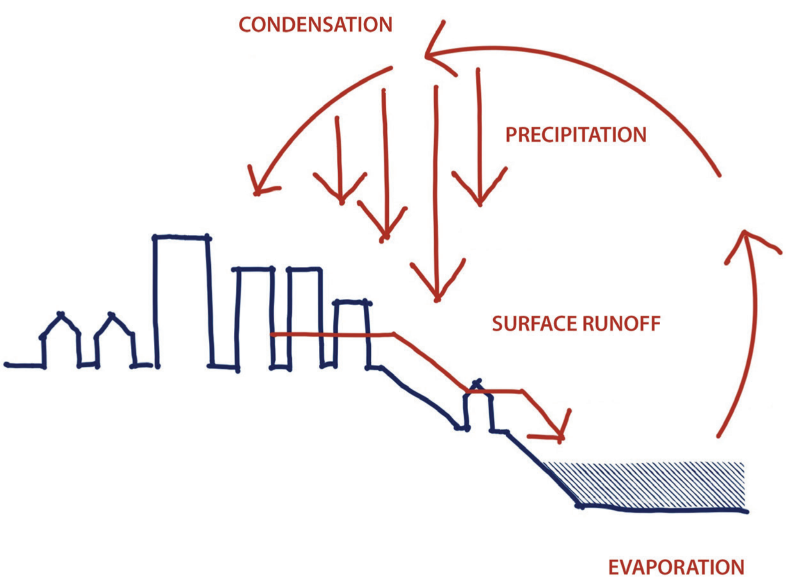

Fig. 2. Circulation of water in build environment with an impermeable surface of over 75%. The authors' own work

Table 1. Comparison of the main assumptions of traditional and integrated approaches. Author's own work based on Nowe podejście do gospodarowania wodami opadowymi by [19]

TRADITIONAL APPROACH	INTEGRATED APPROACH
drainage systems	ecosystems
problem solving	preventing problems
dominant role of engineers	multidisciplinary teams
property protection	property and environment protection
pipes and ducts	copying natural processes
administrative decisions	consensus-based decisions
local government ownership	broad partnership
focus on extreme phenomena	storm water management integrated with land use
affecting "the peak flows"	affecting "the capacity of the catchment area"

stormwater in the city, based on landscape features and the presence of water and land ecosystems.

The strategies and solutions to the urban water problem described from different perspectives and programmes, regardless of the scale of activities and local conditions, share some common characteristics, which are referred to in this article as "common practises":

1. on-site water management and reduction of pressure on sewers and stormwater collectors. Depending on the individual situation, often in conjunction with the traditional method using existing combined sewer and storm drain infrastructure;

2. supporting decentralised infiltration and retention in the urban watershed by increasing the amount of biologically active and permeable surfaces in the urban watershed, including: plantings, modification of street profiles, green roofs, and design of catch basins and swales;

3. stormwater treatment and pollutant movement reduction (including naturally, such as through the use of constructed wetlands);

4. renaturation of rivers and coasts, restoration of natural floodplains;

5. storage and use of rainwater – surface and subsurface water retention systems;

6. application of selected aspects of the circular economy to urban water management systems – limiting the use of the highest quality water where it is not necessary. Use of rainwater and recycling of water from households;

7. recognition of water as one of the elements of a high quality public space;

8. education and social engagement through coordination of different entities - local communities, decision makers, public-private partnerships, spatial policy, academic environmental integration.

In order to highlight the main features of the integrated approach to blue infrastructure, it was compared to the traditional approach (see table 1.) and evaluated in presented case studies.

Case studies[1]

Selected examples represent two levels (urban planning and local scale) from the three-level water management system most associated with the scale of the city.

Urban Planning scale

Green Roofs Policy in Hamburg, Germany

Green roofs in cities have a variety of functions – they insulate in winter and in hot periods they reduce the heating of buildings and prevent the urban heat island effect. During periods of increased rainfall they retain water and reduce the load on the drainage system by up to 50%, and through evaporation they improve humidity and the local microclimate. Green roofs purify the air by absorbing

[1] Presented case studies has been divided into two categories: Urban Planning scale and Architectural scale. Because of limitation of this article planning, supra-regional scale has been excluded from good practices review, as most complex and ambiguous, thus cumbersome for comparison

Table 2. Comparison and evaluation of good practices at urban scale, according to the main features of the integrated approach to blue infrastructure. Authors' own work

Elements of the integrated approach to blue infrastructure	Green Roofs Policy in Hamburg, Germany		Cloudburst Management Plan, Copenhagen	
	+/-	Short description	+/-	Short description
Ecosystems	+	Green roofs use natural parameters of greenery	+	Plan is based on natural phenomenon of water surface flow.
Preventing problems	+	Increased area of green roofs minimizes water runoff and prevents sewage system from overflow.	+	Water management system would keep surplus of water in safe place and prevent damages of city's tissue.
Multidisciplinary teams	+	Yes	+	Yes
Property and environment protection	+	Green roofs are encouraged (and from 2020 would be obligatory) on both public and private buildings.	+	Interventions are planned both on private and public land
Copying natural processes	+	Green roofs mimics some of the features of natural green areas.	+	System of designed water runoff mimics natural processes
Consensus-based decisions		n/a		n/a
Broad partnership	-		+	
Storm water management integrated with land use	+	Green roofs are not only good in terms of water retention but also has aesthetical values and prevents from overheating. Part of green roofs is also available for leisure activities	+	Interventions increases also recreational usage of places
Affecting "the capacity of the catchment area"	+	Each green roof increases the catchment area	+	During huge downpour most of the water would be kept on the surface.
Savings in comparison to traditional approach		n/a	+	Plan created savings around 50% greater than conventional solutions with the same water retention possibility.
Effect of synergy: environment / public space / savings	+		+	

some of the pollutants and harmful substances. By extending their lifespan, they reduce the cost of maintaining and servicing roof surfaces and offer the possibility of using them for a whole range of additional functions in the compact and dense urban fabric.

Faced with the inevitable consequences of climate change, the Hamburg authorities decided in 2014 to take countermeasures and were the first in Germany to adopt a multi-disciplinary "Green Roof Strategy" (German: Gründachstrategie für Hamburg) with the aim of increasing the area of green roofs in the city by 100 ha by 2020. To this end, the Ministry of the Environment and Energy is providing nearly 3 million euros by the end of 2019 to support building owners, who can receive grants amounting to 60% of the cost of green roofs. The city has set a target of making 20% of green roofs on new buildings available to residents or employees for recreational activities such as sports fields, parks and gardens [23]. Information activities and dialogue with stakeholders will be used to promote sustainable water management systems, increase biodiversity in the city and reduce temperature rise and the heat island effect. The green roof strategy complements the Rain Infrastructure Adaptation 2030 (RISA) project on sustainable stormwater management. The sustainable urban development activities are also supported by HafenCity University, which provides substantive assistance, develops recommendations and collects data on water retention and green roof outcomes. The campaign has resulted in almost 44 ha more green roofs by 2019 [23]. Councils plan to make green roofs a statutory requirement by 2020.

Cloudburst Management Plan, Copenhagen

The Cloudburst Management Plan for Copenhagen is a very good example of WSUD. The whole system was planned in close connection with the whole Copenhagen Finger Development Plan of 1947, which states that the development of the city should be as concentrated as possible and that the built-up areas should be surrounded by green corridors – similar to the palm and its five fingers. Also noteworthy is the comprehensive planning and design at all levels of the city – consistent from the urban master plan to details such as street design. Stormwater runoff is planned at the city level – as a system: street grades have been coordinated so that excess water flows by gravity into detention basins. Many discharge points have been identified throughout the city. These interventions vary in size and scale, but mainly they prepare the city to receive large amounts of water. For example, many recreation areas have been redesigned to capture water in the event of a heavy rain and hold it on their surface until the

Photo 1. Hohlgrabenäcker Development in Stuttgart, Germany, Author: MSeses

Photo 2. Ekostaden Augostenborg in Malmo, Sweden, Author: Sanna Dock for the City of Malmo, Environmental Department

Photo 3. Ekostaden Augostenborg in Malmo, Sweden, Author: Sanna Dock for the City of Malmo, Environmental Department

drainage system clears. All permanent infrastructure, such as benches and sidewalks, is designed to not be destroyed by water. In addition, the water would gradually fill the areas to keep the plazas open for recreational use as long as possible.

The entire process was formalized as Copenhagen Cloudburst Formula, a six-stage process to integrate the Blue-Green Approach. The first stage involved studying, identifying and ranking the most vulnerable areas. The second stage was to divide the urban regions into stormwater catchments to map the areas at risk. It became clear that conventional piped solutions alone were not sufficient. The third step was to determine the cost of doing nothing: The authorities calculated that the cost would be between 55 and 80 million euros a year if nothing was done to adapt the city to climate change. In the fourth stage, the "Cloudburst Toolkit" was developed as a set of universally applicable, multifunctional, flexible elements. Strategic planning was applied to human scale experience. The fifth stage defined an overall strategy for a public participation program for the citizens who would be affected by the investment. And the final, sixth step was a detailed socioeconomic Cost-Benefit Analysis (CBA) that tested two master plan options – traditional and Blue-Green Approach. The option with the highest percentage of Blue-Green solutions created potential savings that were about 50% greater than conventional solutions alone. Additional social benefits, such as improvements in health, environment and quality of urban space, would potentially drive this figure even higher.

Urban scale – Summary

Table 2. shows that both examples studied meet the main characteristics of the integrated approach to water management. Both manage water-related problems with ecosystem-type solutions, are linked to land use, and consider a variety of stakeholders.

Architectural scale

Hohlgrabenäcker Development in Stuttgart, Germany

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Hohlgrabenäcker is a housing estate in the Stuttgart suburban area with decentralized water management, which has been under development since 2003. The final development, covering an area of 16.7 hectares, is planned to include 265 owner-occupied homes and 9 apartment buildings. At the beginning of the project, according to the Water Act for Baden-Württemberg, the development plan, the requirements of Stuttgart City Council and Environmental Impact Assessment, some basic conditions regarding the drainage system and the ecological aspects of the site had to be fulfilled [20]:

- stormwater from new development areas should be infiltrated or separately drained;
- a maximum runoff rate of 30% should be observed for the planned new development area "Hohlgrabenaecker" due to the limited capacity of the existing sewer network;
- the existing soil types on the site are only suitable for the infiltration of rainwater to a limited extent and the topography severely restricts the possibilities for surface infiltration;
- green roofs were required on detached garages, carports and areas with flat and shed roofs.

Due to the above conditions, the water management system was implemented through a number of different solutions:

- 18,300 m^2 of green roofs were constructed;

Table 3. Comparison and evaluation of good practices at architectural scale, according to the main features of the integrated approach to blue infrastructure. Authors' own work

Elements of the integrated approach to blue infrastructure	Hohlgrabenäcker Development in Stuttgart, Germany		Ekostaden Augustenborg in Malmo, Sweden		Benthemplein Water Square in Rotterdam, the Netherlands	
	+/-	Short description	+/-	Short description	+/-	Short description
Ecosystems	+	Integration of green roofs and facilities for rainwater storage and use, implementation of permeable coverings;	+	Waste recycle system, implementation of solar energy systems, usage of SulDS and green roofs;	+	Water square – integration of high-quality public space with water retention reservoir connected with city's open water system;
Preventing problems	+	Flood prevention, responding to limited capacity of existing sewers and restricted possibility of surficial infiltration of existing topography;	+	Decreasing waste generation, minimising the negative impact of intense rainfalls, responding to harsh geomorphologic conditions, eliminating combined sewer overflow;	+	Reducing heat island effect and flooding risk in dense city area, lowering pressure on the existing drainage infrastructure;
Multidisciplinary teams	+	Cooperation of architects and urban designers, landscape designers and civil engineers;	+	Engagement of local inhabitants and land users in the process of revitalisation;	+	Partnership of specialists from different fields with city authorities, involvement of local communities into project;
Property and environment protection	+	Re-usage of stored rainwater, increasing infiltration, maintaining natural water cycle;	+	Decreasing carbon emission, growth of biodiversity, positive impact of local microclimate;	+	Maintaining water balance, soil hydration and city greenery growth;
Copying natural processes	+	Increasing infiltration and evapotranspiration processes of water;	+	Open water system inspired by natural hydrographic system;	+	Adaptation of natural water cycle in city environment;
Consensus-based decisions	+	Involving residents, for example by enabling partial usage of water from the underground cisterns for toilet flushing, washing clothes and irrigation;	+	Constant community involvement enabled the project to accommodate residents' concerns and preferences regarding the design of the stormwater system;	+	Wide collaboration of designers, city authorities and local communities;
Broad partnership	+	Involvement of	+	EU URBAN programme, The Swedish Department of the Environment, The Swedish government's Local Investments Programme for Ecological Conversion and Eco-Cycle Programme;	+	Involvement of future users in
Storm water management integrated with land use	+	Public streets and development areas restricted to a minimum to reduce the impervious degree;	+	Public spaces between housing blocks integrated with open storm water system. Attractive places for leisure and children activities, small allotments with local food production;	+	Integration of local meeting point and areas of sport activities with stormwater's storage system;
Affecting "the capacity of the catchment area"	+	Integration of 18,300m^2 of green roofs with development of building site, impervious degree of 20% of development areas;	+	Open stormwater system has improved not only stormwater management in the area, but also the performance of the combined sewer system that serves the surrounding area;	+	Collecting water from a greater area around the square and transporting it to city's open water system;
Savings in comparison to traditional approach	+	40% of total realization costs and annual savings due to stormwater fee reduction;	+	Open stormwater system was considered to be the most sustainable for revitalization project. Conventional separated stormwater system for Augustenborg would have meant major earthworks;		No specific data;
Effect of synergy: environment / public space / savings	+		+		+	

- underground rainwater cisterns were built on all residential lots (47 for single-family houses and 9 for multi-family houses). The water from the cisterns can be partially used by the property owners for toilet flushing, laundry and irrigation;
- paved areas have been provided with water-permeable pavements wherever possible (in total about 1600 m^2);
- the master plan of the development was redrawn to minimize the area of car roads, so that impervious surfaces could be reduced to a minimum (a permeability level of 20% was achieved). It is estimated that the implementation of decentralized water management saves 40% of the total implementation costs compared to conventional drainage and results in annual savings of €25,600 due to the reduction in on-site stormwater fees [20].

Ekostaden Augustenborg in Malmo, Sweden

Ekostaden Augustenborg is a comprehensive project of revitalization of a 32-acre mid-20th century urban housing development based on the idea of sustainable development. It is a mid-20th century project based on the idea of sustainable development. A wide range of works included overhauling 1600 homes (89% of the estate), developing the waste collection and reuse system, improving energy efficiency through the use of photovoltaic cells, solar panels and heat pumps, and investing in sustainable transport. In response to difficult geomorphological conditions (clay soil with low permeability) and an inadequate stormwater drainage system that led to flooding, the project envisaged the use of the Sustainable Urban Drainage System (SuDS) to minimise the negative impact of heavy rainfall while creating high quality space. The work resulted in the construction of a network of channels, receptive ditches, rain gardens, and detention basins connected by surface and subsurface swales that resemble the natural hydrographic system. Before flowing into the sewers, stormwater passes through open detention facilities, which has reduced the velocity and volume of runoff by approximately 20% compared to the conventional system (due to evapotranspiration from the channels and retention basins between rain events) and reduced the risk of flooding, while having a positive impact on the local microclimate. The system was designed for a 15-year rainfall event baseline. There has been no flooding in the area since implementation [21]. During the works, the number and variety of green spaces was increased and more than 11,000 m^2 of green

Photo 4. Benthemplein Water Square in Rotterdam, the Netherlands, Author: Arnoud Molenaar

roofs were created, the largest of which, 9,000 m^2, was converted into a botanical garden. It is estimated that the green roofs in Augustenborg intercept about 50% of the total annual stormwater runoff and about 90% of this is directed from the roofs into the residential water system. In addition, compared to the standard black bitumen roofs, the green roofs have a significant cooling effect in the summer and provide additional thermal insulation in the winter. There are a number of other benefits of the Augustenborg revitalisation project and the open stormwater system – biodiversity in the area has increased by 50% and carbon emissions and waste generation have reduced by 20% [21]. An important aspect of this work has been the involvement of local residents and land users in the process of revitalising the estate at every stage of the project. It is estimated that almost 20% of residents were involved in the participation process. Apart from the spatial and environmental aspects, the process of revitalising the Augustenborg estate, which took seven years, has also had a significant positive impact on the local community, which is now better integrated, crime levels have been reduced, employment has increased and residents are better integrated socially.

Benthemplein Water Square in Rotterdam, the Netherlands

Designing cities in times of climate threats requires a new model of urban design. A model that combines high quality public space with a sustainable approach to stormwater management. The typology of a water square was born to meet the needs of Architecture Biennale in Rotterdam in 2005, whose main theme was "flood". In the following years, designers from Studio DeUrbanisten developed the concept in collaboration with City Hall and Rotterdam Climate Initiative and with the involvement of local communities, and in 2013 the world's first such facility was opened – Benthemplein Water Square. The plaza consists of three troughs with different depths and multiple functions. Two smaller and shallower ones are used as local meeting places and for sports activities, while they act as water retention basins during rainfall. A deeper and also largest trough, located in the middle of the site, serves as a playing field with spectator stands and acts as a retention basin with a capacity of 1700 m^3 during particularly heavy storms, significantly reducing peak runoff and pressure on existing infrastructure by lowering and slowing runoff into the drainage system. Water is collected from a larger area around the square using steel gutters that can be used as skate park elements on a normal day. To make the square more attractive and emphasise its specificity, it has some additional elements, such as a "storm wall" that directs water into the largest of the gutters, water cascades or a fountain. The water from the water squares does not flow into the combined sewer system after rainfall, but is used in a more sustainable way. From the deepest trough, the water flows back into the city's open water system within a maximum of 36 hours. From the two smaller troughs, it is transported into the underground infiltration system and then gradually released back into the groundwater. This maintains the water balance, hydrates the soil, keeps the urban green alive even in dry periods and reduces the heat island effect [25].

Architectural scale – Summary

Table 3. shows that all the examples studied meet the main characteristic of the integrated approach to water management. One of the most important results of the presented projects are synergies between environmental, social and economic effects. In modern urban planning there is no place for investments with only one goal.

Conclusion

In all these European showcase examples, the traditional approach to urban stormwater management was completely replaced by an integrated approach. The complexity of the processes and their scale in a modern city make the top-down model of resource management insufficient. A solution to the dynamically changing conditions and urban development planning in a long-term perspective is a change in urban policy. The new policy must be integrated and based on human capital and cooperation of many sectors (planners, engineers, decision makers, private sector and the residents). For this reason, 3 out of 10 items in the good practises assessment address issues of collaboration. Taking into account the needs of a wider range of stakeholders in the planning process gives us a broader perspective on the problem, allows us to optimise solutions and reduce their cost, and finally – it favours the exchange of knowledge and experience and ensures continuity of actions in a long-term perspective.

The main differences between the traditional and integrated approaches to water-related infrastructure were identified in this research (table 1.). Based on the characteristics distinguished in this comparison, the best practises in blue infrastructure were evaluated at both urban (table 2.) and architectural (table 3.) levels. This evaluation showed that the integrated approach should be used as a model for further work in urban stormwater management. In addition, all examples demonstrated the synergistic effect of bringing together environmental, social and economic objectives to ensure a new quality of space.

The above examples do not exhaust the problems associated with water management in cities, but they allow us to assess the benefits of addressing the issue: increasing the city's resilience to the effects of climate change, building a healthy living environment through the development of green and blue infrastructure and its impact on the local microclimate, supporting economic growth, positive impacts on nature and the quality of urban space, and integration and opportunities for local development for different social groups.

Bibliography:

[1] Zalewski Maciej, (2014), Woda jako podstawa jakości życia w miastach przyszłości, [in:] „Zrównoważony rozwój – Zastosowania. Woda w mieście", Fundacja Sendzimira, pp. 10–15.
[2] Twaróg Bernard, Kęsek Zbigniew, (2015), Floodpolis – Powodziowe miasto przyszłości, „Czasopismo Inżynierii Lądowej, Środowiska i Architektury", JCEEA, v. XXXII, z. 62 (2/15), April–June 2015, pp. 553-564, online source: http://doi.prz.edu.pl/pl/pdf/biis/352 (access: 21 Oct 2019).
[3] Samoliński Bolesław et al., (2014), Epidemiologia chorób alergicznych w Polsce (ECAP), online source: https://www.researchgate.net/publication/262921691_Epidemiologia_Chorob_Alergicznych_w_Polsce_ECAP (access: 21 Sep 2019).
[4] Januchta-Szostak Anna, (2008): Błękitna krew miasta. Woda jako ożywcza siła przestrzeni publicznych, [in:] Built Environment (z 3-A), pp. 21–28. Available online at https://suw.biblos.pk.edu.pl/resources/i8/i7/i3/r873/JanuchtaSzostakA_BlekitnaKrew.pdf (access: Aug 2020).
[5] Januchta-Szostak Anna, (2011), Woda w miejskiej przestrzeni publicznej. Modelowe formy zagospodarowania wód opadowych i powierzchniowych. Wyd. 1. Poznań: Wyd. Politechniki Poznańskiej (Rozprawy / Politechnika Poznańska, nr 454).
[6] Kozłowska Ewa, (2008), Proekologiczne gospodarowanie wodą opadową w aspekcie architektury krajobrazu, Wyd. Uniwersytetu Przyrodniczego we Wrocławiu.
[7] Kronenberg Jakub, Bergier Tomasz, (2012), Przyroda w mieście. Usługi ekosystemów niewykorzystany potencjał miast, Fundacja Sendzimira.
[8] Rayss Joanna, (2018), Zielona infrastruktura miasta a wody opadowe. Potencjał zrównoważonego rozwoju Gdańska [praca doktorska], Politechnika Gdańska.
[9] Solarek K., Ryńska E. D., Mirecka M., (2016), Urbanistyka i architektura w zintegrowanym gospodarowaniu wodami, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa.
[10] Geiger Wolfgang, Dreiseitl Herbert, Brzeski Jan, (1999), Nowe sposoby odprowadzania wód deszczowych. Poradnik retencjonowania i infiltracji wód deszczowych do gruntu na terenach zabudowanych. Bydgoszcz: Oficyna Wydawnicza Projprzem-EKO.
[11] Haase Dagmar, Larondelle Neele, Andersson Erik, Artmann Martina, Borgstrom Sara, Breuste Jurgen et al., (2014), A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. In Ambio 43 (4), pp. 413–433. DOI: 10.1007/s13280-014-0504-0.
[12] Hurley Stephanie Elizabeth, (2009), Urban Watershed Redevelopment: Design Scenarios for Reducing Phosphorus Pollution from Stormwater in Boston's Charles River Basin, USA [praca doktorska], Harvard University, Graduate School of Design.
[13] White Iain, (2010), Water and the city. Risk, resilience and planning for a sustainable future. New York: Routledge (The natural and built environment series).
[14] Brown Rebekah, Keath Nina, Wong Tony, (2008), Transitioning to Water Sensitive Cities. Historical, Current and Future Transition States. In R. Ashley (Ed.), Conference Proceedings: 11th International Conference on Urban Drainage [CD-ROM]. Iwa Publishing.
[15] Djukic Aleksandra, Vukmirovic Milena, Stankovic Srdjan, (2015), Principles of climate sensitive urban design analysis in identification of suitable urban design proposals. Case study: Central zone of Leskovac competition, [in:] Energy and Buildings, DOI: 10.1016/j.enbuild.2015.03.057.
[16] Novotny Vladimir, Ahern John; Brown Paul, (2010), Water centric sustainable communities. Planning, retrofitting, and building the next urban environment. Hoboken, N.J.: John Wiley & Sons.
[17] Krauze Kinga, Wagner Iwona, (2014), Woda w przestrzeni miejskiej a zintegrowane zarządzanie miastem „Zrównoważony rozwój – Zastosowania", Issue No. 5: Woda w mieście, Fundacja Sendzimira, pp. 95–111.
[18] Gajewska Magdalena, Rayss Joanna, Szpakowski Wojciech, Wojciechowska Ewa, Wróblewska Dominika, (2019), System powierzchniowej retencji miejskiej w adaptacji miast do zmian klimatu – od wizji do wdrożeń, Gdańsk.
[19] P. Łabaj, online access:
http://www.pie.pl/materialy/_upload/Konf_prawo_wod_2017/Prezentacje/P2_2_PLabaj.pdf.
[20] Ansel Wolfgang, Diem Alfred, (2010), Sustainable Urbanism with Green Roofs – Natural Stormwater Management, online source: https://programm.corp.at/cdrom2010/papers2010/CORP2010_120.pdf (access: 13 Sept 2020).
[21] Carter Jeremy, Kazmierczak Aleksandra, (2010), Adaptation to climate change using green and blue infrastructure. A database of case studies, The University of Manchester, pp. 88–96, https://orca.cf.ac.uk/64906/1/Database_Final_no_hyperlinks.pdf (access: 12 Sept 2020).
[22] Central Statistical Office (GUS), (2015), Zdrowie i zachowania zdrowotne mieszkańców Polski w świetle badania EHIS, online source: https://stat.gov.pl/obszary-tematyczne/zdrowie/zdrowie/zdrowie-i-zachowania-zdrowotne-mieszkancow-polski-w-swietle-badania-ehis-2014,10,1.html (access: 14 Sep 2019).
[23] Green Roof Policy, online source: https://climate-adapt.eea.europa.eu/metadata/case-studies/four-pillars-to-hamburg2019s-green-roof-strategy-financial-incentive-dialogue-regulation-and-science (access: 11 Oct 2019)
[24] Ekostaden Augustenborg, online source: https://www.worldhabitat.org/world-habitat-awards/winners-and-finalists/ekostaden-augustenborg/#award-content (access: 18 Oct 2019)
[25] Benthemplein Water Square, online source: http://www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein (access: 15 Oct 2019).

DOI: 10.5604/01.3001.0014.9350

PRAWIDŁOWY SPOSÓB CYTOWANIA:
Dziedzic Sebastian, Twardoch Agata, 2021, European cities facing climate change: water management issue, „Builder" 7 (288). DOI: 10.5604/01.3001.0014.9350

Abstract: The article provides an overview of spatial and legal solutions related to the issue of water management in cities in the context of climate change. The aim of the research is to identify the main differences between the traditional and integrated approaches to water-related infrastructure based on case studies of European Cities at different scales. Gathering, ordering and comparing adequate solutions will allow to establish guidelines for the development of Polish cities and point out directions for architects and urban planners designing urban spaces. The comparison of good examples with theory would make it possible to verify whether practise corresponds with theory, and whether it can actually - through the synergy of measures – bring new quality to urban areas.
Keywords: Climate change, European cities, water retention, urban design, blue infrastructure, Sustainable Drainage System, SuDS

Streszczenie: MIASTA EUROPEJSKIE W OBLICZU ZMIAN KLIMATYCZNYCH: KWESTIA GOSPODARKI WODNEJ. W artykule dokonano przeglądu rozwiązań przestrzenno-prawnych związanych z problematyką gospodarki wodnej w miastach w kontekście zmian klimatycznych. Celem badań jest zidentyfikowanie głównych różnic między tradycyjnym i zintegrowanym podejściem do infrastruktury wodnej na podstawie studiów przypadków europejskich miast w różnej skali. Zebranie, uporządkowanie oraz porównanie odpowiednich rozwiązań pozwoli na wyznaczenie kierunków rozwoju polskich miast i wskazanie kierunków dla architektów, a także urbanistów projektujących przestrzenie miejskie. Porównanie dobrych przykładów z teorią pozwoliłoby zweryfikować, czy praktyka koresponduje z teorią i czy rzeczywiście – poprzez synergię działań – może przynieść nową jakość na obszarach miejskich.
Słowa kluczowe: zmiany klimatyczne, miasta europejskie, retencja wody, projektowanie urbanistyczne, niebieska infrastruktura, zrównoważony system drenażowy, SuDS