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Large shopping centres in Poznań as a source of rainwater recovery and irrigation of urban green areas

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Abstract: Large-scale facilities in the city cause the loss of significant amounts of rainwater, greenery and biologically active areas. Remedying this situation requires the implementation of a number of spatial planning demands. Increasing the attractiveness and spatial value of urbanised areas state fundamental importance for meeting the needs of local communities in the era of predicted climate change. The study shows that appropriate management of water recovered from the roofs of large-scale buildings can be used to supply significant areas of urban greenery.

Keywords: rainwater harvesting, rainwater management, shopping malls, urban greenery, city landscape, Poznań

Introduction

Shopping malls have become the spatial mark of Polish cities in recent decades. The forms of large-scale shopping mall buildings usually differ in external design and façade structure. In contrast, their dimensions are in many cases mutually similar and usually scaled back from the structures of adjacent development. Shopping mall facilities are substructures that more or less successfully mimic urban spaces, in the form of walkways, alleys and pedestrian galleries under a roof on several floors, enclosed by commercial premises (Fig.1).

Unfortunately, shopping malls do not generate green areas, but on the contrary, they contribute to the development of large areas of land and loss of water in the city landscape. This is essential in the context of steppe formation and predicted drought periods in Polish areas. Cities are particularly vulnerable to water deficit in the landscape due to the intensive urbanization of space and the irretrievable loss of significant amounts of rainwater discharged into stormwater drainage systems. The large-scale developments that have been taking place in Poznań in recent decades are contributing even more to the loss of rainwater. Huge roof areas cause rapid discharge of rainwater into the city's storm drains. These waters are mostly not retained and are not used to supply the greenery that is so necessary in the city. Water retention in the city is essential to regulate summer temperature and mitigate the urban heat island effect [1, 2].

Fig. 1. King Cros shopping mall in Poznan

Photo: Szumigała P., Urbański P., 2021.

State of research

The scope of research on the issue of rainwater recovery is wide and covers various aspects. Topics discussed include rainwater recovery in hotels and the reuse of so-called „grey water". Issues related to the economics of the action taken and to environmental protection are described, including discussion of advantages, disadvantages and other problems. Examples of hotels using such solutions and descriptions of water recycling techniques are also presented, including schematic photographs. The Rafayel Hotel in London and the NH Campo de Gibraltar Hotel in Spain are particularly described [3]. Rainwater harvesting and recovery of „grey water" in shopping malls in Brazil is an important issue. Although abundant in rainfall, winter water shortages do occur. A water reuse study was undertaken which showed that there was not enough „grey" water to fully replace the water requirements of the sinks and toilets, while there was enough rainwater to even replenish the air conditioning. Additionally, the study touched on techniques related to the actual measurement of water consumption in galleries, and methods of measurement [4]. The topics of reclaiming water in an ecological context and creating water harvesting projects are addressed. The problems of people's high consumption of water for daily activities and the need to replenish it are discussed. Consumer surveys are being conducted on this and campaigns are being created to encourage people and businesses to harvest rainwater. The biggest problem is the dependence of such projects on rainfall, which is not satisfactory in this regard. This problem is discussed using the example of rainwater recovery from the roof of the Southside shopping centre in London [5]. Legal solutions for the creation of large-scale buildings and dedicated architectural and structural solutions in the context of rainwater use were discussed using British examples. Key sites discussed are the Millennium Dome, Museum of London, Velodrome, Honda Dealership, Imperial Tobacco Head Office and Rochdale, where large-scale rainwater recovery and use is being implemented. Evidence is presented that using such water is financially viable, good for the environment, and that rainwater is better than treated tap water [6]. Water exploration issues are presented extensively with examples, including a discussion of the Millennium Dome water recovery project. Due to the huge number of visitors, the water demand in the toilets in this facility is as much as 500 m^3 per day. Three sources of water were found for reuse: rainwater, „grey water"and groundwater. It is one of the largest water reuse projects in Europe. Thanks to this system, the recycled water satisfies up to 55% of the daily demand. It is also the most studied site in terms of water conservation in the public environment. Measurements were made using professional equipment. Great care was taken to ensure that the installation was made of good materials and regularly maintained to avoid water loss. Studies have also shown high satisfaction among visitors with the implementation of this project [7, 8]. Another publication describes a system for recovering rainwater from the roof of a supermarket, which is collected and then used as domestic water, e.g. for flushing toilets. The installation of such a system has reduced building maintenance costs. The system was monitored for 8 months – recording water consumption versus rainwater recovery from the roof, so that

the efficiency of the system could be calculated, and thus the costs and savings from such an installation. The result was to determine the period over which the costs of setting up the system paid off. Further, the paper also discusses alternative payback periods for different locations in the UK, which depended on rainfall abundance, among other factors. Finally, the effects of alternative roof and tank sizes on system economics were compared. Other solutions have also been presented that can reduce the payback period by up to 3 times [9]. Research is also being conducted into the performance of water recovery systems according to climate type. In a study conducted in Iran, systems were installed in three different cities; Tabriz in a Mediterranean climate, Rasht in a humid climate and Kerman in a dry climate. Daily rainfall statistics were collected for the areas in question, as well as data on roof areas and rainwater storage tank volumes, which were compared against domestic water demand. The results confirmed that the highest demand coverage was for the city in humid climates and the lowest in dry climates [10]. Water shortages in urban water systems due to increased demand with aging infrastructure and climate change are significant problems. Rainwater harvesting systems are an alternative to increase the flexibility and robustness of water supply systems. A study of the system's efficiency is carried out in the form of a simulation comparing the demand for usable water in relation to the size of roof areas of residential and large-size commercial buildings from which water is recovered. The economic aspects and the amortization time in which the system installation cost will be recovered with a given configuration are studied [11, 12]. It also discusses water recovery in cases of small facilities and how to manage such water in three areas: recovery, collection and transport, and storage, programmes being developed by the Centre for Alternative Technology UK [13, 14]. Polish publications discuss the issues of systemic rainwater management on the example of solutions from several Polish cities. A project of an ecological housing estate Wolne Miasto in Gdańsk is described, in which numerous environmentally friendly solutions have been introduced. One of them is the rainwater management system, which imitates natural processes occurring in nature. The systems make maximum use of rainwater. Another example is the system for rainwater recovery from the roof of the stadium in Wrocław. The collected water is collected in tanks and then used to irrigate the turf and operate sanitary facilities. The study also discusses a „Good Practice Catalogue" that provides information on stormwater management from road surfaces [15]. In Poland, there are problems with water management due to the lack of effective instruments of spatial policy and planning related to water management within urban catchments [16]. There is a lack of tools for comprehensive evaluation and monitoring of the implemented solutions, which is one of the significant barriers to introducing multifunctional methods of managing rainwater and surface waters in Polish cities. Points to the lack of economic instruments to encourage economical and sustainable water management. The author presents solutions for better rainwater recovery, including infiltration without retention, infiltration with surface or subsurface retention, and rainwater retention using retention tanks and hydrophytic facilities. Similar views were presented on the example of water recovery from Potsdamer Platz [17]. Another important issue is the treatment of rainwater, for utility purposes and according to DWA-M153 standards and the presentation of GreenLife systems dedicated to these needs described by Wavin [18]. Research on water recovery from the roofs of large-scale commercial buildings on the example of Galeria Dzierżoniów, which has an area of 5000 m2, presented by the Polish Chamber of Civil Engineers in 2021, is also relevant [19]. A holistic approach to the issues of water retention and overall urban water retention is presented with examples of different water management concepts in urban areas, which mainly focus on water retention and prevention of urban flooding during heavy rainfall [20].

Methods and material

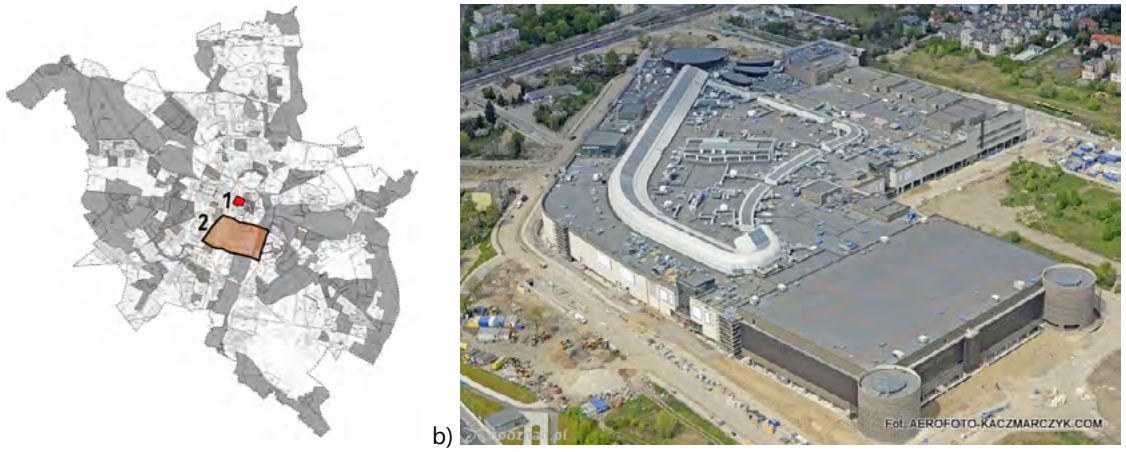
We used quantitative methods and comparative analysis in our research. General analyses were conducted for the area of the city of Poznań and shopping centres located in its area. On the other hand, the material of detailed studies was limited to the eight largest in terms of floor space and surface area of shopping malls in Poznań.

In the first stage of the study, we made balances of the total usable floor area of large-area buildings in Poznań and compared them with the public spaces of the city of Poznań. In the second stage of the study, we conducted analyses in two ranges: what amounts of rainwater can be recovered from the roofs of the eight largest malls in Poznań and for how many trees can the recovered water constitute a resource necessary for growing these trees in urban conditions.

Results

Analysis – the size of the city's land developed with shopping malls

Poznań belongs to the infamous group of cities in Poland with the largest number of shopping malls. In the Study of Conditions and Directions of Spatial Development of Poznań, as many as 23 areas are reserved for the location of large-area centres and services [21]. Only eight of Poznań's largest shopping centres: Plaza, M1, Pestka, King Cross Marcelin, Malta, Stary Browar, City Center and Posnania, not counting several smaller ones, gather as many as 1,355 retail units and occupy a total area of over 642,000 sqm (64.2 hectares), i.e. almost 32 times the area of the Old Market Square in Poznań. At the city scale, this is almost 1/3 of the very centre-the area delimited by Solna Street, Marcinkowskiego Avenue, Świętym Marcin Street, and Niepodległości Avenue (area 1 in Fig. 2). However, the total size of the areas reserved for large-format services in Poznań is over 11 times greater than the above-mentioned area. At the scale of the city, this area is slightly larger than the fragment delimited by Głogowska, Hetmańska, Zamenhoffa and Królowej Jadwigi Streets (area 2 in Fig. 2) [22].



a) b)

Fig. 2. Comparison of the size of areas 1 and 2 designated for large-area services in the scale of the city of Poznań – description in the text:

a) Source: study by Szumigała K.O., based on: [23] http://www.mpu.pl/plany.php, access: 05.05.2020,

b) roof of the Posnania mall, source: [24] http://labocacafe.epoznan.pl/news-news-66890-Poznan_na_zdjeciach_z_lotu_ptaka_ogrom_Posnanii_i_rosnacy_Baltyk, access: 05.05.2020.

For several years now, the opposite trend has been observed in urban centers of the United States of America, where a large number of large-scale shopping centers have been realized [25]. The retreat from large shopping malls is caused by the dynamic development of online sales. Where galleries empty, there is the problem of how to adapt such structures to other functions, as they continue to block significant areas of the city. Analysts predict that there is still demand for around 200 large shopping centres in Poland in addition to the existing 400 facilities. However, this situation may change favourably as the reverse trend has been confirmed and dynamised by the current pandemic situation resulting in the withdrawal of service and retail entities from shopping malls.

Analysis – how many trees can be fed with recycled water from the roofs of Poznań's eight largest shopping malls

Taking the annual precipitation in Poznań as a reference [26] – the theoretical (without taking into account evaporation, absorption and other coefficients) amount of rainwater obtained from the surface of roofs of only 8 biggest commercial galleries in Poznań, amounts to over 333,000,000 annually m^3. The actual amount of rainwater recovered in this way is about 20–30% less, but it is still a large value amounting to about 250 thousand m^3.

Comparing this value with the amount of water needed to maintain the urban greenery, it is clear that these amounts are significant. For example, young trees need about 20 liters of water per tree per week [27].

Therefore, the amount of water recovered from the above-mentioned eight shopping malls in Poznań can provide cultivation and maintenance of about 500 young trees for a period of 25 weeks, i.e. for 6 months of intensive vegetation from spring to autumn. The area planted with such a number of small trees, whose crowns are about 7 m in diameter, in the form of a compact complex of high greenery, creates an area of about 25,000 m^2 (2.5 ha), and for the variant in which the tree planting structure may create park greenery along with alleys, paths, lawns, etc. , this area should be increased by 50–100%. Then we obtain an area comparable to a medium-sized city park of 3.8–5 ha. This fact, in the context of climate change, becomes an extremely important argument in maintaining urban living standards by maintaining an adequate amount of urban green space [28, 29]. At the city scale, the potential for rainwater recovery from roofs and paved surfaces is much greater, which in the current realities should absolutely be recovered and managed in the city landscape. Widely available water treatment technologies also make it possible to harvest rainwater from traffic surfaces. Reclaimed rainwater from roofs can also be used to nurture small Urban Farming type gardens. Such activities can significantly contribute to enriching the city landscape and improving the microclimate, economic condition of small businesses, individuals, and enriching the biocenosis of the urban environment [30].

The results obtained in the research indicate that the city of Poznań has a considerable number of completed large-area objects – shopping galleries and belongs to the most invested cities in Poland in this aspect. The quantities of water recoverable from shopping mall roofs can feed significant areas of high and low greenery. On the scale of Poznań, the eight largest commercial buildings can meet the water demand of a medium-sized city park with an area of up to 4–5 ha, where about 500 trees can be planted. On the scale of the city of Poznań, these are significant values and at the same time measurable savings in the maintenance of green areas. The amount of rainwater that can be recovered depends mainly on the climatic zone and the amount of precipitation in the area and on how the roofs of the buildings from which the water can be recovered are managed.

Conclusions and requests

The development of green areas and worsening water scarcity results in a steady decline in the quality of the cityscape [31]. The decision makers' ill – considered attempt to supposedly improve the functionality by constructing more shopping malls resulted in a significant functional impoverishment and lowering of the spatial and landscape values in the existing and most valuable areas of Poznań city centre [32]. The negative impact of large-scale facilities on the city space manifests itself in the loss of, above all, large areas of greenery and the loss of rainwater which could be used for the care of these areas. Improvement of this situation should be the goal of decision makers and investors, and the implementation of a number of postulates should be included in the city's spatial development programs and plans [33]. In connection with the planned construction of further large-format facilities in Poznań, the most urgent and up-to-date postulates in this area should be included:

- development of large-size facilities could not take place without a parallel development of new green areas: e.g. parks, representative, usable and recreational areas implemented in a sufficiently large scale in relation to the development areas, e.g. in the relation 1:1, i.e. the **area of new green areas would be equal to the development area of commercial facilities**;
- the absolute principle of appropriate environmental compensation for the lost greenery(in exchange for one removed tree the obligation to plant 1700–2000 new seedlings and the obligatory care of them for 10 years);
- additional compensation could be provided by mandatory, usable **"green roofs"** on facilities [34, 35];
- **obligation to retain rainwater** for supplying green areas in the city obtained from roof surfaces and paved areas.

Some of the listed postulates concerning the use of facilities should be implemented within the technical possibilities of redevelopment of the existing large-area facilities. The current technological progress makes it possible to apply a variety of solutions for rainwater retention in urban areas in the form of surface and underground reservoirs, even under road and pedestrian traffic surfaces.

Summary

The creation of new green areas, especially in the form of planting high greenery, for the maintenance and care of which considerable amounts of water are needed, is a necessary action in the context of predicted climate changes and droughts [36, 37, 38]. In an urbanized space, any wooded area that provides the opportunity to benefit from a priceless patch of shade is desirable and extremely valuable [39]. In sunny areas the temperature of traffic surfaces, including concrete pavements, rises to 50–60 degrees Celsius in summer, not to mention dark asphalt pavements which are even hotter. This is an extremely disruptive impact, especially for children, the elderly and our pets. Therefore, it becomes so important in the urban space to maintain and acquire every even the smallest area of high greenery creating shaded space and the necessary amount of water to produce it. It should be noted here that the creation of a shadow zone by means of high greenery is the most economical and desirable action in the city landscape. Shopping malls as spatial structures "capturing rain" can also join the mainstream of rainwater recovery efforts. Space and cityscape standards are a shared value – a community value. Management in this sphere requires responsible and thoughtful decisions – it becomes all the more timely and important in the context of the predicted and already occurring climate changes [40, 41].

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Duże centra handlowe w Poznaniu jako źródło odzysku wód opadowych i nawadniania miejskich terenów zielonych

Streszczenie: Obiekty wielkopowierzchniowe w mieście są przyczyną utraty znacznych ilości wód opadowych, zieleni oraz powierzchni biologicznie czynnych. Naprawa tej sytuacji wymaga realizacji szeregu postulatów w zakresie planowania przestrzennego. Podnoszenie atrakcyjności i wartości przestrzennej terenów zurbanizowanych ma podstawowe znaczenie dla zaspokajania potrzeb lokalnych społeczności w dobie przewidywanych zmian klimatycznych. Z przeprowadzonych badań wynika, że wodą odzyskaną z dachów obiektów wielkopowierzchniowych można zasilać znaczne obszary zieleni miejskiej.

Słowa kluczowe: galerie handlowe, retencja wody opadowej, centra handlowe, zieleń miejska, krajobraz miasta, Poznań