

Use of vegetation and natural management of rainwater and grey water resources in the external space of the building

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Abstract. The purpose of the publication is to focus attention on the potential of vegetation application and revitalisation of non-industrial sewage and rainwater in contemporary architectural design. Use of plants, along with the natural water resources management system in the external zone of the building and in the public space, has an ecological justification, characterised by numerous advantages, making it easier for us to live in an urbanised area. These are: simplicity of implementation, thermal and acoustic benefits, energy saving, the possibility of using local plants, health and aesthetic values, as well as low maintenance costs.

*"Trouble in nature appears only there,
where there has been human interference."*
Shaun Ellis

1. Introduction

Drinking water is definitely scarce these days, which is why it is so important not to use it only for activities such as watering plants, flushing toilets, washing or doing laundry. In the 21st century, in the era of strong urbanisation, when water became an indispensable element of the civilised world, we completely forgot how valuable this life-giving substance is and how much we contribute to the deterioration of its quality, treating its resources as unlimited. The amount of drinking water is constantly decreasing due to the rapidly growing industry, increasing number of areas with hardened surface, as well as the uneconomical management of water in our daily life. The system designed to manage the collected rainwater could be one of the solutions to the aforementioned problems, making it an alternative source of water.

2. Recycling of rainwater and grey water

Advanced rainwater collection systems have been known and have already been present around 3,000 years BC in Jordan [1]. In Poland, rainwater was used mainly for washing in the 1960s [2], mostly in rural areas. Rainwater collected from roofs, paved areas such as driveways, car parks, squares, etc. is collected by a system of gutters and downpipes, then goes to a tank (most of the time located underground). Subsequently it is filtered and pumped to the place of water demand. Rainwater cannot be used interchangeably with tap water in a completely arbitrary way, because their parameters differ from each other. It is obvious that rainwater cannot be used for food purposes, but due to the lower sanitary quality it is a good solution for watering lawns and vegetation in a garden, a patio, living walls or a green roof. An additional advantage is that rainwater has less calcium compounds, so it is more easily absorbed by plants than tap water. For the same reason, rainwater as soft water has no destructive effect on the elements of washing machines and it facilitates the dissolution of detergents (which reduces their amount). Rainwater can be successfully used for flushing the toilet bowls, which enlarge savings of drinking water. Moreover, rainwater can be also used for various activities such as washing a gardening equipment, a terrace or driveways. Undoubtedly there is a possibility of making significant savings of tap water in a daily consumption. The water used to rinse a toilet and urinals is called black water (black sewage), while the water that does not contain faeces and urine named grey water is a significant part of the general sewage as reported in the summary (Table 1). To sum up:



grey water makes up about 51% of the total sewage and this is the amount that we can recover and re-use-water for this type of use does not have to be drinking water. It is also very important that the use of a rainwater management system makes it possible to avoid including given estate in "rain tax" (fee for maintenance of rainwater and snowmelt infrastructure in proper technical efficiency to remove or minimise any hazards associated with its deficit and excess, such as floods and droughts).

Table 1. The structure of the consumption of water intended for living and household needs [3].

Water consumption structure	Usage rate [dm ³ /Mxd]		%
	min.-max.	average	
Drinking and cooking	05-mar	4	3
Washing dishes	15-paź	12	10
Washing the body	15-paź	12	10
Bathing in the shower or in the tub	25-40	33	26
Rinsing the toilet bowl	30-45	38	30
Laundry	16-20	18	15
Cleaning and other needs	10-cze	8	6
Total	100-150	125	100

Education about how to properly dispose water in the world is an important aspect of human life, especially due to the fact that the space around us is more and more filled with concrete and asphalt (especially in cities), limiting the natural resources of the Earth (both flora and fauna are connected with it). In the era of technological progress, ways of water purification can be more advanced without a doubt, unfortunately they involve higher costs and require well-trained and qualified staff. These reasons alone, often make it impossible to apply these methods and technologies in practice, which is why development of simple, cheaper and more cost-effective natural methods of cleaning water arouses interest. Among the natural water treatment systems, we can distinguish: phyto-purification (Figure 1), lagoons and storage in reservoirs.

3. Features of natural water treatment systems

Undoubtedly, the priority aspect of natural grey and rainwater treatment systems is the pro-ecological aspect, which is environmentally friendly and does not harm the ecological balance of natural resources. Another important features are as follows: the simplicity of the system construction, the ability to conduct care treatments even by unqualified staff, the ease of designing vegetation and its application in practice. Vegetation is a cost-effective undertaking because it does not require high construction, maintenance or energy costs. The lack of use of mechanical devices reduces maintenance costs. The only limiting factor is the land cost on which the establishment of a natural wastewater treatment system is designed. Storage of rainwater increases the independence of the owner from the water supply. The rainwater collection system reduces the amount of rainwater discharged to the network and thus prevents the collector to overflow, it is also a sustainable investment that increases the value of the land. Most of the contaminants can be removed, so natural water treatment systems are very efficient (however, climatic conditions determine its effectiveness - at lower temperatures the efficiency is lower). Another feature of the discussed systems is high reliability even under extreme operating conditions (the ability to absorb a wide range of organic compounds).

4. Impact of the use of vegetation on human health, urban climate and the environment

A natural environment conducive to human health is a rich ecosystem, that we are fully dependent on and it is crucial to keep us alive. Therefore, in the era of strong urbanisation affecting the impoverishment of the natural living space, it is very important to pay special attention to the use of vegetation in a city.

The most important benefits [4] of plants are the reduction of carbon dioxide and, of course, oxygen production. Bushes and trees absorb CO_2 and “build it” into the wood structure, which is not possible for herbaceous plants. These plants rot in the winter hence they emit carbon dioxide in the same year or the next one, while their organic material decomposes and creates organic fertiliser. Plants also contribute to the filtration of the air from industrial dust, keeping it on their surface, acting as a self-renewing biological filter rinsed by rainfall.

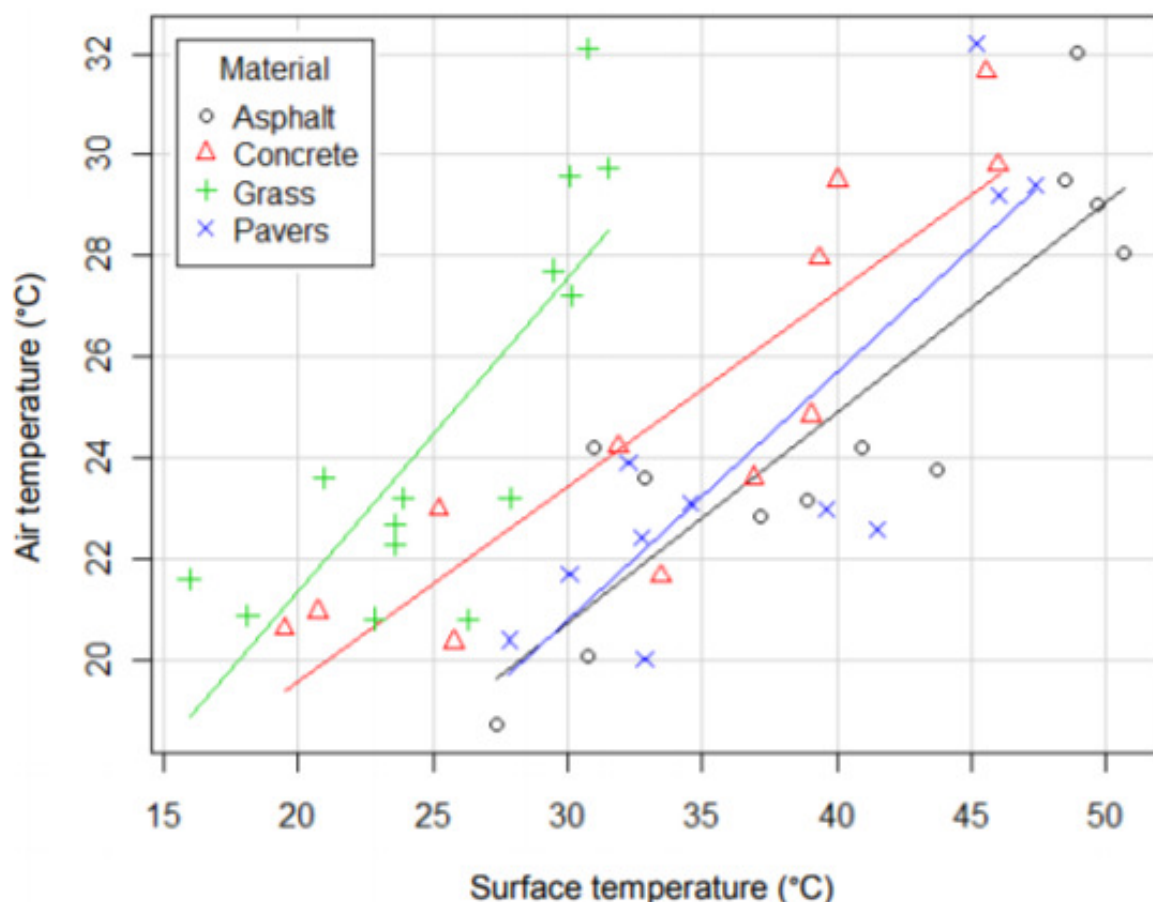


Figure 1. Differentiation of air in relation to the ground in the case of asphalt, concrete, grass and pavement [5].

Greenery has a positive effect on the climate in urban space. It was found that over the area of an ordinary lawn, the temperature at noon is even 20 degrees lower than above the asphalt surface [Figure 1]. Results of study carried out by Katharine Gaun [5] showed no significant difference in surface temperatures between asphalt, concrete, asphalt and pavers, but there was a significant difference between all artificial materials and grass. During the summer months when the sun's radiation is highest, the materials absorb more heat and the surface temperature increases. The ambient

temperature will also increase due to convection from materials. However, the temperature remains relatively lower compared to the natural cover due to evapotranspiration. Similarly, the humidity of the air, where even a single tree produces its irreplaceable microclimate, raising the humidity of the air in the immediate area, also lowering the temperature preventing the formation of "urban heat islands". As it is written [6] water in the environment helps to reduce heat adsorption by: encouraging evaporation and transpiration; keeping pervious surfaces cool; and enhancing the effectiveness of vegetation for shading.

Heat Island is a term for the phenomenon that involves a significant absorption of heat during the day by extensive artificial surfaces such as concrete, asphalt, pavement, located mainly in a city. The most reliable indicator of the intensity of the urban heat islands is the temperature difference between a city and its suburban areas. In large, mostly in European and American agglomerations, in time of the highest intensity such as at night, the difference can reach 10-15⁰C.

Green roofs and their vertical equivalents so-called living walls, set an example and inspire local councils to some groundbreaking activities in favour of saving energy and maintaining a healthy climate. For example, every new building in France, an office building, a hotel or a warehouse will require installation of greenery or solar cells on the roof. This is due to the law adopted in France [7] in March 2015, which requires the development of roof surfaces in harmony with climate and natural environment.

In Berlin, neighbouring buildings covered with green roofs with a total area of 40,000 m² were built on Potsdamer Platz [8]. Such a large area of the green roof together with a reservoir storage of a total of 3500 m² and an artificial lake of a total of 13,000 m² constitute an effective natural element of the rainwater collection and cleaning system by landscape management. This is a perfect example of a conscious policy in this area.



Figure 2. Green roofs at the Potsdamer Platz in Berlin [8] photo. K. Wolańska.

A research [9] conducted in New York shows that the surface temperatures on the regular roofs in hot summer days can be up to 40⁰C higher than the roof surface covered with properly selected

vegetation. Relatively the surface temperature of the standard roof was 19°C higher during the day and it was 8°C lower at night comparing to the green roof (measurements were carried out in July 2003). However, the temperature inside the building with the green roof was on average 2°C lower during the day and 0.3°C higher at night.

To avoid the occurrence of heat islands, we should seriously approach the subject and rationally plan the urban space taking into account also the creation of green roofs with large areas. Measurable results of reducing the effects of the urban heat island are possible to achieve with significant green areas located close to each other. Installations that are scattered over a large area may have no effect on lowering the air temperature.

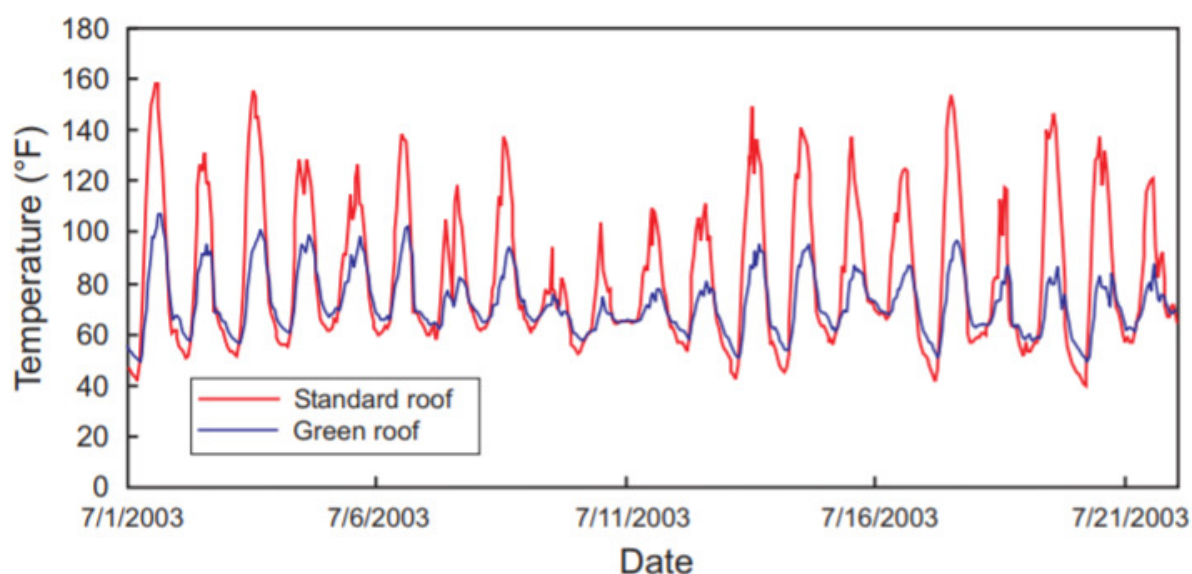


Figure 3. Example of the average surface temperatures on green roofs and standard roofs [9].

Green roofs can also be ideal for bee breeding as well as for vegetable growing. Located in the city, they could ensure production at the level of 3/4 of the vegetables consumed in it, as suggested by the Bologna case study in Italy [11]. In 2010, Bologna became the first city in Italy testing roof gardens on public buildings as a part of a project run by local authorities, universities and non-profit organisations. The specialists observed the process for three years in the period from 2012 to 2014. At that time, gardeners, working on the roof, cultivated lettuce, cabbage, chicory, tomatoes, aubergines, chilli peppers, melons and watermelons in the structures of plastic pipes and in recycled pallets filled with compost.

The researchers estimated that such a hypothetical garden can produce more than three tons of vegetables a year. Then the researchers estimated potential efficiency of a network of vegetable gardens, occupying all potential flat roof surfaces throughout the city of Bologna. This means that, based on current consumption data of the city, roof gardens could satisfy 77% (12,500 tons of vegetables) of the demand for fresh vegetables grown locally.

In addition, a map of the spaces located in the area of 500 meters from each other was made, showing that thanks to this type of solution, it is possible to create a network with a length of 94 kilometres of corridors for wildlife, including pollinating insects. A distance of 500 meters has been considered by scientists as adequate because most of the popular pollinating insects have a flight over a distance of 750-1500 m.

5. Examples of the use of vegetation with the possibility of using purified grey water and rainwater in the city space

The above features make these systems competitive to the conventional methods of wastewater treatment, and in addition can be part of a landscape, urban space or green architecture in themselves,

as well as fulfil the function of irrigating vegetation. The cities and areas with dense buildings are a problematic environment for rainwater. This is the reason why more and more emphasis is placed on the design of sustainable rainwater management systems. Their advantage is the management of rainwater at their place of installation [12].

The first example of using greenery along with the possibility of using managed rainwater and grey water in the architecture of the building and its immediate surroundings is the Pure SPA facility in Vietnam¹⁵ (figure 4, figure 5, figure 6, figure 7). The openwork building is flooded with greenery, its inner courtyard is filled with pools, plants are present in almost every corner of it, and translucent walls with hanging vegetation contribute to the wonderful play of light and shade. Greenery and water not only have aesthetic value but allow you to fully use the character of the building as a place of peace, stimulating all the senses and relaxation of both the body and the mind. A healthy, natural environment was created using local vegetation, which has become a part of architecture.



Figure 4. Pure SPA, Vietnam [12]. Photo: Oki Hiroyuki



Figure 5. Pure SPA, Vietnam [12]. Photo: Oki Hiroyuki



Figure 6. Pure SPA, Vietnam [12]. Photo: Oki Hiroyuki



Figure 7. Pure SPA, Vietnam [12]. Photo: Oki Hiroyuki

Another example of rational management of greenery and water in the city is a small building with a vertical herb garden on the façade in the centre of Lisbon [13]. It delights not only with its appearance, but also with the scent of plants, which are a compilation of 25 different species of herbs found on the Iberian Peninsula. The most original aspect of the design and implementation is the fact that each floor has a different smell - the aroma of lavender in the bedroom, rosemary in the living room, etc.



Figure 8. A vertical herb garden in the center of Lisbon [13].Photo: Fernando Guerra



Figure 9. A vertical herb garden in the center of Lisbon [13].Photo: Fernando Guerra

Something from "our yard" – objects presenting the green roof as examples of green infrastructure in cities, contributing to the reduction of pollution contained in the air, as well as fulfilling the above-mentioned pro-ecological tasks. As we can see in the illustrations below - the green roof can be found on objects of different functions.



Figure 10. A flower meadow on the terrace of an office building in Cracow [14]. Photo: Piotr Wolański APK Dachy Zielone



Figure 11. Green roof as terrace by the pool – a private house in Cracow [14], Photo: Piotr Wolański APK Dachy Zielone



Figure 12. Roof available for visitors at the Copernicus Science Center in Warsaw [14] Photo: Katarzyna Wolańska .



Figure 13. Extensive roof near the office building in Cracow [14]. Photo: Piotr Wolański APK Dachy Zielone



Figure 14. Shopping gallery Tarasy Zamkowe in Lublin [14], Photo: Katarzyna Wolańska



Figure 15. Polish sky-high gardens at the Centre for the Meeting of Cultures in Lublin [14], Photo: CSK Dorota Bielak

6. Conclusion

The management of rainwater and its reuse for specific purposes leads to savings in tap water and is rational, safe and most importantly - compatible with nature. The use of complete rainwater management systems is undoubtedly a pro-ecological activity that brings many benefits not only to current generations, but also to future ones and is consistent with the message of Native Indians, for whom nature is very close: "*We do not inherit our earth from our parents, we borrow her from our children*" (Chief Washaki).

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