THE POTENTIAL OF ALTERNATIVE WATER SOURCES FOR POTABLE WATER SAVINGS IN UKRAINE'S RESIDENTIAL AREAS

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Abstract. Universal access to safe drinking water is not only a fundamental need but also a basic human right. Water reuse and rainwater harvesting systems provide essential technical alternatives for water supply management. There are several alternative water sources available for reuse after some needed treatment: rainwater, stormwater, greywater, drainage water etc. The integration of on-site non-potable water reuse enhances the environmental goals of a green building by lowering the consumption of potable water and decreasing the volume of storm-water and wastewater that must be sent to the City's Wastewater Treatment Plants for treatment. The purpose of the article is to analyze two approaches for partially replacing tap water (rainwater harvesting and treated greywater reuse), to compare the constructive characteristics of these systems and calculate annual volume the potential water savings in Ukraine's residential areas using each option. Both methods offer sustainable solutions to alleviate water scarcity but differ significantly in construction, application, and operational mechanisms. For a comparative analysis of the two indicated alternative sources, are present the constructive features of water supply in the context of rainwater collection and use, and greywater. The volume of greywater generated in low-rise residential areas and rainwater that can be harvested from roofs was counted using Ukranian normative documents. The result shows at a building density of 0.4, the greywater volume is 1.45 times greater than that of rainwater; at a density of 0.54, it is 1.49 times greater under Ukraine's maximum annual precipitation of 750 mm. With comprehensive water recycling systems, it is possible to reduce freshwater demand by approximately 30% through grey-water reuse and by around 10% with rainwater harvesting. These savings offer both economic and environmental benefits, making water recycling especially advantageous for water-scarce regions seeking to mitigate the impacts of climate change.

Key words: alternative water sources, rainwater harvesting, greywater reuse, runoff, residential areas.

INTRODUCTION

Water scarcity is the shortage of freshwater resources needed to meet the population’s demand for drinking water and use for household needs. The issue of water scarcity has started to be considered on a global scale, as it affects all continents, in recent decades [1]. Reliable and sustainable water resources are crucial for socio-economic development, yet in modern society, water is often misused and wasted. By 2011, 41 countries faced water scarcity issues, with 10 of them nearly exhausting their water resources [2]. Expert forecasts from the Organization for Economic Co-operation and Development (OECD), which are based on the levels of 2000 and 2050, indicate that by 2050, freshwater shortages may impact 3.3 billion more people than in 2000. Limited access to traditional water resources necessitates the search for new approaches, including the integration of alternative sources in future water use strategies and the creation of programs for their implementation.

The European Union's environmental management policy and strategy, particularly regarding natural waters, aims to achieve sustainability in the water management sector within the member states. To this end, the Water Framework Directive (2000/60/EC) was adopted in 2000 [2]. According to this document: achieving sustainable development, environmental protection must be an integral part of the development process and cannot be considered (Water Framework Directive). Universal access to safe drinking water is not only a fundamental need but also a basic human right. Water reuse and rainwater harvesting systems provide essential technical alternatives for water supply management. Traditionally, engineers and decision-makers have approached infrastructure development as a purely technical issue aimed at supporting economic growth. In buildings, most water systems are focused on meeting basic human needs like drinking, hygiene, cooking, and cleaning. However, the introduction of new methods, such as water reuse and rainwater harvesting, is changing the way we interact with water [1; 3–6].

These innovations are not just technical solutions but are contributing to the broader transformation of the relationship between people and their environment. By using resources like rainwater and reclaimed water, communities are beginning to shift away from conventional water supply methods that rely heavily on centralized systems. This shift encourages a more decentralized and resilient approach to water management, where technology plays a crucial role in rethinking how humans use and conserve water [7; 8].

The integration of on-site non-potable water reuse enhances the environmental goals of a green building by lowering the consumption of potable water and decreasing the volume of stormwater and wastewater that must be sent to the City's Wastewater Treatment Plants (WWTPs) for treatment [6; 7].

The purpose of the article is to analyze two approaches for partially replacing tap water: rainwater harvesting and greywater reuse, examining their roles, benefits, and limitations within the broader context of sustainable water management. It aims to compare the design characteristics of these systems and calculate annual volume the potential water savings in Ukraine's residential areas using each option.

MATERIALS AND METHODS

There are several alternative water sources (AWS) available for reuse after some needed treatment. The most common is rainwater, that collected from roof surfaces or other above-ground surfaces. Very close to the previous is stormwater. In this type of AWS precipitation from roads, sidewalks, paths in parks, and other surfaces is collected to the drainage system. Another type of AWS is greywater, that refers to wastewater that has not been contaminated by toilet discharge, infectious or hazardous bodily waste, or unhealthy substances from industrial processes. Greywater typically includes treated wastewater from bathtubs, showers, bathroom sinks, washing machines, and laundry tubs, but excludes wastewater from kitchen sinks and dishwashers. In the some way people should use drainage water as AWS. Foundation drainage refers to nuisance groundwater that is removed to protect the structural integrity of a building or facility. This groundwater would otherwise seep into the foundation, potentially causing damage, and is typically diverted away from the structure. In many cases, this drainage is prevented from entering the sewer system to avoid overloading it. Foundation drainage differs from non-potable groundwater extracted for a beneficial use, such as irrigation or industrial processes.

At the article are deeply studied, two types of AWS greywater and harvesting rainwater.

Historically, the first alternative water source utilized was the collection and use of rainwater runoff. This practice dates back thousands of years, with evidence from ancient civilizations such as Mesopotamia, Egypt, and Rome, where rainwater was collected and stored to supplement local water supplies [9].

These early systems allowed societies to survive and thrive in arid regions or during seasonal droughts. Today, rainwater harvesting remains a crucial water management technique, adapted for modern infrastructure to support sustainable water use and resilience against water scarcity.

Countries around the world have successfully integrated rainwater harvesting into their water management strategies, adapting techniques to meet local needs. Percentage of water consumption per capita for various household needs in different country that can be substituted with rainwater are shown in Table 1.

Table 1. Percentage of water consumption per capita for various household needs that can be substituted with rainwater

Country	Household needs		
	toilet	laundry	cleaning
USA [14]	32,1–28,0	24,2–22,0	2
Canada [14]	30	20	5
Iran [3]	16	14	12
India [5]	20	11–21	up to 6
Ukraine [14]	32,7	15,7	6,1
Germany [15]	5-45	20-30	10-20
Italy [4]	31	12	no data
Japan [16]	25-40	no data	15-25

In Australia, rainwater is widely used in rural areas for agriculture and domestic purposes, providing a critical buffer during drought periods [10]. Similarly, Germany has incorporated rainwater harvesting into urban planning by utilizing green roofs and cisterns to manage stormwater runoff and support municipal water systems [6]. In India, rooftop rainwater harvesting plays an essential role in supplying potable water to rural communities, offering a reliable water source in regions with limited infrastructure [11]. Japan has adopted rainwater systems in commercial settings, with facilities like the Tokyo Dome using harvested rainwater for non-potable purposes and as an emergency reserve [12]. Meanwhile, in the United States, cities like Portland and Seattle encourage rain gardens and cisterns to reduce urban flood risks and improve water quality [12].

Another type of AWS is greywater. It is reported that about 25–30% of potable water consumption can be reduced by reuse of greywater [17]. Treats greywater generated by a community and the treated greywater is used in subsurface irrigation of fruits and vegetables. For toilet flushing, pavement and car washing, irrigation of vegetables [18].

The amount of greywater produced in a household can vary significantly, depending on various factors such as: geographical location and climate, lifestyle, culture and habits, type of infrastructure etc (Table 2). For instance, greywater production can be as low as 15 L/day per person in poor country but may reach several hundred liters per person in more affluent regions Oteng-Peprah [7] According to research greywater can account about 69% by Jamrah [19] or up to 75% Hernandez Leal [20], of total household wastewater.

Table 2. Amount of greywater in some regions from household

Regions	(L/day)	Reference
Jordan	50	[21; 22]
Switzerland.	110	[23]
Vietnam	72–225	[24]
Mali	30	[25]
Oman	151	[26]
Sweden	65	[27]
Arizona, USA	123	[28]
Ukraine	45	[29]

CONSTRUCTIVE FEATURES OF SYSTEMS OF USING ALTERNATIVE WATER SOURCES

For a comparative analysis of the two indicated alternative sources, we will present the constructive features of water supply in the context of rainwater collection and use (Fig. 1) and greywater (Fig. 2). Both methods offer sustainable solutions to alleviate water scarcity but differ significantly in construction, application, and operational mechanisms.

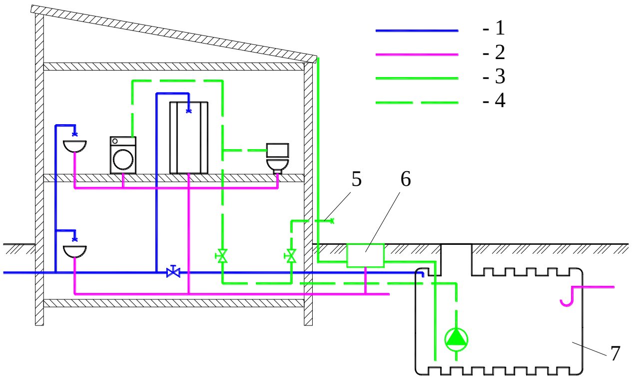

Fig. 1. Collection, Filtration, and Reuse of Rainwater: 1 – potable water supply; 2 – household sewage system for "black" wastewater;3 – rainwater drainage (gutter); 4 – rainwater reuse; 5 – outdoor use; 6 – mesh filter;7 – rainwater storage tank

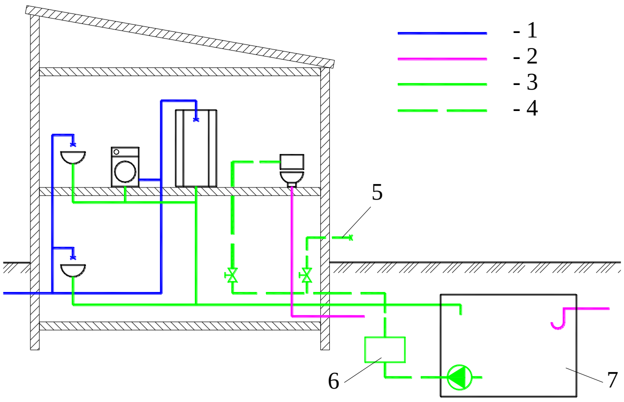

Fig. 2. Collection, Filtration, and Reuse of Greywater: 1 – potable water supply; 2 – household sewage system for "black" wastewater; 3 – household sewage system for greywater; 4 – greywater reuse; 5 – outdoor use; 6 – ultraviolet disinfection; 7 – mechanical filter

Rainwater harvesting involves the collection and storage of rainwater from rooftops, pavements, and other surfaces. This system includes collection components 3 (gutters and downspouts) as shown in Fig. 1, which channel water into storage tanks or cisterns 7 and allow for the storage of significant volumes for various purposes. These systems require filtration and treatment to ensure water quality 6 and have distribution systems 4 and 5 that integrate with existing water supply networks 1.

In turn, greywater reuse involves the collection and treatment of wastewater from sinks, showers, and washing machines, using separate plumbing systems to direct this wastewater 3 (Fig. 2). Treating greywater is technologically more complex, as it requires not only filters but often more advanced biological and/or chemical processes. Additionally, treated greywater is stored for further use, such as for irrigation or toilet flushing.

The comparative analysis of rainwater harvesting and greywater reuse reveals distinct constructive features tailored to their respec-tive functions. Understanding these differen-ces is crucial for selecting the most suitable alternative water source, depending on local conditions, regulations, and specific water needs.

VOLUMES DETERMINATION

Rainwater for reuse is most commonly collected from roofs, as they require minimal treatment compared to other surfaces. Precipitation for European cities has such a regime and volume that allows year-round use of it in water supply systems. [30–33].

When planning new residential developments, it is essential to incorporate rainwater harvesting for non-potable uses in the initial design phase. Based on successful international practices [31, 32], it is possible to estimate rainwater volumes for hydraulic calculations in water supply networks based solely on the built-up area. Research focused on estimating the amount of water that can be sourced from alternative, non-potable supplies based on territory size and building density is wellwrited in the works of Tsanov [32, 33].The authors indicate that harvesting systems can reduce water usage for toilet flushing by 48% to 267%, depending on specific design parameters.

Regulations specify maximum allowable land coverage for residential buildings– ranging from 30% to 50% – depending on building density (DBN B.2.2-1-01), in Ukraine.

In Ukraine, the total runoff volume of rain and meltwater discharged into stormwater systems can be determined according to Usage Rules or DSTU 3013-95 for warm and cold periods. The runoff volume

$$W_r = 10\, h_r\, \Psi_r\, F,$$

where h_r is the average annual precipitation depth (mm); Ψ_r is the total runoff coefficient accounting for initial retention, infiltration, and evaporation, depending on the surface type, for improved roof coverings is 0.7 (DSTU-N B V.2.5-61:2012); F is the surface area of runoff (ha).

The results for the calculated annual water volumes from low-rise developments, resulting from rainfall with varying precipitation depths ranging from 350 to 750 mm, as well as greywater volumes, are presented in Fig. 3.

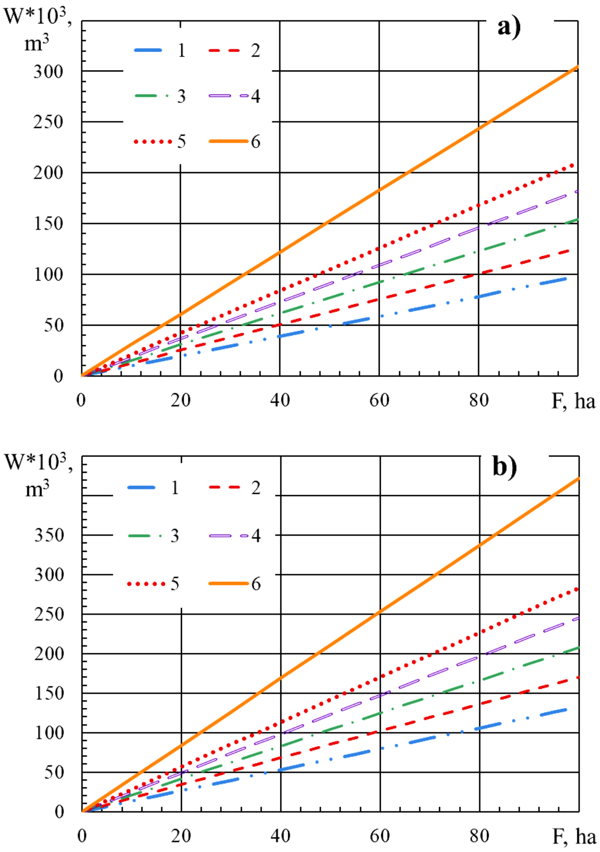

Fig. 3. Dependence of the annual volume runoff of harvested rainwater collected from a roof with a runoff coefficient of 0.7, depending on the area of residential quarters with different degrees of development: a) 0.4, b) 0.54, for different precipitation depth h_r: 1 – 350 mm, 2 – 450 mm, 3 – 550 mm, 4 – 650 mm, 5 – 750 mm and 6 – the annual volume grey water.

To determine the annual volume of greywater generated from a specific residential area, the following initial data specified in DBN B.2.2-1-01 were used: population density for low-rise development, depending on building density, is 0.4 – 130 persons/ha and 0.54 – 180 persons/ha. The volume of gray water is calculated based on data [29], with 1.364 l/person per month for showering and 589 l/person per month for laundering. At the article was determined annual volume (m^3) that collected from residential area (ha) by combining all the above prescribed data.

As shown in the graphs, the volume of greywater that can be collected from low-rise residential areas exceeds the volume of rainwater that can be harvested from roofs, even at Ukraine's maximum precipitation depth of 750 mm.

From Fig. 3a, at a building density of 0.4, the volume of greywater is 3.11 times greater for 350 mm of rainfall and 1.45 times greater for 750 mm. Similarly, at a building density of 0.54, the volume of greywater is 3.19 times and 1.49 times greater, respectively (Fig. 3b).

CONCLUSIONS

Rainwater and greywater can be effectively used as substitutes for freshwater in various applications, including toilet flushing, cleaning, and irrigation. This substitution reduces both freshwater consumption and wastewater discharge, which in turn lowers associated costs. Implementing rainwater and greywater recycling systems in all new buildings would promote sustainable water use and reduce pressure on potable water supplies and sewage systems.

Notably, the volume of greywater generated in low-rise residential areas exceeds the volume of rainwater that can be harvested from roofs, even under Ukraine's maximum annual precipitation of 750 mm. At a building density of 0.4, the greywater volume is 1.45 times greater than that of rainwater; at a density of 0.54, it is 1.49 times greater.

With comprehensive water recycling systems, it is possible to reduce freshwater demand by approximately 30% through greywater reuse and by around 10% with rainwater harvesting. These savings offer both economic and environmental benefits, making water recycling especially advantageous for water-scarce regions seeking to mitigate the impacts of climate change.

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Потенціал альтернативних джерел води з метою збереження питної води в місцях житлової забудови України

Вадим Орел, Леся Вовк, Володимир Фем'як, Ірина Балінська

Анотація Загальний доступ до безпечної питної води є не лише фундаментальною потребою, але й основним правом людини. Системи повторного використання води та збирання дощової води є важливими технічними альтернативами для управління якісним водопостачанням. Є кілька альтернативних джерел води, доступних для повторного використання після певної необхідної обробки: дощова вода з дахів, дощові стоки, «сіра» вода, дренажна вода тощо. Інтеграція повторного використання непитної води покращує екологічні цілі «зелених» будівель за рахунок зниження споживання питної води, а також зменшення обсягу стічних і зливових вод, що їх направляють на очисні споруди для очищення. Метою статті є аналіз двох підходів до часткової заміни водопровідної води (збирання дощової води та повторне використання очищеної «сірої» води), порівняння конструктивних характеристик цих систем водопостачання та розрахунок річного обєму води з метою визначення потенційної економії в населених пунктах України за кожним із варіантів. Обидва методи пропонують стійкі рішення для подолання дефіциту води, але суттєво відрізняються застосуванням і робочими механізмами. Для порівняльного аналізу двох вказаних альтернативних джерел води наведено конструктивні особливості водопостачання в контексті збирання і використання дощової води та «сірої» води. Обсяг «сірої» води, що утворюється в малоповерхових житлових кварталах, і дощової води, яку можна зібрати з дахів будівель, розраховували за нормативними документами України. Результат показує, що при щільності забудови 0,4 об’єм «сірої» води в 1,45 рази перевищує об’єм дощової води; при густині 0,54 він в 1,49 раза більший за максимальну річну кількість опадів в Україні, що становить 750 мм. За допомогою комплексних систем циркуляції води можна зменшити потребу в прісній воді приблизно на 30% за рахунок повторного використання «сірої» води та приблизно на 10% за рахунок збирання дощової води. Ця економія забезпечує як економічні, так і екологічні вигоди, що робить циркуляцію води особливо вигідною для регіонів з дефіцитом води, які прагнуть пом’якшити наслідки зміни клімату.

Key words: альтернативні джерела води, збирання дощової води, повторне використання «сірої» води, дощовий стік, житлові райони.

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