Case Study on Reducing Potable Water in Residential Buildings by Implementing Rainwater Storage Systems

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Abstract: *Given that water is an indispensable and valuable resource, the water shortage faced by some areas of the globe has recently attracted the attention of the European Environment Agency (EEA). For this reason, the paper deals with aspects regarding the possibility of using water from precipitation, taking into account, for the study, buildings from two rural localities adjacent to Timișoara (Giarmata and Moșnița Nouă). An analysis was carried out regarding the amount of drinking water that can be replaced in indoor sanitary installations with captured and stored water from precipitation. The amount of potable water that can be replaced was considered only for household needs such as: flushing toilets, washing clothes, watering green spaces and gardens and washing impervious spaces (lanes, yards, etc.) on the property. The study considered 5 stages of approach through which the quantity and quality of rainwater that can be collected, the technical solutions that can be implemented and the reduction of the amount of drinking water were evaluated, taking into account two consumption scenarios (reduced and increased). Based on the data obtained, it was concluded that for a low level of consumption, in the two buildings, the amount of water collected from precipitation fully covers the consumption of the household needs taken into account, and for the scenario of increased consumption, only 2 and 3 weeks of consumption remain uncorrelated which are the equivalent of a normal vacation period in which no consumption is recorded. In conclusion, the installation of rainwater storage systems is reliable for residential buildings, especially in rural localities where properties benefit from larger land areas.*

Keywords: *Rainwater storage, residential buildings, reduction of drinking water consumption*

1. Introduction

Water is an indispensable and valuable resource for mankind, but unfortunately, in recent times, there has been a decrease in both water reserves and the depth of groundwater, especially in regions where consumption exceeds the regeneration capacity of groundwater [1]. Regarding Europe, since 2009, the European Environment Agency draws attention to the water shortage faced by the southern areas and which has extended to the northern parts, problems that will probably worsen due to climate change [2]. Although Romania is included among the countries with relatively limited water resources, together with Spain and Turkey, by the EEA [3], Romania still has a fairly sustainable water resource system, except for some areas where problems related to quantities of water can be observed [4].
These problems can become a threat for several areas, among which: public health, food security, ecosystems, etc. On the other hand, the unsustainable use of water resources leads to increased costs in drinking water supply systems (in treatment plants, on distribution networks). Moreover, population growth in urban areas and their adjacent areas in recent years has become a problem of the present and probably a stress for the future in terms of consumption of water resources. The migration of the population towards these localities determined the emergence of densely populated areas, which led to a considerable increase in the consumption of drinking water, which, being also used for green sap maintenance, implicitly led to the overloading of the drinking water supply systems. All these aspects lead to the need to save water by implementing measures to reduce drinking water consumption in buildings. The reduction of potable water consumption for installations in residential buildings, in a percentage of about 30%, is possible through the collection, storage and use of stormwater [5]. For this reason, the paper addresses issues regarding the return on investment in stormwater storage and use systems for residential applications in regions in western Romania, more precisely in the Timiş Plain, where the population density is continuously increasing, resulting in a large number of water consumers. drinking water

[4] (approximately 86.1 inhabitants/km), of which 59% of the population is located in the urban environment, and the remaining 41% in the rural environment [6], with the highest concentration in the rural areas adjacent to Timisoara.
For this reason, two localities from Timiș County, located near the town of Timișoara (Giarmata and Moșnița Nouă), were chosen for the study, where, in the last period, there has been a considerable increase in built space and implicitly in population growth. For these localities, an analysis was carried out regarding the opportunity of investing in rainwater storage systems and its use, both in indoor sanitary installations for washing WC bowls and for washing machines, as well as for irrigating green spaces, watering gardens and for various cleaning activities outside buildings.
Moreover, when designing and dimensioning water supply systems in a centralized system, a water requirement for irrigating green spaces and watering gardens on private properties is not taken into account. So the storage and use of meteoric water for the needs of a household outside the building would satisfy a need that is not provided by the water supply systems and at the same time would ensure the reduction of the pressure placed on the water systems by these unforeseen consumptions in the design and dimensioning. The design standards and regulations in Romania [7,8] establish a specific daily flow of water/person for household needs depending on the type of facility equipment of the buildings. Thus, for the localities of Giarmata and Moșnița Nouă that are equipped with centralized water supply systems and indoor sanitary installations of cold and hot water, sewerage and individual preparation of hot water, the normative NP 133/2023 [7] considers a specific flow of water of 100-120 l/person/day which also includes the flow required for washing WC bowls and for washing machines. Thus, by replacing the water requirement for these facilities with water from precipitation, the water requirement in l/person/day would be reduced.
For this purpose, meteoric water samples were collected for which the water quality was analyzed by determining the physico-chemical and microbiological parameters. Solutions for its use are also proposed, in order to reduce drinking water consumption and implicitly costs.

2. Case study

2.1 Methodology

As Europe risks facing water shortages in many regions, it is necessary that water consumption in buildings is an important factor in the management of water resources and the efficient use of the environment. Therefore, an alternative and viable source of water is water from rainwater, which, however, requires several stages of approach:
- Stage I - evaluation of the amount of water from precipitation that can be collected;
- Stage II – analysis of the quality of the collected water and possibly the establishment of treatment solutions;
- Stage III – analysis of solutions that can be implemented;
- Stage IV – estimation of the volume of water from precipitation that can be collected and, respectively, that can be used at consumption points;
- Stage V – estimation of water consumption reduction.

2.2 Results and discussion

The study was carried out by approaching the three stages, as follows:

Stage I – for this stage, an assessment of the amount of precipitation was carried out for the two localities (Giarmata and Moșnița Nouă) by consulting the data provided by Meteoblue AG [9], for which the amounts of monthly precipitation were determined, according to Fig. 1 and Fig. 2.
It can be seen that location can affect investment as rainfall is unpredictable, fluctuating and seasonal in different regions. However, an estimation of the precipitation leading to the correct sizing of the storage reservoirs is necessary. The study was carried out taking into account the period September 1, 2022 - August 31, 2023, for which the total amount of rainwater was calculated (Q_{tr}) which can be collected for the two localities, based on the data provided by Meteoblue AG [9]. Rainwater values for the period September 1, 2022 - August 31, 2023 are presented in Fig. 1 for the town of Giarmata and in Fig. 2 for the town of Moșnița Nouă.

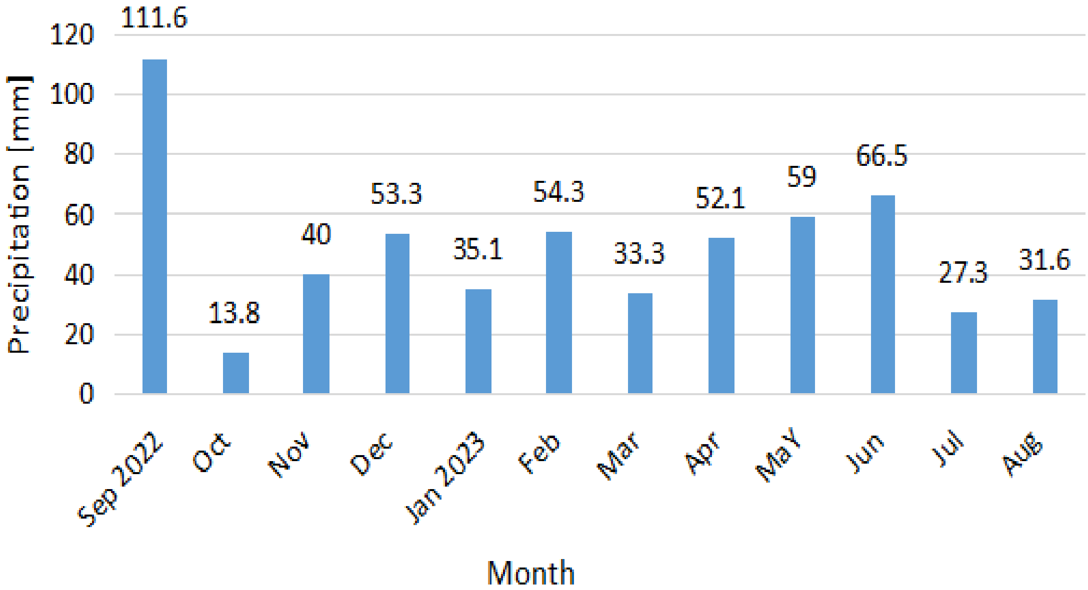

Fig. 1. Monthly rainwater – Giarmata [9]

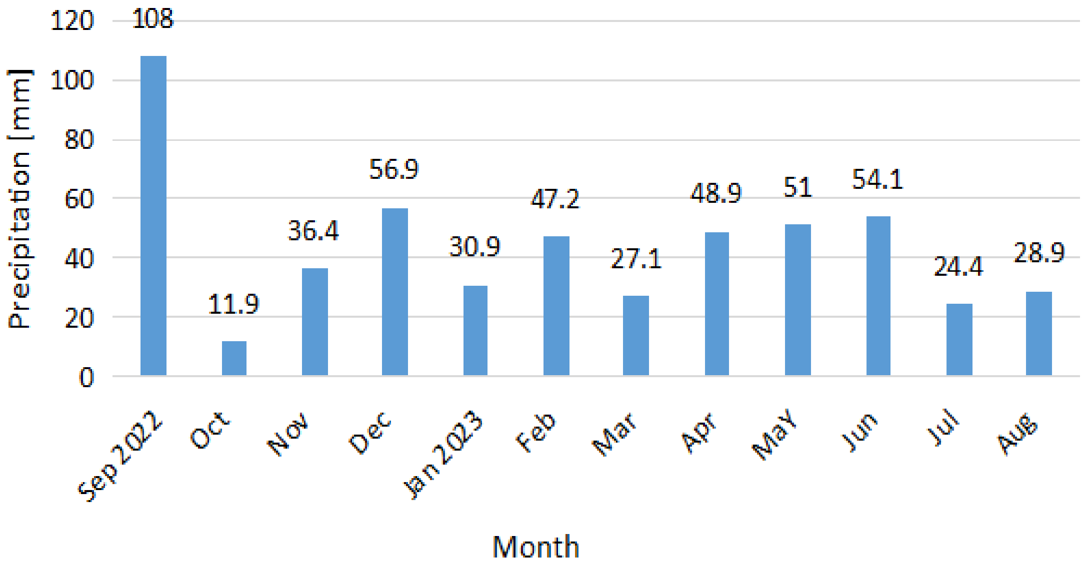

Fig. 2. Monthly rainwater - Moșnița Nouă [9]

For the two localities, the result was:

- for the town of Giarmata, resulted a value of 577.9 mm/year;
- for the town of Moșnița Nouă, resulted a value of 525.7 mm/year.

Stage II – analysis of water quality from precipitation was performed after collection and storage for 15 days in sterile plastic containers. The water was kept at a temperature of about 20°C in the containers in which it was stored and protected from sunlight. Two buildings, from the two localities, were chosen for the collection of meteoric water, which have the same type of covering (tile) and the same collection system (gutters and downspouts made of galvanized sheet). Water collection was done at the base of the downspout, after the water had washed the casing and discharged through gutters and downspouts.
The quality analyzes of the water samples were performed in the laboratory of the ICER Research Institute of the Polytechnic University of Timișoara. Table 1 shows the results obtained for the main water quality indicators in comparison.

Table 1: Results obtained for the main water quality indicators

No.	Analysis executed	Unit	Giramata rainfall water sample	Moșnița Nouă rainfall water sample	Recommended values for drinking water	Test method
1	pH (temperature)	unit. pH (^{0}C)	6.7 (23^{0}C)	5.7 (23^{0}C)	6.5 – 9.5 / la max. 24^{0}C	POL-CM-09, ed.1/rev.0
2	Conductivity (20^{0}C)	µS/cm	40	50	2500 µm/cm (20^{0}C)	POL-CM-42, ed.1/rev. 0
3	Nitrites	mg/L	-	0.08	max. 0.5	POL-CM-17, ed.1/rev.0
4	Nitrates	mg/L	< 10	10	< 50, adults < 10, baby	POL-CM-16, ed.1/rev.0
5	Ammonium	mg/L	bdl	0.04	max. 0.5	POL-CM-18, ed.1/rev.0
6	Content of Ca	mg/L	-	2.0	< 100	POL-CM-14, ed.1/rev. 0
7	Content of Mn	mg/L	-	0.035	max. 0.05	POL-CM-12, ed.1/rev. 0
8	Content of Fe	mg/L	bdl	bdl	max. 0,2	POL-CM-12, ed.1/rev. 0
9	Content of Cd	mg/L	-	bld	-	POL-CM-12, ed.1/rev. 0
10	Content of Ni	mg/L	-	0.2	not normed	POL-CM-14, ed.1/rev. 0
11	Content of Cu	mg/L	-	bdl	-	POL-CM-12, ed.1/rev. 0
12	Content of Zn	mg/L	bdl	bdl	not normed	POL-CM-14, ed.1/rev. 0
13	Total dissolved solids (TDS)	mg/L	2.0	1.0	max. 500	gravimetric analysis

Note: bdl (below the detection limit)

Table 1 shows the slightly acidic nature of the stored meteoric waters, which can be easily corrected with solutions to increase the PH.
From the point of view of electrical conductivity, nitrates, nitrites, ammonium, the content of metals Ca, Mn, Fe, Cd, Ni, Cu, Zn and the total dissolved solids, it can be observed that the stored meteoric water falls within the potability limits.
Based on the results of the analyzes of the water quality indicators, it was concluded that:

- for the Giarmata locality it can be appreciated that the water from precipitation can be used for household needs considered without treatment;
- for the town of Moșnița Nouă, it can be appreciated that the water from the precipitation can be used for the household needs considered with a slight correction in terms of the pH of the water.

Stage III – the analysis of the solutions that can be implemented was carried out by taking into account the following directions of use of meteoric waters:

• use to reduce drinking water consumption;

Meteoric water is collected from roofs, balconies, terraces, or other surfaces with a low degree of pollution, roofs being the preferred surface for their collection. The quality of the collected water depends on the surface with which it comes into contact, as well as the quality of the air, and it will be treated as necessary.

The analysis of the solutions that can be implemented, from the point of view of reuse in order to reduce the consumption of potable water, was carried out by identifying the points of consumption in the indoor sanitary installations where the potable water can be replaced by the collected meteoric water, as well as the identification of the spaces outside the building where meteoric water can be used.

Thus, solutions are proposed that involve changes in the classic design of cold water supply sanitary installations that serve buildings by separating and grouping consumption points that require potable water (drinking, cooking, personal hygiene and washing dishes) and those that can use water from precipitation that has been collected and stored (flushing toilets, washing machines, washing driveways, sidewalks, parking lots and yards).
At this stage, general systems were proposed (Fig. 3) that can be adapted according to the configuration of the indoor water supply plumbing. Also, the type of system is chosen according to the availability of land in each location.

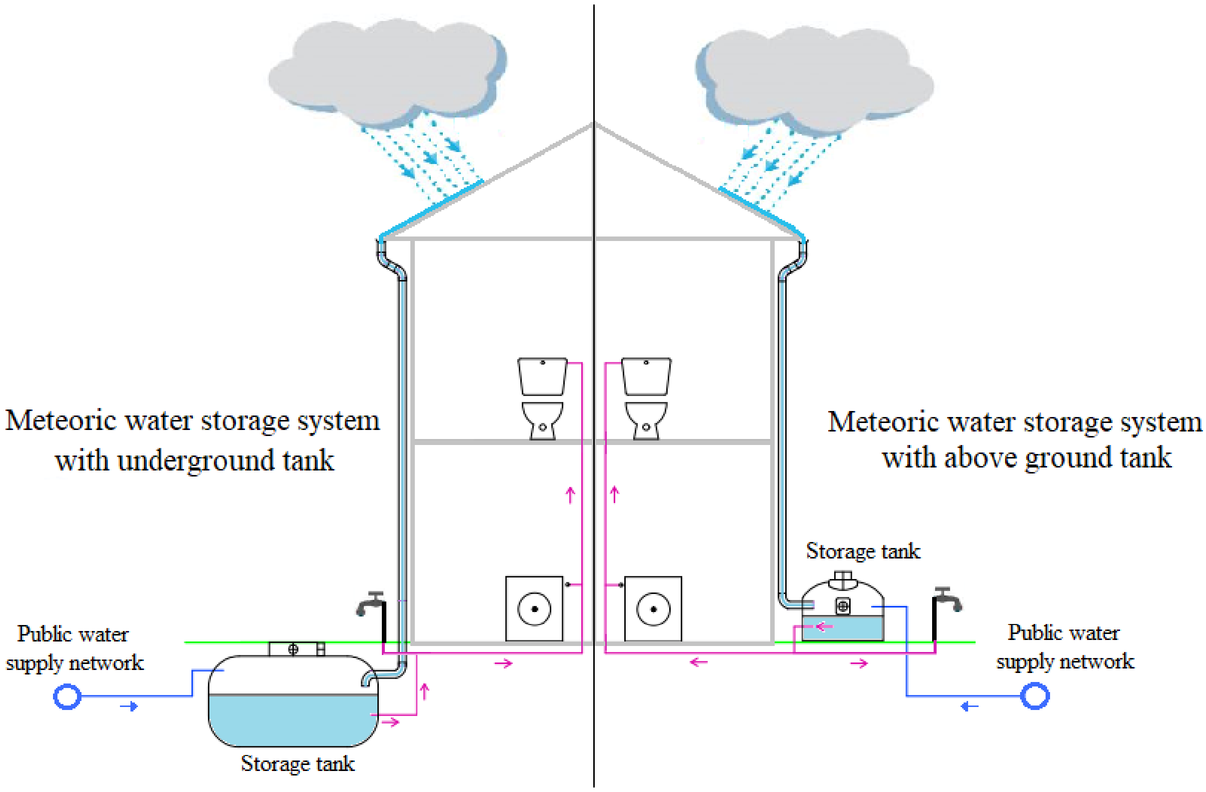

Fig. 3. Meteoric water storage systems

• use for underground water conservation.

From this point of view, it is necessary to make an assessment of the need to enrich the underground water layer in the areas where the collection and storage is done. Thus, to conserve groundwater and protect the environment, stormwater can be collected, stored and used for artificial infiltration into the soil, ensuring both the natural water cycle and for irrigating gardens and green spaces during periods of drought.
From the analysis of the two directions of reuse of the collected and stored meteoric waters, the optimal use solution will result.

Stage IV – involves carrying out a study to estimate the volume of water from precipitation that can be collected and then used in indoor plumbing.

• volume of water that can be collected from precipitation

To evaluate the amount of water from precipitation for the two households in the two localities, the amount of water from precipitation determined in Stage 1, the useful surface of the roof from which it can be collected, was taken into account. The calculation of the volume of water that can be collected was determined with the relation (1) [10]:

$$Q_{mwc} = \frac{S_u \cdot Q_{tr} \cdot k}{1000} \quad (1)$$

where:
Q_{mwc}- meteoric water collected [m^3];
S_u- useful roof surface [m^2];
Q_{tr}- total annual rainfall [m^2];
k - water collection efficiency coefficient [-].

The coefficient k, depending on the material of the roof and the particularities of the construction, can take values between 0.8-0.94 (Table 2) [10]. For the two buildings that have a frame-type roof covered with concrete tiles, the coefficient k = 0.8 was considered.

Table 2: Consumption of potable water for household needs that can use stored meteoric water

Roof type	Coefficient k
Tin roof	1
Fired Clay Tile	0.9
Slate tile, concrete	0.8
Gravel screed	0.6

About 80% of the useful roof surface was considered for the useful roof surface:
- for the town of Giarmata, a water volume of 60,102 liters resulted, which can be collected;
- for the town of Moșnița Nouă, a water volume of 54,673 m3 resulted that can be collected.
• volume of water that can be used at points of consumption in indoor plumbing

Starting from the specific water flow (100-120 l/pers/day) taken into account when designing water supply networks for localities of the type considered for the study (Giarmata and Moșnita Nouă), an estimate of water consumption was made for household needs such as: washing toilets and washing clothes. Two residential buildings in the two mentioned localities, in which 4 people live, were taken into account.
The estimation was carried out considering, for the mentioned household needs, the weekly consumptions from Table 3. For washing machines, two classes of energy efficiency were considered: class A, capacity 7 kg and a water consumption/cycle of 36l and class D, capacity 7 kg and a water consumption/cycle of 44l. For the values in Table 3, a class A washing machine was accepted for the low consumption category, and a class D washing machine was accepted for the high consumption category [11].
For the estimated calculation of the weekly consumption, relation (2) was used:

$$Q_{wtotal} = n_u \cdot q_u \cdot N_p \cdot n_z \text{ [l/week]} \quad (2)$$

where:
n_u - number of uses/day [-];
q_u – consumption/use [l/use];
N_p - number of people [-];
n_z - number of days/week [-];
Q_{wtotal} - total consumption [l/week].

Table 3: Drinking water consumption for household needs that can use the stored meteoric water

Household needs	n_u [-]	q_u [l/ use]	N_p [-]	n_z [-]	Q_{wtotal} [l/week]	Q_{atotal} [l/year]
Low consumption						
Toilet bowl washing	5	6	4	7	840	43,680
Washing clothes	1	36	4	2	72	3,744
Total						47,424
Increased consumption						
Toilet bowl washing	5	9	4	7	1260	65,520
Washing clothes	1	44	4	2	88	4,576
Total						70,096

Considering an average of 4 weeks/month, the monthly consumption was calculated for the two variants of consumption degrees:

- for reduced consumption: Q_{lunar} = 3,648 l/month;
- for increased consumption: Q_{lunar} = 5,392 l/month.

Stage V – for an estimate of water consumption reduction it is necessary to make an annual assessment of the annual amount of water consumed/household and the amount of rainwater collected and stored. As the amount of water from precipitation is seasonally variable, a monthly assessment at this stage is most likely irrelevant. Thus, a number of 52 weeks was considered for a common year.
Thus, for the two consumption categories, an annual amount of water consumed by:

- for reduced consumption: Q_{atotal} = 47,424 l/year;
- for increased consumption: Q_{atotal} = 70,096 l/year.

Comparing the consumption with the amount of water from precipitation that can be collected and stored in the two localities considered for the study (Giarmata: Qstocat = 60,102 l/year and Moșnița Nouă: Qstocat = 54,673 l/year) the amount of water recovered (Qrec by the difference between the two amounts of water, with relation (3):

$$Q_{rec} = Q_{stocat} - Q_{atotal} \text{ [l]} \quad (3)$$

where:
Q_{rec}- the amount of drinking water recovered [l];
Q_{atotal} - the amount of drinking water used [l];
Q_{stocat} - the amount of rainwater stored [l].

Based on the data obtained, the amount of recovered water was calculated for the two buildings in the two localities, and obtained:

- for the town of Giarmata:
  - for reduced consumption: Q_{rec} = 12,678 l/year;
  - for increased consumption: Q_{rec} = -9,994 l/year.
- for the town of Moșnița Nouă:
  - for reduced consumption: Q_{rec} = 7,249 l/year;
  - for increased consumption: Q_{rec} = -15,423 l/year.

3. Conclusion

Based on the data obtained, it can be found that both for Giarmata and Moșnița Nouă localities, in the scenario of reduced consumption, the entire amount of drinking water used for the two categories of household needs (washing WC bowls and washing clothes) is fully covered, even resulting in a surplus that can be used for other needs outside the buildings (watering green spaces, gardens, etc.), respectively 12,678 l/year for Giarmata and 7,249 l/year for Moșnița Nouă.

This quantity may be sufficient during the vegetation period of the plants, but that obviously depends on the type of crops.
Conversely, in the case of the increased consumption scenario, the amount of water required for household needs is not covered for any of the localities, registering a deficit of 9,994 l/year for Giarmata and 15,423 l/year respectively for Moșnița Nouă. These deficits will not cover the considered household needs for approximately 2 weeks for the Giarmata locality and for approximately 3 weeks for the Giarmata locality, obviously related to the increased consumption scenario.
On the other hand, even in the case of increased consumption, for the two localities considered for the study, it can be considered that the entire amount of recovered water can be recovered if it is taken into account that during the holidays (2-3 weeks), no drinking water consumption is recorded in the two buildings.

As future directions, we propose to do a comparative analysis over a period of 3 years in which to include several localities from the Timișului plain.

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