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Economic analysis of water recovery from greywater and rainwater in households in Poland

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Abstract: The article presents the results of the viability economic analysis of the use of an installation for the treatment of greywater and/or rainwater, in order to reuse the recovered water for flushing toilets and watering the garden. The economic indicator in the form of simple payback time (SPBT) was used in the analysis. The use of a dual water supply system should theoretically reduce costs for water supply and sewage disposal, ensuring investment profitability. The analysis was carried out assuming the possibility of using water recovery from only greywater, only rainwater or from greywater and rainwater in a single household inhabited by 4 people. It was also assumed that the building could be connected to the water supply and sewage network or only to the water supply network and the sewage tank. Based on the results of the analysis it showed that the cost of the water supply and sewage disposal is crucial to the profitability of using the water recovery system in a single household. For prices above 12 PLN/m^3, water recovery should be considered.

Keywords: greywater, rainwater, economic analysis, water recovery

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Introduction

In the last years, we have been observing the problems of waterworks more often in ensuring adequate water intake efficiency due to climate changes, lowering of water levels or exhaustion of existing sources. This translates into the need for new investments, thereby increasing prices for water supply and wastewater disposal. In many cities, the unit price for water and wastewater is maintained at a relatively acceptable level by residents through budget subsidies. However, the range of real prices for utilities in Poland is very large, from around 5 to even 26 PLN/m^3. Increasing costs for recipients incline them towards new pro-ecological solutions that reduce expenses. This reduction can be obtained as a result of the use of home furnishings with reduced water demand, rational use of water, but also from water recovery of greywater and/or rainwater (Willis et al., 2011). Greywater includes wastewater streams such as laundry drains, which results in less pollution than blackwater. The basic criteria for the use of dual water and sewage systems for the recovery of water from wastewater in single households should include the selection of the appropriate technology for their treatment and the carrying out of an economic analysis to evaluate cost-effectiveness (Kujawa-Roeleveld et al., 2011; Mourad et al., 2011). In 2014 Jabornig proved that the cost of investing in a single-family building system is too high to pay back in less than 15 years. According to the publication by Ludwińska and Paduchowska (2017), the payback for a residential building is around 20 years. This does not encourage investors to use a water recovery system in their households. However, it can be assumed that the increase of public awareness and decrease of deepwater resources will contribute to greater interest in water recovery. As Friedler and Hadali (2006) correctly noted, a much faster return on investment costs can be expected in the case of multi-family buildings. For example, a system recovering water from greywater from two residential buildings will make a return in 14.3 years. However, for ten objects, the time is reduced by almost five times to 3 years. A similar position, referring to the simple payback time of a dual system in a single-family house, was taken in (Dobrzański & Jodłowski 2016). The analysis was carried out on a single household inhabited by 4 people and gave a negative economic result. According to the results of the research, it was found that at the current cost of water supply and sewage disposal, a recovery system for greywater in a single household is unprofitable. According to an analysis by Ghisi and Mengotti de Oliveira (2007) for two single-family homes in Brazil, the recovery system for greywater and/or rainwater has many benefits. The publication draws attention to the high payback time for both the greywater and rainwater variant as well as the combined variant. A significant problem was also the lack of appropriate legislation. For this reason, the public does not use dual installations in their households. This is also a problem for people in Poland who want to use the recovery system, which reduces the negative impact on the environment.

The article presents a comparison of water recovery from greywater and/or rainwater in a single-family house, based on an analysis of economic efficiency, taking into account the impact of prices for water supply and sewage disposal.

1. Methodology

1.1. Subject of research

The subject of the economic research was a water recovery system for greywater and/or rainwater in a single-family house inhabited by 4 people. For the system that takes into account greywater and rainwater together, it was assumed that the wastewater will flow from two washbasins, a bath, a shower, and a washing machine. The wastewater will be collected in a tank for the recovery of the greywater. For this purpose, the tank should be equipped with a greywater treatment system, for example from the company Intewa (2019). The greywater will be pre-filtered before entering the bioreactor, removing surface impurities. Biological degradation will be achieved in the bioreactor due to increasingly active sludge and aeration. The final stage is the ultrafiltration on the membrane module. An automatic pump performs the periodic sludge removal function. After the treatment process, the greywater ends up in a second tank for rainwater recovery. It is recommended to equip the tank with a highly effective filter in rainwater treatment, for example from Aquatechnika (2019).

For the greywater recovery system, greywater is collected in a tank. Then, after cleaning, it is pumped into a second tank. From there, as needed, it will be delivered to the toilet bowl or for watering the garden. The rainwater version is based on a dedicated tank. It should be equipped with a filter for removing impurities and a pump that pumps the recovered water into the household.

In each of the variants, the system will be managed by the control unit. At the time of demand, it will provide treated water to the source of demand. The control unit is required to ensure the continuous operation of the installation. The control unit should be designed for the tap water supply pipe. This solution will ensure an uninterrupted water supply in the event of a shortage of recovered water.

1.2. Economic analysis

A detailed economic analysis of the water recovery system requires information about the analyzed object. This concerns the number and type of sanitary accessories, the frequency of use, and the unit quantity of sewage generated. In addition, it is necessary to estimate the volume of water recovered and the demand for it. In the calculations for a single-family house, values based on literature data were adopted (Dobrzański & Jodłowski, 2016; Jabornig, 2014). The article analyzes several hypothetical locations of a single-family house to investigate the impact of media prices and two variants of its connection to a water source and sewage receiver. In the first variant, the building is connected to the water supply and sewage network, in the second variant, to the water supply network and a private wastewater tank.

A simple payback time (SPBT) was used for the economic assessment of the water recovery system (Memon et al., 2005; Patusiak, 2010). The SPBT indicator described by formula (1) determines the time after which an investment begins to generate economic profit, taking into account the investment incurred.

$$SPBT = \frac{K_S}{Z - K_E} \ \text{[years]} \tag{1}$$

where:
K_S - cost of system [PLN],
K_E - total exploiting costs [PLN/year],
Z - profit obtained from the installed system [PLN/year].

The system's investment costs, exploiting costs and profit resulting from water savings were determined while calculating the SPBT indicator. The total cost of the system consists of material costs, assembly costs and commissioning of the water recovery installation. However, the operating costs include the cost of water pumping and the cost of replacing consumable items such as filters. The use of the water recovery system is primarily to bring profit. It was assumed that costs would be incurred for the consumption of water and discharging it to the sewage system in the volume that was replaced with recovered water. It is the aforementioned profit. In the case of wastewater discharging into a drainage tank, the reduced frequency of wastewater disposal was determined using a slurry tanker.

The annual profit from recovered water includes as follows:

$$Z = V_{sw} \cdot C_w \cdot \eta \ \left[\frac{\text{PLN}}{\text{year}}\right] \tag{2}$$

where:
V_{sw} - volume of recovered water per year [m^3/year],
C_w - unit price of water and sewage disposal from the tank, or unit price of water supply and wastewater disposal [PLN/m^3],
η - factor taking into account system efficiency [–].

An important aspect of the system is its ability to cover water demand through reclaimed water. For the greywater and rainwater recovery variant, a η factor of 1.00 was established, while only greywater 0.75 and the last variant of 0.90 for reuse of rainwater.

2. Results and discussion

Assuming the reuse of greywater and/or rainwater for flushing the toilet and watering the garden, the volume of water that can be saved during the year was estimated at 141.93 m^3/year. It was also assumed a reduction of wastewater disposal from the tank by 6 per year. The cost of the system for recovering water from greywater and rainwater was determined on the basis of offers from companies dealing with their distribution, including installation costs. The cost statement is presented in Table 1.

In order to research the impact of the price for water supply and sewage disposal on the profitability result of using recovery water, 7 towns were selected in which the total cost of mediums is within ±4.0 PLN/m^3 compared to the average price in Poland of about 9.40 PLN/m^3 net (Table 2).

Table 1. Costs of water recovery systems (*own study*)

Costs of systems	Greywater and rainwater recovery system	Greywater recovery system	Rainwater recovery system
	Net price [PLN]		
Greywater recovery system	12062.75	12062.75	–
Rainwater recovery system	7686.00	–	7686.00
Control unit	3112.83	3112.83	3112.83
Installation assembly	1800.00	1500.00	1500.00
Total	24661.58	16675.58	12298.83
Exploiting, PLN/year	595.00	595.00	25.00

Table 2. The cost of water supply and sewage disposal in selected towns in Poland in 2019 (*own study*)

Water supply and sewage disposal		Town						
		Slupsk	Lodz	Warszawa	Poznan	Wladyslawowo	Sieradz	Szklarska Poreba
Net price, PLN/m^3, with municipal subsidies*	Water	2.72	4.09	3.6	4.43	3.27	4.49	6.05
	Sewage	5.11	4.08	5.52	6.03	9.43	8.54	7.67
	Total	7.83	8.17	9.12	10.46	12.7	13.03	13.72

* if there are

Based on the adopted data, the SPBT indicator was calculated for the buildings located in various towns in option 1 with connection to the water supply and sewage network (Fig. 1) or only to the water supply network and the contained tank - option 2 (Fig. 2). In Figure 1 it can be seen that with the increasing price for water supply and sewage disposal in cities (from left to right), the SPBT value decreases for all variants of water recovery sources. Between Slupsk, where the price is about 8 PLN/m^3 and Szklarska Poreba, with a price of about 14 PLN/m^3, the simple payback time is reduced by more than half. This proves that the price of „water and sewage" is correctly chosen as the main criterion for the economic analysis of the profitability of water recovery. In towns where the current price is higher than 12 PLN/m^3, assuming its current increase, it is definitely worth investing in a dual system.

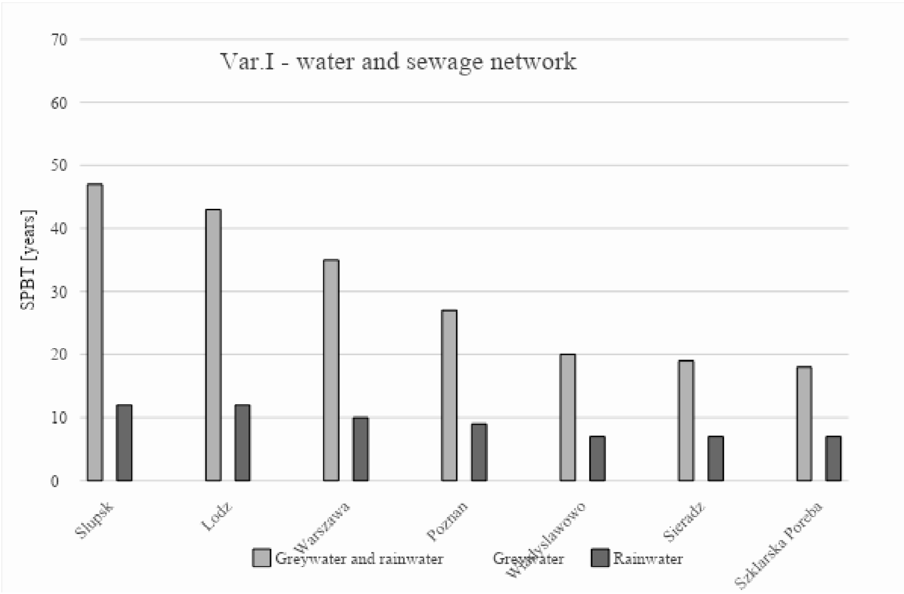

Fig. 1. Simple payback time SPBT for recovery water from greywater and/or rainwater in selected towns in Poland for Variant 1 (*own study*)

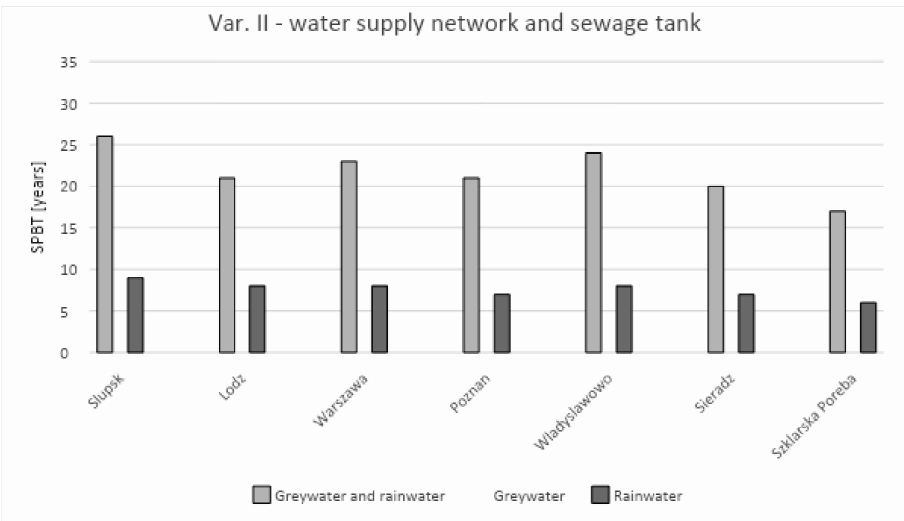

Fig. 2. Simple payback time SPBT for recovery water from greywater and/or rainwater in selected towns in Poland for Variant 2 (*own study*)

In the second variant, the building is connected only to the water supply network. The main criterion is the water supply fee. Wastewater is discharged into a drainless tank. Thanks to water recovery, it is possible to limit the frequency of wastewater disposal. From the results obtained in Figure 2 it can be seen that for all towns, the SPBT value is at a similar level of about 20-25 years. This is due to a small difference in the price of water in these cities. Ultimately, therefore, it can be concluded that the price for wastewater disposal should be the main deciding factor in choosing a water recovery system. The second issue presented in Figures 1 and 2 concerns the choice of the water recovery source. It can be seen that the longest payback time is obtained for the recovery system of only greywater. It amounted to almost 70 years for the town of Slupsk. Such a result coincides with the observations of other researchers (Dobrzański & Jodłowski, 2016; Kujawa-Roeleveld et al., 2011) and is caused by the relatively small volume of greywater generated by the household in relation to the costs of a dual system.

The best in terms of economy is the recovery of water from rainwater. Due to the relatively low cost of purchase and exploiting it allows SPBT to be acheived at an average level of about 8 years. However, it should be remembered that this system does not guarantee 100% coverage of the demand for recovered water. It is caused by the unevenness of rainfall or its periodic absence. For this reason, in order to be able to fully use the potential of water recovery in economic and performance terms, it is worth choosing a system based on the reuse of greywater and rainwater at the same time. Although the payback time is not as short as in the variety of rainwater reuse.

Table 3. The cost of water supply and sewage disposal in selected towns where there are municipal subsidies in 2019 (*own study*)

Town	Water supply and sewage disposal	Net price	
		with municipal subsidies	without municipal subsidies
		[PLN/m^3]	[PLN/m^3]
Makow Podhalanski	Water	4.43	5.80
	Sewage	8.53	16.52
	Total	**12.96**	**22.32**
Szklarska Poreba	Water	6.05	10.68
	Sewage	7.67	16.00
	Total	**13.72**	**26.68**

With a price of water above 4 PLN/m^3 and a price of „water and sewage” above 12 PLN/m^3 brings reimbursement in less than 20 years. This time may be shortened within planned increases in fees for water supply and sewage disposal. When collecting information on the price of water supply and sewage disposal, it was noticed that in some places in Poland, this price is very high. Reaching even 26.68 PLN/m^3 (Szklarska Poreba). However, this is not the price paid directly by the household (only indirectly through taxes). It is reduced through co-financing from the municipal subsidies, in the case of Szklarska Poreba, to 13.72 PLN/m^3. So this is the price range that occurs in Poland. The article does not attempt to explain this situation. However, it was checked on the example of two locations (Table 3) how the profitability of using a water recovery system is affected by this situation. It was assumed that the community could stop paying extra for „water and sewage".

It should be emphasized that the cities selected for research are one of several in Poland. They are characterized by the highest prices for water supply and sewage disposal despite additional payments. Referring to the data from Figure 3, we see a two-fold reduction in SPBT time in favor of prices without subsidies. Assuming the amount of the fees set by the water and sewage company in selected cities, water recovery becomes a „necessity". It will help reduce bills and the investment outlays will be paid back in about 8 years (recovery of water from grey sewage and rainwater). The presented example shows what the future may be regarding the use of dual systems. This can help if announcements regarding increasing water prices and sewage disposal are implemented.

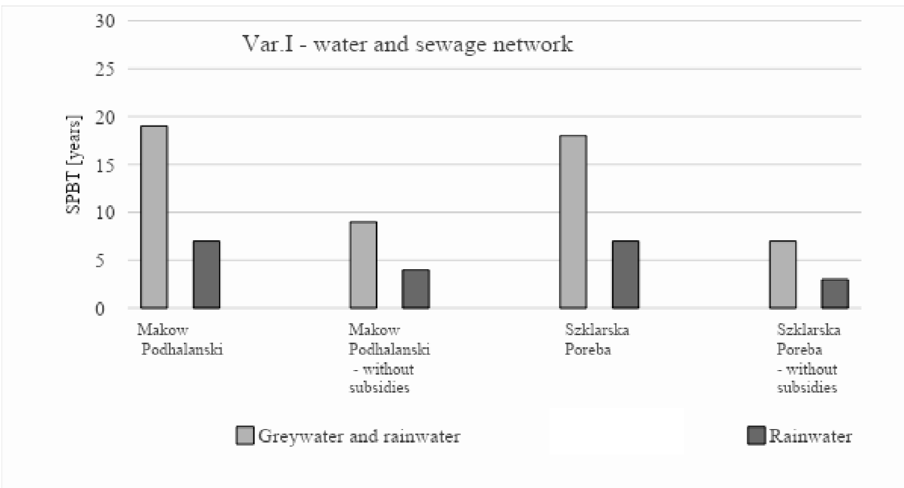

Fig. 3. Simple payback time SPBT for recovery water from greywater and/or rainwater taking into account price differences due to municipal subsidies for Variant 1 (*own study*)

In conclusion, it is also worth mentioning the ecological aspect. At the time of popularizing the use of dual systems from economic premises, we will obtain a positive ecological effect by greatly reducing the overall demand for water supplied from the intake to the water supply network.

Conclusions

1. Water recovery systems are cost-effective for buildings connected to the water supply and sewage network for prices of „water and sewage" above 12 PLN/m^3.
2. Rainwater recovery is currently the most cost-effective solution.
3. In the case of a building connected only to the water supply network, the low price for water in most cities in Poland translates into a long payback time.
4. Lowering the prices of water by municipalities subsidies causes a lack of economic motivation to use water recovery and thus reduce its consumption.

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Analiza ekonomiczna odzyskiwania wody z wód szarych i deszczowych w gospodarstwach domowych w Polsce

Streszczenie: Przedstawiono wyniki analizy ekonomicznej zastosowania instalacji do oczyszczania wody szarej i/lub deszczowej w celu ponownego wykorzystania odzyskanej wody do spłukiwania toalet i podlewania ogrodu. W analizie wykorzystano wskaźnik ekonomiczny w postaci prostego czasu zwrotu (SPBT). Zastosowanie podwójnego systemu zaopatrzenia w wodę powinno teoretycznie obniżyć koszty zaopatrzenia w wodę i odprowadzania ścieków, zapewniając opłacalność inwestycji. Analizę przeprowadzono przy założeniu możliwości wykorzystania odzysku wody tylko z wody szarej, tylko wody deszczowej lub z wody szarej i wody deszczowej w jednym gospodarstwie domowym zamieszkanym przez 4 osoby. Przyjęto również, że budynek można podłączyć do sieci wodociągowej i kanalizacyjnej lub tylko do sieci wodociągowej i zbiornika ściekowego. Na podstawie wyników analizy wykazano, że koszt zaopatrzenia w wodę i odprowadzania ścieków ma kluczowe znaczenie dla opłacalności korzystania z systemu odzyskiwania wody w jednym gospodarstwie domowym. Odzysk wody należy wziąć pod uwagę w przypadku cen powyżej 12 PLN/m^3.

Słowa kluczowe: woda szara, woda deszczowa, analiza ekonomiczna, odzysk wody