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MULTICRITERIA EVALUATION OF DOMESTIC SEWAGE AND STORMWATER MANAGEMENT IN NEW HOUSING ESTATE WITH AHP SUPPORT

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A b s t r a c t

The progression of urbanization means that new housing estates are being built on the city outskirts, not fully equipped with technical infrastructure. This article presents three examples of solutions for managing domestic wastewater and stormwater for a housing estate: when the receiver is a watercourse or ground, and with devices enabling graywater and rainwater recovery. A SWOT analysis was conducted, and optimal variant was selected using AHP (Analytic Hierarchy Process). Typical selection criteria were applied: economic, ecological, and operational, as well as a climatic criterion, taking into account the amount of greenhouse gases emitted into the atmosphere, which is relevant in the era of climate change and related threats but is not taken into account when planning water and sewage management. Attention was paid to the importance of preferences assigned to individual selection criteria, changing their value in subsequent analyses.

Keywords: domestic sewage, stormwater, water management, AHP (Analytic Hierarchy Process), greenhouse gases

1. INTRODUCTION

In recent years, we have been observing intensive development of cities, related to, among other things, people movement from rural areas. This results in the need to build new apartments, which are sometimes located in suburban areas not fully equipped with technical infrastructure. Most often, these deficiencies concern sewage systems, so local management of sewage and rainwater is required. Currently, there are many technically diverse facilities and devices and available that enable effective, environmentally safe treatment of domestic sewage before it is discharged to the final receiver, which may be surface water or ground. In Poland, the same requirements apply in both cases regarding the composition of treated sewage and/or the required degree of treatment. However, they are different

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depending on the size of the agglomeration in which the investments are located - the requirements increase with the increase in the population equivalent (PE). One of the criteria for selecting devices for wastewater treatment is therefore their required efficiency, but it is not the only criterion. Of course, investment and operating costs are taken into account, as well as reliability, ease of operation, and location requirements. The growing ecological awareness in societies means that more and more attention is paid to pro-environmental aspects, such as the protection of water receivers from pollution related to sewage discharge, the possibility of reducing water demand through its reuse, and thus protecting available water resources, as well as reducing energy consumption and greenhouse gas emissions. Household wastewater treatment units can sometimes become a source of environmental nuisance. In the case of improper use, they can be a significant source of water pollution [1, 2]. In addition, sewage treated in local treatment devices is often characterized by significant variability of composition [3].

The task of local wastewater treatment plants is to reduce the emission of pollutants contained in sewage discharged into the environment. However, their operation, like many other engineering facilities, is associated with the emission of greenhouse gases. The analysis of ecological costs and benefits in connection with the implementation of various types of construction and installation investments takes into account, among others, CO_2 emissions [4, 5]. Greenhouse gas (GHG) emission responsible for climate change is increasingly included in the assessment of the impact of sewage treatment plants on the environment [6, 7]. Municipal wastewater treatment plants (WWTPs) consume significant amounts of energy and are also responsible for 5% of global GHG emissions other than carbon dioxide (mainly CH_4 and N_2O) resulting from the biodegradation of organic matter [8]. Optimization of the operating conditions in WWTP can, however, reduce this emission [9, 10]. GHG production depends on the treatment technology and the efficiency of the devices used, including energy efficiency. Gupta and Singh [11] found that in the case of treatment plant equipped with Sequencing Batch Reactors (SBR), greenhouse gas emissions resulted mainly from the consumption of electricity by SBR processes and associated equipment, only a few percent were the result of the production of CH_4 and N_2O. In the case of membrane reactors, the consumption of electricity was responsible for 80% of GHG production, and the consumption of chemicals about 17% [12].

The impact of urbanization on the environment is also associated with the disruption of the natural water cycle. Residential construction generates a large amount of impervious surfaces (roofs, streets, sidewalks), which limits the natural ecosystems and reduces natural retention. During precipitation, a significant amount of rainwater is drained from sealed surfaces in a short time. It should be managed on site, stored and used in the household, or directed through infiltration into the ground. Systems for local stormwater management have been intensively developed for many years, providing an opportunity to increase biodiversity in urban areas [13, 14]. However, the choice of solutions is also associated with economic aspects, as well as the need for the acceptance by residents, who expect reliable solutions that ensure the safety in the conditions of observed climate change and increasingly frequent heavy rainfall. Until recently, residents preferred using traditional methods and stormwater discharging through the sewer system to the nearest surface receiving waters. Nowadays, other solutions, including green infrastructure, are gradually gaining acceptance. They can also contribute to improving the aesthetics and microclimate of cities [15 - 17]. The use of alternative water sources in buildings is also gaining popularity. The use of rainwater harvesting system (RHS) limit the tap water demand but also allows for reducing runoff volume and peak flow [18 - 20]. In the case of single-family houses, rainwater harvesting systems are very effective as are greywater recycling systems [21 - 23]. Reuse of treated greywater for toilet flushing, garden watering and other non-potable purposes can reduce the total mains water demand in a household by up to 50%, and domestic use is the best alternative to reusing greywater [[24].

The multitude of possibilities and criteria that can be used when selecting even seemingly simple drainage systems such as those built in housing estates means that various decission supporting methods are used, which allow for taking into account and comparison both quantifiable and unquantifiable factors. This paper analyzes three different variants of sewage and stormwater disposal for a newly built small housing estate. All options meet the formal requirements for this type of investment, but they differ significantly in terms of other criteria, including economic, pollutant emission levels and environmental impact. After making the necessary calculations in this area, a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) was conducted for each solution and the optimal solution was selected using the AHP (Analytic Hierarchy Process) method.

2. CASE STUDY

The subject of the analysis is a housing estate consisting of 8 residential houses, the location of which is shown in Fig. 1.

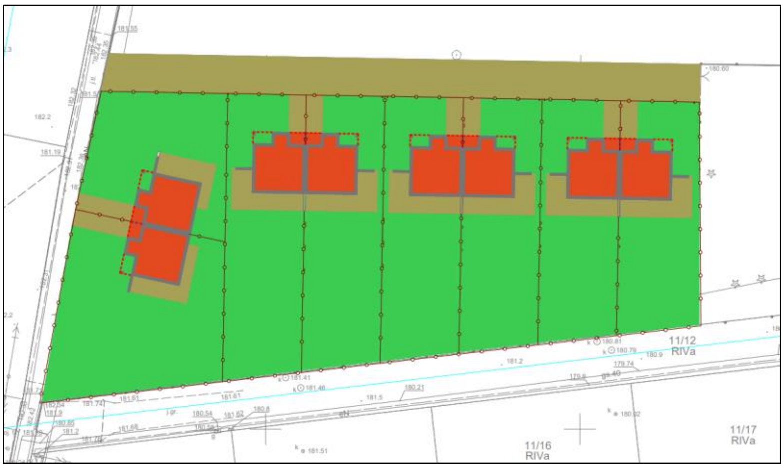

Fig. 1. Housing estate plan

Three variants of solutions were assumed in the scope of management of domestic sewage and stormwater discharged from impervious surfaces. In the first variant, the receiver is surface water, in the second - ground, the third is based on a graywater recovery system and a system for harvesting rainwater from roofs. It was assumed that all methods of wastewater treating allow for achieving the formally required degree of treatment and sewage can be discharged into surface water and ground.

- ***Variant 1*** – Receiver: surface water. It was assumed that a domestic biological treatment plant would be used – Sequencing Batch Reactor (SBR) for each house, from which the treated sewage would be discharged through a sewer into receiving water. Stormwater from individual plots and roads would be discharged into receiver through the same sewer providing the necessary storage capacity in accordance with the water-law permit. The pipe diameter was determined based on the amount of sewage and stormwater (15-minute rainfall) discharged The resulting storage capacity allows for limiting the outflow into the receiving water body to the required level.
- ***Variant 2*** – Receiver: ground. The use of onsite sewage facilities is planned, i.e. a septic tank with a drainage system on a gravel layer, individual for each house. Stormwater from roofs, roads and pavements will be drained into the ground through a system of infiltration boxes.

• ***Variant 3*** – The reuse of greywater and rainwater in the household is assumed. Treated greywater and rainwater from roofs will be a supplementary source of water for non-potable use (flushing toilets, garden watering). An individual dual installation is planned for each house with a greywater treatment system using an ultrafiltration membrane. Rainwater from roofs will be managed in RHS and its excess will be directed, for example, to a rain garden. Blackwater will be collected in tank and periodically transported to the municipal wastewater treatment plant. Stormwater from the housing estate road will be drained to the green area.

The diagrams of the individual variants are shown in Fig. 2.

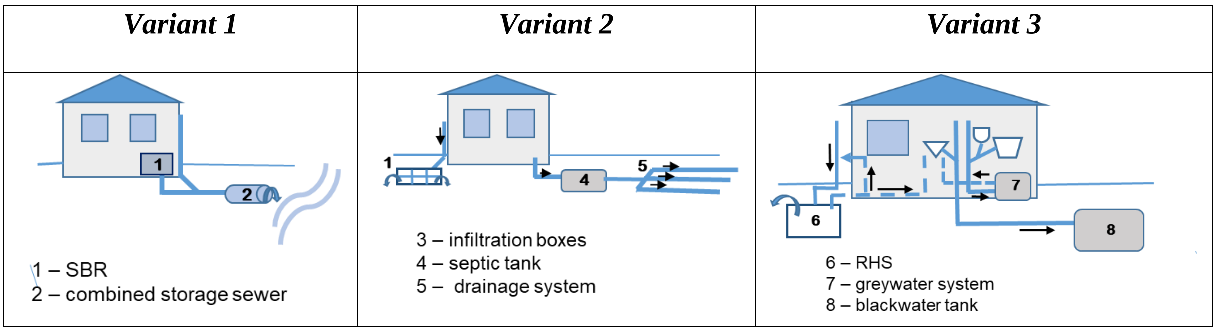

Fig. 2. Diagrams of individual variants of domestic sewage and stormwater management

The basic output data regarding the analyzed housing estate and its location are presented in Table 1.

Table 1. Characteristics of the analyzed housing estate

No	Parameter	Unit	Value
1.	Roof area of 1 house	m^2	75.4
2.	Green area in 1 plot (average)	m^2	324.5
3.	Impervious area in 1 plot (average)	m^2	62.7
4.	Common roads and sidewalks	m^2	570
5.	Rainfall intensity	l/s ha	200
6.	Soil infiltration rates	m/s	10^{-3}-10^{-4}
7.	Average water consumption in 1 building (for 4 people)	l	600
8.	Load of pollutants (BOD_5) from 1 building	g O_2/day	240

For all variants, investment costs (materials and construction) and operating costs (cost of electricity, costs of chemicals and biopreparations, costs of equipment maintenance, cost of sewage disposal and analysis) were calculated. Based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [25] the greenhouse gas emission rate for the analyzed systems was determined. Gas emissions resulting from sewage treatment processes (methane CH_4 and nitrous oxide N_2O) and carbon dioxide CO_2 emissions based on electricity consumption were taken into account. Total emissions were expressed in kgCO_2 eq/year, assuming a GWP (global warming potential) of 25 for CH_4 and 298 for N_2O. The calculation results are presented in Table 2.

Table 2. Parameters of facilities for each variant

Parameter	Unit	Value
Variant 1		
Main components: - SBR, volume - combined sewer, diameter/length	 m^3 mm/m	 2,0 500/222
Investment costs for estate	$	116 500
Investment costs for 1 house	$	14 560
Operating costs for 1 house	$/year	950
GHG emission (1 house)	kg CO_2eq/year	250
Variant 2		
Main components: - onsite sewage facilities: septic tank, volume drainage system, length - stormwater infiltration boxes, dimensions, pieces (for the entire estate)	 m^3 m m, number	 3,5 42 0,6/0,6/1,2; 108
Investment costs for estate	$	51 250
Investment costs for 1 house	$	6 400
Operating costs for 1 house	$/year	155
GHG emission (1 house)	kg CO_2eq/year	660
Variant 3		
Main components: -greywater reuse system, capacity raw and treated greywater tanks, volume - tank for black wastewater, volume - RHS with tank, volume	 m^3/d m^3 m^3 m^3	 0.2 2×1,15 10,0 4,0
Investment costs for estate	$	130 000
Investment costs for 1 house	$	16 250
Operating costs for 1 house	$/year	1 450
GHG emission (1 house)	kg CO_2eq/year	260

The analyzed options differ significantly, both in terms of economy, operation and environmental impact. The choice of the solution should be made after a very thorough assessment of the operating conditions of the facilities, because it is mainly the homeowners who will be responsible for their proper functioning, guaranteeing the comfort of living in this estate. Table 3 presents a SWOT analysis - strengths, weaknesses, opportunities and threats for each variant, supplemented by Table 4, which illustrates the mutual connections for the criteria used in the SWOT analysis.

Table 3. SWOT analysis – main aspects for three variants

Variant 1	
S *(Strengths*)	W *(Weaknesses)*
High, constant efficiency of wastewater treatment. Simple device operation. Modern solution, high technological standard of wastewater treatment.	High investment and operating costs. Common sewer for wastewater and stormwater disposal for the entire estate.
O *(Opportunities)*	T *(Threats)*
If the requirements for treated wastewater become more stringent, the treatment efficiency can be increased by adding a coagulant.	Possibility of failures and interruptions in operation. Difficulties with wastewater and stormwater disposal in the event of flood.
Variant 2	
S *(Strengths*)	W *(Weaknesses)*
Low investment and operating costs. Almost maintenance-free system, does not require electricity supply. Sustainable stormwater management.	Relatively low efficiency of wastewater treatment. Necessity of dosing biopreparations and periodic sludge removal. High GHG production.
O *(Opportunities)*	T *(Threats)*
Reducing the risk of lowering groundwater levels and soil stepping thanks to rainwater infiltration.	Improper operation of in-site wastewater treatment plant may cause unpleasant odors. If the requirements for treated wastewater become more stringent, the entire system will need to be rebuilt.
Variant 3	
S *(Strengths*)	W *(Weaknesses)*
Reducing tap water demand and the amount of wastewater discharged. A very modern, environment friendly solution, high technological standard. The removal of black sewage to the municipal wastewater treatment plant will ensure a very high treatment efficiency.	The highest investment and operating costs. The need to periodically remove black wastewater from the tank. Greater supervision and control of systems operation required.
O *(Opportunities)*	T *(Threats)*
Possibility of significantly reducing fees for tap water. Counteracting the effects of drought by managing rainwater on site.	Possibility of failures and interruptions in operation.

Table 4. Matrix of relationships for the SWOT analysis (0 – no impact, 1 – low impact, 2 – high impact)

	O1	O2	O3		T1	T2	T3
S1	1	-	-		1	-	-
S2	-	2	-		-	0	-
S3	-	-	2		-	-	1
W1	2	-	-		2	-	-
W2	-	1	-		-	1	-
W3	-	-	1		-	-	1

3. RESULTS OF ANALYZES WITH AHP METHOD

In order to select the optimal variant for the management of sewage and stormwater from the housing estate, the AHP method was used, which is a frequently used method in the analysis of possible solutions in water and sewage management [26 – 29], as well as sustainable urban area development and ecosystem services [30, 31]. This is a multi-criteria optimization method that allows for the simultaneous use of both measurable and non-measurable indicators in the assessment. It was developed in 1972 by T.L. Saaty [32] and has been improved since then [33,34].

The main steps of the AHP method:

- Selecting the optimization criteria
- Creating a comparison matrix to prioritize them, i.e., comparing them pairwise using Saaty's 1-9 scale (Table 5) to determine their final weights.
- Checking the consistency of the matrix (to ensure the judgments are logical) by calculating Consistency Index (CI) and Consistency Ratio (CR).
- Variant pairwise comparison against each criterion and calculating the final ranking.
- Selecting the optimal variant with the highest score (maximum weighted sum).

Table 5. The fundamental scale in AHP method

Definition	Intensity of importance
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
Intermediate significance	2, 4, 6, 8

In the case of selecting the optimal method of wastewater treatment using the AHP method, various criteria are used, most often quantifiable. As a rule, investment costs, operating costs, ease of use, possibilities and location conditions are taken into account [27, 29, 35]. The following 4 selection criteria were used in the conducted analysis:

1. *Economic criterion* – a countable criterion taking into account investment costs and operating costs.
2. *Ecological criterion* – adopted as an uncountable criterion, taking into account the pollutant load emitted into the environment (surface water and soil), as well as the possibility of reducing tap water demand and sustainable rainwater management which helps maintain the natural water cycle in the environment and protect water resources

3. *Climatic criterion* – a quantifiable criterion taking into account greenhouse gas emissions resulting from the formation of CH_4 and N_2O in sewage treatment processes and CO_2 from electricity consumption.
4. *Operational criterion* – an unquantifiable criterion taking into account the ease of use and reliability of equipment operation.

When comparing the criteria, it was assumed that from the point of view of both the investor and the property buyer, the most important will be the price and operating costs of the equipment, and in the case of the user, also the ease of use and reliability of operation. In the case of meeting the formal requirements for the installation, for most people the remaining factors will not be of primary importance. Table 6 presents the comparison matrix for the adopted criteria, as well as the results of the calculations of the priority vector and priority row.

Table 6. Pairwise comparison matrix

Criteria	1. Economic	2. Ecologic	3. Climatic	4. Operational	Geometric mean	Priority vector
1. Economic	1	3	4	2	2.21	0.455
2. Ecologic	0.5	1	3	0.5	0.93	0.191
3. Climatic	0.25	0.33	1	0.33	0.41	0.083
4. Operational	0.5	2	3	1	1.32	0.270
Sum	2.25	6.33	11	3.83	4.87	
Priority row	1.023	1.211	0.918	1.036		

The correctness of the assumptions was confirmed by calculating the Consistency Index (CI) and Consistency Ratio (CR) according to the following formulas (3.1), (3.2):

$$CI = \frac{\lambda max - n}{n-1} \tag{3.1}$$

λ_{max} – maximum eigenvalue
n – number of criteria

$$CR = \frac{CI}{RI} \tag{3.2}$$

R.I. –Random Index depending on the number of criteria (Table 7), for n=4
Inconsistency ratio CI= 0.07, recommended value is CI<0.1 (max.0.2).

Table 7. Average random consistency index (R.I.) according to [34]

N	1	2	3	4	5	6	7	8	9	10
Random consistency index (R.I.)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The next step was normalization and determination of criteria (Table 8).

Table 8. Normalization and determination of criteria weights

Criteria	1. Economic	2. Ecological	3. Climstic	4. Operational	Weighting coefficient average value
1. Economic	0.44	0.47	0.36	0.52	0.45
2. Ecological	0.22	0.16	0.27	0.13	0.20
3. Climatic	0.11	0.05	0.09	0.09	0.09
4. Operational	0.22	0.32	0.27	0.26	0.27

As can be seen, the criteria according to the calculated weights are arranged as follows:
economic - operational - ecological - climatic
The next step was to conduct a mutual assessment of the variants in terms of the next criteria. The following assessment methodology was adopted:
Economic criterion – a quantifiable criterion based on the sum of investment costs for 1 house and 10-year operating costs. The variant with the lowest costs received a score of 7.00, the variant with the highest score of 1.00, the third score resulted from the proportion of costs and points.
Ecological criterion – due to the large number of factors taken into account, it was assumed that this would be an unquantifiable criterion. The highest score was given to variant 3 due to the recovery of grey water, the use of rainwater and its local infiltration into the ground, as well as effective and reliable treatment of black sewage. The lowest score was assigned to variant 2.
Climatic criterion – a quantifiable criterion. The assessment was made as for the economic criterion.
Operational criterion - a non-quantifiable criterion, taking into account the workload and supervision of the devices included in the system, the possibility of failure, operational difficulties in the event of floods, power outages, etc. The highest score in this respect was variant 2, almost maintenance-free and requiring no electricity supply.
The evaluation of the variants in terms of the adopted criteria is presented in Table 9.

Table 9. Evaluation of variants in terms of four criteria

Economic criterion				Ecological criterion			
Variant	1	2	3	Variant	1	2	3
1	1.00	0.19	2.76	1	1.00	4.00	0.33
2	5.24	1.00	7.00	2	0.25	1.00	0.20
3	0.36	0.14	1.00	3	3.00	5.00	1.00
Suma	6.60	1.33	13.76	Sum	4.25	10.00	1.53
Climatic criterion				Operational criterion			
Variant	1	2	3	Variant	1	2	3
1	1.00	6.00	1.12	1	1.00	0.33	2.00
2	0.17	1.00	0.17	2	3.00	1.00	3.00
3	0.89	5.88	1.00	3	0.50	0.33	1.00
Sum	2.06	12.88	2.29	Sum	4.50	1.67	6.00

Then, the ratings were normalized and averaged across rows (Table 10). For each variant, a weighted sum of the products of the criteria ratings and their weights was calculated (Table 11), the highest value of which indicates the optimal variant.

Table 10. Assessment normalization of individual variants

Economic criterion					Ecological criterion				
Variant	1	2	3	Weight	Variant	1	2	3	Weight
1	0.15	0.14	0.20	0.17	1	0.24	0.40	0.22	0.28
2	0.79	0.75	0.51	0.68	2	0.06	0.10	0.13	0.10
3	0.05	0.11	0.07	0.08	3	0.71	0.50	0.65	0.62
Climatic criterion					Operational criterion				
Variant	1	2	3	Weight	Variant	1	2	3	Weight
1	0.49	0.47	0.49	0.48	1	0.22	0.20	0.33	0.25
2	0.08	0.08	0.07	0.08	2	0.67	0.60	0.50	0.59
3	0.43	0.46	0.44	0.44	3	0.11	0.20	0.17	0.16

Table 11. Final evaluation and selection of the optimal variant

Criteria / Variant	1. Economic	2. Ecological	3. Climatic	4. Operational	Weight sum
1	0.07	0.06	0.04	0.07	0.24
2	0.31	0.02	0.01	0.16	0.49
3	0.04	0.12	0.04	0.04	0.24

Variant no 2 turned out to be the optimal variant. This is the solution in which the ground is the recipient of sewage and rainwater. In this case, simple methods were used (septic tank with a drainage system), which are still quite commonly used in suburban areas and in the case of scattered development. Recently, however, attention has been drawn to the relatively low efficiency of sewage treatment in this case and the rather limited control of the system operation, which creates a risk of groundwater contamination. Septic tanks pose a risks to stream ecology, water quality and human health [36]. For this reason, it is preferred to expand this type of systems with elements that increase the efficiency of pollutant removal [37=41].

Considering the importance of the significance and mutual comparison of the criteria used (Tables 5 and 6) in the process of selecting the optimal solution using the AHP method, re-analyses were carried out by changing the order of the criteria according to the weights (Table 10). Taking into account the need for greater care for the environment (protection against pollution, counteracting climate change, protection of water resources), as well as the increase in residents' awareness and, perhaps, also in formal requirements in this area, it was assumed that the most important criteria are ecological and climatic, followed by economic and operational ones (Table 12).

Table 12. Hierarchy of criteria for the environment friendly option

Criteria	1. Economic	2. Ecological	3. Climatic	4. Operational
1. Economic	1	0.33	0.33	2
2. Ecological	3	1	2	4
3. Clmatic	3	0.5	1	4
4. Operational	0.5	0.5	0.25	1

In this case, variant no 3 turned out to be the optimal. This variant creates the possibility of reducing tap water demand by using grey and rainwater and the remaining, unused rainwater is drained into the ground. Treatment of grey wastewater using membrane techniques provides significant benefits, such as the possibility of reducing the tap water used and the amount of sludge generated in the treatment process, but is associated with high membrane costs and the consumption of a significant amount of electricity [29]. Greenhouse gas emissions in the case of this solution are similar to those for Variant 1 and much lower than in Variant 2. The result in the case of variant 2 was largely influenced by the high methane production, determined according to the IPCC recommendations. However, it should be added that the studies conducted by Diaz-Valbuena et al. [42] showed lower emission values by septic tanks (11 g/d M). Similar results were obtained by Huynh et al. [43].

Analysis of the next option, in which all criteria in the assessment were equal, indicated variant 2 as the optimal one (Table 13).

Table 13. The impact of the importance of selection criteria on the final assessment

Order of criteria by weight	Weight	Weighted sums	Optimal variant
Economic – operational - ecoligic - climatic	0.45; 0.27; 0.2; 0.09	0.24; 0.49; 0.24	2
Ecologic – climatic - economic - operational	0.44; 0.31; 0.14; 0.11	0.33; 0.23, 0.44	3
Equal criteria	0.25; 0,25; 0.25;0.25	0.30; 0.36; 0.32	2

In none of the analyzed cases, Variant 1, in which treated sewage and stormwater are discharged to surface waters by one common sewer, was the optimal option. Variant 3, due to its high costs, is optimal only in the case of high preference for pro-ecological solutions. According to Roefs at al. [44] who analyzed various sanitation systems, with current development trends building traditional centralized systems is the most cost-effective. However, when population growth is lower than expected, the source-separated system (on-site source separation of gray water and black water treatment) is more cost-effective.

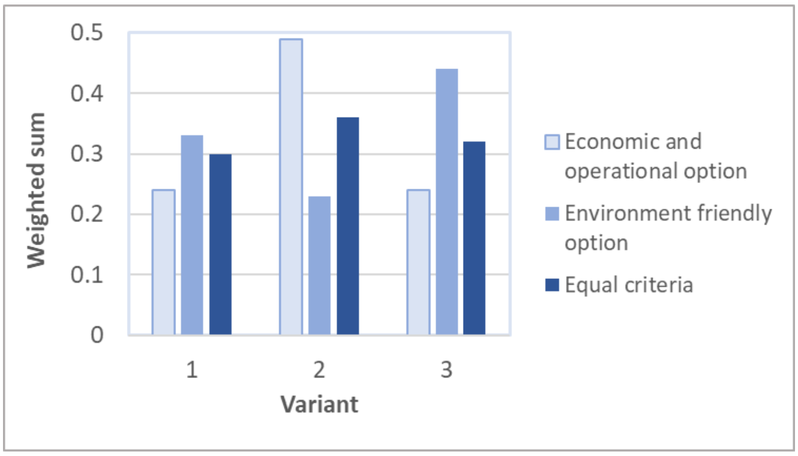

Fig. 3. Evaluation of individual solutions depending on the preferences used

Figure 3 presents the evaluation results of all analyzed variants for the three adopted choice preferences, expressed as a weighted sum, on the basis of which the optimal variant was selected. The data in Table 13 and on Fig. 3 show that the selection of criteria for assessing the analysed solutions and their hierarchy have a very large impact on the final result.

The choice of decision-making criteria is one of the key elements in selecting optimal solutions in urban planning and development of urban areas [45, 46]. Providing urban areas with reliable water supply and wastewater disposal systems is crucial to urban development, but meeting these needs should be based on a thorough assessment of their environmental impact, especially in times of increasing water shortages resulting from climate change [47, 48]. Therefore, on the one hand, a very thorough analysis of individual variants is necessary (not only in relation to the current formal requirements and economic criteria, but also taking into account the broadly understood impact on the environment and living conditions of residents), and on the other hand, very careful assignment of preferences to individual criteria. When choosing solutions in water and sewage management, it is necessary to strive to preserve the natural water cycle in the environment, to protect water resources and their quality, but also control greenhouse gas emissions. As many studies show [49, 50] implementing sustainable methods in water management requires a holistic approach, cooperation in many areas and it is not always a simple process. Currently, there are many modern sustainable solutions available that meet even very demanding criteria for environmental protection, but very often they are more expensive and complex. Hence the need to look for a way to optimally select them, taking into account financial, technical, environmental and local conditions. Cities often prioritize economic goals over social and environmental objectives [51], however, sustainable urban development requires the implementation of solutions that enable environmental protection and adaptation to climate change.

3. CONCLUSIONS

The growth of the world's population, intensive development of urban areas, climate change and growing shortages of drinking water mean that scientists, politicians and decision-makers have to face new challenges in the area of water and sewage management.

This paper presents the possibility of using the Analytic Hierarchy Process when selecting a method of managing domestic sewage and stormwater in an area not equipped with a sewer system. Analytic Hierarchy Process is a simple, effective tool used in decision-making when different selection criteria are taken into account, both quantifiable and non-quantifiable, rational and intuitive. The analysis used economic, ecological and operational criteria, as well as climatic criterion, taking into account the greenhouse gas emissions. It is not currently used, especially when selecting solutions in local water and sewage systems. However, striving to maintain the best possible state of the environment should result in the assessment of investment projects to the widest possible extent, even when there is no formal basis for this, as in the case of the assessment of greenhouse gas emissions when selecting a small onsite wastewater treatment plant for residential buildings. Although it might seem that such emissions are not significant, in the case of the widespread use of solutions characterized by high GHG production, they will contribute to the progress of climate change. It is difficult to expect that similar analyses as those conducted in the paper using the AHP method will be conducted by investors or buyers of new houses, but they should be taken into account by decision-makers in the field of spatial planning and environmental protection. The three variants of solutions analyzed in the article do not exhaust the possibilities of wastewater disposal and stormwater management in suburban areas. However, they prove that the construction of a sewer system that discharges sewage and stormwater to surface waters is not the best solution, or at least not universal for all location conditions.

In the search for optimal solutions that enable sustainable water and sewage management, new criteria must undoubtedly be adopted and an environmentally friendly priority system should be applied, taking into account both costs and benefits. The selection criteria should take into account not only water protection, but also other environmental components and climate protection. They must also gain the acceptance of users, even in the case of increasing expenditure on purchasing and operating equipment. This can be helped by developing new guidelines based on credible analyses of needs, possibilities and effects, as well as a system of appropriate training and subsidies.

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