NATURAL RESOURCES MANAGEMENT BY THE EXAMPLE OF COMPARATIVE ANALYSIS OF METAL AND PLASTIC SEPTIC TANKS

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Abstract

Issues related to reducing the use of natural resources, including metals and fossil fuels, are an important element of environmental management in the European Union. The paper presents the results of the LCA (Life Cycle Assessment) and the use of natural resources for various options of septic tanks. An assessment of septic tanks made of reinforced concrete, glass-reinforced plastic and high density polyethylene was made. Based on the carried out analyses it has been shown that concrete tanks are characterized by the lowest indicator of fossil fuels depletion and at the same time the highest indicator of depletion of metals, especially iron, chromium, manganese, molybdenum and nickel. The highest consumption indicator of fossil fuels is characteristic for septic tanks made of glass reinforced plastic. The carried out works enable the design of septic tanks with the lowest consumption of natural resources.

Keywords: Metal septic tanks, plastic septic tanks, metal and fossil fuels depletion, life cycle assessment, natural resources management

1. INTRODUCTION

Septic tanks are one of the elements of the wastewater collection system. Their task is to collect sewage from households or buildings where domestic sewage is formed which needs to be treated. The basic feature of septic tanks is the isolation of wastewater from the groundwater environment. A sealed tank requires systematic emptying and disposal of wastewater into a collective treatment plant for treatment [1-6].

Septic tanks can be made of different materials; however, most often they are made of:

- reinforced concrete,
- HDPE - High-Density Polyethylene,
- GRP - Glass-Reinforced Plastic.

Reduction of natural resource depletion is one of the key elements of the strategy in the European Union for many branches of industry [7]. Based on a critical review of reference literature, it has been stated that no work has yet been done related to the analysis of the consumption of natural resources, including metals and fossil fuels, with regard to residential wastewater septic tanks. No potential environmental burden associated with the construction and use of tanks, which would make it possible to choose such tanks which are the least environmentally harmful, and in particular minimize the depletion of natural resources, has been presented.

The aim of this paper is to present the LCA technique to indicate all factors that have potential impact on the consumption of metals and fossil fuels used in the production of septic tanks.

2. METHODS

Septic tanks made of reinforced concrete, high density polyethylene and glass-reinforced plastic were subjected to life cycle analysis. The analyses were carried out for real conditions of application of septic tanks in Żory. The city of Żory is in over 90% operated by a sewage network transporting wastewater to a collective sewage treatment plant, while the rest of the users use individual solutions with respect to collection and treatment of wastewater, including septic tanks. The number of exploited septic tanks in Żory at the end of 2015 was 793, of which 567 made of concrete, 155 made of HDPE and 71 made of GRP [8]. The average capacity of the tank is 10 m^3, which allows the monthly collection of sewage from a typical household. Septic tanks in Żory serve 2 379 ENI (equivalent number of inhabitants understood as a charge of biologically-degraded organic substances in tanks expressed as a five-day biochemical oxygen demand (BZT_5) in the amount of 60 g oxygen per day [9]. Septic tanks in Żory are mainly located in the suburban area, in the area of one-family houses, where the sanitary sewage network does not exist. Wastewater from the tanks is transported by sewage trucks to Żory sewage treatment plant.

(a) (b) (c)

Figure 1 Examples of septic tanks made of a) reinforced concrete, (b) high-density polyethylene (c) glass-reinforced plastic
Source: own photo collection

Septic tanks made of reinforced concrete have the shape of a monolithic roller or cuboid of any capacity. It may have one or two chambers separated by an overflow plate with a 160 mm diameter hole located at the top edge. Tightness of the tank is achieved by the use of high-grade reinforced concrete and asphalt-rubber sealant. The bottom of the trench for the septic tank is covered with the thin layer of concrete (class B 7.5) and then the reinforcement and the main concrete layer are laid. Concrete for walls is laid in a formwork (tank walls should be 15 cm thick and be reinforced), remembering to connect a sewer pipe. Similarly, the plate covering the tank is treated. Concrete mix must be of class B 20, it must contain sealers in appropriate proportions, and after laying it must be compacted using specialized equipment. The material from which septic tanks are made additionally include waterproofing admixture. The advantage of the tanks is the high external load bearing capacity, also caused by considerable mass (several tons). As a rule, there is no need to anchor them in the ground. At present, septic tanks are made as prefabricated products, ready to mount in the ground.

Glass-reinforced plastic septic tanks are light in weight (they are easily transported and placed in the trench) and in various shapes (flat, cylindrical, rectangular), usually specially reinforced. They are also durable, resistant to chemical corrosion and environmental impact, and the only disadvantage of plastic waste tanks is low load resistance. They can be crushed by a layer of earth or damaged by rocks, for example, while being covered with earth. Before covering the tank with earth, the tank is filled with water so that it is not crushed during covering with earth while performing leakage test.

SimaPro 8 and ecoinvent 3 were used to assess natural resources consumption in the life cycle of the system. The ReCiPe Midpoint methodology was used to assess the life cycle of the tanks, which allows the presentation of the main potential environmental hazards associated with the technology and product life cycle [10]. Analyses were made for three tank options depending on the materials used. Option 1 refers to the production of steel-reinforced concrete tanks, option 2 for the manufacture of glass-reinforced plastic (GRP) tanks, and option 3 for high-density polyethylene (HDPE). The limit of the system includes the stage of tank construction. The functional unit (FU) is 1 piece of a septic tank.

For septic tanks used in Żory, Life Cycle Inventory (LCI) was performed, which is essential for the life cycle assessment of the tank construction phase. The source of data was real data on the construction of tanks obtained from users and tank producers, as well as the Municipal Office of Żory [8, 11]. The data analysis for the stage of septic tanks construction includes the processes of materials and raw materials consumption and earthworks for both the tank itself and the section of the canal ∅160 made of PVC draining wastewater from the building to the tank. In the data inventory also own research related to the implementation of investments in this field was used. The collected data is shown in **Table 1**.

Table 1 Data inventory for septic tanks - construction stage, in reference to FU.

	Construction of one septic tank	Unit	Option 1	Option 2	Option 3
1	Sand consumption	kg	3 274.08	3 274.08	3 274.08
2	Gravel consumption	kg	1 591.20	0.00	0.00
3	Concrete consumption	m^3	3.49	0.00	0.00
4	Steel consumption	kg	163.33	0.00	0.00
5	Cast iron consumption	kg	63.50	0.00	0.00
6	PCV consumption	kg	25.08	24.10	24.10
7	Asphalt-rubber sealant consumption	kg	27.96	0.00	0.00
8	Plastic consumption	kg	0.00	240.00	0.00
9	HDPE consumption	kg	0.00	0.00	210.00
10	Earthworks	m^3	29.28	29.28	29.28
11	Water consumption - leakage test	kg	7 000.00	7 000.00	7 000.00

Source: Own calculations based on user data and tank manufacturers

3. RESULTS AND DISCUSSION

The results of the LCA assessment carried out in accordance with the ReciPe Midpoint method are shown in **Table 2**. It was shown that HDPE tanks generate the lowest greenhouse gas emissions while GPR tanks have the highest GHG emissions. **Table 3** shows the determinants of metal consumption in tank production, while **Table 4** shows the determinants of fossil fuel consumption in the tank production process.

Table 2 Life cycle assessment of the process of septic tanks production with respect to FU

Impact category	Unit	Option 1	Option 2	Option 3
Climate change	kg CO_2 eq	1431.186	1841.319	605.4882
Ozone depletion	kg CFC-11 eq	6.19E-05	0.000169	0.001612
Terrestrial acidification	kg SO_2 eq	3.622	5.199	4.368
Freshwater eutrophication	kg P eq	0.313	0.369	0.006
Marine eutrophication	kg N eq	0.181	0.239	0.132
Human toxicity	kg 1.4-DB eq	387.575	417.637	79.233
Photochemical oxidant formation	kg NMVOC	4.099	4.919	10.468
Particulate matter formation	kg PM10 eq	2.576	2.367	1.292
Terrestrial ecotoxicity	kg 1.4-DB eq	0.059	0.159	0.081
Freshwater ecotoxicity	kg 1.4-DB eq	14.311	14.651	0.598
Marine ecotoxicity	kg 1.4-DB eq	14.509	14.196	1.302

Impact category (continue)	Unit	Option 1	Option 2	Option 3
Ionising radiation	kBq U235 eq	156.396	98.325	128.557
Agricultural land occupation	m^2a	19.604	72.562	0.189
Urban land occupation	m^2a	11.450	8.180	0.151
Natural land transformation	m^2	0.222	0.123	0.008
Water depletion	m^3	42.795	51.595	24.937
Metal depletion	kg Fe eq	852.428	59.401	5.618
Fossil depletion	kg oil eq	274.037	574.353	413.401

Source: own analysis

Table 3 Metal consumption in the process of septic tanks production, kg Fe eq/FU

Metals	Option 1	Option 2	Option 3
Chromium	126.364	9.519	0.152
Iron	250.866	7.981	2.323
Manganese	276.453	3.768	0.206
Molybdenum	16.460	0.159	0.009
Nickel	163.252	11.382	0.137
Remaining substances	19.033	26.592	2.790

Source: own analysis

Table 4 Fossil fuels consumption in the process of septic tanks production, kg oil eq/FU

Fossil fuels	Option 1	Option 2	Option 3
Brown coal	7.630	18.172	0.613
Hard coal	115.555	87.842	2.357
Natural gas	34.773	199.096	11.733
Petroleum gas	0	0	19.614
Crude oil	113.623	267.716	362.818
Remaining substances	2.449	1.527	16.265

Source: own analysis

As a result of the LCA analyses for septic tanks, it has been shown that reinforced concrete septic tanks are characterized by the highest consumption indicator for metals, especially manganese, iron, nickel and chromium. The lowest metal consumption indicator is characteristic for tanks made of plastics. It has also been shown that tanks made of reinforced concrete have the lowest fossil fuels consumption indicator, while the highest value of this indicator has been shown by tanks made of glass-reinforced plastic. This is related to the high consumption of crude oil and natural gas in the equipment production process. The highest consumption of crude oil occurs during the production of HDPE tanks. In subsequent stages of the work, LCA analyzes are planned to be carried out for the stage of tank operation and decommissioning, to show the cumulative consumption of metals and fossil fuels throughout the life cycle, including the management of the individual materials they are made of.

4. CONCLUSION

Efficient use of metal resources and fossil fuels is at the heart of European Union policies aimed at promoting sustainable development. That is why analyses are important to identify the depletion of these resources in production processes. The paper presents an analysis of the use of metals and fossil fuels in the production processes of septic tanks. It has been shown that septic tanks made of reinforced concrete are characterized by the highest value of metal consumption indicator and fossil fuels consumption indicator. The value of the metal consumption indicator at the tank construction stage is determined first and foremost by the amount of steel used in this case to reinforce the tank construction. In order to obtain a full picture of the analyses carried out, a full environmental analysis for plastic tanks covering the construction, operation and decommissioning stages is planned.

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