Applying of LCA methodology on the sludge management operation

Ing. Réka Csicsaiová, prof. Ing. Štefan Stanko, PhD., prof. RNDr. Ivona Škultétyová, Ing. Jaroslav Hrudka, PhD.

Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering

Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia

e-mail: reka.csicsaiova@stuba.sk

Souhrn

The aim of the paper is the LCA methodology application in the evaluation of sludge management operation. Increasing the number of wastewater treatment plants and their upgrading stimulate an enhance in the demand for sludge treatment and disposal. Therefore, it is necessary to focus on assessing the negative impacts of the sludge management on the environment. The environmental impacts evaluation of sludge management operation was carried out using OpenLCA software. As the evaluation method was determined the ReCiPe midpoint (H) rating method.

Klíčová slova: *sludge management, LCA, sewage sludge, environmental impacts*

Introduction

The assessment of waste water status and negative environmental impacts of wastewater treatment plants has been devoted to the introduction of Directive 2000/60 / EC of the European Parliament of 23 October 2000. The purpose of the Directive is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater [1]. Another Directive dealing with the topic of water protection is Directive 91/271 / ECC (UWWTD), which provides for the construction of new sewage networks and WasteWater Treatment Plants (WWTPs) [2]. To comply with the EU requirements, a new Government Regulation was introduced. 269/2010 Coll., which also establishes requirements for achieving good status of waters and determines the limit values of indicators of pollution of discharged waste water [3]. Points of Directive 91/271 / EEC should be met by 2015. However, this has not been achieved. To meet the requirements of the guidelines, the old WWTPs were gradually rebuilt, and new ones built. During the reconstruction of the WWTPs, higher demands for environmental protection have been put in place and new optional instruments for environmental impact assessment have been used in the process of new trends in environmental management.

Such an optional tool is the Life Cycle Assessment (LCA), which was used to evaluate the impacts of WWTPs in the 1990s. By enhancing environmental quality requirements, LCA processes have been progressively developed. The creation of new assessment methods for modeling and computing the urban water cycle describes several scientific publications [4]. The assessment of municipal wastewater treatment plants falls into the end-of-pipe category and focuses on determining all emissions from the wastewater treatment process. All the processes taking place at WWTPs are monitored as part of the evaluation, and special emphasis is placed on sludge processing and disposal technology [5]. Recent studies have shown that WWTPs are highly involved in the production of greenhouse gases, especially methane (CH_4) and nitrous oxide (N_2O). It can be stated that the greatest amount of these pollutants is released into the sludge treatment and storage [6,7].

The aim of the paper is to present the results of the LCA analysis of the sewage sludge management of the sewage treatment plant. Because of the sludge management is the last stage of wastewater treatment, it is necessary to clarify the amount and composition of potential pollution.

Materials and methods

Life Cycle Assessment

In Act no. 24/2006 Coll. are provided the mandatory tools for environmental impact assessment. In addition to these mandatory tools, the use of optional environmental management tools for the assessment of wastewater treatment is a major trend. At present, we are working on implementing LCA analysis to evaluation the environmental impacts of wastewater treatment plants.

LCA analysis evaluates environmental impacts of objects with respect to their entire lifecycle. It is among the optional environmental management tools that can be used for its versatility in several part of industry [8]. The main idea behind the use of the LCA study is to limit or even to eliminate the adverse environmental impacts arising from the increase in product quality [9].

The assessment is based on the four steps that are immediately involved and influenced. The entire evaluation process is defined in ISO 14040. The standard describes the individual phases of the analysis and defines their parts. The first task is the precise definition of the goal and scope of the study. This step identifies the basic elements i.e. function of system, system boundaries, function units and allocation methods. The second phase is Life Cycle Inventory, including inventory of input and output parameters, as well as their assignment to system processes. The third phase is characterized by the interconnection of inputs and outputs with environmental impact categories. The last step is to interpret the results of the analysis in accordance with the defined boundaries of the system [10].

Figure 1 represents the individual phases of the LCA analysis.

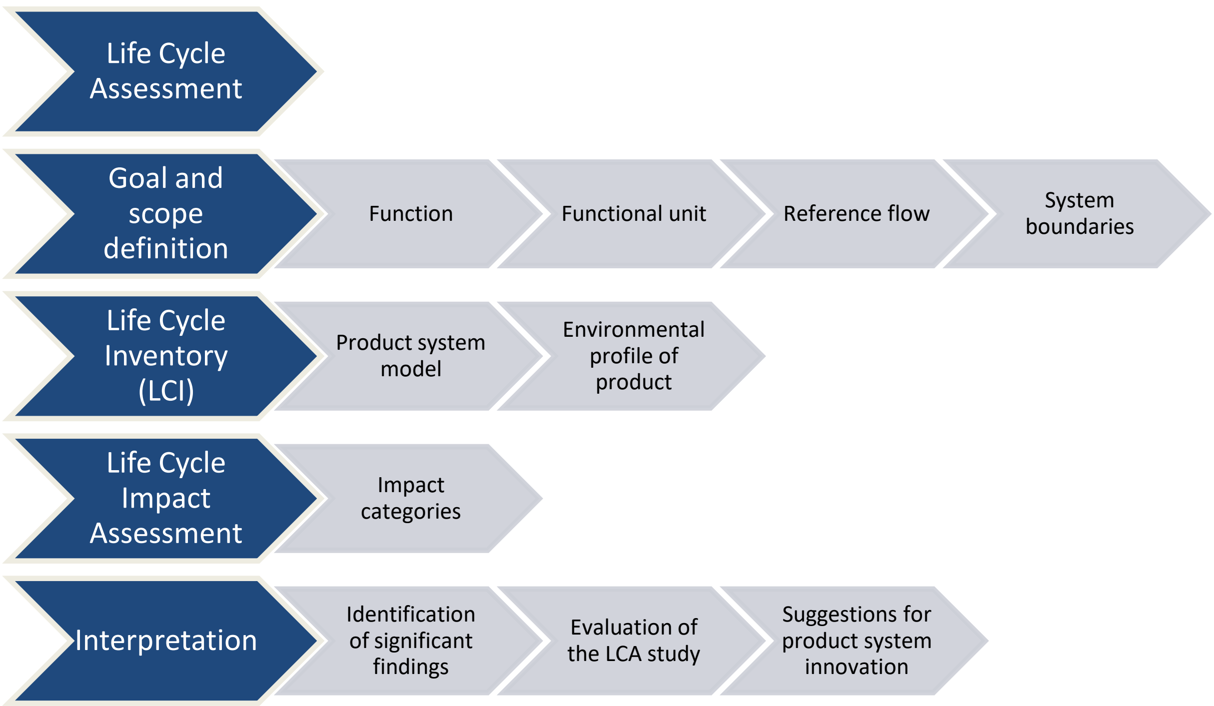

Figure 1 Phases of LCA (based on 8.)

Description of the WWTP under study

The assessed WWTP was built in 1944 and in 2013 underwent intensification and extension to a capacity of 22 300 EO. At present, three communities are connected to the WWTP. By 2030, at least four other communities are expected to be connected. The wastewater treatment process is a low-pressure activation process that operates on the principle of sequential nitrification and denitrification to remove nitrogen contaminants with simultaneous aerobic sludge stabilization. The sludge management consists of a thickening and storage tank. Both tanks are equipped with aeration with drainage of sludge water and a hinging hose for draining water from the surface. The aerobically stabilized sludge is drained on a centrifuge (type Alfa Laval Aldec 45). The drainage sludge is subsequently interposed under the shelter.

Goal and scope definition

The aim of this analysis is to assess the benefits and disadvantages of running the sludge management of the municipal waste water treatment plant to the environment. The product system is divided into two subsystems based on the potential sludge impact of the sludge treatment process and the impact of sludge storage on the landfill. In this study, a functional unit defines the amount of sludge that is composed of real measured data. The system boundaries define the important life cycle processes that need to be included in the LCA analysis. They have a significant impact on the results of the analysis, so they need to be precisely defined [11]. The boundaries of the system are limited to the sludge management line. System boundaries include thickeners, storage tanks, sludge deposition, sludge transport and landfilling.

Life Cycle Inventory (LCI)

Determination of input and output material flows is made based on an inventory analysis. LCI is one of the most important phases of analysis. Specifies amount of primary pollutant streams. Inventory matrices summarize material flow eco-vectors [8] and form the basic input data necessary for the implementation of the next phase. The function of inventory analysis is to focus on environmentally relevant information about participating processes belonging to the product system, which is then modeled using a specialized database [12]. LCI is based on real measured data in WWTPs and data derived from literature. Table 1, table 2 and figure 2, 3 present input data for LCA assessment. Sludge treatment is accomplished by dispensing lime and phosphorus precipitation with Prefloc. The average daily inflow to WWTPs was calculated from average monthly flows, its value being 0.8 $m^3 . s^{-1}$.

Impact assessment method converts the emission into several environmental impacts using characterization factors. The ReCiPe midpoint (H) evaluation method was used for this study. The midpoint indicators focus on individual environmental problems. The method allows for easier and more flexible access to LCA [13].

Table 1: Average monthly flow measured at the outlet in the period 2012 - 2016

Month	1	2	3	4	5	6	7	8	9
Flow rate [m^3/s]	0,04	0,06	0,11	0,07	0,05	0,03	0,02	0,02	0,02

Table 2: Inventory table

	2012	2013	2014	2015	2016	Average 2012-2016	Pollutant content v g/p.e./day
Inflow [kg/d]							
BOD5	1827	1726	1862	2219	5537	1862	31033.3
COD	5143	4459	4690	5432	21910	5142	85715
P total	75.6	65.8	82.6	91	421.4	82.6	1376.7
N total	382	324.1	377.3	413.7	287	377.3	6288.3
DS	3387	3123.4	3346	3549	3290	3346	55766.67
Outflow [kg/d]							
BOD5	7.70	9.10	14.00	11.90	12.60	11.9	198.3
COD	133.00	155.40	161.70	146.30	168.70	155.4	2590
P total	9.80	6.30	9.10	1.89	1.33	6.3	105
N total	85.40	34.30	20.30	36.19	51.30	36.19	603.16
DS	63.00	70.00	72.80	82.60	14.00	70	1166.6
			2014	**2015**	**2016**	**2017**	
Amount of sludge dry matter [kg/rok]			13 726	17 680	19 330	18 225	
Electricity consumption (MWh/year)			8106	9021	8997		

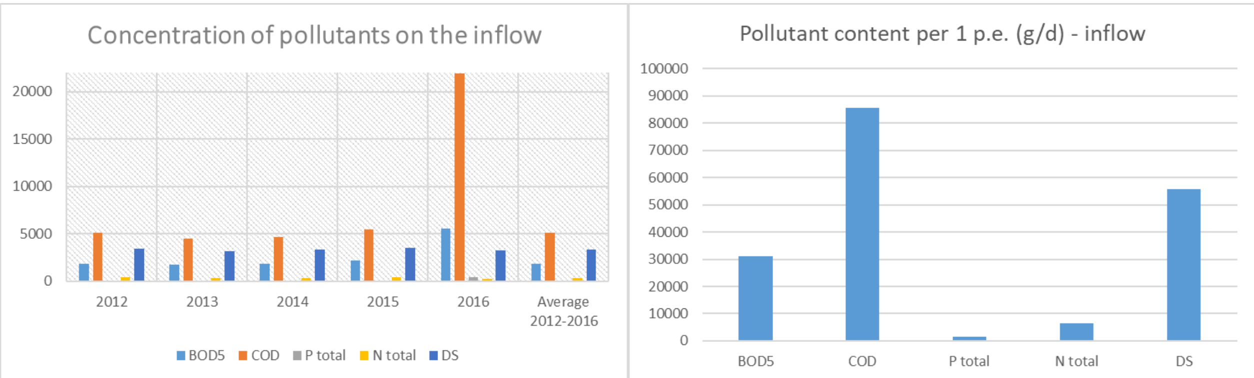

Figure 2 Pollutants on the inflow

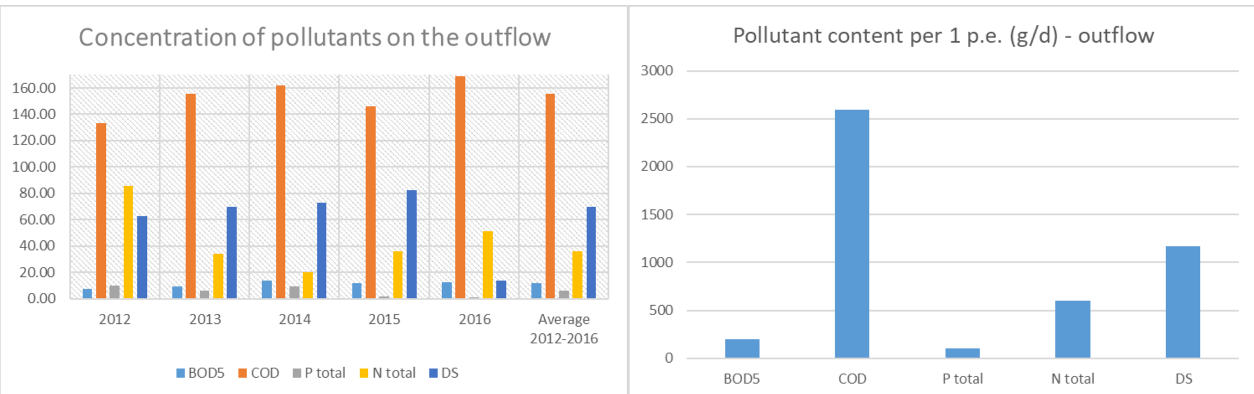

Figure 3 Pollutants on the inflow

Life cycle impact assessment

The basis for this phase is the transfer of the eco-vectors to the impact categories, which subsequently determine the characterization profile [8]. The ISO Standards 14040 and 14044 set out the mandatory elements of the analysis, which were used in this assessment [12].

The evaluated scenario was modeled on OpenLCA based on inventory tables. The individual elementary flows in the inventory tables are converted to impact category indicators using LCIA methodologies.

Characterization models of the LCIA methodologies were developed based on long-term research. They characterize individual impacts on the environment and represent a set of characterization models [8].

Impact assessment method converts the emission into several environmental impacts using characterization factors. The ReCiPe midpoint (H) evaluation method was used for this study. The midpoint indicators focus on individual environmental problems. The method allows for easier and more flexible access to LCA [13].

Results and discussion

Figure 4 presents LCIA results and potential negative impacts of WWTP operation and sludge management on the environment. The most significant is the global impact of the operation on climate change. To the deterioration of conditions is contributing to the crating of greenhouse gases (CH_4, N_2O, CO_2) in the use of electricity, fossil fuel combustion in sludge transport and gas release during landfilling. It can be stated that the greatest amount of CH_4 is produced by sludge treatment and storage and N_2O and CO_2 in the activation process.

The results of the assessment are expressed in units of species-years. This unit is characterized as a local species loss integrated over time [14].

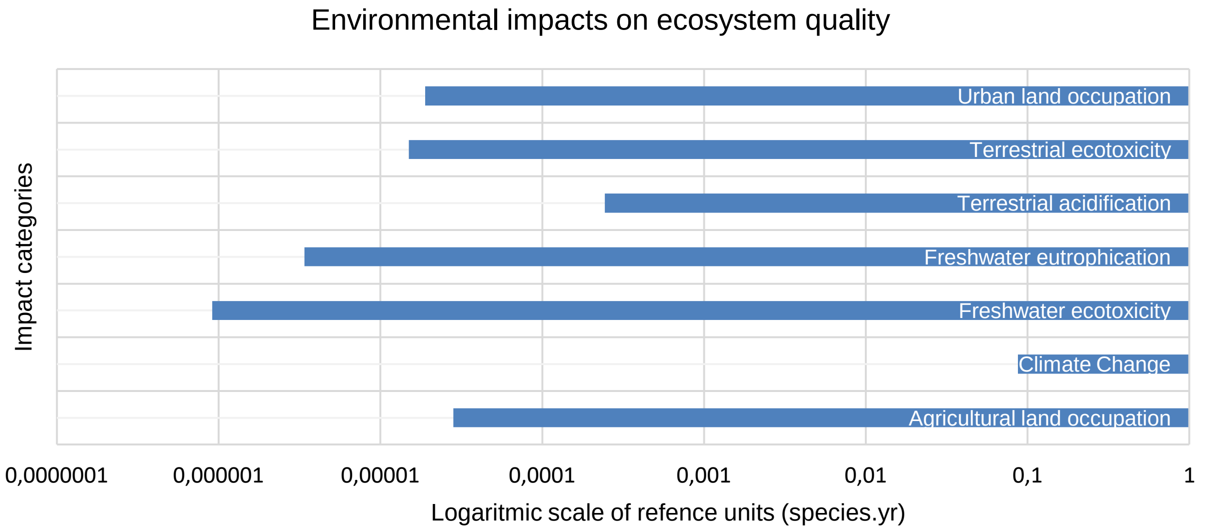

Figure 4 Environmental impacts on ecosystem quality

When assessing the WWTP, it is also necessary to focus on local impact categories that appear directly near the source. The ReCiPe midpoint (H) impact assessment method evaluates the impact on human health, which can be characterized by the following subset of impacts (see figure 5):

- Climate change is also the most significant component in this assessment. It is influenced by the amount of greenhouse gases in the air.
- Humane toxicity is a midpoint impact category and expresses the degree of toxic stress on humans.
- Ionizing radiation is the impact that is mainly caused by the production of electricity in nuclear power plants. It is also necessary to assume this impact as we cannot precisely determine the source of electricity,
- Ozone depletion,
- Particulate matter formation,
- Photochemical oxidant formation.

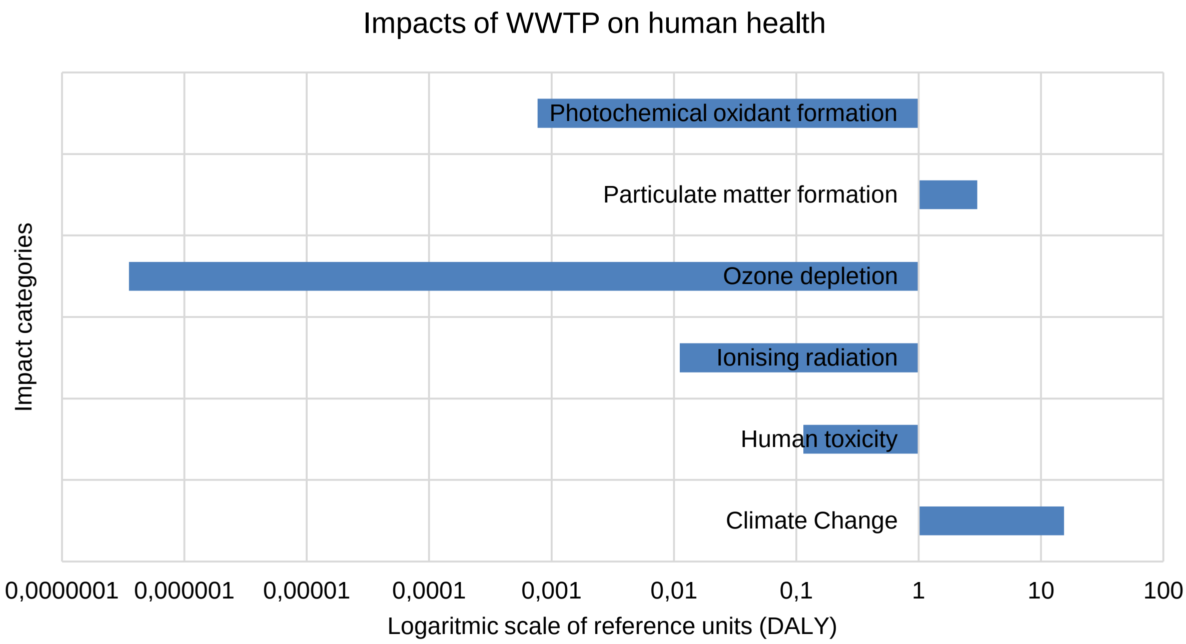

Figure 5 Impacts of WWTP on human health

These indicators are expressed in DALY units. DALY means disability adjusted life years. It is relevant for human health assessment. It represents the years that are lost or that a person is disabled due to a disease or accident [14].

Conclusion

The aim of the paper was to evaluate the potential environmental impacts of municipal waste water treatment plant and sludge management operation. The LCA analysis method assessed the operation of the wastewater treatment plant using the ReCiPe midpoint (H) evaluation method. Subsequent assessment is based on the knowledge gained during the literary search and the input data obtained during the observation of WWTP operation and sludge management. The evaluationt process was performed based on ISO 14040 and ISO 14044 standards.

The ReCiPe midpoint (H) impact assessment method aims to identify potential environmental impacts on the ecosystem, human health and resources. The analysis showed high values in the use of fossil fuel in the use of electricity and the combustion engines of vehicles transporting treated sludge to the landfill. The most significant indicators related to human health and the ecosystem are the impact categories: climate change, particle formation and human toxicity. It can be state that the impact of WWTP operation on climate change was most pronounced. Direct emissions produced at WWTPs during waste water treatment as well as sludge treatment are methane (CH_4) and nitrous oxide (N_2O). Indirect greenhouse gas emissions are emissions that are generated with electricity, the fossil fuel combustion during transport, the use of chemicals and the sludge treatment.

Over time, LCA methodology has become more conscious in Slovakia. It is used mainly for waste management. Assessment of wastewater treatment plants applying this methodology serves mainly to streamline their status and to create environmentally acceptable solutions for sludge management.

Acknowledgements

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