MULTI-CRITERIA ASSESSMENT OF NEW TECHNOLOGIES – CASE STUDY: INNOVATIVE TECHNOLOGY OF COMPOSTING

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Abstract

Multi-criteria assessment represents a decision-making tool that is utilized for solving complex issues in cases where it is essential to assess individual alternatives according to multiple viewpoints. Individual viewpoints are expressed in the form of criteria. The objective is to select one of the assessed alternatives that best fits given preferences. The quality of this assessment depends on the selection of the criteria and on defining their measurable indicators and on weights given to the selected criteria. Decision making in the area of new technologies, technologies based on utilization of renewable resources, can be unambiguously classified as a complex problem where attention must be given both to economic and to environmental aspects and impacts. It is possible to find some inspirational examples in scientific literature where multi-criteria assessment is used for assessment of such new technologies. The aim of this paper is to discuss various approaches to multi-criteria assessment of composting technologies with focus on new technology utilizing additives that make possible to better processing of household waste.

Key words: multi-criteria assessment, economic and environmental aspects, composting

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Introduction

Proper disposal of waste is a challenge for sustainable development (Hyršlová, 2012), and the lack of suitable sites and high waste treatment costs have prompted many regions to implement an integrated waste management policy. Municipal waste generation is increasing in Europe every year. Kabbe et al. (2015), estimate that 2,000 tonnes of phosphorous - a resource that the EU has placed on the list of critical raw materials that is to be used in a sustainable way (European Commission, 2014), can be generated annually from municipal

waste produced in Europe. The dominant component of municipal waste is household food waste. The total volume of food waste accounts for 27% of total agricultural production for both food and non-food usage (Kabbe et al., 2015).

Waste generation and composition depends on consumer structure, living standards, and disposable income (Akinci, Guven and Gok, 2012). The problem of food waste logically concerns especially developed countries. The EU Waste Framework Directive 2008/98 / EC has recommended the following waste management hierarchy: prevention, reuse, recycling, further energy recovery, and ultimately landfilling (European Commision, 2008). Landfilling of food waste leads to methane greenhouse gas, which has a 25 times higher global warming potential than CO2 in the 100-year scale (Abbasi and Abbasi, 2010). Therefore, the EU Directive issued in 2008 mandates a reduction in the amount of biodegradable components of municipal waste, (where food waste is included), deposited in landfills (European Commision, 2008). The EU supports projects contributing to the solution of the circulation and reuse of nutrients, and other technologies of circular economy. The management of biodegradable waste must respect the legislative instruments. Certain measures to minimize the health risks associated with the use of biodegradable waste, are set out in Decree No. 341/2008 Coll (MECR, 2008). The Decree lays down the requirements for biowaste treatment plants and their hygiene. By meeting these limits, in particular by keeping a sufficient temperature, the result of the hygienisation process is a quality "secondary" raw material applicable to agricultural and forestry land. The appropriate waste management and effective use of nutritients is closely connected with the soil management. The Czech Republic faces real danger here, as the actual retention capacity of agricultural land is currently 40% less than the retention capacity within the optimal use. Therefore, there is a need to develop and implement new technologies for waste management, and consequently there is a need for their evaluation.

Composting plant operators are one of the most important elements in the process of collecting, sorting and efficiently using waste from municipalities and households. At present, mixed municipal waste and bio-waste are collected separately, due to the ambiguous interpretation of the waste sorting requirements in municipalities regarding household food waste, which may contain animal waste and gastropods. It is precisely because of the processing of wastes containing animal waste and gastropods that the practice is not equipped with adequate technology that would allow for its safe composting. Problems with increased leaching and odour, due to different rates of biodegradation, can lead to the production of

ammonia and volatile organic compounds (Plachá et al., 2013). These problems are addressed by the new composting technology development project, which was supported by OP Enterprise Innovation Competitiveness (hereinafter „OP PIK“)

The aim of this paper is to discuss various approaches to the multi-criteria assessment of composting technologies, focusing on new technology that utilises additives that make more effective processing of household waste possible. The purpose of this paper is to provide a simple evaluation for the novelty and contribution to sustainable development of the promising new technology for municipal waste management.

1 Materials and methods

Multi-Criteria Analysis is a tool for solving complex problems where the resulting decision is based on an assessment of often conflicting criteria. A typical example is the choice between an inversely proportionate price and quality when choosing the resulting technology. The success gained using this method is mainly due to the choice of criteria, the determination of their measurable indicators, and the judging of the criteria as they participate in the final evaluation. Several inspiring examples of the use of multi-criteria analysis in renewable sources can be found in the literature (Nzilaetale et al., 2012; Abbasi and Abbasi, 2010).

Nzilaetale et al. (2012) used a combination of environmental and economic criteria in evaluating renewable energy systems, including environmental equivalence, greenhouse gas savings, and energy balance. The economic criteria were represented by the period of return on investment in the form of energy and operational reliability. This approach is consistent with Hyršlová (2012), which recommends assessing both the economic and environmental performance in strategic projects, together with the long-term impacts. Dereli and Altun (2013) proposed three evaluation criteria for renewable projects: (1) the potential for commercialisation, (2) the innovation potential, and (3) the trends of future usage of the new technology. One of the best-known theories for innovation assessment was created by Valenta (2001). The theory is based on the assumption that an enterprise has an innovation process under control, and works on the principle that a new generation or variant of a product is already in decline when compared to the previous product. Valenta (2001) defines the innovation order as the difference between the old and the new product, and recognises 11 orders - from the zero and negative innovations, in which none, or even negative innovation takes place after the most radical innovations of the ninth order, which represents a revolutionary coup. The first four orders are the improvement of the current state

(rationalisation), whilst the next five orders represent a qualitative change which can be protected by patents. When exploring the innovation process, Koners and Goffin (2007) recommend qualitative research.

The most sophisticated set of evaluation criteria was created by Budzianowski (2016), who applied it to assess the innovation of a biogas processing plant. The first overall evaluation criterion is the level of technology readiness, which includes two sub-indicators: verification of the principles of the effective functioning of the proposed technological concept, and the results of experimental testing. When evaluating the first criterion, both the validation of the technology in the laboratory, and the assessment of the pilot operation in the industrial environment take place. The second overall criterion is the commercialisation potential, which evaluates the potential of the proposed process from the point of view of the current market situation. This criterion also takes into account possible changes and developments on the market, due to the potential of new technology to affect public access to new technology, or its legislative impacts. Budzianowski (2016), called the energy, environmental, and climatic impact, the third comprehensive criterion that includes these sub-criteria for assessing innovation: energy balance, overall energy efficiency potential, reduced fossil fuel use, increased use of renewable resources, reduction of emissions and global warming, and opportunities for biogas manufacturers. For the determination of the partial criteria, Budzianowski (2016) recommends an expert prognosis.

The assessed new composting technology was, when this article was written, at the experimental stage and at the beginning of operational verification, therefore the qualitative assessment of the new technology's potential was split into in three perspectives - innovative, environmental, and application - which is summarised in the following table 1.

Composting is the controlled aerobic biodegradation of organic matter down to a stable, humus-like product called compost. It is the same process - natural decomposition, which is promoted and accelerated by mixing organic wastes with other substances in order to optimise microbial growth, and the activities of microorganisms when transforming biowaste into compost (Váňa, 1997). Quality compost promotes and enhances the sorption properties of the soil, and is used by transformation into the arable land (Stoffela and Kahn, 2001), or to protect and establish permanent grassland.

Tab. 1: Evaluation criteria of the new composting technology

Perspective	Innovative	Environmental	Application
Criteria	Innovative potential	Environmental potential	Potential for commercialization
Sub-criteria	Innovation order	expanding the efficient use of renewable resources	Need for praxis
		reducing emissions and global warming	trends in the future use of new technology

Source: Adjusted according to: Nzilaetale et al. (2012), Dereli a Altun (2013), Budzianowski (2016), Valenta (2001)

2 Results and discussion

The main objective of the project, which was supported by OP PIK, is to create a new and proven composting technology that will optimise the raw material by adding additives, and furthermore the application of special nonwoven fabrics to ensure the homogeneity of the indoor environment, including a stable temperature for the required time (over 70 degrees) during the entire compost profile. Additive enrichment will allow for a controlled way of leaching nutrients during the composting process, and will affect the rate of the decomposition of organic matter. The new technology will increase the water holding capacity of the compost, especially by using additives (eg thermally activated organic material such as mulch, wood chips, etc.). At the same time, the technological process will intensify, and a qualitatively different compost of better quality, with increased sorption capacity, will be created. This modified compost positively affects the release of nutrients into the soil, and better retention of water in the soil. After demonstrating success using thermally activated biomass or adding other additives, a material with increased water retention capacity would be a very promising substance for improving soil fertility. This new composting technology will intensify the technological process, create a qualitatively different and better quality compost with increased sorption capacity, and allow for the composting of secondary raw materials. This is why technology can be ranked in a higher 4th grade innovation - qualitative adaptation.

New technology, respectively the composting recipe, allows for composting operators to expand the volume of services offered by composting waste from households and gastropods, in order to make better use of capacity, and improve the quality and added value of the services provided. Another output of the project will be software that allows for a more accurate determination of the maturity of the compost, whereby it can be moved from a specially modified (hardened) area, to a field. The use of this area is costly, so this output will enable composting operators to make better use of the capacity, and make the production process overall more efficient. The evaluation of the new composting technology according to the criteria given in Table 1 is summarized in Table 2.

Tab. 2: Evaluation of the new composting technology

Perspective	Innovative	Environmental	Application
Criteria	Innovative potential	Environmental potential	Potential for commercialization
Sub-criteria	Higher 4th innovation order - higher quality compost for composting secondary raw materials.	Increasing the efficient use of renewable resources - suitable organic material for improving soil fertility	The need for practice - lowering traffic, improving capacity utilization, and expanding the product portfolio
		Reduction of emissions and global warming - reduction of methane and leachate emissions	Trends in the future use of new technology - improving phosphorus recycling by selecting the appropriate adivites

Source: Own research

Conclusion

Proper waste disposal is one of the main challenges faced when achieving sustainable development, despite efforts to prevent waste from municipal waste production in Europe rising annually. The dominant component of municipal waste is food waste. At European level, a number of measures have been prepared to contribute to the better use of biodegradable municipal waste components, and to support developmental projects that enable nutrient recycling. One technology that promotes better raw material circulation is composting. Current composting technologies do not prevent the excessive production of ammonia, volatile organic compounds, and lower fatty acids that cause odour. The aim of the analysed project is the technological transformation of the process of enrichment of the compost with additives, which allows for a controlled way of leaching nutrients. During the process of composting itself, it will affect the rate of the decomposition of organic substances. The present project brings about environmental benefits by eliminating leachate and associated odour, and increasing the water sorption capacity of the soil, which is particularly important at present when facing minimal precipitation totals. The new composting technology is very promising, both in innovation, commercial potential, and in terms of positive environmental impact. If confirmed, some research hypotheses can also be considered to formulate proposals for the modification of the existing legislative instruments applicable to the production of compost, which further expands the potential commercialisation of new ones in accordance with (Budzianowski, 2016). In subsequent phases of the project, researchers will validate additives in the raw tracks in the laboratory, and operational testing will continue regarding additives and nonwovens for verifying the homogeneity of the internal environment, and technology readiness will be assessed in accordance with Budzianowski (2016). After evaluating the results of the operation and the field experiments with the resulting compost, it will be possible to assess the impact on arable land, and to elaborate the economic and environmental evaluation of the new technology in accordance with (Stoffela and Kahn, 2001; Hyršlová, 2012).

This article summarises the process of evaluating the perspectives of new waste treatment technology. The purpose of the article is to show how the project can be evaluated, even in the early stages of preparation and solution. Based on a literature review, a combination of qualitative criteria has been chosen to assess the potential of the new technology, and its estimated impact on applicability, innovation and the environmental benefits.

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