ECONOMIC AND ENVIRONMENTAL EVALUATION OF MUNICIPAL WASTE – NEW FERMENTATION TECHNOLOGY OF SMALL-SCALE BIOGAS STATIONS

Marie Kubáňková – Jaroslava Hyršlová – Jan Nedělník – Jiří Rusín – Kateřina Chamrádová

Abstract

Solid waste has significant impacts on the environment. As a result of changes in consumers' habits in recent years, the volume of solid waste is constantly growing. Public administrations attempt to treat solid waste in an environmentally friendly way. There are many efforts being made for the integrated management of solid waste, a comprehensive solution to its disposal and recovery with elimination of the environmental consequences and social impacts, both at EU and regional levels. The EU announced targets for reducing the amount of landfilled biodegradable waste, which prevents the storage of organic matter in landfills from 2016. In accordance with this Directive, it is necessary that partly composted or processed form of digestion exists. The aim of this paper is to present approaches to economic and environmental assessment of selected technologies for the processing of municipal waste, with close attention being paid to a new technology, and the fermentation process of small-scale biogas stations.

Key words: environmental evaluation, economic appraisal, municipal waste, anaerobic digestion

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Introduction

Production of solid waste has significant impacts on the environment. With the increasing number of inhabitants and with changes in consumer behaviour the volume of solid waste has been increasing in recent years. Municipal solid waste is a big worldwide problem. Within the sustainable development of society context there is growing pressure on the public and also on public administrations to deal with the area of municipal solid waste management. There appear some efforts for integrated municipal solid waste management that means efforts for deal with municipal solid waste utilization in a complex manner, to dispose of it while at the same time the environmental and social impacts of this disposal are mitigated. An integrated management (of municipal waste) includes also the prevention of waste production, waste production reduction, recycling and utilization of its energy potential respectively. Using landfills is the least welcome option of waste management. Integrated management of waste can be seen both on the EU level and in partial regional strategies.

EU for instance introduced its targets for reduction of volume of landfilled biologically degradable waste. The relevant Directive on the landfill of waste prevents the storage of organic substances (biologically degradable) in landfills from year 2016 (EC, 1999). The general objective of this Directive is to define measures, by means of relevant technical and operational requirements for waste and landfills, for prevention or for maximum reduction of negative impacts of using landfills for waste storage on the environment (that means pollution of surface water, ground water, soil and air). All issuing risks and impacts on human health are taken into consideration here (during the entire life-cycle of the landfill). In agreement with this Directive it is thus essential to manage this part of the waste by composting it or treated it by digestion. Anaerobic digestion is the name for controlled microbiological transformation of organic substances without the access of air resulting in origination of biogas and digestate. Anaerobic digestion has a few synonyms that are partially or fully identical: anaerobic fermentation, bio-methanization, methane fermentation, anaerobic stabilisation, anaerobic putrefying and anaerobic decay. In case of aerobic decay this is de-composition of organic substances by means of organisms' and micro-organisms' activities that require oxygen from air for their activities. In some EU countries such as are for instance Denmark, Sweden and Germany landfilling of selected types of waste (in particular flammable waste or untreated organic waste) is prohibited. On the EU level there are efforts to implement alternative approaches and processes for treatment of biologically degradable waste in other ways than by landfilling so that it is possible to utilize their energy-producing potential. The aim of this paper is to present approaches to the economic and environmental assessment of selected technologies for the processing of municipal waste.

1 Materials and methods

In some countries it is a widespread solution to burn municipal solid waste with recuperation of energy. This alternative was dramatically criticised in the 80th and 90th of the last century in connection with producing emissions into air. That is why strict limits have been introduced which has prevented installation of new burning facilities. There have been created new technologies equipped with waste gases treatment that provide for management of air pollution and thanks to energy recuperation they can be suitable for waste management, for instance waste-to-energy plants (Psomopoulos, Bourka and Themelis, 2009). Waste-to-energy plants were in year 2003 acknowledged by the United States Environmental Protection Agency (US EPA) as a clean source of energy. It issues from scientific studies that the highest share of recycling is achieved in those countries that dispose of a dense network of waste-to-energy plants. The Netherlands ranks the highest with 97% of recycling share (composting respectively) and heat treatment; only 3% of waste is landfilled in the Netherlands. For comparison, in the same time period, in the UK 74% of waste was landfilled.

One of the most common options for treatment of organic fraction of municipal solid waste used in separated collection is anaerobic digestion. Anaerobic processes allow for production of biogas that is important source of energy. By-product of anaerobic digestion – digestate – has a potential for use in fertilization (Alburquerque, et. al., 2012). In many cases treatment of digestate is necessary due to its potential fyto-toxicity (Poggi-Varaldo et al., 1999; Young et al., 2012), complicated manipulation (Lü et al., 2015) and to soil application technology that may require complicated and expensive machine equipment (Abdullahi et al., 2008). Biogas stations process, by means of anaerobic processes, a wide range of materials or wastes of organic origins. Next to agriculture by-products they also process municipal and industrial bio-waste. Biogas stations can be agricultural – they are usually operated by large agriculture companies – or they can be municipal or industrial and linked to waste water treatment plants operated usually by a city or by an industrial company. Landfill gas also falls under the category biogas stations. This gas is produced in a managed manner and it is collected from landfills. As a small-scale biogas station we can understand a facility that processes biologically degradable waste in the amount not exceeding one ten tons load and the annual volume of processed biologically degradable waste may not exceed 150 tons. One of the current trends is to process the organic fraction of municipal solid waste in the combined anaerobic and aerobic systems that allow utilization of methane from biogas and nutrients from digestate. Various organic substances are being processed on these combined facilities (Kokabian, Bonakdarpour and Fazel, 2013).

The aim of this paper is to present approaches to economic and environmental evaluation of the selected technologies for processing of municipal waste, with close attention being paid to new technologies, and to the fermentation process of small-scale biogas stations. This paper is based on analysing scientific literature focused on the studied issues and on results obtained from projects in which the authors of this paper actively participated. In the following text the obtained results are summarized and discussed.

2 Results and discussion

One of the most suitable tools for evaluation of technologies for processing solid organic waste with utilization of the combination of anaerobic and aerobic processes is mass balance (Cesaro, Russo and Belgiorno, 2015). Mass balance works with terms „input“ and „output“, while the principle of the balance is the equality between the inputs and outputs. Cesaro, Russo and Belgiorno (2015) used this method for the evaluation of optimum utilization of the organic fraction of municipal solid waste. The authors elaborated mass balance for the total mass of dry matter, for solid substances – that means for both compostable and non-compostable materials. In their calculation they assumed that during the initial screening there is 45% loss of the organic fraction of municipal solid waste (Pognani et al., 2009) and also that 60% of outputs from the pressure machine are solid wastes determined for aerobic stabilization. The mass balance of the anaerobic part was executed with the assumption of an ideal even division of the output where the following applies:

- dried digestate represents 9%, the remaining 91% is liquid fraction of digestate (fugate),
- losses from processing during the active time of composting represent 25% and 5% in the compost stabilization phase,
- infusion represents about 9% of the mix determined for composting,
- amount of oversize material removed by screening is approximately 10%-13%; 8% out of this is circulated.

Alcántara, Garcína-Encina and Munoz (2013) also recommend mass balance as a tool for evaluation. They used mass balance for estimate of potential for production of bio-energy and regeneration of nutrients from anaerobic digestion of biomass of seaweeds. The authors constructed mass balances for individual elements (P, C, N) and they presented changes in biomass compositions.

Ngyuen et al. (2016) tested dry semi-continual anaerobic digestion for utilization of food waste as an energy renewable source. They evaluated the system performance and they simulated prediction of biogas production and energy balance. From this study it has issued that this manner of processing food waste is technologically manageable and it may significantly make the production of bi-methane and sludge reduction more effective. This model example has showed that balance can be achieved between energy consumption and energy recuperation potential with the objective to maximize self-sufficiency and to minimize energy requirements.

Ngyuen et al. (2016) also focused on economic analysis. The result from this economic analysis was the calculation of average costs for processing waste by anaerobic digestion technologies. The costs oscillated in a big range from 18.25 to 278.91 USD per a ton of processed food waste (the authors used the then current costs of electricity energy 0.059 USD per 1 kWh). For comparison the authors state the following costs parameters:

- 310 USD / t when putting sludge to landfill,
- 176 USD / t of treated sludge,
- 100 – 300 USD / t sludge for thermophile aerobic system, for industrial sludge treatment,
- 200 – 500 USD / t sludge treated by conventional technology.

Based on the economic analysis the authors have come to the conclusion that thermophile dry fermentation should be used in particular in case of high load where it contributes to increased effectiveness of energy production from renewable resources and to improved environmental impacts.

Leme et al. (2014) proceeded in the framework of the evaluation in such manner that they have executed techno-economic assessment and consequently environmental impact assessment. In the economic assessment they assessed two basic scenarios for energy production:

- The first alternative assesses waste-to-energy plant that burns municipal solid waste in a controlled combustion furnace (at the temperature 870-1200◦C) and produces electricity energy. Burning of wastes makes the volume and mass smaller by 90%, by 70% respectively (Ofori-Boateng, Lee and Mensah, 2013). Ashes from the incineration plant, that represent about 10% of the original waste, are usually landfilled – this however represents another hazard for the environment.
- The second alternative – processing in a fermenter – utilizes as source of energy biogas originated in municipal landfill. Landfill biogas usually includes 50% of CH4 and 50% CO2 (energy content 18.0-19.0 MJ / Nm3). One of the processing options is to collect this biogas, to treat it and to burn it with the objective to produce electricity energy (Ofori-Boateng, Lee and Mensah, 2013). In order to obtain biogas from the landfill it is essential to carry the gas by piping to energy conversion station with special technology for production of electricity energy.

Within environmental assessment it is always necessary to take into consideration the concrete situation of the given region. The authors have recommended using approaches of the International Standard Organization (ISO), and that ISO 14040 and ISO 14044. ISO 14040:2006 describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14044:2006 specifies requirements and provides guidelines for LCA. Leme et al. (2014) draw attention to the need to include into the assessment also externalities that are caused by emissions of particles O3, CO, SOx, NOx and non-methane volatile organic compounds (NMVOC), hydrocarbons (CxHy), dioxins, and similar that have dramatic impacts on human health. Within economic assessment it is essential to take into consideration also other external costs linked with other (non-health) impacts. For instance SO2 is the main pollutant of concern for building-related damage, though ozone also affects certain materials. Secondary polluting substances created from SO2, NOx and NMVOC also have impact on crops of overland and water ecosystems. The authors have also pointed out the need to consider social aspects of potential solutions.

Based on the above-stated results it is possible to formulate recommendations for proceeding under the evaluation of the individual manners of municipal waste managing. In the first step it is purposeful, for finding the optimal manner of utilization of the organic fraction of municipal solid waste, to elaborate the mass balance. Based on this it is possible to make an estimate of the potential for bio-energy production and for renewal of nutrients from anaerobic digestion. In the next step it is essential to consider energy balance with the objective to find out if there is a possibility of balance between energy consumption and energy recuperation potential. Based on the outputs from the previous steps it is possible to elaborate an economic analysis. In the framework of this analysis there are evaluated costs and benefits related to the individual alternatives of municipal waste management. It is possible to calculate indicators commonly used in economic feasibility analysis, such as cash flow, Net Present Value (NPV) and Internal Rate of Return (IRR). A significant step in this evaluation is the environmental impact assessment. Environmental impacts should be assessed with LCA utilization. All relevant important externalities should be taken into consideration and any important social impacts should be included into the evaluation. In the framework of the integrated solid waste management a rational approach must be taken that shall deal with the system as a whole and any solutions shall be searched for through the employment of multiple methods and collaboration among all stakeholders.

Conclusion

The ever increasing emphasis on economic growth in line with sustainable development of society principles requires complex decision-making tools that shall be used by management in private undertakings as well as authors of public policies and that shall be also used in the framework of public administration. Sustainable development issues are so complex that it is essential in the framework of decision-making processes to apply a multi-dimensional approach. Management in line with sustainable development principles requires cooperation of all interested parties along the entire management cycle – from setting a management system and defining strategic objectives to tactical-operational management to communication with significant stakeholders. Participation of stakeholders in decisions about projects that are important for sustainable development of a region shall provide for an integration of strategic goals into the tactical-operational management and at the same time it shall provide for the coordination of economic objectives with the environmental and social objectives. Public administration use generally for its management formalized processes based on valid legislation, however, in recent years we have witnessed utilization of new innovative approaches and management methods inspired by approaches and methods used in private sector. Sustainable development of society requires new managerial approaches and tools that allow, in public administration, to evaluate and manage projects with regard to their economic, environmental and social aspects and impacts.

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Contacts

Marie Kubáňková
Research Institute for Fodder Crops, Ltd. Troubsko
Zahradní 400/1, 664 41 Troubsko
mariekubankova@gmail.com

Jaroslava Hyršlová
Faculty of Transport Engineering, University of Pardubice
Studentská 95, 532 10 Pardubice
jaroslava.hyrslova@upce.cz

Jan Nedělník
Research Institute for Fodder Crops, Ltd. Troubsko
Zahradní 400/1, 664 41 Troubsko
nedelnik@vupt.cz

Jiří Rusín
VŠB - Technical University of Ostrava
Institute of Environmental Technology
17. listopadu 15/2172, 708 33 Ostrava – Poruba
jiri.rusin@vsb.cz

Kateřina Chamrádová
VŠB - Technical University of Ostrava
Institute of Environmental Technology
17. listopadu 15/2172, 708 33 Ostrava – Poruba
katerina.chamradova@vsb.cz