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Original Research

Biodegradable Waste Management in the Czech Republic. A Proposal for Improvement

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Abstract

Our paper analyzes the development of the current approaches to biodegradable waste (bio-waste) management in the Czech Republic in compliance with the European Union (EU). A proposal for the improvement of bio-waste management following the authors' long-term research for the Czech Ministry of the Environment has been introduced. The experience of bio-waste management from EU is included in our proposal. The solution to the current situation of the Czech Republic is proposed as a logistically interconnected integrated bio-waste management system of technologies that would optimally manage the specifications of individual groups of biological wastes, the needs of customers, and the possible sale of the final products and/or energies. The proposed solution could also be used by other EU accession countries.

Keywords: bio-waste, bio-waste management, bio-waste treatment costs, integrated bio-waste management

Introduction

Biodegradable waste (bio-waste) under the terms of the Waste Framework Directive (WMF) [1] of the European Union (EU) means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. The EU, naturally, is at the forefront of these activities as well as dealing with biodegradable waste [2-5]. Approximately 120 to 140 million tons of bio-wastes are produced every year in the EU. This corresponds to approximately 300 kg of bio-waste produced per EU citizen per year [6].

Biowastes can be used to obtain several bio products through composting [7, 8], anaerobic digestion or another processing technology [9]; or even to obtain biofuels such as biogas or bioethanol. (For more details see Bernstad and la Cour Jansen [10], who reviewed 25 LCA studies of bio-waste treatments, and Morris et al. [11], who performed a meta-analysis of 82 studies assessing the management of organic waste.) However, the composition of biowastes can be very different and variable and the determination of production factors can be complicated, although these wastes could be included in the model as another type of waste separately; if the necessary data are available, wastes of this type are taken into account with the mix of the remaining waste after the separation of plastics, glasses, paper, and metal [12-14, 29-32].

It was difficult to find an appropriate optimal biowaste management strategy in the Czech Republic, one that would be developed and implemented in compliance with the EU.

In the 19th century Czech lands were among the leading countries in composting. It was here that the world's first controlled composting of bio-waste was launched [14]. In addition, organic wastes were usually collected as a sepa-

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rate type of waste used as food for pets and domestic animals. Both types of bio-waste reuse were severely affected by the advent of modern chemistry and artificial fertilizers. They have only been recovering with difficulty.

Biowaste management is currently governed in the Czech Republic by an extensive system of legislative requirements [15, 16]. This indicates that the process introducing relevant treatment standards to govern bio-waste and municipal bio-waste management is rather complex [16].

The basic framework for biowaste in the municipal waste in the EU is Directive 1999/31/EC of 26 April 1999 on the landfill of waste (Landfill Directive), which requires that the weight of biowastes in the municipal wastes should be reduced to 75% of the weight of such waste type produced in 1995. By 2013 and 2020 the weights should drop to 50% and 35%, respectively [5]. The Czech Republic accepted this Landfill Directive as early as 2001 by Decree No. 383/2001 Coll, on the details of waste management.

Fig. 1 shows deviations in the fulfilment of the Landfill Directive on elimination of municipal bio-wastes from landfills by EU member states.

The current situation in the reuse of bio-waste in the Czech Republic has been influenced by logistical requirements in the collection and transport of separated municipal biowaste, unsuitable processing capacities, complicated compost sale, and low landfill fees [16]. This situation is more adverse than in e.g., Poland [17] and Slovakia.

The Czech Republic will not be able to fulfil within a long-term horizon the Landfill Directive (Table 1) without essential changes in biowaste management. But if, compared with other EU member states, the Czech Republic has set up measurable indicators in the national Waste Management Plan (WMP) [18] and possesses, at least to some extent, the necessary laws and economic support needed for the fulfilment of those indicators [19].

The objective of this paper is to introduce a specific solution for the improvement of biowaste management in the Czech Republic following the authors' long-term research for the Czech Ministry of the Environment (MoE) [20-22]. We propose a logistically interconnected integrated bio-waste management system of technologies that would optimally manage the specifications of individual groups of biological wastes, the needs of customers, and the possible sale of the final products and/or energies [16, 20]. This system will be presented in Section 3. In Section 2, we introduce the current situation of biowaste management in the Czech Republic. Our results are discussed in Section 4.

Analysis of Bio-Waste Management in the Czech Republic

According to the report [23], the situation in biowaste management has not changed a great deal since 2007, when agricultural wastes were moved from the "waste" category into the "organic fertilizers" category. The data shown in Table 1 have proven this trend. A large amount of biowaste was deposited in landfills in 2006-12, the reason being that the largest share of biowaste consists of biodegradable components of household municipal wastes.

The study [23] provides a very objective evaluation of biowaste and municipal biowaste management after 6 years of efforts to find solutions to that specific type of waste. It is entirely in line with the authors' analyses performed by [14-16] and the results of the R&D project [20] of MoE. They are based on bio-waste management experience gained in the EU member states [3, 9, 17] which defined 6 common boundary conditions that should comply with proposed solutions to those specific groups of wastes:

- A preventive approach and preventive measures are less efficient for biowastes if compared with other waste types.

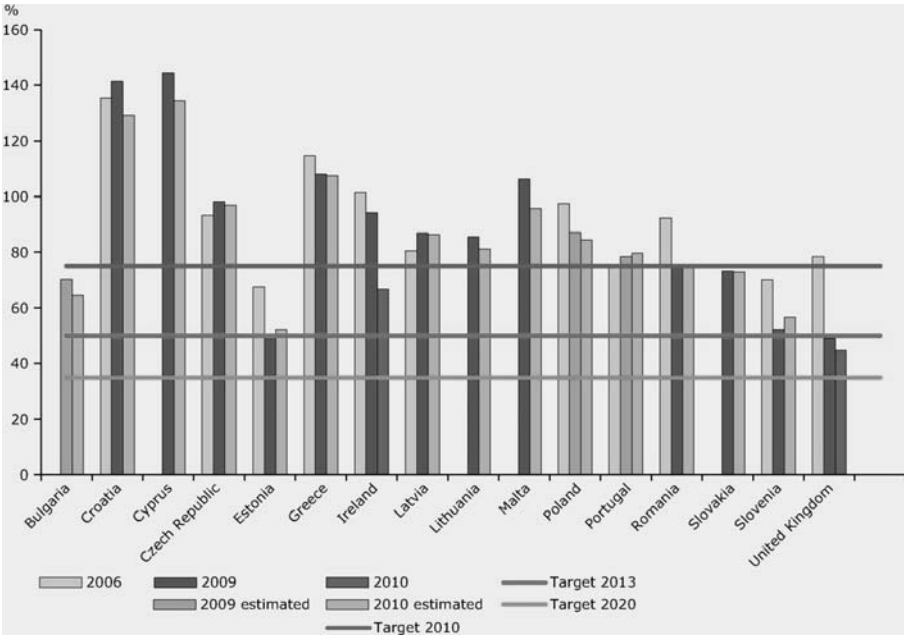

Fig. 1. Percentage of biodegradable municipal waste landfilled in 2006, 2009, and 2010 compared with the amount generated in 1995 — countries with derogation periods [6].

Table 1. Biowaste landfilling in 2006-2012 in the Czech Republic [23].

Year	2006	2007	2008	2009	2010	2011	2012
Production [Tg]	3,978	4,012	4,3	4,314	4,193	4,477	4,325
Landfilling [Tg]	2,12	1,609	1,662	1,602	1,483	1,325	1,242
% Biowaste at landfills	53.1%	40.1%	38.7%	37.1%	35.4%	29.6%	28.7%
Landfilling index (1,530 in year 1995=1)	1,38	1.05	1.08	1.04	0.96	0.86	0.81

- It is not possible to sort out the biodegradable components from the MSW by waste producers only.
- Simple composting is not a suitable technology for the efficient treatment of all quantities of biowastes.
- It is essential to integrate the needs of individual waste producers and organic waste types into one logistical unit.
- Constraints exist for the collection and transport of wastes because organic wastes are unstable in terms of physical and chemical properties (for instance temperature, access of oxygen, or moisture).
- It is not realistic to sell top-quality compost with a high profit.

If follows from our research [20]: "*No reasonable integrated systems exist so far for waste management at regional levels in the Czech Republic. Capacities are, in particular, insufficient for the processing of municipal biowaste*."

Only a few local projects in biowaste management have been performed in the Czech Republic in the past five years. In most cases, these are small composting plants (capacity from 500 to 2,000 Mg per year). Investment costs are high and such plants are typically co-financed from EU funds. This is entirely in conflict with the difficulty in filling up the planned capacity, the low efficiency of composting processes, and problems with selling the ready-to-use compost.

Eventually, such facilities cannot compete with the plain landfilling of municipal bio-waste unless heavily subsidized (the subsidies are typically hidden in fees paid for the collection and disposal of municipal wastes) [21, 22]. This is a clear consequence of the new Waste Act that has not yet been adopted.

If agricultural wastes are not taken into account (the European Waste Catalogue currently in force does not mention them), the biowaste and municipal biowaste market has not yet been started in the Czech Republic. This branch of waste business is not attractive in terms of income for specialized companies in the Czech Republic – they create composting plants as secondary activities only, typically on landfill sites. The compost produced there is of low quality and is used for reclamation of landfills [24, 25].

The market conditions and the way toward a permanently efficient and effective solution to biowaste and municipal biowaste management are even more distorted by EU structural funds, which are granted to municipalities for the construction of low-capacity composting plants. Such municipalities later face problems with filling up even such small capacities. The total amount invested from public sources into the construction of almost 190 composting plants was slightly under EUR 40 million. The total costs with respect to the construction of the composting plants were almost EUR 58 million.

The situation is even worse in investments into anaerobic digestion technologies [16], where it was originally planned to combine agricultural products with bio-waste. The total amount invested from public sources into the construction of 7 subsidized biogas stations was slightly under EUR 9.5 million. The total costs with respect to the construction of the biogas stations were EUR 29 million.

The biogas stations use biowaste for the production of biogas, which is incinerated in cogeneration units that also produce electricity. The efficiency of cogeneration units is about 40% and the heat is utilized in technologies [26]. Excess heat is not typically used. According to different sources [2, 20] the average yield is believed to be ca. 120 m3 biogas from each ton of bio-waste of plant origin. Incineration of this quantity can generate approximately 260 kWh of electricity.

More than 40% of the combined biogas stations (for both waste and agricultural products) face considerable economic problems. The remaining combined biogas stations currently in operation are only filled up at ca. 80% during the year. The operation of the biogas stations that use only wastes can be regarded as a pressing issue as well.

Three municipal waste incinerators are in operation in the Czech Republic at present. All three incinerators were designed as facilities for the generation of energy from waste. These are the SAKO Brno incinerator (put in operation in 1989 and reconstructed in 2011), the Praha Malešice incinerator (put in operation in 1998), and the Liberec incinerator (put in operation in 2000). The total net capacity of the incinerators is ca. 650,000 tons of MSW per year and 632,000 tons were incinerated in 2012 [23]. The energy potential of MSW ranges between 10 and 13 GJ per ton and each incinerator uses it for the generation of heat and electricity.

Table 2 provides the approximate comparison of total costs with respect to the processing of one ton of biowaste for different reuse or disposal methods. The costs are based on known investment costs and the operation of specific high-capacity facilities operated by the global group SUEZ ENVIRONMENT in the CZ [27]. Those costs should be regarded as approximate only. As mentioned above, it is complicated to make calculations if subsidies are granted for investments and if the collection and disposal of biowaste/municipal biowaste is subsidized as well.

Table 2. Comparison of costs for bio-waste treatment in the Czech Republic and the EU [own results].

Method of treatment	Czech Republic [EUR]	EU [EUR]
Separated collection of biowaste and composting	25-35	35-75
Separated collection of biowaste and anaerobic digestion	50-60	85-125
Disposal of biowaste at landfills	35-45	55
Energy recovery of biowaste with household municipal waste	35-50	90

When determining costs, comparison also was made with existing and proven economic models [21, 22]. The costs for the EU 15 were taken from [2].

Results

The above-presented experience of biowaste management in the past five years in the Czech Republic has clearly proven that a radical change is needed with respect to the biowaste management strategy of EU [2-4]. The subsidies only granted for investments into new composting and anaerobic digestion technologies were EUR 51 mil. and the total investments are estimated to have reached ca. EUR 120 mil. This resulted in a 11.4% decrease in the quantity of bio-waste placed at landfills (367,000 fewer tons if comparing the years 2007 and 2012). From the point of view of the return on investment, one ton of such bio-waste not deposited at landfills costs nearly EUR 327.

We can prove from our research that a more comprehensive approach would be needed in the Czech Republic with respect to bio-waste [16, 20, 23]: It is necessary to find a logistically interconnected system of best available technologies (BAT) based optimally on specifications of individual groups of biological wastes, needs of customers, and possible sales of the final products and/or energies.

We proposed the "Integrated Management System for Bio-Waste" based on the results of research projects [15, 16, 20, 23] of the MoE, which brings an appropriate solution. In order to identify such a system, the analyses of biowaste management should focus on the following four specific objectives:

- to find an optimum region for waste collection,
- to divide the biodegradable waste into specific groups,
- to select suitable technologies,
- to perform financial analysis.

We explain how these objectives can be fulfilled in the following paragraphs.

Choice of Optimum Waste Collection Region

One key weakness of biowaste management systems is the fact that such systems are focused on one group of biowaste. In the Czech Republic (and in the EU as well) there are often systems that focus on MSW only or on MSW combined with municipal organic waste [4, 6, 9]. Most of these systems are only able to manage other waste types and related needs with difficulty. In spite of the high investment into the reconstruction of original facilities, the required performance has not been reached so far and the efficiency of such hybrids is very low.

The outcome of our research [15, 16, 20] concludes: A suitable logistic region for bio-waste appears to be more important than the focus on a specific group of wastes. Only then can an optimum, technically efficient, and profitable system be designed.

Naturally, it is very complicated to set model parameters for the region. Such parameters are linearly related to different variables, such as the density of population, occurrence/quality of individual waste categories, logistics, configuration of the region or cultural differences and habits. It is possible to use for this purpose models and software obtained from research tasks [15, 16, 20-23] and foreign projects [13, 17, 28]. In spite of this, it is possible to use foreign experience and proven efficiency of systems operated in the Czech Republic as well as solutions of the aforementioned research projects and to define approximate minimum parameters: population (200,000-350,000 inhabitants); total minimum quantity of biowaste (35,000 tons), and maximum coverage (60-80 km). If the values in the region are lower, it is recommended to make the region larger and/or export the wastes from other territories.

Dividing Specific Groups of Biodegradable Waste

In order to propose a holistic solution to the integrated biowaste management system, it is essential to transform individual waste list categories of biowaste into the below-listed specific groups, which will make it possible to collect and transport the wastes more efficiently.

Selection of Suitable Technology

A basic opinion before starting any specific actions of biowaste management can be based on a simple suitability matrix for the use of systems and technologies for specific waste types, which constitutes the results of our research [14, 16]. This represents the intersections of the systems and waste types.

Financial Analysis

Even if all the recommendations above are followed, no biowaste management system will be permanently sustainable if there are no other legislative and, in particular, finan-

Table 3. Specific types of biowaste by the origin of occurrence [14].

Waste type	Description
Household waste	The wastes produced by households, such as organic leftovers, mown grass wastes, pruning wastes, and cultivar wastes.
Municipal waste	Mown grass wastes and pruning wastes produced by the upkeep of municipal parks and forests.
Sludge	All types of biodegradable wastes, including the contents of cesspools and drain pits.
Wastes from services/ commercial wastes	Wastes from stores, including supermarkets, retailers/small businesses, kitchens, restaurants, hotels, and catering facilities (canteens in schools and factories, cafeterias in universities, ect.).
Industrial wastes	Waste from food processing industry.
Agricultural wastes	Wastes produced in agriculture and forestry.

Table 4. Suitability matrix for the use of systems and technologies for specific waste types [own results].

Waste type/system/technology	Household waste	Municipal waste	Sludge	Food Animal by-products	Waste from business and services	Industrial waste	Agricultural waste
Prevention	Limited	No	No	Limited	Yes	Yes	Yes
Separated waste collection	Yes	Yes	Yes	Limited	Yes	Yes	Yes
Sorting	Yes	Limited	No	No	Yes	Limited	Limited
Recycling/reuse	Yes	Yes	Yes	No	Yes	Yes	Yes
Mechanical and biological treatment	Yes	Yes	Limited	No	Yes	Limited	Limited
Incineration	Yes	Limited	Yes	Yes	Yes	Limited	Limited
Composting	Limited	Limited	Limited	No	Limited	No	Yes
Biogas station	Limited	No	Limited	Yes	Limited	Limited	Yes
Landfilling	Yes	Yes	Limited	No	Yes	Yes	Yes

YES means that the system or technology is suitable for that waste type.
LIMITED means that the system or technology can be used with certain limitations (for example wastes should be pre-treated); the system or technology is suitable only for some categories from this waste type; there are limitations in laws; there are other secondary consequences.
NO means that the system or technology is not suitable for that waste type.

cial tools [14, 21, 22]. The economy of each biowaste solution is closely linked to investment and total operation costs. In our research we investigated the investment and operation costs for biowaste treatment (Table 5), which enables us to calculate the economy of the chosen technology.

Discussion of Results

The conclusions of the research projects [15, 20, 21] have supported the approach of national WMP but did not result in the creation of legislative and financial tools by the Czech MoE.

Fig. 2 shows relations between laws in force, financial tools, best available technologies and the formation of the market. The bigger bubble shows the other waste quantity of waste in the CZ without biodegradable waste, while the smaller bubble is the quantity of bio-waste. The absence of suitable technologies and techniques (two grey arrows leading to the smaller sector) is not a pressing issue in the CZ. Enough sources for investments are available from private investors who currently operate more than 60% of the waste market. The only issue is that legislation and financial support tools (third grey arrow) are not sufficient and

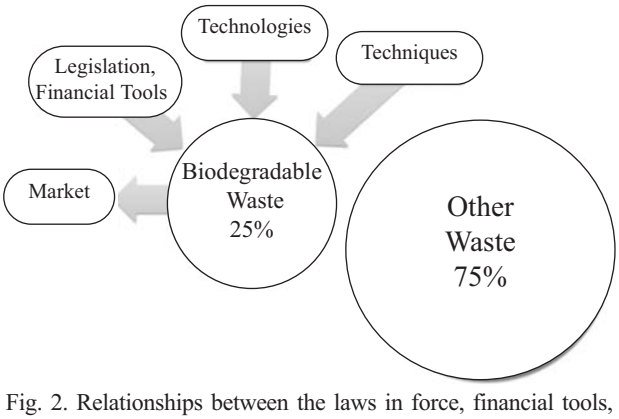

Fig. 2. Relationships between the laws in force, financial tools, best available technologies, and formation of the market. [Own result]

Table 5. Investment and operational costs for biowaste reuse/disposal facilities [own research].

Technology	Investment costs [EUR/Mg]	Operational costs [EUR/Mg]
Composting in storage pits, boxes (capacity: 20,000 tons per year)	13.6	4.2
Composting in halls, containers, tunnels (20,000 tons per year)	14.6	4.8
Landfilling of household waste (60,000 tons per year)	3.8	9.6
Energy recovery of household waste (120,000 tons per year)	19.2	26.9
Anaerobic digestion (20,000 tons per year)	22.3	4.8

easy to survey. Optimizing those two parameters would immediately create a sustainable market environment for bio-waste. This would help the CZ to fulfil its commitments toward the EU, and a long-lasting solution for biowaste would exist and could also be used in Poland and Slovakia.

The weaknesses of existing laws and financial tools of the Czech Republic for biowaste management have been analyzed in our paper and the following elements have been identified as missing for the Czech Republic:

- Higher fees for plain landfilling of municipal wastes – from EUR 20 (now) gradually up to EUR 60
- A directive with respect to biowastes where reuse of materials and production of energy from wastes would be mentioned as the preferred solutions
- Focused financial support for products and energies obtained by composting/anaerobic digestion
- Emphasis placed on regional biowaste solution rather than on local bio-waste solutions in subsidy policies (the terms "minimum collection territory" and "minimum facility capacity" should be introduced).

The recommended tools should in no case result in immediate or incremental increases in prices for waste producers. If the landfill fees go up, this would be a motivation for material reuse and, in particular, for separated collection of municipal biowaste, which is becoming the main component in the MSW in the Czech Republic, contributing considerably to the formation of gas emissions and contamination of leakage water at landfills [23].

A similar approach could also be applied in other EU accession countries, where the current situation in biowaste management shows a delay in the fulfilment of the Landfill Directive.

Conclusion

Our paper analyzed the current situation in biowaste management in the Czech Republic. The proposal for the improvement of biowaste management following the authors' research for the Ministry of the Environment was introduced. This solution consists in a logistically interconnected integrated biowaste management system of technologies that would manage optimally the specifications of individual groups of biological wastes, the needs of customers, and the possible sale of the final products and/or energies. The solution developed could be used simply by other EU accession countries.

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