Analysis of the model application of mechanical equipment for hydrothermal treatment

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Abstract

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Two model applications of mechanical equipment for hydrothermal treatment were analysed. Alternative 1 consisted of a treatment output of 2,000 Mg of processed material, the annual compost production of 1,000 Mg, total capital expenditure of 15,838,000 CZK, unit capital expenditure of 7,919 CZK per 1 Mg of processed material and annual operating expenses of 1,300,000 CZK. The net present value (*NPV*) is 1,482,800 CZK, the internal rate or return (*IRR*) totals 7.6% and the discounted payback time (T_{sd}) is 16.9 years. Alternative 2 employing the mechanical equipment proved a potential increase in the treatment output to 2,600 Mg, and an increase in the compost production to 1,300 Mg thanks to the shortened intensification of composting. At the same time, the total capital expenditure rose to 18,997,000 CZK, the operating expenses rose to 2,080,000 CZK. The unit capital expenditure of alternative 2 amounts to 7,306 CZK per 1 Mg of the treatment output. The *NPV* totals 6,984,200 CZK, *IRR* is at 10.7% and T_{sd} totals 11.8 years.

Keywords: composting; thermal hydrolysis; technological equipment; biodegradable waste

Production of waste by the human society is a limiting factor for further development. As a part of the Sixth Community Environment Action Programme, priorities for waste management were set – most of the waste should be returned to the cycle mainly through recycling. Waste either in utilisable form, such as compost, or in harmless stabilised form, should be then returned to the environment (Decision of the European Parliament and of the Council No. 1600/2002/EC).

The hydrothermal treatment method was tested with biologically degradable materials of various characteristics mainly in order to increase methane production during the consequent utilisation of the treated material in the anaerobic fermentation process (Kumar et al. 2011). The objective of this method is to improve the utilisation of the material components such as lignocellulose (Hendriks, Zeeman 2009). The hydrothermal treatment method was also tested with sanitary sewage in order to improve its utilisation in the anaerobic fermentation process (Climent et al. 2007). Wilson and Novak (2009) validated the effect of various temperatures of hydrothermal treatment on the specific components of sanitary sewage. This method was also applied for the treatment of pig manure for the same purpose – to increase the methane production during anaerobic fermentation (Carrére et al. 2009). Abroad, the thermal pressure hydrolysis method was validated for the treatment of biological materials intended for bio ethanol production (Piementel, Patzek 2005).

The objective of this study is to analyse the potential influence of the model application of the SBM (biomass stabiliser) mechanical equipment for hydrothermal treatment of waste on the operational and economic characteristics of a composting plant.

MATERIAL AND METHODS

The SBM mechanical equipment (Strojírny Olšovec s.r.o., Olšovec, Czech Republic) is made up of parts that ensure mechanical treatment (crushing and mixing) of the processed waste. Thus a stationary crushing and mixing piece of equipment is designed for the treatment of waste to obtain a suitable particle size and an adequate proportion of the individual material components. Crushing and mixing take place in a crusher with a chain crushing system and a pair of screw conveyors. The equipment is driven by a three-phased asynchronous electric motor and a gearbox. Hydrothermal treatment of waste in the SBM mechanical equipment is ensured by means of three screw presses. The processed material (crushed and homogenised) is conveyed by the screw conveyor to a dosing silo from where it is dosed onto screw press 1. In the first section – screw press 1 the material is partly dewatered and heated from the ambient air temperature to a temperature of 95–130°C at an overpressure of 0.2–0.3 MPa. The material is then fed to the screw press 2 where it is heated up to a temperature of 175–190°C and subject to an overpressure of 0.6–0.8 MPa. Water vapours and volatile gases are released from the material. When the material is fed from screw press 2 to screw press 3, the temperature drops rapidly to the value of 130–150°C and the overpressure drops to 0.1 to 0.2 MPa. Screw press 3 ensures the finalisation of the hydrothermal treatment process. Due to the changes in physical conditions at this stage (temperature and pressure), the biomass cells undergo transformation changes.

As a part of the model application of the SBM mechanical equipment at the composting plant it is considered that the mechanically treated sludge will be transported by a belt conveyor to the storage silos in the hall where the mechanical equipment is situated. Following the hydrothermal treatment in the SBM mechanical equipment, the treated material will be conveyed from another storage silo and spread as belt piles in the composting area.

For the purpose of the economic analysis we made use of the economic evaluation of the investment used for the Feasibility Study. The specific economic parameters were quantified and the monitored indicators were calculated. The alternative solutions to composting plant were evaluated without the application of the SBM mechanical equipment and with the application of the SBM mechanical equipment.

The capital expenditure of the civil structures at the composting plant is determined by means of the method of aggregated building work items (itemised budget), using a software for budgeting building work BUILDpower (RTS corporation, Brno, Czech Republic) by RTS corporation. The prices of the technological units are set based on the price quotations submitted by specific manufacturers.

When evaluating the project rate of profit we prefer the cash flow (*CF*) evaluation. The cash flow evaluation is defined as a difference between the revenues and expenditure in the relevant year and is used to evaluate the simple rate of return and the internal rate of return. The cash flow calculation is based on the net present value (*NPV*) method most frequently applied in the feasibility studies. Synek et al. (2007) state that the calculation of the net present value consists of discounting of all revenues and expenditures at a constant rate up until now. The *NPV* is based on the formula:

$$NPV = PVCF - C_0 = \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t} - C_0 \quad (1)$$

where:

NPV – net present value of the investment
PVCF – net present value of the cash flow
CF – expected cash flow value in period t
C_0 – initial investment
r – discount rate
t – period
T – service life of the investment

The present value of the cash flow (revenues from investment) *PVCF* is calculated according to the following formula:

$$PVCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \ldots + \frac{CF_T}{(1+r)^T} = \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t} \quad (2)$$

Roušar (2008) states that the discount rate is a rate of the available investment tool with a real possibility of investing funds. The discount rate varies according to the field of business that the evaluated project falls into. According to the data provided by the Ministry of Industry and Trade of the Czech Republic, a discount rate of 8% is recommended for the evaluation of investments in the field of waste management.

The service life usually expresses the economic service life of the equipment for which the investment is evaluated. This period need not always correspond to the technical service life of the equipment.

Revenues and expenses growth index expresses the price of energies and services in the individual fields of business. As regards the calculation of the economic evaluation carried out as a part of the feasibility study we can consider that it equals the average yearly inflation rate.

Total yearly revenues include the sum of revenues from sales and savings. Total yearly expense covers the sum of the equipment operating expenses and other expenditures. Cumulated cash flow expresses the cumulative cash flow balance in the evaluated year and it is a continuous sum of all cash flows from year zero to the relevant year.

Discounted cash flow expresses the contribution over the relevant year to the total project economy. The cumulated discounted cash flow expresses the total economy of the project until the relevant year taking into account the time value of money. It is a continuous sum of all discounted cash flows from year zero to the relevant year. The value in the last year of the project service life equals the net present value.

Simple payback time is the period necessary to recover the total capital expenditure through the project net income. The simple payback time is simplified because the future net income is not discounted and, as a result, it does not respect the time value of money.

The simple payback time (T_s) is calculated on the basis of the following formula:

$$T_s = \frac{C_0}{CF_t} \quad (3)$$

where:
C_0 – initial investment
CF – expected cash flow value in the relevant period
t – period when the discounted cash flow is calculated

The discounted payback time includes the aspect of the present value of money and it expresses the time necessary to recover the total capital expenditure by the project net income while reflecting the time value of money.

The discounted payback time (T_{sd}) is calculated as follows:

$$T_{sd} = \frac{C_0}{DCF} \quad (4)$$

$$DCF = \frac{CF_t}{(1+r)^t} \quad (5)$$

where:
C_0 – initial investment costs
DCF – discounted cash flow
CF – cash flow
r – discount rate
t – period when the discounted cash flow is calculated

Generally, it may be stated that if the net present value (*NPV*) of the relevant year has a positive value, the project is economically efficient.

Internal return rate (*IRR*) expresses the discount rate at which the net present value (*NPV*) of cash flow equals zero. Thus, it is the lowest discount rate at which the project is not loss-making.

The internal return rate (*IRR*) is calculated as follows:

provided that $$NPV = C_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t} \quad (6)$$

when $NPV = 0$ (7)

then $IRR = r$ (8)

where:
NPV – net present value of the investment
C_0 – initial investment costs
CF – cash flow
r – discount rate
t – period when the discounted cash flow is calculated
T – service life of the investment
IRR – internal return rate

The revenues from the sale of compost are determined on the basis of data provided in literature and the data obtained from real composing plants. Specifically, Kratochvíl (2004) states that revenues ranging from 0–500 CZK per 1 Mg of processed biodegradable waste (BDW) can be considered. For example, as regards registered industrial compost the price of 1 Mg, at the composting plant EKOSO Trhový Štěpánov (Trhový Štěpánov, Czech Republic) totals 900 CZK, at the composting plant HUCUL (Vítkovice v Krkonoších, Czech Republic) the price is 850 CZK, at the composting plant Červenka Jirny (Jirny, Czech Republic) it is 800 CZK, at the composting plant Kompostárna Hořátev (Hořátev, Czech Republic) it is 500 CZK. Reclamation composts are usually provided to the inhabitants for free (e.g. the composting plant in Slavkov u Brna, composting plant in Třinec both in the Czech Republic). The calculation considers a selling price of 400 CZK per 1 Mg, which reflects the situation in the region.

RESULTS

Alternative 1 – without the application of the SBM mechanical equipment

The processing output of the composting plant is 2,000 Mg of processed BDW. Duration of the composting cycle is 13 weeks. Number of weeks in a year when composting takes place is 42. Composting surface with a size of 27 × 55 m (1,485 m^2).

Balance of processed materials and compost production:

– total weight of the BDW processed in a year totals 2,000 Mg,
– weight of biologically degradable communal waste (BDCW) processed at the composting plant per year is 1,640 Mg,
– weight of other biological materials processed in a year totals 360 Mg,
– volume of produced compost totals 1,000 Mg.

Summary of economic characteristics:

– total capital expenditure .... 15,838,000 CZK
– average yearly inflation rate in the CR in 2010 .... 1.5%
– total annual income.............. 2,860,000 CZK
– yearly composting operating expenses (650 CZK per 1 Mg of processed BDW) .... 1,300,000 CZK
– unit capital expenditure (construction and mechanical equipment) per 1 Mg of processed BDW (output of the composting plant) .... 7,919 CZK

The results of economic evaluation of Alternative 1 are presented in Table 1 (summary results) and Fig. 1 (cumulated discounted cash flow).

Alternative 2 – with the application of the SBM mechanical equipment

The processing output of the composting plant is 2,600 Mg of processed BDW.

Duration of the composting cycle is 10 weeks.

Number of weeks in a year when composting takes place is 42.

Composting surface with a size of 27 × 55 m (1,485 m^2).

Balance of processed materials and compost production:

– total weight of the BDW processed in a year totals 2,600 Mg,
– weight of biologically degradable communal waste (BDCW) processed at the composting plant per year is 2,110 Mg,
– weight of other biological materials processed in a year totals 490 Mg,
– volume of produced compost totals 1,300 Mg.

Summary economic characteristics:

– total capital expenditure .... 18,997,000 CZK
– average yearly inflation rate in the CR in 2010 .... 1.5%
– total annual income.............. 4,420,000 CZK
– yearly composting operating expenses (800 CZK per 1 Mg of processed BDW) .... 2,080,000 CZK
– unit capital expenditure (construction and mechanical equipment) per 1 Mg of processed BDW (output of the composting plant) .... 7,306 CZK

Table 1. Summary results of economic evaluation – Alternatives 1 and 2

	A 1	A 2
Total capital expenditure (CZK)	15,838,000	18,997,000
Discount rate (%)	8	8
Evaluation period (service life, years)	20	20
Investment evaluation period	2010	2010
Simple payback time (T_s, years)	10.2	8.1
Discounted payback time (T_{sd}, years)	16.9	11.8
Income and expenses growth index (%)	1.5	1.5
Revenues per year – sale of compost (CZK)	400,000	520,000
Other revenues/year (cost BDW recovery – not land filled, CZK)	2,460,000	3,900,000
Operating expenses/year (CZK)	1,300,000	2,080,000
Net present value (CZK)	1,482,800	6,984,200
Internal return rate (%)	7.6%	10.7%

A1 – Alternative 1, A2 – Alternative 2, BDW – biodegradable waste

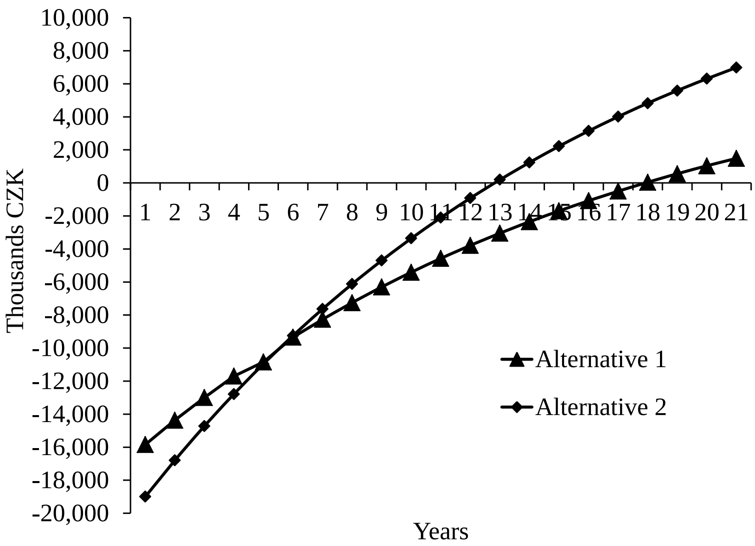

Fig. 1. Cumulated discounted cash flow – Alternatives 1 and 2

The results of economic evaluation of Alternative 2 are presented in Table 1 (summary results) and Fig. 1 (cumulated discounted cash flow).

DISCUSSION

Thanks to the use of hydrothermal treatment of biological materials in the composting fills and the more intensive microbial aerobic processes we may consider reducing the composting cycle to 10 weeks (of the total time, we can deduct 3 weeks which are usually stated in the literature as the period necessary for the decaying phase). If the SBM mechanical equipment is used, we can expect – while keeping the original parameters of the composting surface in Alternative 1 – that the total annual volume of processed waste will increase by approx. 600 Mg and the compost production will increase by approx. 300 Mg. However, the application of the equipment requires a modification of the transport solution on site and construction of a new building for hydrothermal treatment. Naturally, these modifications have an influence on the increased capital expenditure related to the construction work by 1,675,289 CZK (of which 293,930 CZK is the cost of modifying service roads and 1,381,359 CZK for a light-weight hall housing the SBM mechanical equipment). Further cost increase is related to the investments in the hydrothermal treatment operating unit (SBM mechanical equipment at capital expenditure of 1,500,000 CZK).

The shortened duration of the composting cycle is also related to the rise in the total volume of processed BDW to approx. 2,600 Mg a year and the volume of produced waste to approx. 1,300 Mg a year (which represents an increase in the revenues from the sale of compost by 90,000 CZK and revenues from non-disposing BDW at landfills by 900,000 CZK a year).

If the original volume of processed BDW is kept, the composting plant upgrade will enable a reduction in the size of the composting surface area by approx. 450 m^2, which amounts to capex savings of approx. 570,000 CZK. As regards the capital expenditure of Alternative 2, it concerns 18,997,000 CZK, which is 3,159,000 CZK more compared to Alternative 1 (while keeping the original size of the composting site).

The unit capital expenditure of 1 Mg of the composting plant output in Alternative 1 totals 7,919 CZK, whereas in Alternative 2 it is 7,306 CZK, which to a great extent corresponds with the data by Kratochvíl (2004) who states the capital expenditure of composting plants of a small output are always higher and he also states that a composting plant with an output of 600 Mg of processed BDW a year and total capital expenditure of 4,300,000 CZK has a unit capital expenditure of 7,166 CZK per 1 Mg of the composting plant output.

On the basis of the identified results it may be concluded that despite the higher total capital expenditure in Alternative 2, the unit capital expenditure per 1 Mg of the composting plant output is lower than in the case of Alternative 1, mainly thanks to the intensified operation. The economic evaluation of the investment concludes that in Alternative 1 the net present value (*NPV*) is at 1,482,800 CZK, the internal rate of return (*IRR*) totals 7.6% and the discounted payback time (T_{sd}) is 16.9 years. In Alternative 2, the *NPV* totals 6,984,200 CZK, *IRR* is 10.7% and T_{sd} is 11.8 years.

CONCLUSION

The analysis of the model application of the SBM mechanical equipment at the composting plant has demonstrated that higher capital expenditure is needed (both for building work and the technological operating units), but the operation will become intensified and the composting plant output will increase, which will result in reduced total unit capital expenditure. Based on the economic evaluation of the monitored indicators it may be stated that under the defined economic conditions the composting plant using the SBM mechanical equipment (Alternative 2) is economically more efficient than a composting plant without such equipment (Alternative 1). The factors that may affect the results of the economic evaluation include, in particular, changes concerning composting operating expenses, availability of other sources of BDW (from surrounding municipalities within an economically profitable distance) for the intensified operation of the composting plant, economic level of charges for waste landfilling and the price of produced compost (in terms of marketability). The above factors may have both positive and negative impacts depending on the area (or areas) where such changes happen and depending on the magnitude of such changes. Looking at the general evaluation of the operating and economic parameters of the alternatives it may be concluded that, under defined conditions, the application of the SBM mechanical equipment is beneficial for the performance and economic efficiency of the composting plant.

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