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SYNERGIC EFFECT OF ENERGY USE OF THE SELECTED TYPES OF WASTES

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Abstract

The dominant means of waste management should be their effective utilization. As the man in his life consumes significant amounts of energy, one of the acceptable forms of waste recovery appears to recover the energy, preferably in combination of different waste types, taking into account their nature and local (regional) specificities.

The presented results showed that a common energy evaluation of selected waste types, in addition energy production has also significant environmental and economic dimension (reducing the amount of waste deposited to landfill, thus saving of substantial funds).

Key words: *municipal waste, waste paper, sewage sludge, energy plants and crops, fast-growing trees, combustion heat, ash*

INTRODUCTION

If mankind will not behave reasonably, the Earth will become very quickly a planet of waste. People produce by their activities a considerable number of different waste types that can be subdivided into several ways (see Waste List established by Decree No.284 / 2001 S.L. under other changes). E.g. according to their origin the waste can be divided into:

- municipal waste
- industrial waste
- energy waste.

Total waste generation in the EU in 2010 was more than 2.5 billion tons, of which municipal waste formed for 218.6 million tons (8.74%) (Jandačka et al. 2014). According to 2012 data everyone in the EU produced 481kg of this waste (euractiv.sk 2013).

In 2014, the SR produced in sum more than 9 million tons of wastes, of which up to 76% (6.84 million tons) represents industrial waste, and more than 1.83 million tons of municipal waste with average of 339 kg/capita, which increase comparing to 2013 by 17 kg/capita. Up to 66% of the total municipal waste ended up in landfills, and only 10% have been recovered energetically (Report on the state of the environment SR 2014).

Municipal sector, industry and agriculture produce more and more wastes that must be eliminated in some way to avoid the negative pressure on the environment. Annual production of sewage sludge through the waste water treatment plants (WWTP) is estimated for 50-60 thousand tons of dry matter (Karkulín 2007).

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The most effective way of dealing with sewage sludge is generally considered their application to land after a previous stabilization and drainage.

Another way of handling the sewage sludge is the energy recovery by combustion wherein waste becomes ash, in which heavy metals may be concentrated.

Several western countries (e.g. Sweden, Switzerland, Belgium and Denmark) are trying to assess energy of the municipal waste for a long time, and they are recovering third to half of their municipal waste (Jandačka et al. 2014).

Advantage of waste combinations - municipal waste and waste biomass (wood and wood waste from forestry, vegetable waste from agricultural primary production and maintenance of landscapes, animal waste, municipal organic waste and waste from food production (Jandačka et al. 2007)), is that the occurrence of both waste types is distributed uniformly throughout Slovakia and there is therefore a prerequisite for the practical implementation.

The aim of this paper is to point out the possible effects of a common energy recovery of selected types of waste in Slovakia.

MATERIAL AND METHODS

The samples used for experiments:

- industrial wastes - pulp and paper sludge, sludge from the production of plywood, waste fibres from the manufacture of fibre board, hemp hurds
- paper based wastes presenting the paper waste that normally collects, recycles and in the case of surpluses or difficult recycling it is possible to utilize also energetically,
- sewage sludge (from WWTP)
- wood, bark and leaves of different tree species,
- agricultural waste - wheat straw, rice hulls,
- energy crops - amaranth (*Amaranthus*), grape hyacinth (*Miscantus sinensis*), couch grass (*Elytrigia repens*)
- fast-growing trees - willow (*Salix viminalis*), poplar (*Populus x euroamericana*).

The samples were tested in the form of pellets, either directly supplied by the producers, or prepared in laboratory.

Tested waste samples were analyzed for combustion heat by calorimeter IKA C 200 using the software Win Cal in accordance with DIN ISO 1928 (44 1352). As the combustion heat values are negatively affected by the content of incombustible constituents in the fuel - ash and moisture, the majority of the samples was treated prior to the determination on the absolute dry weight (w_r = 0%) for better comparison of the energy content of the individual samples,.

The present percentage ash content was calculated from the content of inorganic residue after combustion of the sample in the calorimeter.

Fig. 2: Pellets of sewage sludge, clean sawdust spruce with an admixture of spruce bark

RESULTS AND DISCUSSION

Tab. 1 shows the combustion heat values and ash content in samples of selected municipal wastes.

Tab. 1 Combustion heat and ash content in samples of the municipal wastes – sewage sludge, wastes from landscape maintenance (wood, bark, leaves)

Sample	Moisture [%]	Combustion heat [MJ.kg^{-1}]	Ash [%]
Pellets of sewage sludge (Austria) *	0	11.614	38.7
Sewage sludge - pieces (Zvolen - Slovakia) *	7.8	13.432	32.2
Spruce (*Picea excelsa*) - wood	0	20.172	0.5
Willow (*Salix viminalis*) - wood	0	19.753	0.2
Spruce (*Picea excelsa*) - bark	0	20.808	3.0
Birch (*Betula alba*) - bark	0	24.058	1.6
Alder (*Alnus incana Moench.*) - bark	0	21.729	3.0
Aspen (*Populus tremula*) - bark	0	20.890	3.7
Hornbeam (*Carpinus betulus*) - bark	0	19.305	5.1
Beech (*Fagus silvatica*) - bark	0	18.536	5.0
Oak (*Quercus robur*) - bark	0	17.392	5.9
Willow (*Salix viminalis*) - bark	0	17.535	6.6
Linden (*Tilia cordata*) - leaves	0	17.396	11.8
Oak (*Quercus robur*) - leaves **	0	18.487	8.1
Maple (*Acer pseudoplatanus*) - leaves **	0	16.046	12.4
Walnut (*Juglans regia)* - leaves **	0	16.972	12.6
Ash (*Fraxinus excelsior*) - leaves **	0	16.514	11.9
Hornbeam (*Carpinus betulus*) - leaves **	0	16.278	13.1
Birch (*Betula pendula*) - leaves **	0	19.754	4.8
Horse chestnut (*Aesculus hippocastanum*) - leaves	0	17.908	8.6

Note: * (Geffertová, Geffert 2011a)
** (Dzurenda, Pňakovič 2015)

Sewage sludge produced in waste water treatment plants (WWTP) contains a large proportion of water and therefore the combustion of solely sewage sludge is not possible due to insufficient dry matter. Heating value of sewage sludge depends on the water content and according to the various authors it varies over a wide range: 2-12 MJ.kg^{-1} (Roubíček et al. 2003), 7-10 MJ.kg^{-1} (Milčák 2003), 8-10 MJ.kg^{-1} (Demko 2003).

Technically there are two models of combustion of sewage sludge - combustion of dried sludge and wet sludge combustion with other fuels. Both methods are equivalent from the thermodynamic point of view in respect to the final energy balance. The combustion of sewage sludge comes with a negative energy balance in the most of cases. The advantage of sewage sludge combustion is considerable reduction in their volume and weight comparing to the original amount.

Actually the combustion of sewage sludge is considered as modern method of waste disposal. This method of sewage sludge disposal also includes numerous environmental risks in relation to air (CO, PAH, PCDD / F) and the disposal of solid of wastes.

Tab. 2 Combustion heat and ash content in samples of the industrial wastes and wastes from agriculture

Sample	**Moisture** [%]	**Combustion heat** [MJ.kg^{-1}]	**Ash** [%]
Paper sludge – SHP *	0	7.520	49.4
Paper sludge – METSÄ *	0	7.861	41.9
Pulp and paper sludge – MONDI *	0	5.732	51.8
Sludge from the production of plywood **	7.84	19.810	5.1
Waste fibres from the manufacture of fibre board *	0	20.328	0.8
Beech veneer	0	19.362	0.1
Beech plywood	0	19.097	0.2
Poplar veneer	0	19.503	0.1
Climatizer plus ***	0	13.130	21.8
Wood waste	0	17.736	3.2
	9.5	16.201	3.3
Pelets – from sewage sludge (1) ****	0	11.614	38.8
	7.2	11.363	37.8
Pelets A (spruce sawdust) (2) ****	0	19.837	0.2
	7.8	18.965	0.3
Pelets B (spruce sawdust and bark 1:2) ****	0	19.474	1.2
	6.4	19.087	1.4
Pelets C (spruce sawdust and bark 1:4) ****	0	19.179	2.9
	6.2	18.680	2.5
Hemp hurds	6.8	18.052	0.4
Rice hulls	0	17.132	14.2
	7.0	15.895	13.1
Rice hulls (charcoal)	0	22.107	28.5
Wheat straw ****	0	18.133	2.6
	9.0	16.670	2.7
Rape seed straw *****	7.2	16.800	6.2

Note: * (Geffertová, Geffert 2011a)
** (Víglaský, Geffertová, Geffert 2007)
*** (Geffert, Mojžišková 2009)
**** (Geffert, Geffertová 2007)
***** (Geffert, Geffertová 2008)

Pulp and paper sludge even dried have a relatively low combustion heat value (5.7 to 7.8MJ.kg^{-1}) due to the high percentage of ash (from 51.8 to 41.9%), which consists mainly of fillers, inks and others.

Similarly, the sample of Climatizer plus contains the residues of printing dyes and fillers, as it represents the waste-based on recycled secondary papermaking fibres.

In contrast, the waste from the manufacture of fiber board and plywood due to the low ash content and in the case of low humidity represents an interesting energetically utilizable fuel.

Ash and moisture constitute ballast - an undesirable proportion of fuel if increasing it decreases combustion heat.

Energy utilization of paper based wastes, mainly hardly recyclable; it may be a good alternative in case of surpluses of waste paper.

Tab. 3 Combustion heat and ash content in the paper wastes and energy plants

Sample	**Moisture** [%]	**Combustion heat** [MJ.kg^{-1}]	**Ash** [%]
Sekundary fibres of waste paper	0	17.077	5.9
Wrappers from 5-layer corrugated cardboard	0	17.061	6.2
Wrappers from 3-layer corrugated cardboard	0	17.425	4.4
Cardboard boxes with paint and printing	0	14.385	18.4
Coated paper with printing	0	14.186	21.1
Paper with printing	0	16.210	11.6
Tetra packaging with Al and PE-foil	0	22.330	13.4
Tetra packaging without internal foil	0	17.743	9.7
Sack paper	0	17.518	1.0
Willow (*Salix viminalis*) clone ULV - wood *	0	19.521	0.2
Willow (*Salix viminalis*) clone ULV - bark	0	19.390	2.8
Willow (*Salix viminalis*) clone RAPP - wood **	0	19.510	0.2
Willow (*Salix viminalis*) clone RAPP - bark	0	19.289	3.3
Poplar (*Populus x euroamericana)* – clone Koltay - chip ***	0	16.861	3.4
Amaranth (*Amaranthus*) ****	0	16.383	3.7
Couch grass (*Elytrigia repens*)	4.6	17.024	4.0

Note: * (Geffertová, Geffert 2011b)
** (Geffertová, Geffert 2010)
*** (Dzurenda, Bartko, Ridzik 2012)
**** (Geffert, Geffertová 2007)

Hardly recyclable waste papers are tetra packaging. The base layer of such containers consists of 75-80% of the wood-free cardboard from long-fibre kraft pulp of basis weight 200g/m^2. Beverage cartons are heat-treated by several thin layers of polyethylene (0.05mm), which closes the surface sufficiently, ensures weldability and impermeability to liquids or bulk content and protects the content against moisture and microorganisms. The next layer is an aluminum foil (0.0065mm) and represents an effective oxygen barrier. Direct contact of aluminum with food is prevented by deposited layer of polyethylene.

The combustion heat of tetra packaging without internal foil was 17.7MJ.kg^{-1} and without removing the foil was increased up to 22.3MJ.kg^{-1} (mainly due to the PE-foil) with the increase of ash content of 10.0 to 13.4% due to aluminum content.

The values of combustion heat of cardboard packaging, secondary fibres and sack papers ranged from 17.0 to 17.5MJ.kg^{-1} for the ash content of 1.0 to 6.2%. Contrary the combustion heat value of coated papers or papers with printing under the influence of surface coatings and inks decreased due to increased ash content.

Tab. 4 Combustion heat and ash content in samples of the combined wastes

Sample	**Moisture** [%]	**Combusting heat** [MJ.kg^{-1}]	**Ash** [%]
Pelets - mixture 1 and 2 in proportion 1:1 *	7.5	15.179	18.8
Paper sludge + spruce sawdust (1:1)	0	11.880	19.8
Paper sludge + spruce sawdust (1:2)	0	14.361	13.1

Note: * (Geffert, Geffertová 2007)

CONCLUSION

Despite prejudices and barriers that in the energy recovery of waste in reigning in Slovakia, common energy recovery of wastes (e.g. municipal waste and waste biomass) is realistic way of resolving this issue, as it is possible to achieve the following benefits:

- saving of primary energy sources
- elimination of mixed household waste from landfill
- removing "residual" municipal waste
- minimizing the volume of the ultimate destruction
- achieving the perfect hygienisation of wastes
- detoxication of organic pollutants (Jandačka et al. 2014).

The presented results showed that a common energy recovery of selected waste types represents energy production and additionally it has also significant environmental and economic dimension (reducing the amount of waste deposited to landfill, thus saving of substantial funds). Another significant benefit appears to be an increase of employment in this segment - development and production of satisfactory combustion plants, operation of such facilities including related service activities. "Green economy" should not remain an unfulfilled term even in Slovakia.

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