Finding sound bio-waste treatment solutions in the Baltic states

Ruta Bendere[1], Inara Teibe[2], Dace Arina[3],

[1]Waste Management Association of Latvia, Riga, LV-1006, Latvia
[2] University of Latvia, Riga, LV-1010, Latvia
[3]Latvian University of Agriculture, Jelgava, LV-3001, Latvia

Presenting author's email: bendere@edi.lv

Abstract

The article focuses on ways to implement the requirements laid out in the European Union (EU) Landfill Directive 1999/31/EC in the Baltic states in order to reduce the amount of bio-waste disposal at landfills. It reflects the main bio-waste treatment possibilities that exist in this region taking into account the environmental impact related to waste recycling, pre-treatment, bio-treatment and disposal. The article focuses on municipal waste as it is one of the main problems for the Baltic states, which are to treat ~50% from their produced municipal waste until 2020. To devise the best solutions for each country, mathematical software is used as a modelling tool of waste management scenarios, taking into account the local plans and discrepancies in the waste content and quantity. In order to minimise the direct disposal of biodegradable organic mass on landfills, five waste management scenarios are analysed in this paper, which involve different technologies of waste treatment, regeneration and disposal. The obtained results are indicative and show only the trend of waste management development in each of the Baltic states.

Keywords: bio-waste, Baltic states, waste management, treatment, Life Cycle Assessment

Introduction

Solid waste landfills are the most important producer of greenhouse gases. In Latvia it was chosen as a low-cost option for final solid waste treatment compared to waste incineration (Boer, et al., 2005). It also allows for disposal of any kind of waste (Mc Dougall, et al., 2003; Tchobanoglous, et al., 1993). This approach allows for transition from a decentralised waste disposal system at more than 500 dumpsites to another – centralised waste management system with 11 regional sanitary landfills. To reduce greenhouse gas production associated with waste decomposition, the Landfill Directive 1999/31/EC lays down specific targets for decreasing biodegradable municipal waste disposal. The targets set for the EU member states, including the Baltic states that have been granted a 4-year derogation due to relatively low maintenance of waste in the baseline year of 1995 (i.e., > 80 % landfill rate in 1995), are as follows: with 1995 as the reference year (100 % by weight), biodegradable municipal waste disposal at landfills must be reduced to 75 % in 2010; 50 % in 2013, and to 35 % in 2020. It is obvious that such reductions are hard to achieve if relying solely on a separate collection of bio-waste at source and its treatment applying aerobic or anaerobic methods only.

Despite all three countries of Estonia, Lithuania and Latvia being small (the population of Lithuania is 2,986 million, Latvia – 2,025 million, and Estonia – 1,229 million) and located in the same geographical area with a rather similar economic and historical background, the ways how they are achieving the EU targets in waste management are slightly different.

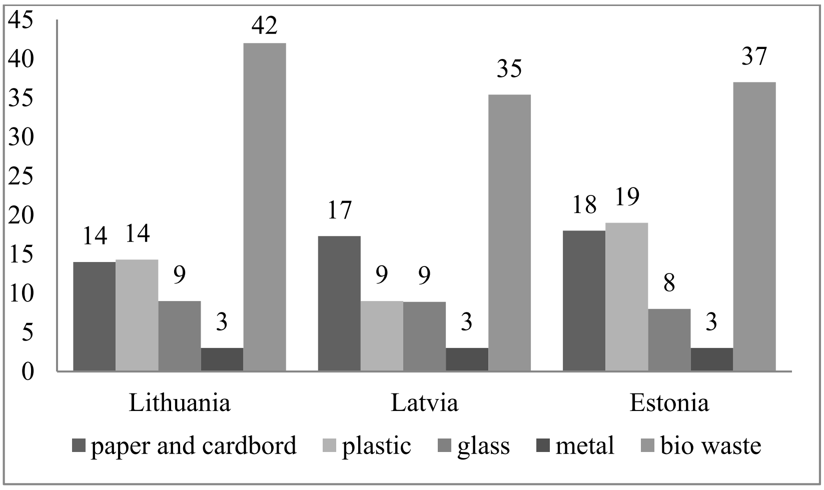

Fig. 1: Municipal waste content in the Baltic states (% by weight in 2010)

The statistical data (see Fig. 1) show that the content of biodegradable waste in municipal waste in the Baltic states reaches over 35 %, most of which is landfilled as mixed waste (see Fig. 2) and only a small part is separated at source and composted (Eurostat, 2013).

The amount of collected municipal waste for each capital per year is 261 kg in Estonia, 304 kg in Latvia and 348 kg in Lithuania (see Fig. 2). In this paper, the amounts of municipal waste are presented in thousand tons to estimate the environmental impact of waste treatment: 1,044 – in Lithuania, 609 – in Latvia and 404 – in Estonia, depending on the number of inhabitants in each country mentioned above. Waste treatment in these countries in 2010 and 2012 is reflected in Table 1 (Eurostat, 2014).

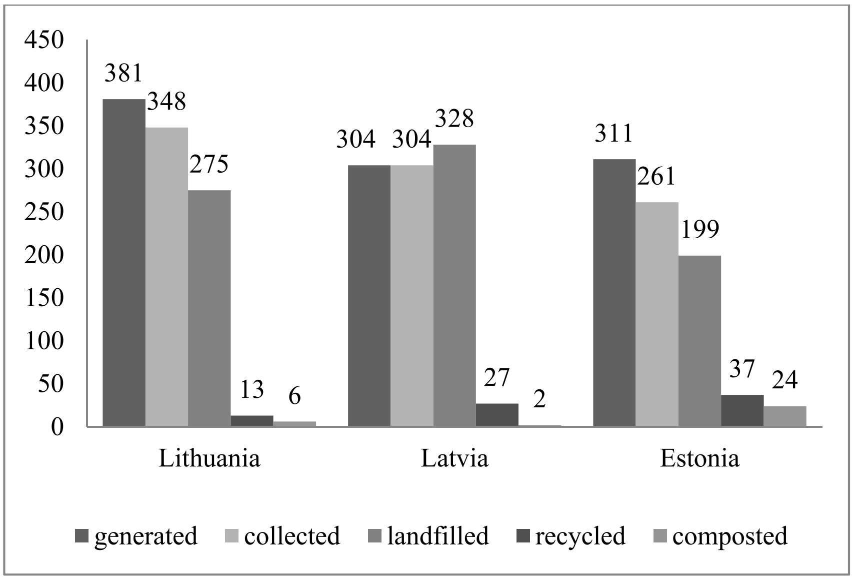

Fig. 2: Generation, collection, landfilling and recycling of municipal waste in the Baltic states (kg per capita in 2010)

Table 1: Waste treatment in the Baltic states in 2010 and 2012 (% from weight)

Country	Landfilled		Recycled		Composted		Incinerated	
	2010	2012	2010	2012	2010	2012	2010	2012
Lithuania	94%	79%	4%	19%	2%	2%	-	1%
Estonia	76%	44%	14%	34%	9%	6%	-	16%
Latvia	90%	84%	9%	14%	1%	2%	-	-

As there are problems with the energy supply and independence in the Baltic states (Latvia and Lithuania lack oil and gas but the oil shale in Estonia contains only 25 % of organic matter), the main treatment method planned for bio waste is the use of organic waste as an energy resource. Estonia has built a new power station in Tallinn with the planned incineration amount of more than 450,000 tons of waste per year. Lithuania is also constructing a new power station in Klaipeda. The fuel to be used is industrial and municipal waste with the energy production of 60 MW heat and 20 MW of electricity per year. Latvia is planning to use organic waste as refuse-derived fuel (RDF) material for Broceni Cement Kiln (250,000 tons per year). At the same time, part of organic bio-waste will be composted and used for biogas production. To devise the best solutions for each country, mathematical software and modelling of the waste management system is used taking into account the local plans and discrepancies in the waste content and quantity.

Materials and methods

Development assessment tool for municipal waste management

The application of the Life Cycle Assessment (LCA) approach in waste management provides outcomes that focus on the comparison of different waste management options and the emissions produced. As Verghese points out, LCA leads to an improved understanding of the environmental ‘bottom line’ of different waste strategies. It is an analytical framework for better understanding material and energy inputs, and environmental impacts associated with the manufacturing, use and disposal of evaluated material. Each waste material has a different greenhouse gases (GHG) impact depending on how it will be treated or disposed at the end of its useful life (Verghese, 2009; Barton, et al., 1996).

The Waste Management Planning System (WAMPS) software has been used as the environmental impact analysis tool for modelling waste management scenarios. The WAMPS is based on the LCA approach, and this tool has been developed by the Swedish Environmental Research Institute as part of the Reco Baltic 21 Tech project activities, and it is a renewed version of the WAMPS Microsoft Excel interface created in 2007.

The new version of WAMPS (see Fig. 3) offers the user to create more scenarios for waste management development, as it has been improved with a mechanical pre-treatment process, where new fractions – metal, fine and RDF – are produced. The new waste material technology – incineration in a cement kiln – is also one of the solutions how to use waste as burning material and replace the fossil resources.

The WAMPS software calculates emissions, energy and turnover of waste streams for processes within the waste management system, e.g., waste collection and transportation, composting, anaerobic digestion, and final disposal – landfilling or incineration (IVL, 2013).

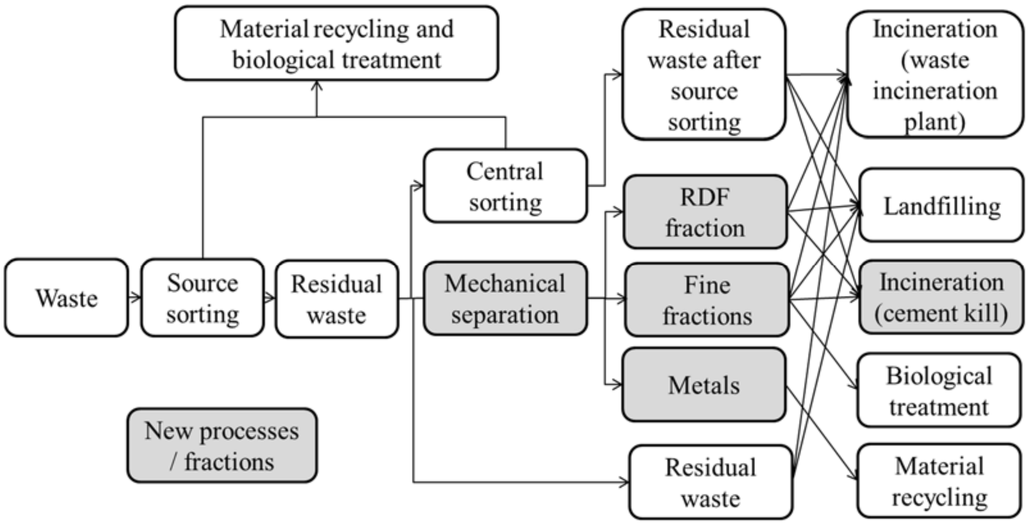

Fig. 3: Overview of WAMPS modelling possibilities

For modelling purposes, the data input is available in five consecutive steps:

1. Detection of waste composition (input data for 24 waste fractions and amounts);
2. Selection of waste sorting activities (recycled waste material from each waste fraction at source);
3. Selection of waste treatment and disposal methods (composting, anaerobic digestion, incineration, combustion, landfilling);
4. Local waste collection where the environmental performance related to waste collection is represented;
5. Waste transportation for long distances (specifies parameters affecting the environmental performance for long distance transportation).

The WAMPS software provides a relatively simple approach to estimate the environmental performance of every waste management scenario. The results are presented in four environmental impact categories: acidification, global warming, eutrophication and photo-oxidant formation, which are characterised by a certain emission. It covers an integrated waste management system starting with the activities where products become waste and have been put into the waste bin at waste generation source to the last point, where the waste becomes either useful material (recycled material, biogas or compost) or becomes part of emissions in the environment after its final disposal at a landfill or incineration plant.

Waste management development scenarios in the Baltic states

Since climate change mitigation (EPA, 2006; ETC/RWM, 2008) is also one of the main priorities in the Latvian sustainable development strategy and in the Baltic states in general – especially as concerns waste management – the estimation of the research results will only be related to the CO_2 emission for further discussion.

The detected environmental impacts of the waste management methods used in the Baltic states have been estimated with the WAMPS software according to the data of each country in 2010 and 2012 (Eurostat, 2013; Eurostat, 2014), as well as appropriate waste management scenarios for each country (see Fig. 1, Fig. 2 and Table 1). For the elaboration of a forecast for the next eight-year period, the experimental data of the waste content and parameters are used for each type of waste detected in case studies carried out in different regions in Latvia. Based on the case study results, the best scenarios are elaborated for waste management development in Latvia and recommendations are given for the neighbouring countries.

Case study territory

In order to find the optimum bio-waste treatment solution for the Baltic states and taking into account the insufficient data available on the content of municipal waste in Lithuania and Estonia, data were gathered from five municipalities in Latvia (Ikskile, Lielvarde, Baldone, Kegums and Ogre) that were chosen for the case study area. The total area of this territory comprises 2,021 km^2 and the total number of inhabitants is 71,483 (see Table 2). The territory is typical for the Baltic region with 26,549 inhabitants in its largest town of Ogre and its smallest towns of Baldone and Kegums with 2,363 and 2,485 inhabitants, respectively. Around 41 % of the total population live in villages and rural areas. The average density of population varies from 12.8 (Kegums) to 67 (Ikskile) capita per km^2. The average municipal waste amount varies from 130 kg per capita per year in Baldone to 219 kg per capita per year in Ikskile.

Table 2: Characterization of case study municipalities

Municipality	Number of inhabitants		Total inhabitants	Area, km^2	Average density, capita / km^2
	City	Rural area			
Ikskile	4 022	4 825	8 847	132,1	67,0
Lielvarde	6 688	4 712	11 400	225,7	50,5
Baldone	2 362	3 362	5 724	179,1	32,0
Kegums	2 485	3 794	6 279	492,2	12,8
Ogre	26 549	12 684	39 233	992,35	39,5
Total	42 106	29 377	71 483	2021,45	12,8-67,0

Table 3: Produced / collected municipal waste amount (total and per capita)

Municipality	Produced / collected municipal waste, tons	Number of inhabitants, capita	Produced / collected waste amount, kg/ year/ capita	Average waste produced amount, kg / year / capita	
				City	Civil parish (pagasts?)
Ikskile	1 936	8 847	219	191-222	131-140, up to 277 rural detached houses
Lielvarde	2 369	11 400	208		
Baldone	742	5 724	130		
Kegums	1 001	6 279	159		
Ogre	7 172	38 354	187		
Total	13 385	71 483	130-219		

Table 4: Breakdown of municipal waste producers by source (% of total)

Municipality	Institutional	Small commercial	Households in apartment houses	Households in private houses and detached houses
Ikskile	10%	19%	26%	44%
Lielvarde	9%	4%	46%	41%
Baldone	23%	13%	32%	31%
Kegums	5%		95%	
Ogre	22%		71%	7%

The main waste generation sources in this area are households: Ikskile – 70 %, Baldone – 63 %, Lielvarde – 87 %, Kegums – 95 % and Ogre – 77 % of all municipal waste comes from inhabitants (see Table 4).

Composition of municipal waste

In this case study, waste composition was assessed for four loads of municipal waste of Ogre municipality from four different waste producer sources. It was measured at a total of 28 tonnes of waste with the waste composition characteristic of the summer season (see Table 5):

1) 13,94 tons of waste from institutions and small enterprises;

2) 5,46 tons of waste from multi-storey buildings in the city;

3) 5,06 tons of waste from private houses in the city;

4) 4,24 tons of waste from detached houses in the rural area.

Table 5: Municipal waste composition (data from Ogre municipality)

Waste fraction	Institutions and small enterprises	Multi-storey buildings in the city	Private houses in the city	Detached houses in the rural area
Paper packaging	14%	5%	4%	2%
Paper and cardboards (unspecified)	18%	5%	7%	6%
Plastic packaging (hard)	12%	15%	9%	7%
Plastic packaging (soft)	9%	11%	10%	9%
Metal packaging (aluminium)	0%	2%	2%	3%
Metal packaging (steel)	1%	0%	0%	0%
Glass packaging	2%	6%	7%	12%
Total packaging	56%	44%	39%	39%
Newspaper, magazines ect.	7%	3%	3%	3%
Plastic (unspecified)	6%	2%	2%	2%
Rubber, incl. tyres	0%	0%	0%	2%
Clothes, shoes, textiles and leather	0%	0%	0%	1%
Wood	7%	0%	0%	1%
Other recycled or combustible	20%	5%	5%	9%
Biodegradable material (mixed	7%	13%	1%	22%
Organic degradable kitchen waste	10%	29%	19%	15%
Garden Waste	0%	0%	20%	2%
Total kitchen and garden waste	17%	42%	40%	39%
Hazardous waste (unspecified)	1%	1%	0%	0%
Hazardous batteries (Cd, Hg, Pb)	0%	1%	0%	0%
Car batteries (accumulators)	0%	0%	0%	0%
Electric and electronic wastes (WEEE)	0%	0%	3%	1%
Total hazardous waste	1%	2%	3%	1%
Inert wastes	3%	5%	4%	5%
Non-hazardous batteries	0%	0%	5%	2%
Steel and metal scrap (mixed)	0%	0%	0%	0%
Glass (mixed)	2%	2%	1%	4%
Total inert waste	5%	7%	10%	11%
Others	1%	0%	3%	1%
Total	100%	100%	100%	100%

Waste management modelling by WAMPS

The results obtained characterise the consequences of waste management performance such as climate change, acidification, eutrophication, and formation of chemical photo-oxidants. In the development of the WAMPS software, a number of limitations have been acknowledged:

1) there is no certain measurement of the amount and composition of produced municipal waste, and waste sorting at source is also very weak, it is therefore assumed that the amount of collected waste also reflects the amount of waste produced by each municipality;

2) all the data about the amount of municipal waste is taken from the volume mentioned in the agreements signed between the end-user and waste operators and not weighed practically by collected tons;

3) incomplete data about waste producers in two municipalities – Ogre and Kegums (see Table 4);

4) the data for research has been given by municipalities and not by waste operators, and no data is available about the waste operator with the smallest market share in this territory (see Table 3);

5) waste composition is measured only in Ogre municipality (see Table 5) and it is accepted that the municipal waste composition is the same in all the five municipalities;

6) in this case study, waste collection and transportation is not taken into account.

Step 1 – Composition of waste

In Step 1, the composition of waste was evaluated for each of the waste generation sources (institutions and small enterprises, multi-storey buildings, private houses in the city, detached houses in the rural area). Waste fractions and amounts are defined in tons and/or in percentage. For the calculations, the average municipal waste composition is based on the measurements provided in Ogre municipality that are used for the modelling purpose.

As shown in Table 5, the amount of waste material that can be used for recycling varies from 39 % of the total amount in household waste bins to 56 % in institutional shop and commercial containers. A rather significant amount of the total waste is kitchen and garden waste – 39 % to 42 % in households and twice less – 17 % from institutional and commercial sources. It means that in the total municipal waste composition at least 84 % to 93 %, depending on the waste generation source, should be recycled, recovered or composted.

Step 2 – Source sorting, centralised and mechanical sorting

In Step 2, the values of waste fractions to be sorted at sources are defined and the extent and types of waste materials that can be recycled and/or treated biologically are determined. For source sorting, the degree of sorting for each waste fraction is entered (between 0 to 100 %). In connection with the next steps of modelling, it also defines how much waste will be taken for centralised sorting (manual or mechanical) and how much waste will not be sorted and will be sent for the final treatment as mixed waste (waste incineration in a waste incineration plant or landfilling).

The subsequent action – centralised sorting – determines how much of the mixed municipal waste enters the process of centralised sorting and is recycled (from 0 to 100 %). Two sorting types – manual sorting and mechanical sorting – are examined.

Step 3 – Waste treatment technologies and development scenarios

In order to estimate the best waste treatment scenarios from the environmental point of view, four waste management development scenarios are modelled, which are compared with the existing waste management situation in the selected territories.

The base scenario characterises the overall exciting situation in the study area. Scenario 1 characterises the main waste management requirements according to the procurement regulations: 1) the ratio of waste sorting at source – 25 % for waste materials such as paper, plastic, glass and metal packaging, and 5 % for kitchen and garden waste; 2) the condition for the manual centralised sorting system – 10 % sorting of all waste material, and technologies for future waste treatment. Scenarios 2 to 4 characterize future waste development scenarios with the same source sorting conditions but using mechanical sorting and additional waste treatment technologies. The waste treatment technologies are described in detail below (see Table 6) and in earlier research (Teibe, 2013).

Table 6: Scenarios for the best waste treatment options

Scenario	Source sorting (recycling material + compost material)	Central manual sorting	Mechanical sorting	Composting	Anaerobic digestion	Landfilling	Landfilling with bio-cell	Incineration in cement kiln	Incineration
Base	4%	Yes	No	No	No	Yes	No	No	No
Scenario 1	25 % +5%	Yes	No	No	No	Yes	No	No	No
Scenario 2	25 %+ 5%	No	Yes	Yes	No	Yes	No	Yes	No
Scenario 3	25 % +5%	No	Yes	Yes	No	Yes	Yes	Yes	No
Scenario 4	25 % +25%	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Base scenario: intensive disposal of non-sorted waste with energy gain.

The base scenario describes the overall situation with waste management in the five case study municipalities in 2012 according to data provided by the state statistics local waste operators and municipalities. In 2012, 88 % of unsorted municipal waste was disposed at the Getlini landfill with collection and regeneration of gases produced there. 9 % of the waste material was sorted manually in the sorting centre and recycled. Only 3 % of recyclable material was sorted out at waste generation source. The fine fraction separated on the sorting line was composted and used as a cover material on the dumpsite nearby. The estimation of disposal technologies includes: the energy turnover; the intensity of gas production and the efficiency of its regeneration; and the emissions into the air and water. The calculated efficiency of landfill gas regeneration is 26–34 % (Arina, et al., 2012) (in the present research, 35 % is assumed).

Scenario 1: medium source sorting scenarios, centralised manual sorting and waste disposal with energy gain.

The output data of this scenario are identical to those of the base scenario, but with a higher sorting rate at the waste generation sources and sorting centre. The source sorting activity is 25 % for paper, plastic, glass and metal packaging and 5 % for bio-waste sorting. Treatment of the sorted biodegradable waste is performed at households (50 %) by using open-field technologies (50 %), with account in this stage of the energy consumption for operation of transport and equipment. The calculations include emissions into the air and water as well as the saved emissions caused by the use of nitrogen and phosphate fertilizers. It is estimated that the obtained amount of compost will be 60 % of the original organic waste mass (LASA, 2005). The sorting station gives additional 10 % of recycled paper, plastic, glass, 30 % of metal and hazardous waste and 35 % of fine fraction, which is composted and used as a cover material. The rest of residuals are landfilled.

Scenario 2–4: medium source sorting scenarios, mechanical sorting, incineration and waste disposal with energy gain.

The models are based on the assumption that at the waste generation source, 25 % from paper and cardboard, glass, plastics, and metal are sorted. Whereas only 5 % of garden and kitchen waste is segregated at source (Scenarios 2 and 3); in Scenario 4, it is 25 %. It is assumed that from the total separated amount of biodegradable waste, 50 % are composted at households, but

50 % of garden and park waste is composted by open-field technology (Scenarios 2 and 3). Whereas in Scenario 4, the anaerobic digestion technology is used for 25 % of sorted biodegradable waste. In this scenario, the sorted bio-waste is divided as follows: 70 % for composting (30 % home composting, 30 % open windrow composting and 40 % reactor composting) and 30 % for anaerobic digestion, where the gas use is 40 % for electricity and 50 % for district heating.

The remaining bio-organic mass that reaches landfill as mixed waste is sorted on a pre-treatment mechanical sorting line. The quality of fine fraction stabilisation is estimated for three technologies: composting (Scenario 2), biocell (Scenario 3), and digestion (Scenario 4). As the derived waste material contains many admixtures (glass, minerals, plastics, etc.), after stabilisation it is used for covering the waste disposed at landfills. The fine fraction is disposed using biocells with an everyday coverage of waste and additional moistening of waste, which accelerates the processes of bio-organic waste decomposition and makes the gas collection more effective than in a traditional cell – from 50 to 70 % (Sonesson, et al., 1997). In the present research, gas collection effectiveness is chosen to be at 60 %.

The environmental impact of the incineration process is estimated by four scenarios, but due to high humidity in the material only 10 % of coarse fraction is incinerated at the cement kiln (Scenarios 1–3). After diverting biodegradable waste from the total mixed waste stream, the quality of the RDF material will be improved and it creates the possibility for 50 % of the RDF material to be incinerated at the plant and 50 % – in the cement kiln (Scenario 4). The derived energy is used for electricity and heat production, and the type of replaced energy in this research is determined as natural gas (similar to gas production and/or gas regeneration at landfill). To facilitate comparison of the results on the environmental impact using different technologies for processing the fine fractions, it is assumed that the remaining waste (medium and coarse fractions) in all the models is disposed with the production of gases (landfilled or incinerated at a cement kiln), while the metallic fraction is processed.

The incineration proceeds in specially built incinerators and gives additional energy, but the emissions into the air and water are also taken into account. Apart from that, the impact caused by ashes and slag (to be disposed at landfills) is calculated. Such an incineration process complies with the requirements set by the EU directive 2000/76/EC.

Incineration at a cement kiln also requires energy and produces emissions; however, the use of refuse-derived fuel in this method implies a reduced amount of fossil fuel; gypsum is not required for clinker production; and the output of iron oxides (metallurgical slag) is also smaller.

The calculations were performed for emissions arising from waste incineration, in the waste management processes in the air and water, and from the consumption of diesel fuel for waste transportation within the landfill territory. Besides, digestion-related emissions are included as well as the savings of summary emissions due to the use of nitrogen and phosphate fertilizers. Currently, it is assumed that in Latvia the biogases obtained will be used for electricity production; however, these can be used for other purposes – e.g., to produce biogas fuel for transport.

Results and discussion

Manual sorting

In this study, the practical statistical results from the local waste operator – the waste fractions and amount of each fraction being recycled at a recycling factory in Ogre municipality – are entered only for the base scenario.

It appears that from the total unsorted waste stream only 5 % of paper and cardboard are separated on the sorting line; 1 % of glass; 1 % of plastic; 3 % of metals and 0.10 % of hazardous waste. Moreover, in the waste sorting process around 35 % of fine fraction (Table 7) is separated out, composted and used as a cover material for the old dumpsite, which is located near the recycling factory. It agrees with Williams (Williams, 2005) that in the pre-treatment process, it is possible to separate only 10-15 % of the waste material from an unsorted waste stream. The main types of such material are metal, HDPE, PET, unspecified plastic, aluminium, paper and cardboard. The rest of this material could be composted, incinerated, or stabilized in bio-cells, for biogas production, whereas the mineralized mass can be used as cover material in the landfill.

Mechanical sorting

The mechanical separation process of waste – which is a new process in the WAMPS – concerns waste refinery from mixed residual waste with the main aim to produce feedstock or RDF. The three output fractions from the process are: RDF fraction, a fine fraction and a fraction consisting of steel and metal scrap.

The WAMPS system provides the default values on how the waste fractions enter the mechanical sorting facility and are distributed between the three output fractions. However, these default values have been improved and compared with the actual waste composition measurement results on the sorting line.

The experiments carried out with different sieves with meshes of 300 mm, 150 mm, 70 mm for mixed municipal waste show that each fraction contains a lot of bio-mass, and paper and plastic dominates in the first tree fractions (see Fig. 4).

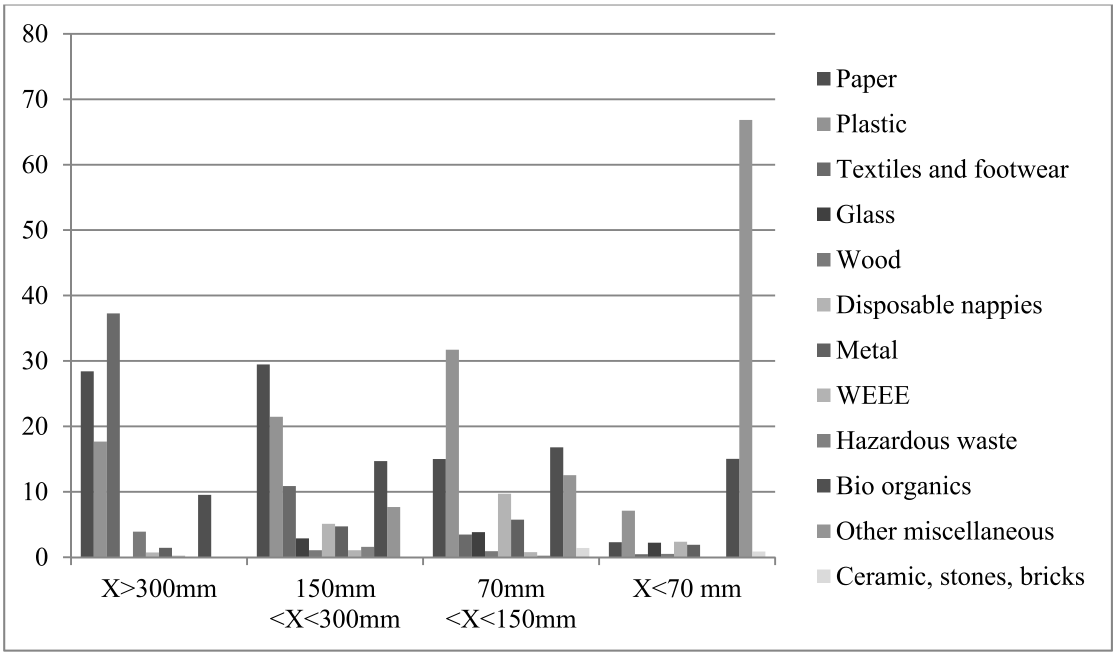

Fig. 4: Content of municipal waste fractions sorted by sieves with meshes 300 mm, 150 mm, 70 mm

A similar distribution is detected by experiments provided with a horizontal disk sorting line (Table 7) dividing the total stream in coarse (X>60-80 mm), medium (10-25<X<60-80 mm) and fine (X<10-25 mm) fractions (Kalnacs, et al., 2013).

Table 7: Average composition of mechanically sorted municipal solid waste fractions (%, for dry waste)

Waste type	Coarse fraction,%	Medium fraction, %	Fine fraction, %
Paper/cardboard	39,5	23,9	2,4
Plastic	38,7	24,5	2,1
Putrescible green waste	0,7	6,6	12,3
Small particles (<10mm)	3,2	6,3	43,7
Hygiene (diapers, pads)	5,1	7,1	0,7
Textile	5,5	4,0	0,1
Rubber/ leather	4,1	3,4	0,1
Wood	1,1	3,6	0,5
Metal	1,5	3,5	0,5
Glass	0,2	9,1	32,1
Inert minerals, ceramics	0,4	8,0	5,5

As shown in Table 7, if source sorting of waste such as paper, plastics, glass, metallic packages and bio-waste reaches 12 %, it is possible to derive – at a landfill equipped with such a sorting line – four fractions from the total unsorted household waste mass, i.e.:

~35 % – fine fraction mainly composed of organic waste;

~40 % – medium fraction of diversified waste;

~22 % – coarse fraction (RDF) containing waste of high calorific value (plastics, paper, textile, rubber);

~3 % – iron-containing.

This percentage was used in calculations of mathematical waste management scenarios. The results of mechanical sorting of mixed waste show that the coarse fraction mostly complies with the standard of RDF material of the local cement kiln. However, the content of moisture in all fractions is too high for RDF (see Table 8) production. Therefore, the drying of material is necessary, but it is too energy-consuming and the prepared material becomes cost-ineffective. The separation of kitchen and garden waste at source must be a high-priority issue in municipal waste management.

Table 8: Average characteristics of waste fractions

Size of fraction	Contents of moisture (%)	Heating value (lowest)	Content of ashes (%)	Content of S (%)	Content of Cl (%)
Coarse (X>60-80 mm)					
Summer	43	13	17	0.2	1.1
Autumn	36	13	19	0.2	2.2
Winter	36	20	8	0.1	0.2
Spring	24	14	9	0.3	0.3
Medium(10-25<X<60-80mm)					
Summer	49	11	15	0.3	4.1
Autumn	48	8	32	0.2	0.7
Winter	43	11	33	0.3	1.7
Spring	30	15	12	0.9	0.5
Fine (X<10-25 mm)					
Summer	49	7	46	0.2	2.0
Autumn	44	3	63	0.2	0.2
Winter	49	5	65	0.2	0.3
Spring	26	7	79	0.2	0.1
Requirements for RDF material of the local cement kiln					
50 x 50 x 5 mm	<25 %	16 MJ/kg ±1	<15%	<1%	<0,8%

Environmental impact assessment

The assessment of the environmental impact for the four modelled scenarios of waste management development in Ogre, Ikskile, Lielvarde, Ķegums and Baldone municipalities selected as case study areas are presented in Figure 5 and Table 9.

The analysis of emissions arising in the waste management processes (expressed in equivalents, see Fig. 5) shows that CO_2 emissions mostly arise due to waste disposal at landfills. A comparatively smaller amount of carbon dioxide arises in the composting process or from the waste material processing industry. Following the best waste management scenario for the five selected municipalities (see Table 9) from the environmental point of view, methane gas (CH_4) emission could be reduced from 798,00 tonnes (base scenario) to 107,70 tonnes (Scenario 4).

An unresolved issue is the involvement in bio-waste management of multi-storey buildings. As shown by the results of pilot projects carried out in Latvia, around 30 % of citizens are ready to participate in kitchen waste sorting (LASA, 2005), which means that around 30 % of the bio waste produced by the country can be collected separately and treated by common biotechnologies.

The rest – around 70 % of bio-waste – has to be collected as mixed waste. In order to divert bio-waste from landfills, countries such as Estonia and Lithuania are planning to incinerate this waste together with other burnable waste materials in the new power plants. In Latvia, organic waste is planned to be treated as RDF material and used in a cement plant.

The findings from experiments carried out on automatic separation lines (Arina, et al., 2012) show that the smallest fraction of bio-waste (60–70 %) contains significant admixtures such as glass, stones and other inert waste. Various experiments using such material for anaerobic processes or aerobic composting are carried out in many countries. The low-quality mineralized material resulting from these technological processes can only be used as covering material for disposed waste. The mechanical-biological treatment method and production of good-quality RDF material from this mixed material is another practical decision for waste management. Nevertheless, there is yet another new attractive technology, i.e. sorting out inert material from the biomass by using new spectral sorting automatic equipment.

As the results show, waste material (paper, plastic, glass and metal packaging) sorting at source from 4 % to 25 % already provides an improvement in the waste management performance from 1,47 tonnes CO_2 eq. per one treated waste tonne (base scenario) to 1,02 tonnes of CO_2 eq. per one treated waste tonne (Scenario 2).

However, centralised manual sorting is less effective than the mechanical treatment technology, which allows for a reduction of emissions from 0,65 (Scenario 2) to 0,24 (Scenario 4) tonnes CO2 eq. per one treated waste tonne and production of RDF material. The results also show that bio-waste sorting at source should be considered a high priority, as it allows for a significant reduction of the environmental impact from waste treatment (Scenario 4), and it also provides for additional use of different technologies for waste recovering. An environmentally friendly approach is ensured if after mechanical treatment the fine fraction is composted (Scenario 2), treated in the bio-cell (Scenario 3) or anaerobic digester (Scenario 4).

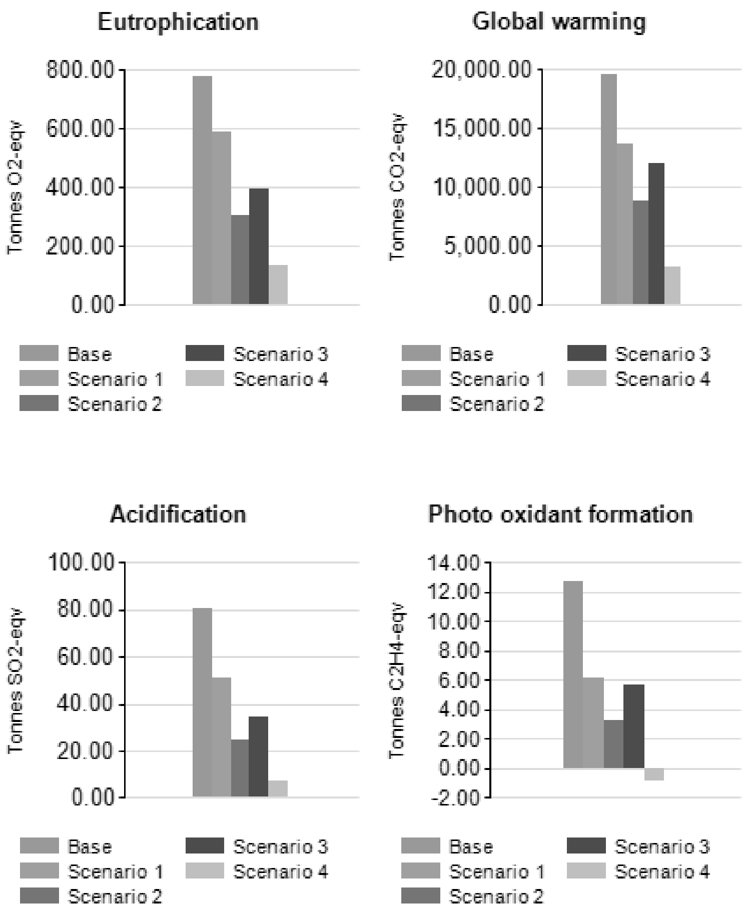

Fig. 5: Environmental impact assessment of waste management development

Table 9: Produced emissions of waste management development scenarios

	Base	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Particles to air (Tonnes)	-1,60	-3,69	-2,03	-2,82	-4,39
NO_X (Tonnes)	14,22	6,58	4,54	12,50	6,17
CH_4 (Tonnes)	798,01	606,49	373,50	515,97	107,70
CO (Tonnes)	4,45	-5,27	-4,19	-1,46	-5,29
SO_2 (Tonnes)	-0,93	-11,38	-7,04	-7,24	-8,30
NH_3 (air) (Tonnes)	3,31	3,65	2,70	0,43	1,31
HCl (Tonnes)	0,00	-0,02	-0,01	-0,01	0,02
CO_2 fossil (Tonnes)	-944,15	-2052,04	-880,41	-1408,44	214,75
N_2O (Tonnes)	1,97	1,76	0,97	1,67	1,17
NMVOC (Tonnes)	7,79	2,61	1,18	2,58	-1,38
P (water) (Tonnes)	0,08	0,07	0,03	0,05	0,04
N-tot (water) (Tonnes)	28,87	22,82	12,26	18,61	7,88
NH_3/NH_4 (water) (Tonnes)	34,69	27,03	12,43	17,15	4,56
COD (water) (Tonnes)	57,15	33,72	21,45	26,68	-1,71
BOD (water) (Tonnes)	15,38	12,33	8,79	8,16	1,40
Lead (water) (Tonnes)	0,00	0,00	0,00	-0,01	0,00
Cadmium (water) (Tonnes)	0,00	0,00	0,00	0,00	0,04
Mercury (water) (Tonnes)	0,00	-0,01	0,01	-0,01	0,07
Zink (water) (Tonnes)	-0,01	-0,01	0,00	-0,01	0,04

Environmental impact of waste management in the Baltic states

Based on the results of calculations of different scenarios for case study areas, the best model – Scenario 4 – was used for preparing the estimate for the Baltic states. The comparison of the data presented by Eurostat for the years 2010 and 2012 indicates that the waste management development in Estonia (see Table 10) shows a significant reduction and even a positive impact on the environment in 2012 due to the possibilities created to treat waste at the incineration plant.

Table 10: Environmental impact of waste management in the Baltic states

(tonnes CO_2 eq. per treated tonne)

Category	Estonia_2010	Estonia_2012	Latvia_2010	Latvia_2012	Latvia_2020_1	Latvia_2020_2	Lithuania_2010	Lithuania_2012
Tonnes CO_2-eqv/ per ton	0,72	-0,14	1,04	0,96	0,48	0,27	1,18	1,03

The development of waste management in Lithuania could also lead to such a reduction of CO_2 emissions when the incineration facility is launched in Klaipeda. For waste management in Latvia, there are two basic development ways: Latvia 2020_1 (as in Scenario 3 – fine fraction is mineralized in the bio-cell and the rest is landfilled) and Latvia 2020_2 (as in Scenario 4 – incineration at a cement kiln and landfill). The first option is to increase significantly waste material sorting at source up to 30 % for recycling and bio-waste for composting, and to treat the rest of bio-degradable waste in the form of fine fraction in the bio-cell at nearby landfills. The second option is similar to the first one, with an additional use of incineration technologies: high quality RDF material for a local cement kiln and mixed waste material for incineration plants in Lithuania and Estonia.

Conclusion

The LCA approach to the waste management development planning process applied in this research using the WAMPS software allows waste management decision-makers and planners to better understand and estimate the environmental impact of waste management development trends according to the chosen scenario.

As evidenced by the results obtained, the disposal of unsorted household waste at landfills creates the greatest environmental impact. Contrastingly, any of the other offered technologies makes it possible to avoid direct organic mass disposal at landfills and reduce GHG emissions substantially.

The development of bio-waste sorting at source allows not only to reduce the amount of disposed waste but also to decrease the moisture content of the unsorted waste mass. As a result, the scenarios should be preferred with an inclusion of waste incineration technologies.

The results of the evaluation of separate collection and treatment costs for bio-waste show that the treatment of such waste is more expensive than for other types of waste material. This is one of the reasons why waste collection companies today show a low interest in bio-waste collection and treatment. According to the law, the main organizers responsible for implementation of bio-waste management are local governments. Their activity is often related to the practical management of the final product of waste water treatment – sludge, garden and park waste from the surrounding territory. The data from monitoring programmes (IVL, 2013) reveal that around 20 % of private households compost their kitchen and garden waste and use compost as fertilizer for their gardens. Bio-waste from cemeteries, local parks and green areas is collected and composted by local government-owned companies.

Unfortunately, the local official statistics of the countries does not reflect such activities by local governments, as the data are collected mainly from waste management companies and the biggest waste producers – industry and commerce – that deal with biodegradable waste. For the elaboration of more exact forecasts of waste management development in the Baltic states by using a software tool, more precise data are required, e.g., waste producers, composition, and the applied waste treatment technologies. As the applied input data from Eurostat data bases are of insufficient quality for LCA and estimation of the environmental impact of waste management development scenarios, the obtained results are only indicative and show the trend of waste management development in each country.

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