Chapter

Life Cycle Inventory (LCI) Modeling of Municipal Solid Waste (MSW) Management Systems in Kosodrza, Community of Ostrów, Poland: A Case Study

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Abstract

The purpose of this study is to perform the life cycle assessment (LCA) limited to life cycle inventory (LCI) related to municipal solid waste operating in Kosodrza, community of Ostrów, in Poland. The current LCI is a representative for year 2015 by application of PN-EN ISO 14040. The system boundary was labeled as gate-to-gate. The data used in this study, involving consumption of energy and fuels, water, materials, and waste, is obtained from (i) site-specific measured or calculated data and (ii) secondary data taken from integrated permit issued by Marshal of the Podkarpackie region in Rzeszów for the establishment of municipal services in Ostrów by entering the records concerning the waste landfill in Kosodrza. This study is based on the deterministic approach to LCI. Hence, uncertainty analysis is not carried out. The LCI model can be used in full LCA study.

Keywords: Poland, life cycle inventory, life cycle assessment, municipal solid waste management, landfill

1. Introduction

The traditional consideration of waste as a pollution has progressively shifted toward a new perspective, in which waste is regarded as a resource that could support societies to become more sustainable [1].

LCA as a tool to analyze waste management systems appeared in the early 1990s.

A number of models for LCA of waste management have been developed, and some of these models are commercially available, while others are affordable only to researchers [2]. All models are developed within the framework of LCA of waste management, and most models also include some kind of economic accounting [2]. Moreover, in [2], a summary of key features of waste management LCA models is presented. Among them are:

- *Integrated waste management-2 (IWM-2)*, updated version of the IWM-1, released by Procter and Gamble in 1995. The IWM-2 and IWM-1 have been used in many case studies in Europe, North and South America and Australia.

- *IWM Canada* was developed in Canada in partnership between Environment Canada and two industry associations. The model is built on an Excel platform and runs with a Visual Basic interface. The model has been used by municipalities across Canada by more than 250 registered users in evaluating environmental and economic impacts of existing or planned waste management systems. In the City of London, the model has been used in the implementation of a continuous improvement system for waste management, and it is used by universities.

- *ORWARE* model (*or*ganic *wa*ste *re*search) was developed in collaboration with several Swedish research institutes and universities. ORWARE was first developed as a tool for systems analysis of organic waste management. ORWARE is implemented in Matlab and in Excel. Several projects have been commissioned by Swedish municipalities, and also it is used in education at universities.

- *Solid waste management (ISWM, MSW-DST)*. The MSW-DST was designed to explore and evaluate the environmental aspect and cost of integrated MSW strategies. The model has been applied in local and regional MSW planning and evaluation for cities, counties and states across the Unites States. This model has also been used by the US Navy to develop an improved waste management plan that meets environmental targets at reduced cost.

- *WISARD* was first developed in 1999 by Ecobilan on behalf of Eco-Emballages in France and the Environment Agency of England and Wales. WISARD has been used by more than 50 local authorities and others in the United Kingdom in the development of regional and MSW strategies, and it has also been used in the development of the Scottish National Waste Plan.

- *Municipal solid waste management system assessment tool LCA-IWM* is a result of a project funded by the European Fifth Framework Program and consists of decision support tools: the waste prognostic tool and the municipal solid waste management system (MSWMS) assessment tool. MSWMS has been applied in case studies of different cities in fast-growing regions in Europe; some examples are Xanthi (Greece), Kaunas (Lithuania), Wrocław (Poland), Nitra (Slovakia) and Reus (Spain).

- *Environmental assessment of solid waste systems and technologies (EASEWASTE)* was developed by researchers at the Technical University of Denmark. Detailed scope of EASEWASTE is presented in [2]. EASEWASTE is designed to compare different waste management strategies, waste treatment methods and waste process technologies and to identify significant sources of environmental problems of the system.

- *Waste and resources assessment tool for the environment (WRATE)* was designed to address environmental aspects and impacts of municipal solid waste management (MSWM), and it was developed on behalf of the Environment Agency for England and Wales, Scottish Environment Protection Agency and Department of Environment. The default database includes 160 waste management technology datasets and energy mix for 40 countries (average and marginal) over a 20-year forecast. Moreover, WRATE also includes a database on materials and their inventories (Ecoinvent database), a default waste composition (national UK waste composition) and the most used impact assessment methods. Detailed scope in terms of material and energy flows and processes is illustrated in [2].

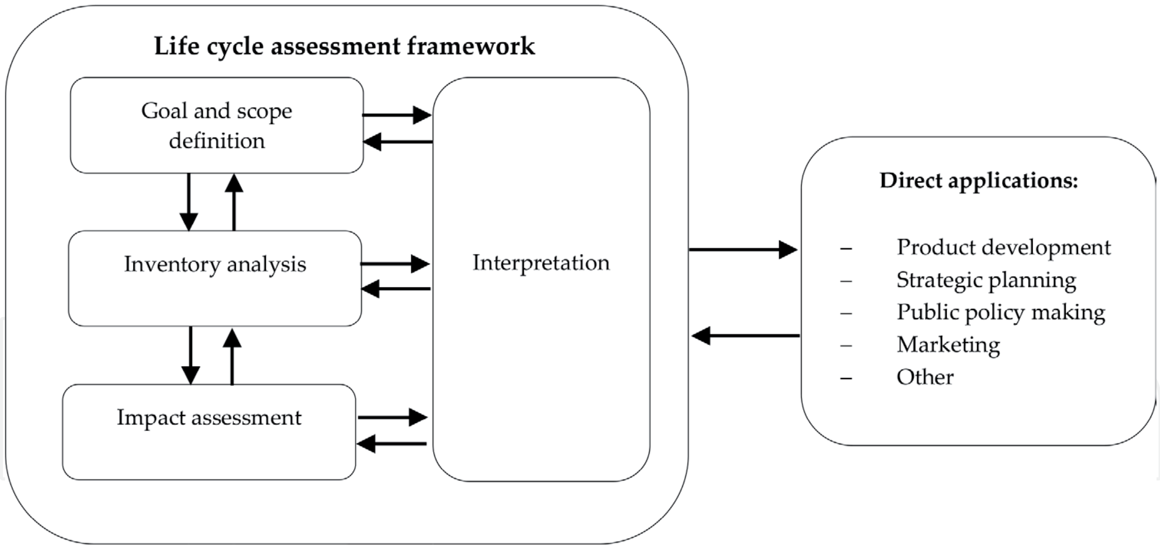

Figure 1.
Components of a life cycle assessment (LCA) according to International Organization for Standardization (Source: [9]).

Life cycle assessment (LCA) is one of the environmental management techniques, which aims to assess potential hazards to the environment of products, processes or entire systems. LCA as a tool to analyze waste management systems appeared in the early 1990s. It is worth noting that among researchers and decision makers, the use of LCA to analyze and develop waste management strategies has increased considerably over the last few years [2]. Moreover, LCA is a useful framework for assessing environmental performances [3]. The role of LCA has been increasing as it was proposed in many EU and Polish official documents [4]. Currently the LCA methodology is more and more frequently used as a tool for evaluating the environmental performance of products or services [5].

The LCA description is based on the ISO standard series 14040-14044 (2006) [6] and the guidelines provided by Guinée [7]. According to ISO, LCA is used for hot spot analysis, product or process improvement, comparative assertion, marketing and environmental policy.

In accordance with the ISO 14040 (2006) [7] standard, describing the principles and framework, LCA consists of the four phases [8] as illustrated in **Figure 1** [9]. Life cycle inventory (LCI), the second valuable step of LCA, is the most effective quantitative environmental assessment tool [10].

2. Methods

2.1 Goal and scope of the study

The goal definition describes the purpose of the study and the decision process to which it provides environmental decision support [8], and the scope includes the way the object of investigation is modeled. The functional unit and system boundaries are also determined at this step. The scope definition of an LCA study must address the following issues:

- the object of the study-functional unit;
- the system boundaries;
- the assessment criteria to be applied;

- the time scale of the study; and
- the technologies representing the different processes as presented by Hauschild and Barlaz [8].

Detailed issues (e.g., *functional unit*, *system boundaries*, *time scale of the study*, *technologies representing the different processes*) in scope definition of an LCA study is discussed by Hauschild and Barlaz [8].

2.2 Functional unit

The functional unit (FU), central concept in LCA [11, 12], is the measure of the performance delivered by the system under study [12], and definition of a FU is essential in LCA [13]. According to [8] for the LCA of waste management systems, the FU of the study could include:

- quantity of waste to be managed;
- composition of the waste;
- duration of the waste management systems; and
- quantity of the waste management (legal emission limits, requirement for residual products).

For the purpose of this study, a suggested FU is defined as amount of waste to be stored during the year—waste other than hazardous—and recovered and stored during the year at Kosodrza landfill (see **Figure 2**). Time coverage is year 2015.

2.3 Data quality

The problem of data quality in building an LCI, which is the foundation of any LCA [14], is discussed in [11]. Collection of LCI data is one of the most important

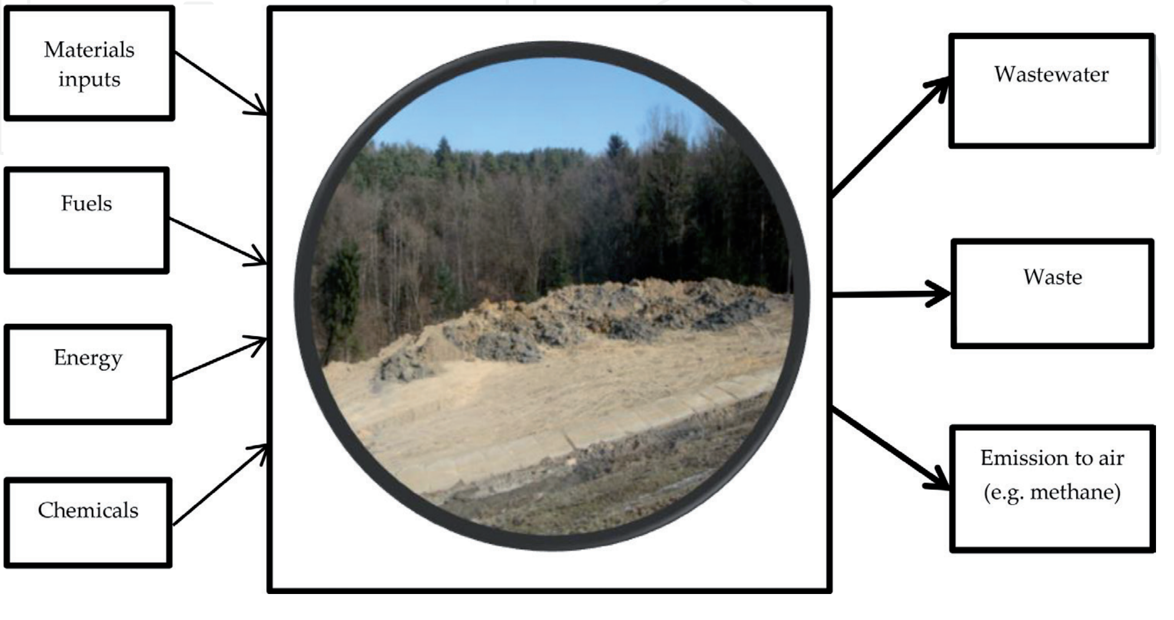

Figure 2.
LCI system boundary of the gate-to-gate for the MSW landfill considered in this study (source: photo from waste landfill in Kosodrza management communication).

stages in an LCA study [15]. Moreover, data quality is multidimensional and not necessarily quantitative [14]. LCI required a lot of data [12, 16] that are well correlated to the study context [14].

The paucity (reliability) of data can be a strong impediment in the conduct of LCA and explain the bias in choice of waste types to study [17].

The data used in this study involving consumption of energy and fuels, water, materials and waste are obtained from (i) site-specific measured or calculated data and (ii) secondary data taken from integrated permit issued by Marshal of the Podkarpackie region in Rzeszów for the establishment of municipal services in Ostrów (e.g., **Figure 3**) by entering the records concerning the waste landfill in Kosodrza (e.g., **Figure 4**), dated October 31, 2015, *and its subsequent amendments* [18]. Integrated permit has been issued *at the request of the interested party*.

The present LCI, as mentioned above, is representative for year 2015 by application of PN-EN ISO 14040:2009 [19].

A full publication of the inventory data used in this study is documented in [18]. In this case study, the system evaluated does not include anything upstream from the waste landfill operation.

As this study was based on the deterministic approach to LCI, uncertainty analysis was not carried out. However, very few assessments include effects of the waste composition, and waste LCAs often rely on poorly justified data from secondary sources, and uncertainty on LCA results associated with selection of waste composition data have been performed [20]. The LCI model can be used in full LCA study.

Figure 3.
Waste landfill in Kosodrza, in the community of Ostrów (source: [18]).

Figure 4.
Landfill for waste other than hazardous and inert wastes with separate hazardous waste facilities containing asbestos in Kosodrza (source: BIP based on https://www.google.pl/maps).

3. LCI of a modern MSW landfill

According to [20] the composition of waste materials has fundamental influence on environmental emissions associated with waste treatment, recycling and disposal and may play an important role also for the LCA of waste management solutions.

According to [21] to carry out a LCA, there is a need for LCI data in order to ensure a representative assessment. Major LCA methodological steps, including among others inventory analysis, are illustrated in [1], based on EC [22, 23]. LCI data on waste management processes involves recycling, source separation, collection, transport and upgrading of recyclables, and it is readily available [24].

Several definitions of solid waste exist. In the review given in [3], waste, according to [25], is neither water (wastewater) nor airborne (flue gases). According to [26] urban solid waste is defined as the waste generated by household, businesses, industries, institutions and markers, as well as the waste coming from the cleaning of streets and public areas [26].

It should be noted that Environmental Research and Education Foundation (EREF), a non-profit organization, is one of the largest sources of funding solid waste research in North America; it defines solid waste as [27]:

- municipal solid waste (e.g., residential, commercial, institutional);
- construction and demolition debris;
- certain industrial wastes (e.g., exploration and production waste, coal ash); and
- other wastes typically managed by the solid waste industry or generated by the public not included in the above list (e.g., electronic waste, disaster debris, etc.).

Agricultural wastes (that are not handled by the waste industry), nuclear waste and land-applied wastewater treatment sludge are generally not included in this definition [27].

4. LCI of municipal solid waste (MSW) management systems in Kosodrza, community of Ostrów

The consumption of energy and fuels, water, chemicals and waste obtained from secondary data taken from integrated permit issued by Marshal of the Podkarpackie region in Rzeszów for the establishment of municipal services in Ostrów by entering the records concerning the waste landfill in Kosodrza is given in **Tables 1–4**, respectively.

The maximum amount of waste to be disposed of through storage during the year will be:

- hazardous waste: 3000 Mg/year (10 Mg/day);
- nonhazardous waste: 156,393 Mg/year (500 Mg/day); and
- in the event of a situation deviating from the normal one—an additional 18,000 Mg/year of other waste.

Total amount of waste accepted for processing in landfill recovery processes is:

- the total amount of waste recovered in R5 processes per year will amount to 20,030 Mg/year (the amount of waste used to build inert layers on the landfill cannot exceed 6700 Mg/year); and
- the total amount of waste subjected to recovery in the R3 process will amount to 12,450 Mg/year during the year.

4.1 The leachate process

The integrated permit was issued for the operation of installations for the disposal of nonhazardous and inert waste with the capacity to receive more

No	Specification		Unit	Amount value
1	Gas oil		Mg/year	117
2	Tap water	Technological utilization	m^3/year	1000
		Sanitary utilization	m^3/year	75
3	*Chemical reagents* used for the reverse osmosis process purification plant	disinfectant sanitizer	Mg/year	1.5
		Sulfuric acid	Mg/year	100
		Hydrated lime	Mg/year	40
		Chlorinated lime	Mg/year	0.2
		Citric acid	Mg/year	3.0
		Sodium hydroxide	Mg/year	20
4	Electric power		kWh/year	300,000
5	Hard coal		Mg/year	3.7

Table 1.
Type of energy, water, chemicals, and fuels—landfill for waste other than hazardous and inert wastes with separate hazardous waste facilities containing asbestos in Kosodrza.

No	Type of waste	Quantity of waste
1	Inorganic wastes	1000
2	Furnace linings and refractories from non-metallurgical processes	23
3	Other wastes	70
4	Mixed wastes from construction, renovation and dismantling	6000
5	Non-composted municipal solid waste	20,000
6	Other unused waste (waste from the mechanical and biological treatment plant)	50,000
7	Digested wastes of anaerobic decomposition of municipal solid waste	2003
8	Screenings	3000
9	Content of sand traps	2000
10	Sludges from non-biological treatment of industrial wastewater	4000
11	Solid wastes from preliminary filtration and screenings	500
12	Glass	2000
13	Other wastes (including mixed substances and objects) from mechanical treatment of waste	50,000
14	Other non-biodegradable waste	6000
15	Waste from marketplaces	3000
16	Sludges from septic tanks used to collect impurities	800
17	Waste from sewer manholes	800
18	Municipal waste not included in other subgroups	7000
19	Insulation materials containing asbestos	3000
20	Construction materials containing asbestos	3000

Table 2.
Types and amount of waste to be stored during the year—waste other than hazardous (all values in Mg/year).

No	Type of waste	Quantity of waste
1	Waste sands and loams	100
2	Waste resulting from cutting and rock cutting	100
3	Slag, bottom ash and boiler dust	300
4	Fly ash from coal	100
5	Defective ceramics, bricks, tiles and building ceramics (after thermal processing)	200
6	Worn (used) tires	200
7	Waste of concrete and debris from demolition and renovation	1000
8	Brick rubble	1000
9	Wastes of other ceramic materials and equipment items	560
10	Mixed or segregated waste from concrete, brick rubble and waste ceramic materials	3000
11	Plasters removed	500
12	Concrete parts and aggregates not containing asphalt	100
13	Soil and soil, including stones	5000
14	Dredging spoil	80
15	Torn rubble (aggregate)	40

No	Type of waste	Quantity of waste
16	Construction materials containing gypsum	200
17	Compost not meeting the requirements (unsuitable)	10,000
18	Stabilized municipal sewage sludge	2200
19	Sludges from water clarification	100
20	Minerals (e.g., sand, stones)	2500
21	Other non-specified fractions collected selectively (ashes and slags)	200
22	Soil and soil, including stones	2000
23	Waste from cleaning streets and squares	3000

Table 3.
Type and quantity of waste recovered during the year (Installation - Landfill for waste other than hazardous and inert wastes with separate hazardous waste facilities containing asbestos in Kozodrza - all values in Mg/year).

No	Type of waste	Quantity of waste
1	Packaging made of paper and cardboard	440
2	Plastic packaging	1200
3	Wood packaging	600
4	Metal packaging	440
5	Multi-material packaging	230
6	Glass packaging	1200
7	Packaging from textiles	220
8	Paper and cardboard	1500
9	Ferrous metals	600
10	Non-ferrous metals	500
11	Plastics and rubber	4000
12	Glass	2000
13	Other wood	500
14	Textiles	40
15	Other wastes (including mixed substances and articles) from mechanical treatment of waste containing dangerous substances	110
16	Other wastes (including mixed substances and articles) for mechanical processing of waste—oversize fraction with a grain size greater than 80.0 mm with the properties of combustible waste—preRDF	21,000
17	Other wastes (oversize fraction with a grain size greater than 80.0 mm—ballast)	14,000
18	Other wastes (biodegradable fraction)	25,000
19	Compost not meeting the requirements (not suitable to be used)	11,250
20	Other unmentioned waste (sieve fraction from stabilizer screening)	13,750
21	Other wastes (including fiberboard, leftover wood contaminated plastic)	700
22	Waste of concrete and debris from demolition and renovation	20,000
23	Brick rubble	2000
24	Iron and steel	100
25	Worn (used) tires	220

No	Type of waste	Quantity of waste
26	Other engine, gear and lubricating oils	1.8
27	Sorbents, filter materials, wiping cloths (e.g., rags, dishcloths) and protective clothing	0.3
28	Oil filters	0.2
29	Other unlisted items (air filters)	0.2
30	Worn out (used) devices containing hazardous elements	0.3
31	Lead-acid batteries and accumulators	0.2

Note: The waste mentioned in No. from 1 to 18 will be generated as a result of processing in the installation for mechanical waste treatment, the waste mentioned in No. 19 will be generated as a result of processing in the installation for biological waste treatment, the waste mentioned in No. from 20 to 23 will be generated as a result of the operation of the large-size waste disassembly point, the waste mentioned in No. from 22 to 24 will be generated as a result of crushing construction debris, the waste mentioned in No. 25 will be generated as a result of the plant's ongoing operation (arising as part of its current operation, machinery and equipment) and the waste mentioned in No. from 26 to 31 will be generated in connection with maintaining the efficiency of installations for mechanical and biological waste treatment.

Table 4.
Types and quantities of waste to be generated during the year and the source of waste generation (all values in Mg/year).

than 10 tonnes of waste per day and a total capacity of over 25,000 tonnes, with separate asbestos-containing hazardous waste units in Kosodrza, Ostrow commune (see **Figure 4**).

Description of the current installation and method of purification/pretreatment of the leachate in the landfill from the integrated permit is given below. The leachate process is performed in the two leachate tanks:

- leachate tank named ZRO1; and
- leachate tank named ZRO2.

The ZRO1 leachate tank is used to retain leachate arising within the existing quarters No. 1–8; it can be used to pump out leachates from the ZRO2 reservoir, i.e., from quarters No. 9, 10, 11, and 12.

Earth tank, insulated with 1.0 m thick, surface reinforced with a wreath and reinforced concrete grate, filled with openwork plates. The walls of the tank were made of grids made of reinforced concrete beams, 30 × 30 cm, creating grid structures over the bottom. Grill grates and slopes above the crown were secured with openwork concrete tiles 100 × 75 × 12.5 cm, on a geotextile with a weight of 400 g/m^2 and densified ballast made of gravel material. The bottom of the tank is a 20-cm-thick reinforced concrete slab.

ZRO2 reservoir located in the north-western part of the land designated for the extension of the landfill in the resulting triangle between the existing quarters No. 8, the factory road to quarters No. 9–12 (e.g., **Figure 5**) and A1 and A2 and the area of the leachate treatment plant.

Terrain open tank protected escarpments and the bottom triangular in plan. The structure of the tank bottom and walls will be sealed with a 1.0 m thick layer, 1.5 mm thick foil and geotextile g = 400 g/m^2, reinforced with a concrete construction.

The ZRO2 tank is the main retention reservoir for leachate from quarters No. 9–12. The leachate from quarters No. 9–12 will flow gravitationally to the P6 pumping station, from where they will be pumped into the ZRO2 leachate retention reservoir.

Figure 5.
New quarter No. 12 (source: [18]).

4.2 Container sewage wastewater treatment plant (CSWTP)—leachate treatment plant in reverse osmosis technology

Container sewage wastewater treatment plant (CSWTP) with a capacity of 30 m^3/d includes system called a single-stage membrane process ensuring obtaining the leachate parameters enabling them to be safely transported to the municipal sewage treatment plant. The treatment plant operates on the basis of the reverse osmosis process (e.g., **Figure 6**), the essence of which consists in passing the leachate from the storage site through a semipermeable membrane under the influence of the pressure set on the inlet side of the effluent.

Membrane separation is a purely physical separation; separated components do not undergo any chemical or biological transformation. The applied solution is a pilot solution for cooperation with the existing pretreatment plant in order to increase the cleaning effects. The effect of the treatment plant is to obtain purified leachate (permeate) and leachate residue (concentrate).

The sewage treatment plant works in a continuous system and cleanses the effluents from the ZRO2 reservoir, i.e., from quarters 9 to 12. The treatment plant will be controlled by means of a computer program and will work in an automatic system. The computer will monitor, through systematic conductivity measurement, the quality of treated leachate discharged into the environment. If the conductivity

Figure 6.
The treatment plant based on the reverse osmosis process (source: [18]).

rises above the programmed value, the installation will automatically stop, and a cleaning program for filters or modules will start.

Sewage plant is located in a paved square for turning vehicles. Container of treatment plant with dimensions of 12.2 × 2.5 m is set on a separate foundation.

The container is made of steel construction with a layer casing made of trapezoid sheet metal from the outside and a polypropylene plate from the inside of the container. The addition between the layers is a mineral wool insulation layer. Tight floor is made of chemically resistant material. The container has mechanical ventilation.

5. Literature review

The LCA literature on waste treatment can be found in [3]. According to [28], the annual total solid waste generation worldwide is approximately 17 billion tonnes, and it is expected to reach 27 billion by 2050 [1, 17]. Based on [29] in this amount, about 1.3 billion tonnes are currently municipal solid waste generated by world cities, which are anticipated to generate up to 2.2 billion tonnes by 2025 primarily due to population growth, increasing urbanization and socio-economic development of low- and middle-income countries [1]. The waste management problem in the EU is characterized by increasing per capita production of waste materials, the need for high levels of investment in physical infrastructure (incinerators, recycling facilities and landfills), institutional barriers, a wide range of stakeholders and a dynamic policy arena.

In this section we describe several studies with numerous examples demonstrating the waste management. Ref. [3] illustrates development of the regionalised municipal solid waste incineration model in France, which can be adapted to regional characteristics and incineration conditions in order to provide the best representation and most accurate predictions of MSW incineration in a given geographic area [3]. The world's largest center for urban waste by 2007, according to [30], was operational in Amsterdam in the Netherlands. This includes the city's sewage treatment plant and the expanded waste-to-energy plant for solid waste (SW) [30].

Details about Latin America, as a region strongly affected by the lack of equality in income distribution and big differences in the quantity of the waste generated daily and in its composition, can be found in [26].

Moreover, according to work presented by Savino [26], the regional assessment report on municipal solid waste management (MSWM), published by Pan American Health Organization (PAHO) in 2005, says: "The composition of waste in Latin America, although it varies among the different centers of population, maintains a strong component of foodstuff waste, with average values from 50 to 70% in weight, while around 25% of waste components is made up of paper, cardboard, metal, textile, leather, rubber and wood." According to studies carried out by national member International Solid Waste Association (ISWA) in Argentina, presented in [26], the percentages are as follows:

- adequate final disposition of SW in the metropolitan area of Buenos Aires at sanitary landfill 45%;
- the rest of Argentina 55%;
- adequate final disposition in sanitary landfill 10%;
- waste disposal in controlled sites 10%; and
- uncontrolled open-air dumps 35% [26].

The composition of waste in Buenos Aires is presented and shown in **Figure 7**.

The case of the sanitary landfill in Buenos Aires is illustrated in **Figure 8**.

In paper [31] a systemic approach for MSWM at both the household and the non-household level has been developed. It summarizes state-of-the-art available tools and compiles a set of guidelines for developing waste management master plans at the municipal level, and it provides a framework in the MSWM field for municipalities in Greece and other countries facing similar problems under often comparable socio-economic settings [31] [ZOTOS]. Moreover, the Hellenic State has defined sufficiently the legislative and political framework for MWSM, in frame of related EU legislative approaches, and the 4R (reduce-reuse-recycle-recover) concept is well promoted by the "National Planning of SWM"(Hellenic) constituted of two Joint Ministerial Decision, legislated in 1997 and 2000, respectively [30]. It is interesting to note that SWOT analysis is performed for MSWM (e.g., [31]).

In China landfill density cannot be as high as in developed countries because its population distribution and economic development are quite different [32]. The amount of MSW collected by local authorities in China has increased in parallel with rapid urbanization. The average rate of increase in the amount of MWS collected annually is about 6% [32]. Moreover, the overall status of

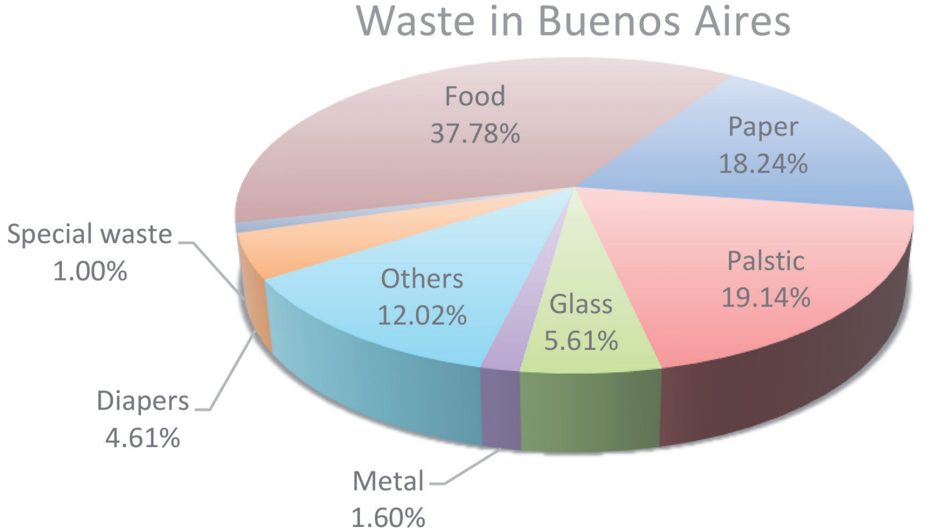

Figure 7.
Composition of waste in Buenos Aires (source: [26]).

Figure 8.
Sanitary landfill Norte III in Buenos Aires (source: [26]).

Figure 9.
Landfill site in Beijing City (source: [32]).

MSW treatment in China is still at the developing stages, with waste collection going from incomplete to complete collection and waste treatment going from decentralized disposal to sanitary landfilling [32]. Landfill site in Beijing City is presented in **Figure 9**.

6. Conclusions

The present LCI modeling of municipal solid waste management (MSWM) systems in Kosodrza, community of Ostrów, Poland case study was given according to PN-EN ISO 14040.

This study is focused on the operational results recorded in 2015, as defined in the goal and scope.

It should be noted that LCI work was performed using the secondary data obtained from integrated permit legislated for waste landfill in Kosodrza, community of Ostrów in Poland.

The results may be useful for MSWM in Poland. In the methodological approach regarding databases, boundaries were transparent and fully documented. Moreover, the results of this study can help MSW management authorities and practitioners to solve environmental and technical aspects and decision makers to understand the nature of the LCA. In addition to LCI, these data can be used to assess life cycle impact assessment (LCIA) as the next step of LCA methodology, and finally, full LCA should be conducted. The LCIA provides the analysis of collected data to evaluate contributions to various environmental impact categories. The final LCA of a modern MSW landfill should include the uncertainty of waste compositions.

The LCI study allows to identify and understand LCA approach from the view of further research work with a view to reduce the negative impact of *waste on* the environment as well as to reduce the negative impacts on ecosystems, on human health or on natural resources.

However this study has examined a case at the country level. This case study could be used by other domestic and international LCA studies of solid waste management systems.

The results obtained from this study can move the LCI on the waste management process one step forward and will assist in developing environmental awareness in the development of the National Waste Plan.

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Conflict of interest

The authors declare that they have no conflict of interest.

The research does not involve human participants and/or animals.

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