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PHD THESIS

- ABSTRACT -

IMPROVING THE PERFORMANCE OF HOUSEHOLD WASTE MANAGEMENT SYSTEMS.

CASE STUDY CLUJ-NAPOCA

SCIENTIFIC COORDINATOR:
Prof. Univ. Dr. CĂLIN BACIU

PHD CANDIDATE:
POP IOANA NICOLETA

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Key words: municipal waste management; solid waste composition; separate collection of waste at source; life cycle assessment; circular economy;

INTRODUCTION

The first chapter of the paper presents the European perspective on waste management, emphasizing also the need, the opportunities and the set objectives of the study, in order to accomplish the goal of the thesis.

Being an important socio-economic issue, waste management requires numerous technical aspects, but it is also influenced by other factors: legislative, cultural, environmental, economic, and availability of resources (Sharholy et al., 2007). Considering waste as a potential resource, as raw material, but also the environmental threats of improper waste deposits, an integrated approach of waste management is a key factor of the sustainable development.

Hence, in the last years, *the issue of waste management is considered within the context of circular economy* that can be translated by separating economic development from the non-renewable resources consume. Moreover, there is the need of abandoning the old linear economy concept that resumes to the use of non-renewable resources turning them into products that, at their end life they result in large waste deposits (CE, 2014).

Considering this framework, the old practice of landfills must be replaced with sustainable solutions that consist in waste preventing, waste recycling, recovery and green designing of products. Furthermore, a proper planning of waste management needs a complete database on waste generation, waste composition and other waste characteristics, this being also agreed by a D Waste Report (www.d-waste.com).

Waste management is one of the biggest challenges that Romanian municipalities have to deal with, considering the growing waste quantities, the environmental issues, and the recycling and recovery targets imposed by the European Union (Tartiu & Petrache, 2009).

Even more attention should be given to this issue since waste management became resource management in the context of circular economy.

In this context, the thesis focuses on household waste and waste similar to household waste generated by the industry and institutions, including special fluxes such as electric and electronic equipment.

The work aims *to identify directions for a proper solid waste management system in Cluj-Napoca* based on useful instruments that can be used by different waste management stakeholders.

Therefore, the objectives of the study are:

(1) Establishing a methodology for waste characterization studies;

(2) Identifying household waste composition generated by population and commercial sector based on 10 waste categories in each season;

(3) Identifying generation rate of household waste in Cluj-Napoca;

(4) Determination of the specific density of not compacted household waste generated in Cluj-Napoca.

(5) Identifying the calorific value of household waste in Cluj-Napoca;

(6) Identifying the degree of Cluj-Napoca City population participation in waste separate collection process;

(7) Evaluation of waste management processes using Life Cycle Analysis (LCA) method (including distinct analysis of collection and transport processes);

(8) Analysing waste treatment options from an economic point of view; Estimation of the economic value of household waste generated in Cluj-Napoca;

(9) Evaluating the recycling and recovery potential of household waste generated in Cluj-Napoca;

CHAPTER 2–THE STATE-OF-THE-ART

The analysis of the state-of-the-art in the field of waste characterisation and waste management was accomplished through bibliography analysis. The focus was on certain aspects: (1) the level of knowledge regarding waste characteristics in Romania, (2) methodological approach of waste characterisation, (3) the utility of the results obtained in different waste characterisation studies and (4) the implementation of Life Cycle Assessment (LCA) within waste management.

2.1 The level of knowledge regarding waste characteristics in Romania

The experience of Romania on this matter is limited to a low number of waste characterisation studies, developed occasionally at a local scale, some only being limited to research. Therefore, the statistics on waste composition, waste density and generation rates are mainly based on estimations and data provided by the sanitation companies (Ecorom Ambalaje, 2013a).

Hence, among the studies on waste characteristics developed in different regions of Romania, some can be listed: (1) Waste composition identified for waste generated in Brașov, in 2004 (SWA Tool Consortium, 2004b); (2) Waste composition identified for waste generated in Bihor County, in 2006 (MMDD, 2007); (3) Studies regarding household waste composition in the Centre Region, in 2011 (ARPM Sibiu, 2011); (4) Study on household and packaging waste composition generated in Pitești, in September 2012 – August 2013 (Ecorom Ambalaje, 2013a); (5) Study on the composition of waste generated in Ploiești and Câmpina, in 2014 (Panaitescu & Bucuroiu, 2014).

The fact that data used in Romania and also other countries (Albania, Bosnia-Herțegovina, Bulgaria, Croatia, Serbia), regarding waste characteristics are based on estimations, is also acknowlegded by other studies (Hristovski et al., 2007).

2.2 The level of knowledge regarding the methodology used in waste characterisation studies

The current chapter presents waste characterisation methodologies used in different studies performed in Romania and other countries.

Although other local waste characterisation studies have been performed in Romania, there is no unitary methodology adopted by law, with mandatory use in these studies. This would be useful not only for studies at regional level, but also for the possibility to compare the results of the studies performed in different countries.

In Romania there is a standard related to waste characterisation – *SR13493/2004 – Waste characterisation. Methodology for household waste characterisation* – ROMECOM, with voluntary use.

The project named *Development of a methodological tool to enhance the precision & comparability of solid waste analysis data – S.W.A. – TOOL*, funded by the EU, has studied aspects related to waste characteristic including waste management in Brasov.

Moreover, the Project *Twinning Phare RO/06/IB/EN/06* must be mentioned in this context since, besides the recommendations regarding the sorting facilities of the packaging waste, the project also recommended a waste characterisation methodology.

A study from 2014 (Pop et al., 2014a) highlighted that at international level there are many studies on waste characteristics in developed countries, e.g.: Alachua, Florida – United States of America (Townsend et al, 2010), Maine, New England– United States of America (Criner & Blackmer, 2011); Vancouver – Canada (TRI Environmental Consulting Inc., 2011), Boulder, Colorado – United States of America (MSW Consultant, Cascadia Consulting Group, 2010); Great Britain (EPA, UK, 2000), Ghana (Bryant et al., 2010) etc.

Regarding the research performed in developing countries, a number of studies can be mentioned: Allahabad, India (Sharholy et al., 2007), Chittagong, Bangladesh (Sujauddin et al., 2008), Kharagpur, Bengal, India (Kumar & Goel, 2009), Nagpur, India (Modak & Nangare, 2011), Abuja, Nigeria (Ogwueleka, 2013), Nigeria, Niger Delta Region (Owamah et al., 2015) etc.

2.3 Use of the Life Cycle Assessement in waste management

Pop et al. (2016a) also presented the state-of-the-art regarding the usage of Life Cycle Assessement in waste management. It can be noticed that there are many studies on this subject mostly in Europe and in the developed countries (Laurent et al., 2014a).

Many reviews have been performed (e.g. Tascione & Raggi 2012; Abeliotis 2011); they highlight that, in general, a number of scenarios between 2 and 24 were analysed, being defined after 4 criteria: (1) standards and recommendations, (2) good practices, (3) studies focused on a certain waste management option and (4) predictions (Tascione & Raggi, 2012).

There are useful studies in performing new Life Cycle Analysis on waste management, for example: (1) the book chapter entitled "Life Cycle Analysis of waste management system" (Hauschild & Barlaz, 2010; Björklundet al., 2010, Christensen et al., 2010) that introduces the use of this method in waste management and debated specific examples: (2) the work of McDougall et al. (2001), that presents case studies and also frameworks the LCA method applied to waste management; (3) the book chapter on critical analysis of studies performed on LCA, within the volume Integrated Waste Management (Abeliotis, 2011); (4) the report on studies that evaluate the environmental impact of recycling, landfilling and incineration of different material types (Michaud et al., 2010).

Laurent et al. (2014a, 2014b) performs a critical analysis on 222 LCA studies from the point of view of their quality, structure, methodology and results, giving a series of recommendations on the best use of this method. Hence, a series of studies are recommended as reliable bibliographic sources (Arena et al. 2003, Jenseit et al. 2003, Blengini et al. 2012 etc).

There is low interest in analysing innovative technologies such as gaseification, pyrolysis and anaerobic digestion while there are waste management treatment options such as landfilling, recycling, composting and incineration that are intensly debated in terms of environmental impact (Michaud et al., 2010).

In Romania, there are few studies that analyse waste management through LCA, e.g.: Gliguța et al. (2010); Popița (2011); Ghinea et al. (2012, 2014); Pop et al. (2016a); Popița et al. (2017). However, these undertakings are not enough to apply LCA in order to establish the best waste management option in Romania (Popița et al., 2017).

CHAPTER 3 – CHARACTERISATION OF THE RESEARCH AREA

Chapter 3 presents the solid household waste management system applied in Cluj-Napoca.

Solid household waste management in Cluj-Napoca – Formal sector

Figure 1 presents relevant events in waste management for Romania and Cluj-Napoca. It highlights that landfilling was the treatment option with the widest use within waste management in Cluj-Napoca. However, in the last few years, authorities are in the process of planning an integrated waste management system.

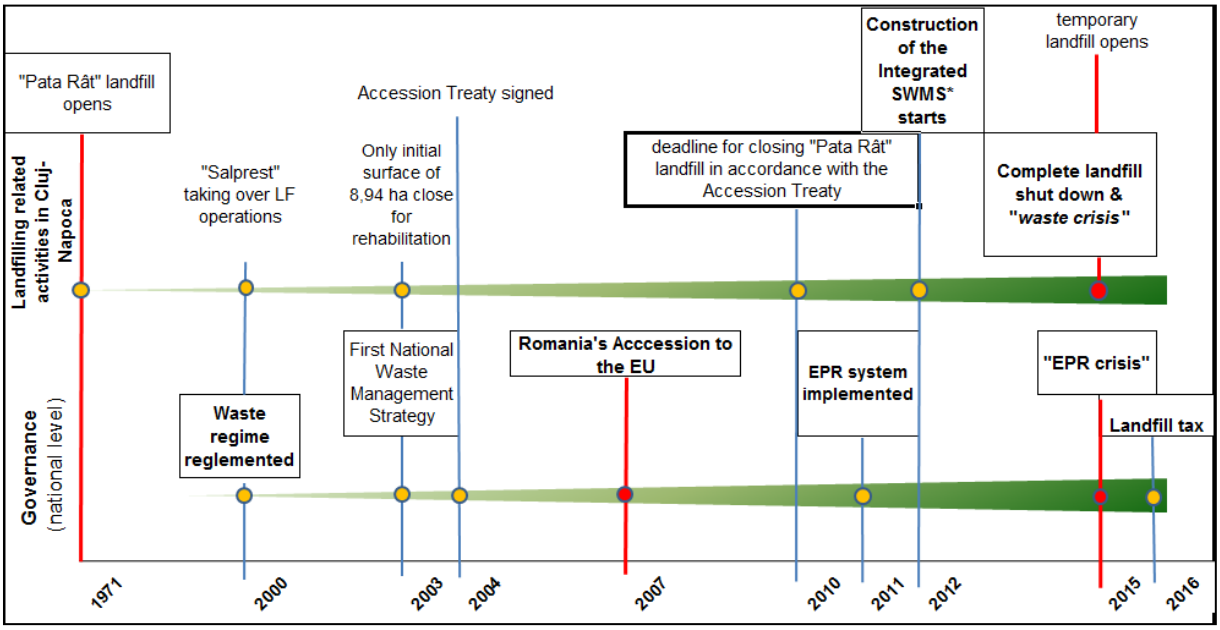

Figure 1 Timeline of selected relevant events at local and national level (după Nicodin et al. 2016)

Since the public authorities are responsible for waste management, in Cluj-Napoca the sanitation services have been delegated to private companies. The main elements of the solid waste management are represented by: separate collection of waste at the generation source on two fractions, "door to door" waste collection, sorting of the dry fraction followed by recycling and landfilling the wet fraction of waste (**Figure 2**).

Figure 2 Household waste management system of Cluj-Napoca (Pop et al., 2015b)

Solid household waste management in Cluj-Napoca – the informal sector

Although there are only two companies in charge with the management of solid household waste, there are also unauthorised persons that collect valuable waste and sell them to collecting companies for recycling.

On one hand, the informal sector leads to a certain decrease of waste landfilling, but on the other hand, it creates problems in the formal sector, sunch as: pilfering already selected waste from the bins destined to packaging waste collection, destroying waste collection infrastructure belonging to the formal sector and scavenging or cherry picking. The advantages and disadvantages of the involvement of the informal sector in waste management in Cluj-Napoca are debated in the study performed by Pop et al. (2015b).

At the time the study is performed, there is no mechanical sorting facility, composting facility of ecological landfill within the waste management system. The landfill is placed at a distance of 5 km from the town and it is not equipped with leachate or gas collecting systems.

According to the data received from the Cluj-Napoca local authorities, the selective collection between 2012 and 2017, through formal sector, represented 15 % from the total collected waste (anuall average).

The thesis also presents a SWOT analysis that synthesises waste management system from Cluj-Napoca.

CHAPTER 4 – METHODOLOGY

Chapter 4 – Methodology explains the instruments used in performing the studies presented in the thesis: (1) characterisation study of waste generated in Cluj-Napoca – composition, density, calorific value, generation rate, (2) analysis of the degree of population involvement in separate collection of waste at the generation source, (3) Evaluation of waste management processes using the LCA method, (4) Analysis of waste treatment options from an economic point of view and (5) Evaluation of the recycling and recovery potential of household waste generated in Cluj-Napoca;

In performing the studies presented in the thesis, the following methods and techniques were used:

- The documentation of every aspect within the thesis – *bibliography study*;
- Waste composition study – *output method* (**Table 1**).

Table 1 Methodology used in the planning of the waste composition study (Pop et al., 2015a; 2015d).

Survey method	- output method -establishing waste composition by sampling, sorting and weighing waste by category
Stratification of the study	(1) waste sector: residential and commerce (2) waste subsector: single-family residential, multifamily residential and commerce (3) waste type: dry and wet fractions of waste (4) seasonal characteristics: summer and autumn 2014, winter and spring 2015
Sampling	- random sampling from the collection bins (wet fraction) and from the vehicle (dry fraction)
	- summer campaign: June and August 2014 - autumn campaign: October and November 2014 - winter campaign: January and February 2015 - spring campaign: April and May 2015
	- 45 samples with masses between 46 -1500 kg; total sample weight: >17 t
Sorting	- 10 waste categories
Statistical Analysis	-Chi Square Test -Standard Deviation

- The quantity of waste generated during 10 days by approximately 9000 persons (2,8% of the total population in Cluj-Napoca) living in residential areas with flat apartments was monitored in order to determine waste generation rate;

- Field determination of uncompacted waste from bins, taking place in February-March 2016 and August 2016, were used to determine specific density of uncompacted waste (**Table 2** and **Table 3**).

Table 2 Data used in identifying specific weight of household waste generated in Cluj-Napoca – *cold season* (Pop et al., 2016)

Date	**08.02.16**	**10.02.16**	**10.02.16**	**20.02.16**	**21.02.16**	**28.03.16**	**Average**	**Total**
Collected waste (m^3)	77.3	63.6	32.3	67.1	75.1	88	**67.2**	**403**
Collected waste (kg)	7520	6420	2680	5640	7640	6560	**6076.7**	**36460**

Table 3 Data used in identifying specific weight of household waste generated in Cluj-Napoca – *warm season*

Date	**18.08.16**	**19.08.16**	**20.08.16**	**20.08.16**	**21.08.16**	**Average**	**Total**
Collected waste (m^3)	58.346	49.252	57.764	84.944	81.538	66.37	**331.844**
Collected waste (kg)	6700	5240	7220	10020	9620	7760	**38800**

- The calorific value of household solid waste was identified using the equation below (Zurbrügg, 2016) and waste composition determined by Pop et al. (2015d):

$$NCV\ [kcal/kg] = 40(a + b + c + d) + 90e - 46W$$

Where: NCV- Net Calorific Value or Lower Calorific Value; percentage of the wet fraction of waste quantity identified by Pop et al. (2015): a – Paper (11%), b – Textile (2%), c – Wood and leafs (1%), d – Food waste – organics (50%), e – Plastic and rubber (17%), W – Water (60%) (estimated – Zurbrügg, 2016).

- The analysis of the involvement of the population within waste management through waste source separation was performed using the questionnaire survey method;
- LCA method was used to evaluate the environmental impact of different scenarios of waste management system through *SimaPro8,* version 8.1.1.16 Developer; **Table 4** present the characteristics of the involved scenarios (Pop et al., 2016a); waste generation data specific to Mănăștur neighbourhood were used.

Table 4 Description of modelled scenarios (Pop et al., 2016a)

Main characteristics/scenario	**SCN 0B**	**SCN 0**	**SCN 1**	**SCN 2**	**SCN 2B**	**SCN 3**	**SCN 4**
Collection & transport type (number of fractions)	1	1	2	2 (+transport optimisation)	2 (+transport optimisation)	5	5
Landfilled waste %	100	94	65	65	65	65	72
Recycled waste %	0	6	35	35	35	35	28
Distance to recycling/type of recycled material (km)	0	340-470	340-470	340-470	30	340-470	340-470

- The economic analysis of different waste treatment options used real costs of these options and market prices of recyclable waste from 2016, expressed in €, without VAT (Pop et al., 2016b); waste composition identified by Pop et al. (2015d) and the waste generation data from 2013 presented by the local Waste Management Strategy (H.C.L. 529/22.12.2014) were used.

CHAPTER 5 – RESULTS AND DISCUSSIONS

Chapter 5 presents the personal contributions, regarding: (1) characteristics of solid household waste generated in Cluj-Napoca – composition, generation rate, density, calorific value, etc., and also (2) the personal contribution regarding identified aspects on population involvement in selective collection of waste at the generation source, application of LCA indifferent waste management scenarios and economic analysis of waste generated in Cluj-Napoca. At the end, after analysing all aspects mentioned above, directions for a proper waste management system were identified, and can be applied by authorities in order to improve the functionality of the system at local level.

5.1 Composition of household waste generated in Cluj-Napoca

The composition study was performed in the period June 2014 – May 2015 and it highlighted that composition of household waste generated in Cluj-Napoca is largely organic, represented by food waste (30–40%), vegetables, yard waste, followed by a quite high percentage of plastics and paper (**Figure 3**, **Figure 4** and **Figure 5**) (Pop et al., 2015d).

Considering the involvement of the informal system in waste management (Scheinberg et al., 2010), the results are representative for solid household waste that are collected by the formal sector.

Household waste composition - wet fraction- on generator type

The composition of the wet fraction of waste generated by the population living in residential areas with multiple-family houses is similar to waste composition generated by population from residential areas with single-family houses (**Figure 3** and **Figure 4**).

Waste generated by economic agents (restaurants, institutions, shops, etc.) has a lower percentage of organic waste and a higher percentage of recyclable material in comparison to waste generated by population, as shown in **Figure 5**. This indicates that waste generated by economic agents have a higher recycling and recovery potential.

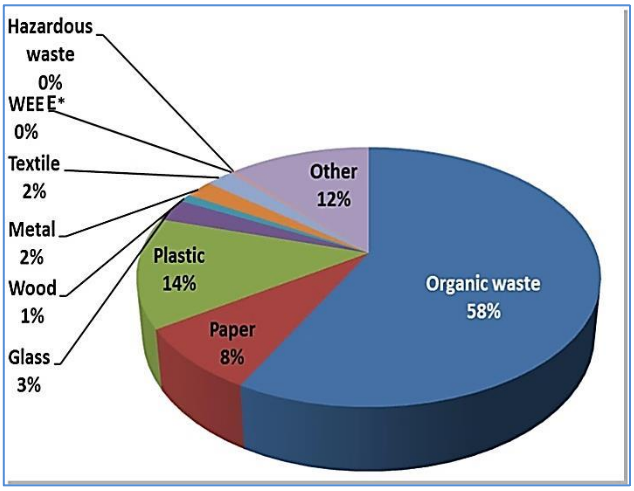

Figure 3 Household waste composition (wet fraction) generated by population living in multiple family houses (Pop et al., 2015d)

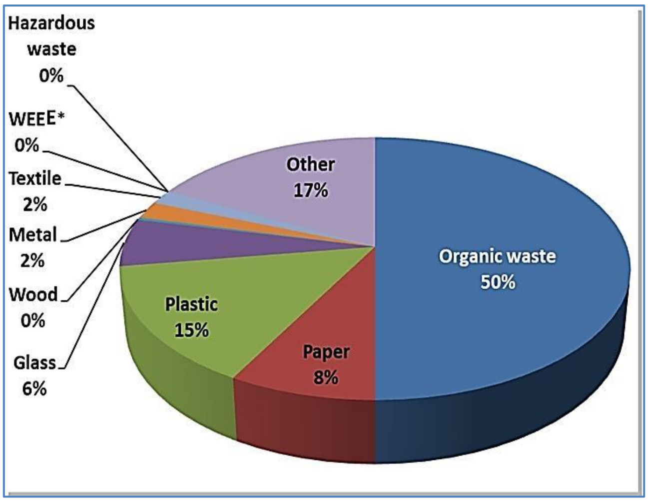

Figure 4 Household waste composition (wet fraction) generated by population living in single family houses (Pop et al., 2015d)

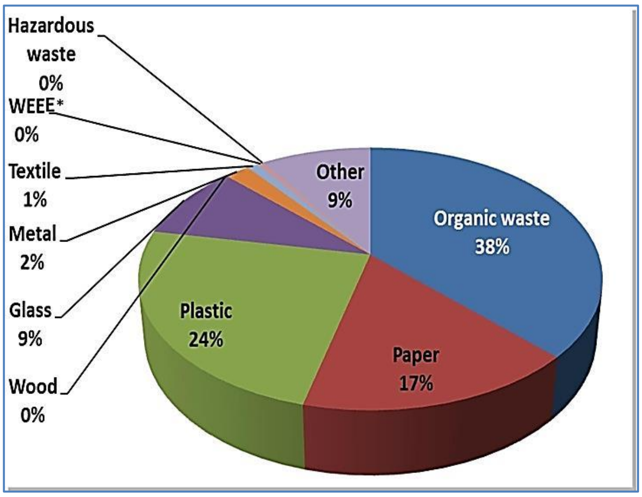

Figure 5 Composition of waste similar to household waste (wet fraction) generated by economic agents (Pop et al., 2015d)

Waste composition on wet and dry fractions

Overall, from the total generated waste that is currently disposed, 50% has the potential to be used for energy recovery and >37% could be recycled (**Figure 6**). However, the informal recycling sector selects recyclable material waste even from the landfill site, minimising the quantity of landfilled waste.

Therefore, new strategies for minimising waste landfilling and increasing waste recycling and recovery should be developed and the results of the study should be taken into consideration in the planning process.

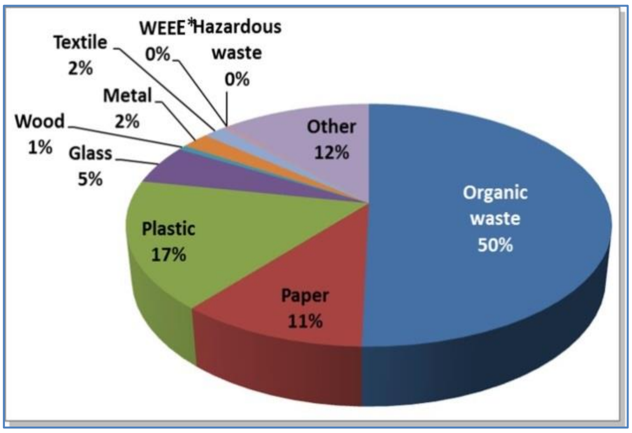

Figure 6 Composition of wet fraction of household waste and waste similar to household waste generated in Cluj-Napoca (Pop et al., 2015d)

Selective collection of waste on two fractions is a system functioning only in a low percentage in Cluj-Napoca, mostly in residential areas with single-family houses and in the case of a small percentage of the economic agents. Moreover, this fact is identified within the composition of the two waste fractions that highlights that generators do not select their waste at the source properly (**Figure 6** and **Figure 7**) (Pop et al., 2015d).

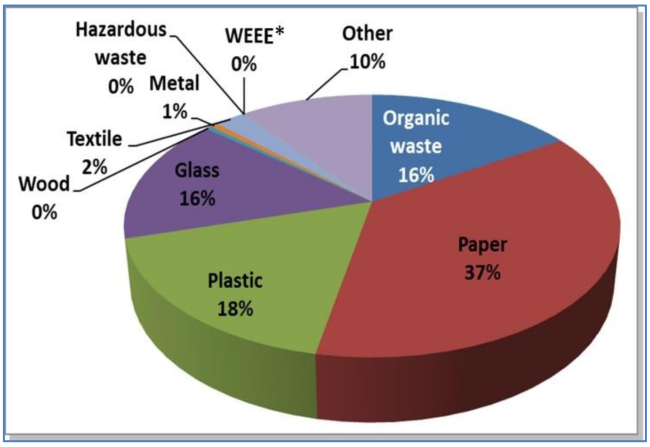

Figure 7 Composition of dry fraction of household waste and waste similar to household waste generated in Cluj-Napoca (Pop et al., 2015d)

The statistic analisys of waste composition in Cluj-Napoca

The chi-squared test applied to the sampled waste quantities on seasons, generator type and waste fractions proofs that waste composition has a preferential distribution according to factors like seasons, generator type and waste fraction, therefore these factors have a high influence upon waste composition. Hereby, the chi square test value for seasons is χ^2= 1586.98, for waste generators χ^2= 677.74 and for waste fractions χ^2=2187.87.

Standard deviation and the variability range indicates that waste composition average values on generators, seasons and waste fractions are representative. However, in cases of fractions that can be found in a low percent in waste composition, the variability range can be higher than the average. In these cases, a higher number of samples are required so that composition of fractions such as wood, textiles and WEEE can be also representative, fact that confirms the theory of Klee & Carruth, 1970 (in Worrell & Vesilind, 2002, p. 40).

5.2 Household waste generation rate in Cluj-Napoca

The amount and composition of household waste generated by population depends on: socio-economic factors, demographic factors, residential structure and climatic factors (Comisia Europeană, 2004; Rusu, 2012; Parfitt et al., 2013, Thitame et al., 2010). Therefore, bibliographic data indicate a high range of waste generation rate, aspects detailed in the thesis.

The applied methodology indicated an average estimated generation rate of de 0.87 kg/pers·day ±0.21. This is similar to the generation rate of 0.8 kg/pers·day estimated in the Local Council Decision no. 152/2009; in this context, the waste generation rate was used in order to determine the number of bins and vehicles required for waste collection in Cluj-Napoca (Local Council Decision no. 152/23.03.2009).

Comparing the generation rate values obtained in the two studied periods, it can be observed that there is a higher value in the warm season (1.039 kg/pers·day- **Table 6**) than in the cold season (0.703 kg/pers·day - **Table 5**); this can be due to differences in the feeding customs in the two periods of the year.

Table 5 Identified waste generation rate in Cluj-Napoca – cold season

DATE	08.02.16	20.02.16	21.02.16	10.02.16	28.03.16	Average	St. dev.
Collected quantity /sector (kg)	7520	5640	7640	8900	6560		
Identified generation rate (kg/pers·day)	0.656	0.665	0.656	0.762	0.774	**0.703**	**± 0.054**

Table 6 Identified waste generation rate in Cluj-Napoca – warm season

DATE	18.08.16	19.08.16	20.08.16	20.08.16	21.08.16	Average	St. dev.
Collected quantity /sector (kg)	5683	5654	5629	10370	11455		
Identified generation rate (kg/pers·day)	1.179	0.927	1.283	0.966	0.840	**1.039**	**± 0.165**

The identified average value of the generation rate is higher than the average national value and this can be explained by the fact that Cluj-Napoca is one of the most developed of the Romanian cities, aspect that also results in the generation of a high anount of waste. Moreover, it is expected that waste generated in Cluj-Napoca will increase in the following years.

5.3 Household waste density

The results of the uncompacted waste density study in the cold and warm periods of the year are presented in **Table 7** (Pop et al., 2016b) and

Table 8.

The determinations were applied on the wet fraction of the waste: in the case of population living in residential areas with block of flats, it is practically represented by comingled household waste. However, there can be cases in which the composition of the generated waste from these areas is affected by the interventions of the informal recycling sector that extracts recyclable waste from the bins situated on public spaces.

Table 7 Results of the campaign of the density measurement of household waste generated in Cluj-Napoca during the cold season (Pop et al., 2016b).

Date	**08.02.16**	**10.02.16**	**10.02.16**	**20.02.16**	**21.02.16**	**28.03.16**	**Average**	**Standard deviation**
Collected waste (m^3)	77.33	63.57	32.29	67.10	75.12	88.04	67.24	±17.47
Collected waste (kg)	7520	6420	2680	5640	7640	6560	6076.67	±1663.67
Specific weight of waste (kg/ m^3)	**97.25**	**100.99**	**82.99**	**84.05**	**101.70**	**74.51**	**90.25**	**±10.28**

Table 8 Results of the campaign of the density measurement of household waste generated in Cluj-Napoca during the warm season

Date	18.08.16	19.08.16	20.08.16	20.08.16	21.08.16	Medie	Standard deviation
Collected waste (m^3)	58.346	49.252	57.764	84.944	81.538	66.37	±14.19
Collected waste (kg)	6700	5240	7220	10020	9620	7760	±1807.36
Specific weight of waste (kg/ m^3)	**114.8**	**106.4**	**125.0**	**118.0**	**118.0**	**116.44**	**±6.03**

The results of the study indicate a density of the uncompacted household waste with a value between 74.5 kg/m^3 and 101.7 kg/m^3, with an average value of 90.25 kg/m^3 ±10.28 in the cold period. The values in the warm period are between 106 kg/m^3 and 125 kg/m^3, with an average value of 116.44 kg/m^3 ±6.03, being higher during the warm season, because more vegetables are consumed this time of the year, that are denser than packaging waste.

However, the difference between the two periods is not considerably high and the results indicate a waste composition with an increased percentage of packaging waste that are bulky but light. This also indicates that waste generated in Cluj-Napoca has a great recycling potential, especially if recyclable waste is being collected separately at the generation source (Pop et al., 2016b).

The analysis of bibliographic sources indicated that there are considerable differences in waste density generated in Cluj-Napoca (Pop et al., 2016b). Nevertheless, due to presence of the high percentage of organic materials, household waste generated in Romania has relatively high density, between 300 and 350 kg/m^3.

5.4 Calorific value of household waste

A high calorific value indicates a higher burning capacity of waste with less additional fuel (JICA, 2005).

Calorific value of waste mostly depends on their humidity and composition. Therefore, based on the economic level of the population, in general waste can be characterised as presented in **Table 9**.

Table 9 Waste properties according to the economic level of the population Cointreau-Levine, 1994)

Properties /economic level	Low economic level	Medium economic level	High economic level
Humidity (%)	40-80	40-60	20-30
Density at transport (kg/m^3)	250-500	170-330	100-170
Minimum calorific value (kcal/kg)	800-1000	1000-1300	1500-2700

Calorific value of waste generated in Cluj-Napoca, according to the performed studies is 1330 kcal/kg (equivalent to 5,56 MJ or 5568 KJ) (PCN: 40(11+2+1+50) + 90x17- 46x60 = 1330 kcal/kg). According to **Table 9** this is assimilated to a medium to high economic level of the generators that is specific to the population living in Cluj-Napoca.

Waste incineration without additional fuel is possible at an inferior calorific value > 1000 kcal/kg, and the process of waste incineration with energy recovery requires an inferior calorific value between 1500 and 1650 kcal/kg (Zurbrügg, 2016).

Moreover, a waste incineration guide states that this process requires an inferior calorific value of at least 7 MJ/kg and that should not be lower than 6 MJ/kg (International Bank for reconstruction and Development, 1999).

Hence, considering all mentioned above, incineration does not represent a solution for waste generated in Cluj-Napoca, at least not without a preliminary sorting.

In cases of low waste calorific values and increased waste humidity, the optimum waste treatment solution is composting or anaerobic digestion (Yousuf & Rahman, 2007). These are also the solutions recommended for household waste generated in Cluj-Napoca considering its characteristics.

5.5 Evaluating attitudes and behaviour towards selective collection of waste

Involvement of waste generators in selective collection of waste is one of the issues that need to be tackled within a waste management system. Therefore, waste generators behaviour and attitude regarding selective collection of waste, recycling and other issues related to waste management are very important within an effective waste management process, helping in the monitoring stage (Pop et al. 2015c).

Pop et al. (2015c) published a study with the following objectives: (1) to determine whether the population has sufficient information regarding the selective collection of waste and is aware of its importance, (2) to identify the opinion and attitude of population regarding the current system of selective collection of waste, (3) to evaluate the behaviour of population concerning the selective collection of waste, and (4) to identify solutions to improve selective collection of waste based on the answers of the population such as: suggesting specific educational campaigns, suggesting ways to minimise the perceived barriers against selective collection of waste.

5.5.1 Awareness level of population on separate collection of waste at generation source

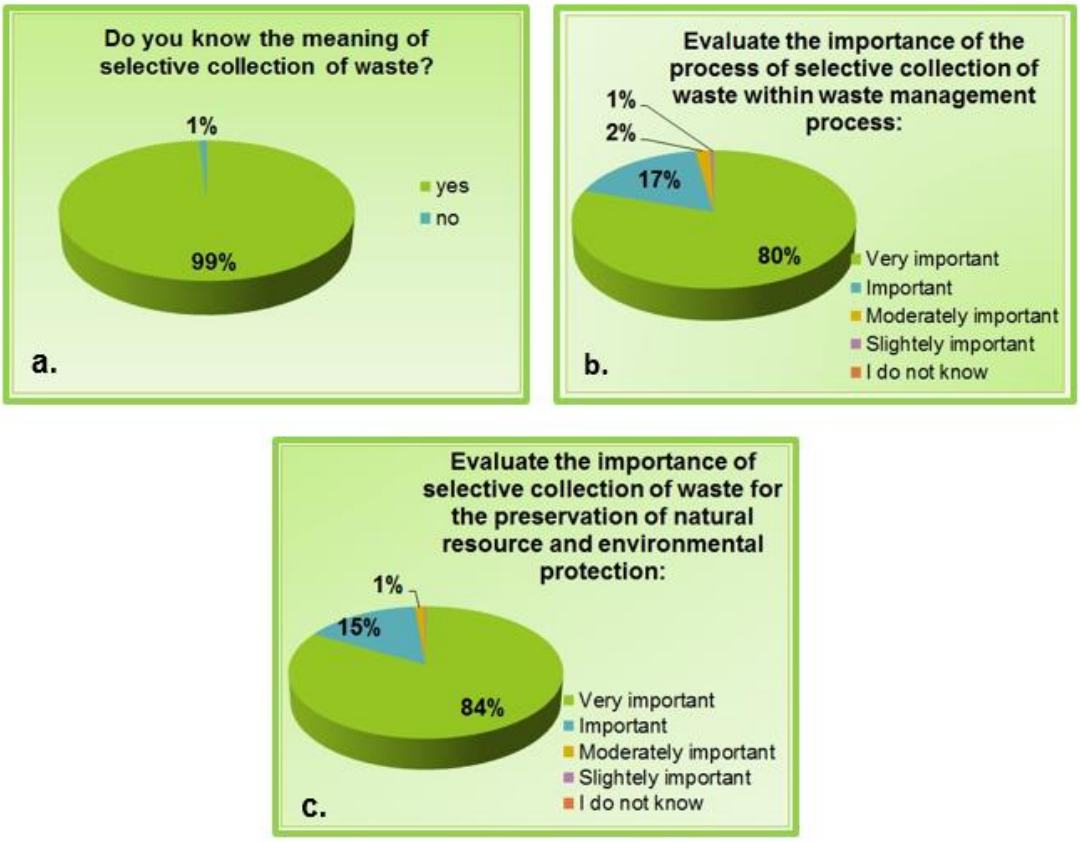

Figure 8. Degree of awareness regarding the selective collection of waste (Pop et al., 2015c)

The answers of the respondents indicate that 99% of them know the meaning of selective collection of waste (**Figure 8**a) (Pop et al. 2015c).

Moreover, they are aware of the importance of the selective collection of waste for the waste management process, and also for the preservation of natural resources and environmental protection, as shown in **Figure 8**b and **Figure 8**c (Pop et al. 2015c).

However, as noticed also in other studies (e.g. De Feo & De Gisi, 2010), the knowledge of rules, or the awareness degree does not really mean translation into action of selective collection at source by waste generators.

5.5.2 Aspects regarding the infrastrucure for separate collection of waste

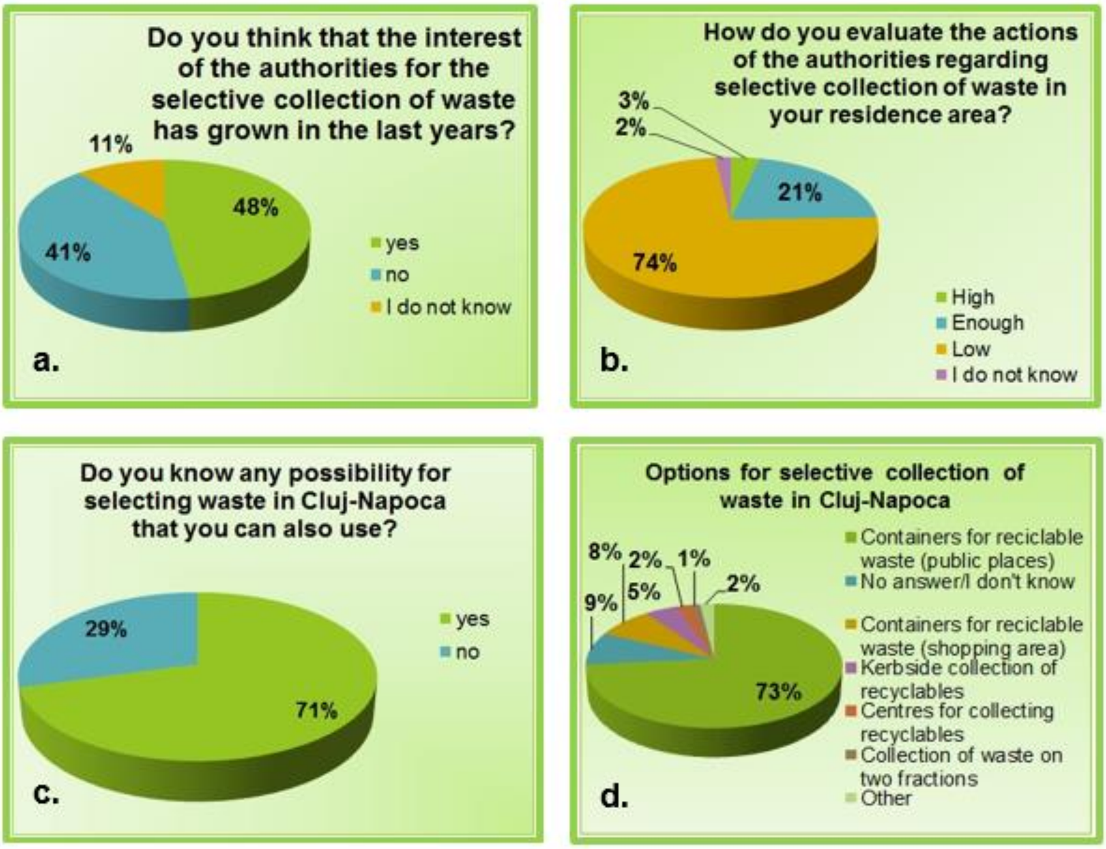

Figure 9 Opinion on the system of selective collection of waste (Pop et al., 2015c)

Respondents were asked to give their opinion on the implemented system of selective collection of waste in Cluj-Napoca. Only less than 50% of the respondents answered that, in their opinion, the interest of public authorities for waste management had increased over the last years, and evaluated the actions of the public authorities in this domain as being low (**Figure 9a, Figure 9b**). (Pop et al. 2015c).

As seen in **Figure 9**c, the majority of the respondents know at least one possibility to collect waste selectively. Moreover, although in Cluj-Napoca the curbside collection system on two fractions is implemented, and it is the most at hand, 73% of the respondents indicated the containers for recyclable waste located on public places as the facility they are using (**Figure 9**d) (Pop et al. 2015c).

The majority of the respondents indicated that the best measure to improve selective collection of waste would be to increase the number of containers for recyclable waste located on public places, and to increase the information, the education degree, and the raising awareness campaigns on selective collection of waste.

5.5.3 Behaviour regarding selective collection of waste and the determining factors

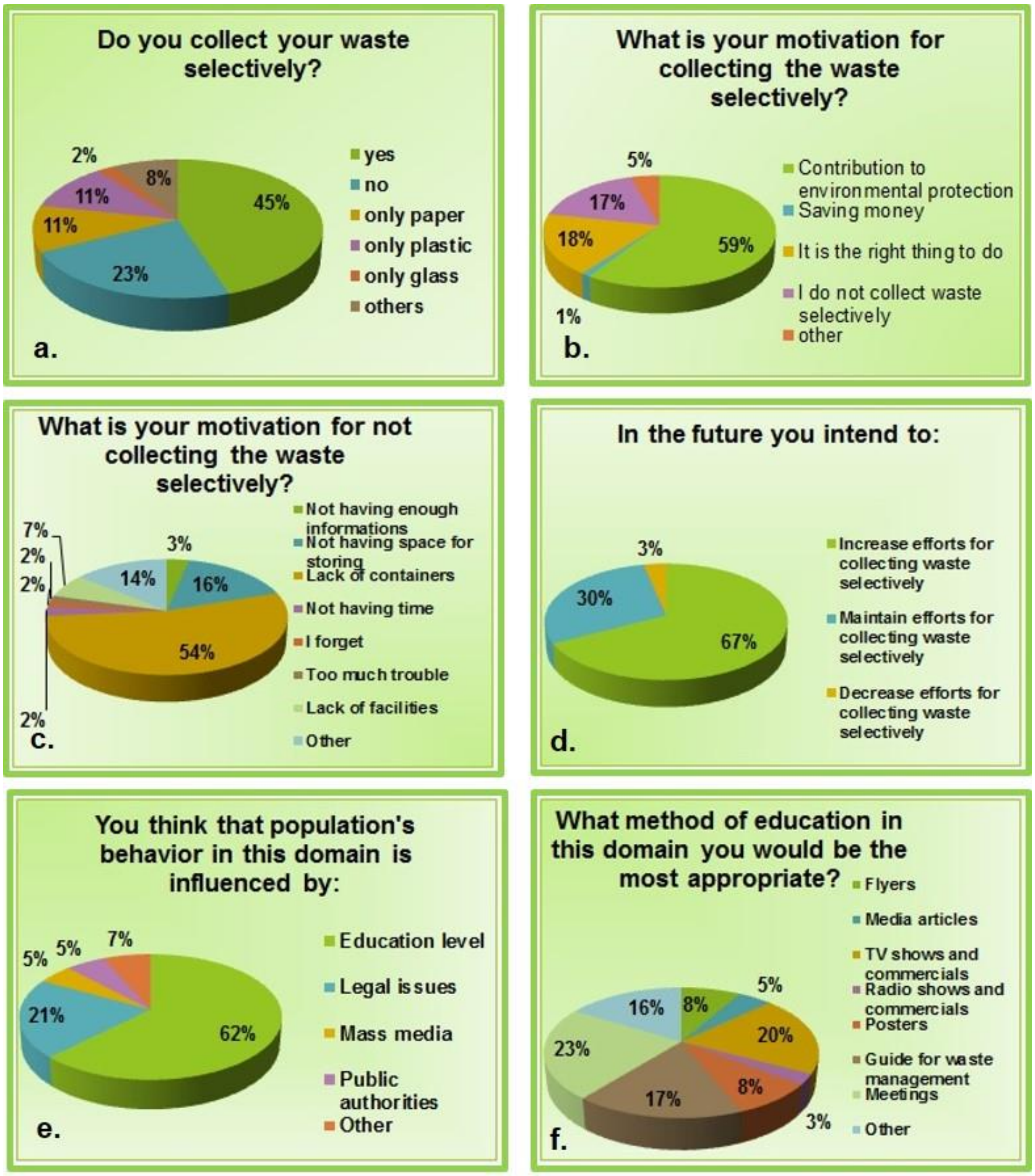

Figure 10 Present and future behaviour of waste generators regarding selective collection of waste (Pop et al., 2015c)

According to their answers, more that 78% state they select their waste, even if partially, and only 22.6% do not collect their waste selectively (**Figure 10**a), although it is clear that it is not entirely true. This large discrepancy between claiming recycling attitudes and actual behaviour was also emphasized by other studies (*e.g.* Omran and Schiopu, 2015). Moreover, 67% of the respondents declare they intend to increase their efforts regarding the selective collection of waste (**Figure 10**d.) (Pop et al. 2015c).

Moreover, the study indicated certain pro-environment behaviour factors that promote a proper behaviour in terms of selective collection of waste, that are mainly environmental protection and money saving (**Figure 10**b.). However, the major perceived barrier against selective collection of waste was also highlighted in **Figure 10**c, and it mainly consists in insufficient infrastructure for this specific purpose (Pop et al. 2015c).

Education is considered the main factor that influences behaviour on selective collection of waste, followed by legal issues (**Figure 10**e.), but there is not only one educational method that stands out in their preferences (**Figure 10**f.) (Pop et al. 2015c).

Furthermore, **Table 10** lists possible reasons that would make generators decrease their efforts of selecting waste.

Table 10 Reasons to reduce efforts regarding selective collection of waste as perceived by waste generators (Pop et al., 2015c)

Reasons that would determine you to reduce your efforts regarding selective collection of waste	No. of answers
Mixing selected waste and not recycling it by the sanitation companies	37
Lack of bins for recyclable waste	22
Long distance to the bins for recyclable waste	6
Lack of interest from behalf of public authorities and sanitation companies	6
Not collecting recyclable waste by sanitation companies	4
Other reasons	7
It is not the case/ I have no reasons to do that	51

Nevertheless, it is clear that in order to increase the number of persons that collect waste selectively, awareness on this matter must be increased and a transparency of the local public system must be promoted so that population understands the cycle of the waste after is being disposed of and until is being recycled. It is indicated that awareness and informing campaigns should rely not so much on the importance of selective collection of waste but on specific information regarding materials that can be recycled and transparency of waste treatment after is being collected. Since public satisfaction with the implemented system of selective collection of waste is rather low, actions should be taken in order to improve the system, mainly regarding facilities consisting in containers for recyclable waste, so that effort of population is being reduced (Pop et al., 2015c).

It can be estimated that the degree of selective collection of waste at generation rate will increase in the future considering the fact that the authorities initiated a project in order to install 100 underground waste collection facilities for population in residential areas with block of flats (HCL 11/2017). This system will resolve many issues: visual and odour aspects, it can be used for separate collection of waste on two fractions without being necessary to use separate bins for the collection of packaging waste that need a lot of space, and restricts access of the informal recycling sector. The underground system offers a greater visibility of the sticker that indicates what type of waste should be collected in a certain container, aspect that can facilitate waste separation together with the novelty of the system itself.

5.6 Life Cycle Analysis in the evaluation of the waste management system

5.6.1 Life Cycle Analysis in the evaluation of the household waste collection and transport in Cluj-Napoca

Life Cycle Impact Assessment (LCIA) using CML method – Normalisation, reveals that the highest impact of the scenarios is on the marine aquatic ecotoxicity followed by global warming and acidification; the lower impact of all scenarios is identified on Abiotic depletion and on Ozone layer depletion (**Figure 11**) (Pop et al., 2016a).

Moreover, the analysis indicates that the most favourable results for almost all impact categories in the transportation phase (CML method) is given by *Scenario* 1 that modelled selective collection and transport of waste on two fractions and a recycling degree of 35% of the generated waste (**Figure 11**) (Pop et al., 2016a).

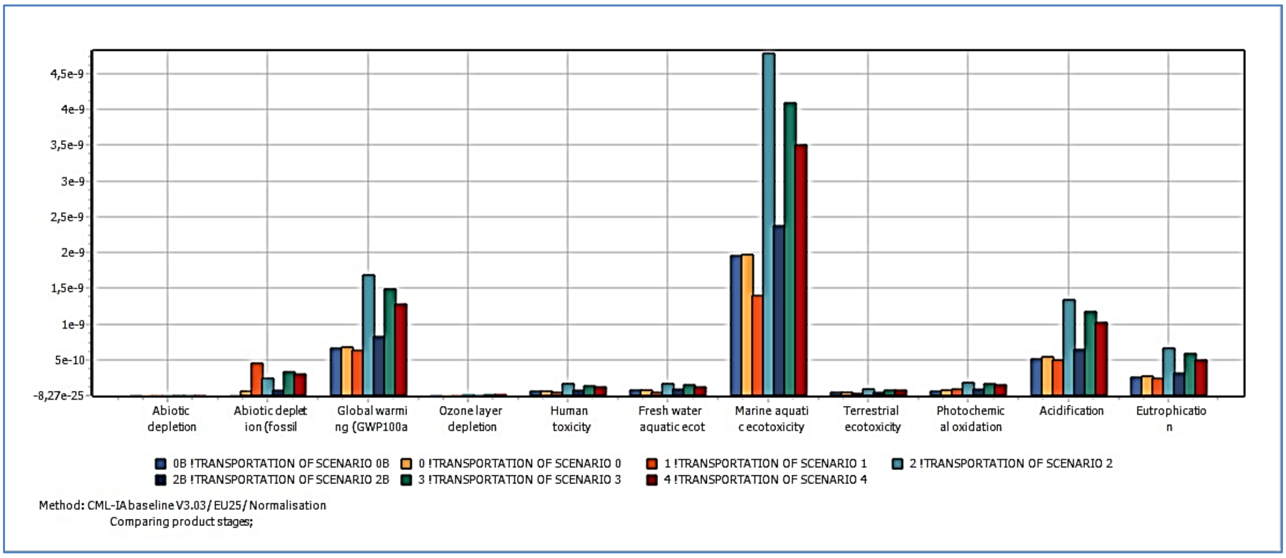

Figure 11 LCIA of transportation phase of all modelled Scenarios – CML –Normalisation (SimaPro8) (Pop et al., 2016a).

McDougall et al. (2001) agree that additional trucks involved in waste collection increase environmental impacts due to vehicle emissions. Moreover, it give solutions for that matter, such as: (1) using a specially designed truck with multiple compartments – two for recyclables and one for organic waste, alternative introduced in Worthing, United Kingdom, or (2) co-mingled collection with one truck but in different colour bags that are afterwards sorted, alternative used in Omaha, Nebraska (Pop et al., 2016a).

Efficiency in both economic and environmental terms means that waste management must be performed with the minimal use of transport (McDougall et al., 2001). Therefore, one of the main measures for environmental impact minimisation can be optimisation of distance transportation to waste recyclers; local investors should be encouraged by the local authorities, so that facilities of waste treatment and recycling would be created (Pop et al., 2016a).

5.6.2 Evaluation of the municipal waste management system in Cluj-Napoca using the Life Cycle Analysis

If reffering only to collection and transport processes, the optimal scenario, from the analysed ones, is Scenario 1, with selective collection on two fractions (Pop et al., 2016a). However, if analysing the whole waste management process, the study reveals that Scenario 4, the one that includes collection of waste on 5 fractions, a landfilling percentage of 72%, and a recycling percentage of 28% of the generated waste is the optimal scenario. Scenario 4 has the lowest impact on the analysed environmental factors of the ones taken into consideration, as seen in **Figure 12** and **Figure 13**.

When referring to impact categories, **Figure 12** indicates that the highest impact of scenarios is on Climate change human health, Particulate matter formation, Climate change ecosystems and Freshwater eutrophication.

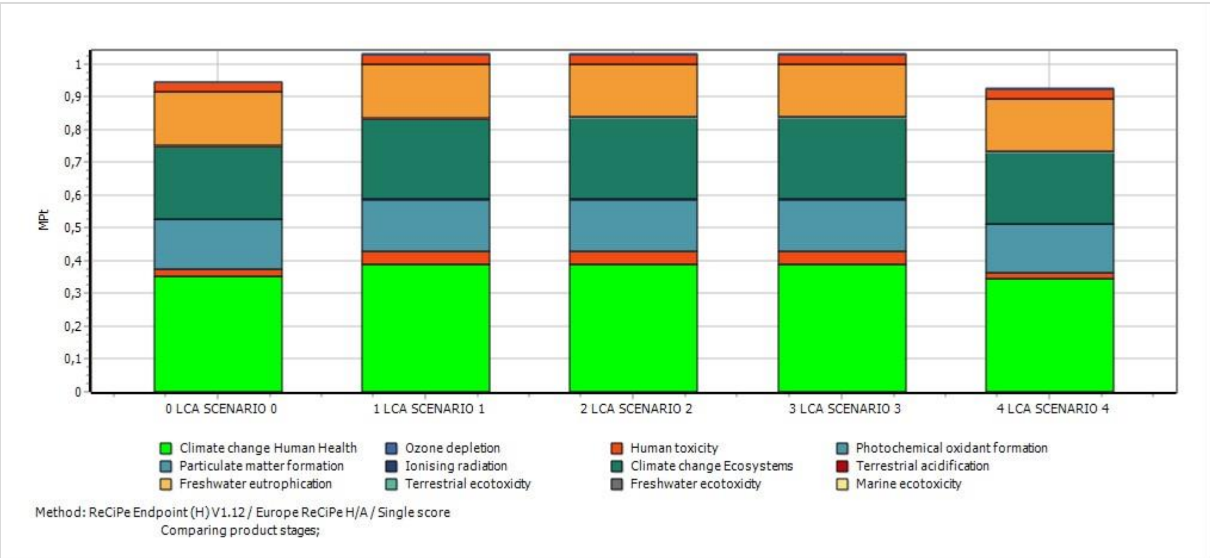

Figure 12 Life Cycle Impact Assessment of waste management system - scenarios 0, 1, 2, 3 and 4 – ReCiPe Method - Single Score (SimaPro8) (Pop et al., 2016a)

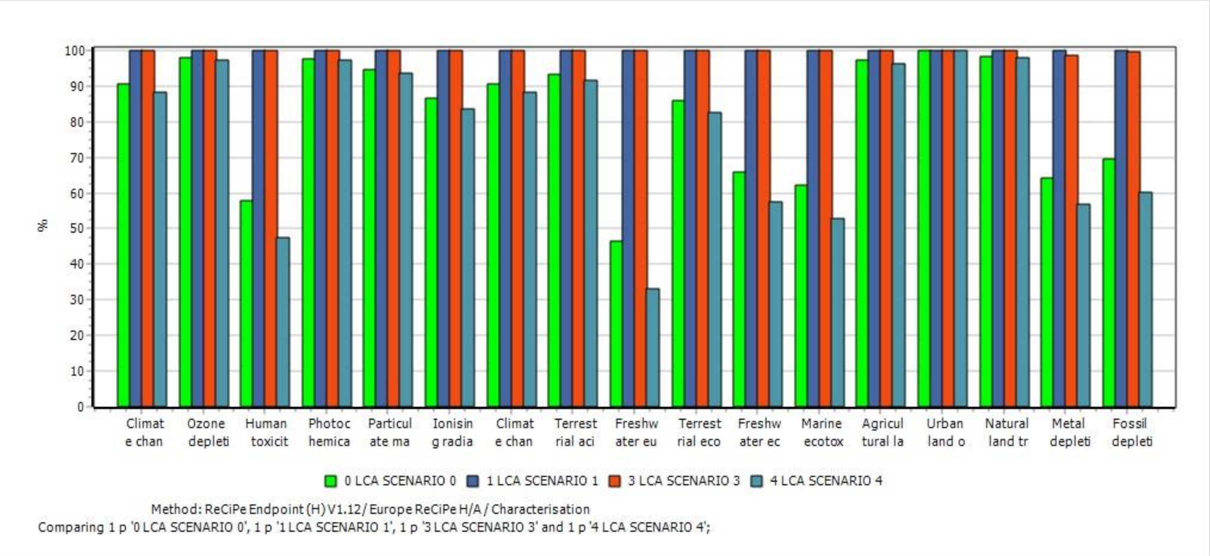

Figure 13 Life Cycle Impact Assessment of of waste management system - scenarios 0, 1, 3 and 4 – ReCiPe Endpoint Method - Characterisation (SimaPro8)

The fact that the scenarios with the highest percent of recycling (35%) have the greatest environmental impact could indicate that the energy used in recycling and transport have an additional environmental impact. However, it would have been expected that scenarios with the highest percent of recycling to have the lowest environmental impact.

The results mentioned above lead to the assumption that transport of recyclable materials to a distance of 340- 570 km has a significant negative environmental impact, fact that increases the impact of scenarios with high recycling percent.

Similarly, in a study that evaluated waste management in Sorocaba, Brazil, using Life Cycle Assessment, Mancini et al. (2016) also concluded that transport is responsible for the highest percentage of the environmental impact (77.9%) followed by the methane emitted by the landfill (13.2%). However, the study did not assess also the recycling process. Moreover, in a study on waste management in Piedade, São Paulo, Paes et al. (2014) also identified that transport together with landfill emissions have the highest impact in terms of climate change. Bovea et al. (2010), in a LCA study performed on waste management in Castellon de la Plana, Spain, also identified that the fuel consumed in the process has a contribution to the environmental factors that were analysed.

The impact derived from the transport stage in case of recycling could be the reason for the fact that the present waste management system from Cluj-Napoca, (with only 6% recycling to a distance of 340- 570 km and a 94% landfilling described in Scenario 0) has a lower impact than scenarios with a higher level of recycling. Hence, the present system does not seem to be the one with the highest environmental impact although the fact that recycling targets are not accomplished has to be taken into consideration.

It must be mentioned that although the study aims to identify optimal waste management solutions for Cluj-Napoca area, there were no data available on the temporary landfill that was being used. Therefore, a landfill from Ecoinvent database was used to model the scenarios in SimaPro Software. The landfill used by Cluj-Napoca municipality is temporary, not ecological, only placed on a concrete platform meanwhile the chosen variant available in the database has a landfill gas and leachate collection system but it is also for the untreated municipal waste which was considered the best available alternative.

However, the tree analyses of the scenarios presented in this workindicate that the landfill process gives the highest percentage of the impact.

Similarly, many LCA studies in waste management identified that landfilling is the least desirable option from the environmental point of view (Manfredi et al., 2011b, Abeliotis, 2011; Pecora et al., 2012, Laurent et al., 2014b, etc.). However, the study developed by Manfredi et al., (2011b) by means of LCA – model EASWASTE (Environmental Assessment of Solid Waste Systems and Technologies), showed that from the point of view of the environmental performance landfilling with energy recovery of organic waste and recyclable paper is comparable to organic waste composting and incineration of recyclable paper.

Furthermore, the same aspect is indicated by the comparison between the impact of recycling and landfill processes. However, in comparison to other studies (Bovea et al., 2010; Sánchez, 2012; Ghinea et al, 2014, etc.), the present LCIA does not indicate positive impact of the recycling process.

Recycling is considered to be “the ideal solution for both economic and environmental principles” and has multiple environmental benefits like energy saving compared to production from virgin material and conservation of natural resources (Pikoń, 2015). However, Pikoń (2015) notes that “recycling processes could also have significant impact on the power system and finally on the environment”.

However, the results of an LCA study is strongly dependent on local conditions such as waste composition or specific characteristics related to waste treatment. Although a previous recent study identified the composition of household waste in Cluj-Napoca, other characteristics of waste management system were still a challenge (energy used in waste recycling for each material, characteristics of the landfill, etc.).

In this context, as a European Commission report (2011) on Life Cycle Thinking and Assessment for Waste Management also observes, Life Cycle Assessment carried out under different conditions could lead to different conclusions. Moreover, a review study on LCA studies of waste management systems performed by Laurent et al. (2014b) also found that there is little decisive agreement in the conclusions of the 222 studies they analysed

5.7 Economic analysis and the recycling and recovery potential of waste generated in Cluj-Napoca

The obtained data regarding economic analysis and the recycling and recovery potential of waste were published by Pop et al. (2016b). The results are prsented in **Table 11**, **Table 12** and **Table 13** (Pop et al., 2016b).

Table 11 Economic analysis of waste treatment – Scenario 1 – recycling 27%, composting 58%, incinerating 3% and landfilling 12% (Pop et al., 2016b)

Waste components	**Quantity of household waste/month-2013 (t) (Local Council Decision no. 529/2014)**	**Composition of wet fraction of waste generated in Cluj-Napoca (Pop et al., 2015c) (%)**	**€/monthly estimated quantity (aveage in 2013 (H.C.L. 529/2014)**			
			↑***Recycling*** *potential* (**27%** of the total generated waste)	↓***Composting*** *potential* (**58%**of the total generated waste)	↓***Incinerating*** *costs* (**3%**of the total generated waste)	↓***Landfilling*** *costs* (**12%** of the total generated waste)
Organic waste	3,322.43	58	-	61,930.16		
Paper	458.27	8	38,952.67			
Plastic	801.97	14	166,007.10			
Glass	171.85	3	4,193.14			
Wood	57.28	1	-		1,019.64	
Metal	114.57	2	8,913.29		-	
Textile	114.57	2	-		2,039.29	
WEEE	-	0	-			
Hazardous waste	-	0	-			
Other	687.40	12	-			11,685.80
TOTAL	5,728.33		**218,066.19**	**61,930.16**	**3,058.93**	**11,685.80**
			↑218,066.19		**↓76,674.89**	

Table 12 Economic analysis of waste treatment – Scenario 2 – recycling 25%, composting 45%, and landfilling 30% (Pop et al., 2016b)

Waste components	**Quantity of household waste/month-2013 (t) (Local Council Decision no. 529/2014)**	**Composition of wet fraction of waste generated in Cluj-Napoca (estimated according to the treating possibility) (%)**	**€/monthly estimated quantity (aveage in 2013 (H.C.L. 529/2014)**		
			↑***Recycling*** *potential* (**25%**of the total generated waste)	↓***Composting*** *potential* (**45%** of the total generated waste)	***Landfilling*** *costs* (**30%** of the total generated waste)
Organic waste	2,577.75	45	-	48,049.26	
Paper	286.42	5	24,345.42		
Plastic	801.97	14	166,007.10		
low quality paper	171.85	3			2,921.45

Glass	171.85	3	4,193.14		
Wood	57.28	1	-		
Metal	114.57	2	8,913.29		
Textile	114.57	2	-		1,947.63
WEEE	-	0	-		
Hazardous waste	-	0	-		
Other	1,432.08	25	-		24,345.42
TOTAL	**5,728.33**		**203,458.94**	**48,049.26**	**29,214.50**
			↑203,458.94	**↓77,263.77**	

Table 13 Economic analysis of waste treatment – Scenario 3 – recycling 22%, composting 40%, incinerating 2% and landfilling 36% (Pop et al., 2016b)

Waste components	**Quantity of household waste/month-2013 (t) (Local Council Decision no. 529/2014)**	**Composition of wet fraction of waste generated in Cluj-Napoca (estimated according to the treating possibility) (%)**	**€/monthly estimated quantity (aveage in 2013 (H.C.L. 529/2014)**			
			↑***Recycling*** *potential* (**22%** of the total generated waste)	↓***Composting*** *potential* (**40%** of the total generated waste)	↓***Incineratin g*** *costs* (**2%** of the total generated waste)	↓***Landfilling*** *costs* (**36%** of the total generated waste)
Organic waste	2,291.33	40	-	42,710.45		
Paper	229.13	4	19,476.33			
Plastic	687.40	12	142.291.80			
Low quality paper	171.85	3				2,921.45
Glass	171.85	3	4,193.14			
Wood	57.28	1	-			
Metal	114.57	2	8,913.29		-	
Textile	114.57	2	-		2,039.29	
WEEE	-	0	-			
Hazardous waste	-	0	-			
Other	1,890.35	33	-			32,135.95
TOTAL	**5,728.33**		**174,874.56**	**42,710.45**	**2,039.29**	**35,057.40**
			↑174,874.56		**↓79.807,14**	

All presented scenarios (**Table 11**, **Table 12** and **Table 13**) indicate that a proper waste treatment could be a sustainable activity from the economic point of view even if additional costs are included; it only has to be performed according to UE regulations so that environmental requirements are also accomplished. Moreover, if packaging waste is involved, extra profit is added to the revenue calculated above, through Producer Responsibility Organizations (Pop et al., 2016b).

A brief calculation indicates that the cost of landfilling the whole quantity generated in a month would be 97,381.67 € while the revenue gained from recycling the 27% would be 218,066.19 € (Pop et al., 2016b).

Therefore, more than the economic benefits, a proper waste management system that includes recycling, composting, incineration and low degree of landfilling has numerous advantages such as minimising environmental issues related to improper waste management, natural resources economy, and avoiding penalties coming from the European Commission for not accomplishing waste recycling and recovery targets (Pop et al., 2016b).

5.8 Directions for a proper waste management in Cluj-Napoca

After analysing the waste characterisation studies presented above, directions for a proper waste management system in Cluj-Napoca were identified.

Known by waste management stakeholders, waste characteristics can contribute to identifying environmental issues that must be improved within the waste management systems. Hence, the aspects that need serious improvement are mainly related to reduction of landfilled waste and increasing the recycled amount of waste with the involvement of population involvement in source separation of waste.

Hence, measures that can be taken in order to improve waste management, to implement ‘zero waste’ strategies are listed below:

- creating a working group formed by professionals that organize frequent activities to engage population in performing a correct waste management;
- engaging population in waste separation at source to be considered a separate activity that is delegated by the municipality to a company specialised in raising awareness campaigns;
- applying economic instruments (different funds or grants) through universities in order to increase population awareness at local level;
- investing in sorting facilities so that only a low percent of waste should be landfilled;
- informing the population on the recovery of organic waste through composting at the generation source in case of population living in residential areas with single family houses, and supporting them to use this treatment option;
- applying higher taxes for waste landfilling so that waste landfilling decreases;
- implementing a tax for waste generators that do not collect waste separately at the generation source;
- reusing programmes (old products fairies) organised or facilitated by the municipality;
- increasing the number of campaigns for different waste streams (WEEE, glass, hazardous waste, bulky waste, etc.) financed by producers or municipality;
- organizing community repairing centres for different products in order to prevent waste formation;

- increasing the number of underground waste collection facilities for the population living in block of flats;
- applying the PAYT system for waste generators;
- partnerships between local authorities and universities in order to improve waste management through research with practical application;
- treatment of organic waste through anaerobic digestion;
- excluding incineration from waste management unless it is co-incineration of a fraction resulted from waste sorting;

CONCLUSIONS

Household waste generated in Cluj-Napoca is composed of: organic waste (50.4%), plastic waste (17.1%), paper/cardboard (10.6%), others (11.7%), glass (5.3%), metals (2.2%), textiles (1.8%), WEEE (0.3%) and wood (0.6%) (Pop et al., 2015d). The *composition* indicates that 50% of the generated waste has a recovery potential through composting or anaerobic degradation and a percentage higher than 37% can be recycled. However, in analysing the composition of waste generated in Cluj-Napoca, the influence of the informal sector must be taken into account (Pop et al., 2015d).

A study performed in 2016 within the doctoral stage determined a *waste generation rate* of 318 kg/person·year ±76.65 kg/person·year, similar to the one specified in the documentation of the sanitation service of Cluj-Napoca – 292 kg/person·year, elaborated in 2010; a tendency of increasing the waste generation rate can be observed.

According to the study performed through determinations in the warm season and also cold season, in 2016, household waste generated in Cluj-Napoca has a relative low *average density* of 102.15 kg/m^3 ±15.63 kg/m^3, meaning that household waste is composed of a high percentage of packaging waste that are bulky but weight less. The low waste density support the thesis conclusions regarding the increased recycling potential of waste generated in Cluj-Napoca.

The determined *calorific value* of 1330 kcal/kg, a relative low value, indicates that waste generated in Cluj-Napoca cannot be treated through incineration. However, anaerobic digestion is the recommended treatment option also suggested by the National Waste Management Plan (2017).

The survey performed by Pop et al. (2015c), applied to 425 persons living in Cluj-Napoca indicates that population (1) has knowledge regarding separate collection of waste, (2) is aware of the importance of this action within waste management process and for environmental protection and (3) considers that a greater involvement degree of the authorities within the waste management is required. Therefore, directions that can be followed in order to improve waste management were identified: improving the accessibility of waste collection infrastructure, increasing the trust in the public waste management system, and increasing the awareness degree regarding waste separate collection; these measures can increase the degree of population involvement in waste management.

The life cycle analysis applied to waste collection and transport highlighted that the scenario with the highest environmental impact is the one characterised by waste collection on two separate fractions and transport to recycling of 35% of the generated waste. Moreover, an additional impact is due to waste transport to recycling, at a distance of 340-470 km, since there are no recycling facilities near Cluj-Napoca (Pop et al., 2016a). However, the life cycle analysis applied to the whole waste management process from Cluj-Napoca indicated that Scenario 4, that implies waste recycling of 25% from the generated waste and separate collection on 5 fractions, is the best option from the analysed scenarios in terms of environmental impact.

These results lead to certain measures that need to be adopted in order to improve waste management in Cluj-Napoca: waste collection on two separate fractions; recycling should be performed considering the closest facility to the generation point so that the impact generated by the transport to be minimised; raising the awareness degree on source separation as the first stage to waste recycling, using a two compartment waste collection facility in order to reduce the operating costs at the sorting facility; integrating a sorting facility within waste management process so that a higher percentage of recyclables to be diverted from landfilling; designing an ecologic landfill that also includes leachate and gas collection; organic waste composting; increasing the recycling rate to 35% of the generated waste (Pop et al., 2016a).

An analysis of various scenarios of waste management from the economic point of view indicated that a proper waste management that also includes recycling, composting and incineration of a small percentage of waste, not only would have environmental benefits, but it would also have economic benefits. Therefore, from this point of view measures such as improving the design of waste collection facilities so that source separation of waste would be easier for population and integrating a composting and a sorting facility in the waste management process, should be adopted at the local level (Pop et al., 2016b).

Studies on waste management are very important in Romania since waste sanitation services are delegated for a period of at least 8 years. In this time interval, the system is rather rigid, considering the investment required, so it needs to be thoroughly documented in order to assure correct involvement of all involved stakeholders.

Therefore, in the context of a continuous growth of waste in a developing economy, the undertakings of the doctoral thesis contribute to integrating the waste management within the circular economy.

RESULTS DISSEMINATION

International Conferences and National Conferences with International Participation:

- **Pop I. N.,** Baciu C., Bican-Brișan N., 2014, Studii de caracterizare a deșeurilor – Suport pentru sisteme performante de gestiune a deșeurilor, oral presentation (poster), ***ConferințaAntreprenoriat, Mediu de afaceri şi dezvoltare durabilă,*** 3-4 iulie 2014, Universitatea Tehnică, Cluj-Napoca.

- **Pop I. N.,** Baciu C., Bican-Brișan N., 2014, Survey of Household Waste Composition in Cluj-Napoca, Romania. Preliminary Resuts, oral presentation (poster), **ELSEDIMA - *“Environmental Legislation, Safety Engineering and Disaster Management”*** *a 10-a Ediţie,* 18-19 septembrie 2014, Cluj-Napoca.

- **Pop I. N.,** Baciu C., Briciu C., Tofana V., Bican-Brişan N., 2015**,** Informal Sector Participation in Solid Waste Management – Study Case: Cluj-Napoca, Romania,oral presentation (poster), **Conferința Internațională *U.A.B. – B.EN.A. CONFERENCE, "EnvironmentalEngineering and Sustainable Development",*** ALBA IULIA, 28-30 Mai, 2015.

- **Pop I. N.,**Baciu C., Rogozan G. C., Bican-Brişan N., 2015, *Seasonal Survey of Household Waste Composition Generated in Cluj-Napoca, Romania*, oral presentation (poster),***Congresul Mondial ISWA 2015***, Let’s make the most of our resources and waste, din Antwerp, Belgia, 7-9 septembrie 2015.

- **Pop I. N.,** Baciu C., Bican-Brişan N., Muntean O. L., CostinD., Rogozan G. C., 2015, Evaluating Attitudes And Behaviour Towards Separate Collection Of Waste In Cluj-Napoca City, Romania, oral presentation (poster), ***10th National Symposium with International Participation Environment & Progress,***30 Octombrie 2015, Cluj-Napoca.

- **Pop I. N.,**Sánchez de Ramírez G. M.,Baciu C., Bican-Brişan N., Muntean O. L., CostinD., 2016, Life Cycle Analysis in Evaluation of Household Waste Collection and Transport in Cluj-Napoca, Romania**,** oral presentation (poster), ***ELSEDIMA 11TH International Conference***, 26 - 28 MAI 2016, Cluj-Napoca.

- **Pop I. N.,**Baciu C., Bican-Brişan N., Muntean O. L., CostinD., 2016, Recycling and Recovery Potential of Household Waste Generated in Cluj-Napoca Municipality, Romania, oral presentation (poster), ***Congresul Mondial ISWA 2016,*** Forward Together – Uniting Ideas for Successful Waste Management, dinNovi Sad, Serbia, 19-21 septembrie 2016.

- Nicodin A., Pop F.,. WilsonD. C., **Pop I. N.,** Soos R.,2016, Analysing the Waste Management Priorities for the City of Cluj-Napoca, Romania, using the Wasteaware Benchmark Indicators, oral presentation (poster), ***Congresul Mondial ISWA 2016,*** Forward Together – Uniting Ideas for Successful Waste Management, dinNovi Sad, Serbia, 19-21 septembrie 2016.

- **Pop I. N.,**Sánchez de Ramírez G. M., Baciu C., Bican-Brişan N., 2017, Evaluation of the Municipal Waste Management System in Cluj-Napoca (Romania) Using the Life Cycle Analysis, oral presentation (poster), ***International U.A.B. – B.EN.A. Conference Environmental Engineering and Sustainable Development***, Alba Iulia,25-27 Mai 2017.

Published articles

- **Pop I. N.,** Baciu C., Bican-Brişan N., 2014, Studii de caracterizare a deşeurilor – Suport pentru sisteme performante de gestiune a deşeurilor, ***Volumul Antreprenoriat Mediu de Afacerişi Dezvoltare Durabilă***, coord. Vasile Filip Soporan, Ancuţa Elena Tiuc, Casa Cărţii de Ştiinţă, Cluj-Napoca, 2014, p. 25-36.

- **Pop I. N.,** Baciu C., Bican-Brişan N., 2015, „Survey of Household Waste Composition Generatedin Cluj-Napoca, Romania During the Summer Season", ***Environmental Engineering and Management Journal,***November 2015, Vol.14, No. 11, 2643-2651.

- **Pop I. N.,** Baciu C., Briciu C., Tofana V., Bican-Brişan N.,2015,Informal Sector Participation in Solid Waste Management – Study Case: Cluj-Napoca, Romania***,ECOTERRA - Journal of Environmental Research and Protection,*** 2015, Volume 12, Issue 3, p. 36-41.

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