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ASSESSMENT OF ENVIRONMENTAL IMPACTS OF MUNICIPAL SOLID WASTE MANAGEMENT IN IASI, ROMANIA

***Cristina GHINEA[1,2], Andreea SPRANCEANA[1], Diana Elena COMANITA[1,3], Gabriela CONSTANTINESCU[2], Maria GAVRILESCU[1,4]**
[1]*"Gheorghe Asachi" Technical University of Iasi, Faculty of Chemical Engineering and Environmental Protection, Department of Environmental Engineering and Management, 73 Prof. dr. doc. Dimitrie Mangeron Street, 700050 Iasi, Romania*
[2]*Stefan cel Mare University of Suceava, Faculty of Food Engineering, 13 Universitatii Street, 720229 Suceava, Romania,* cbghinea@yahoo.com
[3]*"Alexandru Ioan Cuza" University of Iasi, 11 Carol I Street, 700506 Iasi, Romania*
[4]*Academy of Romanian Scientists, 54 Splaiul Independentei, RO-050094 Bucharest, Romania*
*Corresponding author
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Abstract: *The aim of this paper was to evaluate from environmental point of view the municipal solid waste management (MSWM) from Iasi, Romania considering two different systems existent in 2008 and 2013, respectively. Therefore, in 2008 the MSWM system included temporary storage of waste in containers, collection and transport and finally landfilling in the old landfill at Tomesti. After 2009 the MSWM system was improved: a new landfill at Tutora was developed according to the legislation, which also included leachate collection and treatment and biogas collection systems; and a sorting and composting plants were opened. In this study we have applied Life Cycle Assessment (LCA) methodology for the evaluation of these two MSWM systems. After analyzing all the results it can be concluded that the environmental impacts of the MSWM system existent in 2013 are lower compared to the environmental impacts of system from 2008, but they are still negative impacts and an improvement of MSWM system is urgently required.*

Keywords: *abiotic depletion, climate change, environment, life cycle assessment, solid waste*

1. Introduction

The amount of solid waste generated in cities over the years increased due to a continuous welfare improving and changes in the life style. Application of environmental, institutional, financial, economic and social tools is required to guarantee a sustainable waste management [1-4]. Different tools for environmental impacts assessment were developed but one of the most commonly used is life-cycle assessment (LCA) [5]. During the 1990s LCA was developed rapidly and become a useful tool in decision-making processes and system performance documentation [6].
The result of an LCA study expresses the performance of the total system life cycle as well as for single life cycle stages.
Up to now, for environmental assessment of the municipal solid waste treatment and disposal, several models based on LCA methodology were developed and applied [7-11].
In the situation when municipal solid waste management systems in different communities are characterized by a quite low level of recycling and recovery of materials and is limited to only some

activities: temporary storage, collection and transport of mixed waste directly to the landfill site located outside the city, these tools allow the results modeling and scenario simulation based on Integrated waste management and LCA concepts [12-13]. In this paper we have applied one LCA tool (GaBi software) to evaluate the environmental impacts of municipal solid waste management (MSWM) system in Iasi, Romania.

For this study we have considered two MSWM systems:

1) the MSWM system existent in 2008 and 2) the MSWM system existent in 2013, both from Iasi. In order to achieve this aim, all the specific steps in an LCA studies were covered: goal setting, establishment of system boundaries, functional units setting and inventory analysis.

2. Waste management in Iasi, Romania

Iasi County is a part of the Region 1 North East (established by Law no. 315/2004 on regional development in Romania), which also includes Botosani, Suceava, Neamt, Bacau and Vaslui counties. Iasi area is 5475.58 km^2, representing 2.3% of the country, being the 23rd largest county in Romania [14].

In 2005 Iasi County had 813943 inhabitants, population increasing in 2008 to 826552 inhabitants with a density of 151 inhabitants per km^2.

In 2013 population number was 849670 from which 404611 in the urban area. Iasi relief morphology is characterized by two major relief units: a high unit (in the West and South) with an average altitude of 300-350 meters and another plain-looking lower (in North, North-East) with an average altitude of 100-150 m. Plateau area is represented by the Suceava Plateau and Central Plateau Moldovan. Plain area is represented by the Plain of Moldavia, namely through its subdivision Jijia-Bahlui Plain, which occupies almost half of the county [14]. Iasi territory belongs to the temperate zone - continental pronounced, under Atlantic anticyclone and the influence of Euro-Asian. The average annual temperature of air is between 8°C - 9°C in the West and South, and between 9°C - 10°C in the North and Northeast, declining with increasing in altitude. Main economic activities in Iasi are represented by trade and transactions properties. In Iasi County there are concerns about the development of organic farming by using bio-fertilizer and organic fertilizers. They were distributed over an area 16100 ha, representing 6.27% of the arable land [14-17]. Municipal solid waste include the waste generated and collected (mixed or selective), as well as uncollected waste. Collected waste represents the waste generated which are collected by sanitation services.

The increase of the amount of municipal waste generated is closely related to *population growth* and higher *consumption of population* [14].

The waste composition consists in **organic waste**, which represents the fraction with the major percentage (approximately 40%) followed by **paper and cardboard, plastic, glass, metals**. The municipal solid waste indicators for Iasi, Region NE and Romania are illustrated in Fig. 1.

2.1. MSWM system in 2008

Municipal solid waste management system existent in 2008 included temporary storage in containers, collection and transport and finally landfilling (in the old landfill) without treatment of leachate and biogas collection (Fig. 2).

2.2. MSWM system in 2013

Municipal solid waste management system in Iasi, in 2013 besides landfilling included also sorting and composting (Fig. 3).

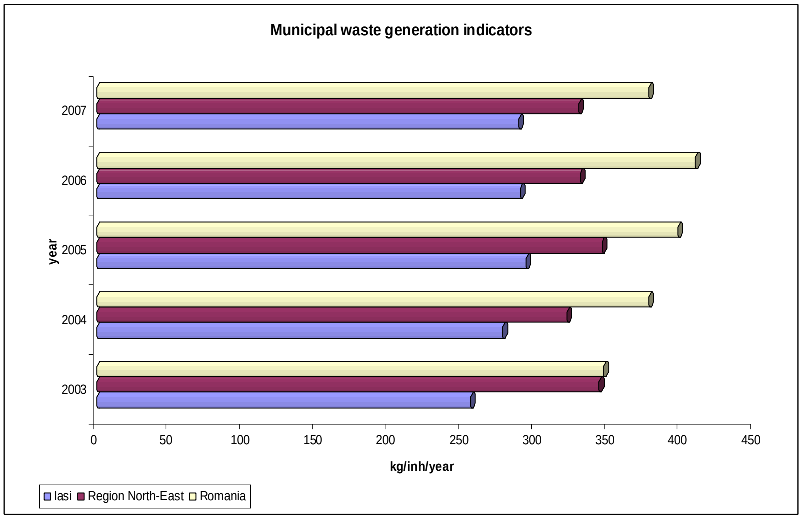

Fig. 1. Municipal waste generation indicators [15, 17, 18]

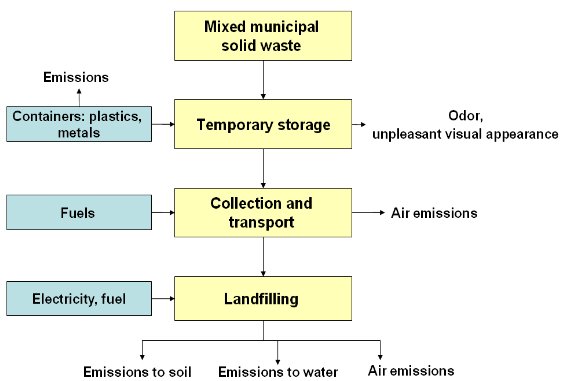

Fig. 2. Municipal solid waste management in 2008, Iasi, Romania

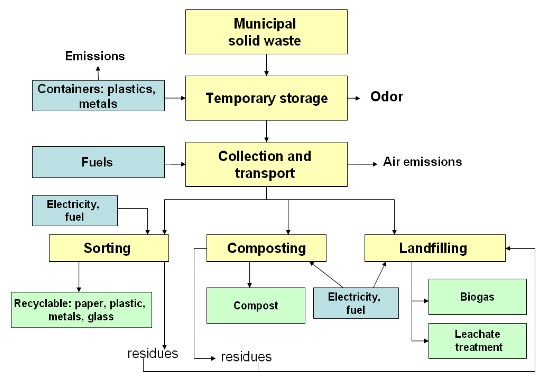

Fig. 3. Municipal solid waste management in 2013, Iasi, Romania

3. Life cycle assessment of municipal solid waste management system

3.1. Goal

The goal of this study was to evaluate from environmental point of view two different municipal solid waste management systems existent in Iasi, Romania in 2008 and 2013 and to compare the environmental impacts of these systems. The functional unit is represented by the amount of solid waste that was generated in Iasi, in these two years.

3.2. Inventory analysis

In the inventory analysis phase are collected, calculated and estimated all the inputs and outputs for each process included in MSWM systems considered for the evaluation. For assessment of a waste management system is necessary the knowledge of the waste amounts generated, fractions (Fig. 4) and elemental composition of waste fractions. For the evaluation of temporary storage process we considered the number of containers and the annual quantity of material required for containers fabrication.

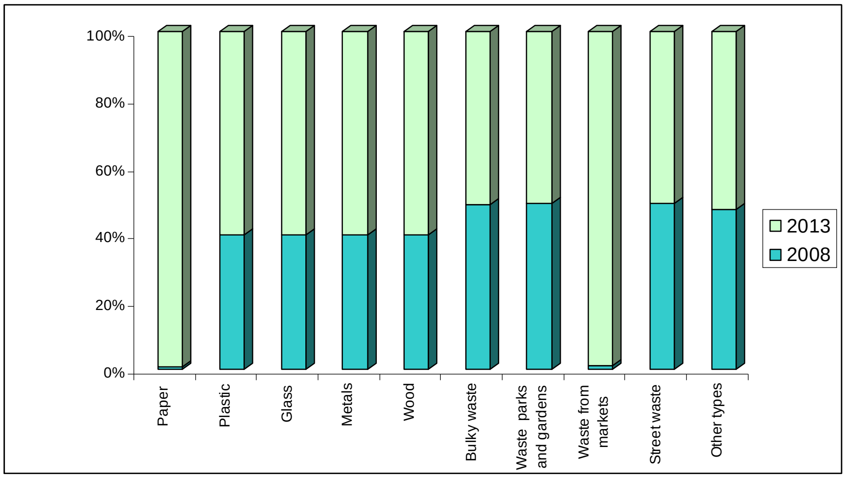

Fig. 4. Waste generated in 2008 and 2013

The following data were considered for 2013: 310 metal containers (4 m^3); 4248 metal containers (1.1 m^3); 244 plastic containers (1.1 m^3); 10904 plastic bins of 240 L and 2146 plastic bins of 120 L.

In order to calculate the amount of material, we considered the following: 1 container 4 m^3 from metal has 463.6 kg metal and 9.1 kg plastic; 1 container of 1.1 m^3 metal has 127.5 kg metals and 2.5 kg plastic; 1 container of 1.1 m^3 plastic has 51 kg plastic and 1.3 kg iron; 1 bin of 240 L has 13.8 kg plastic and 0.2 kg metal [19].

The necessary data for collection and transport processes include: number of vehicle and loading capacity, transport distance, fuel consumption and emissions resulted from fuel consumption. Iasi had 30 vehicles in 2008 and 36 vehicles in 2013, for waste collection and transportation. Diesel consumption is estimated to be 30 L/100 km for truck of 18 m^3 and 25 L/100 km for truck of 12 m^3 [20]. Emissions from the combustion of diesel fuel used to transport waste are shown in Table 1.

Tutora sorting station has an area of 1622 m^2, a 51,000 tons/year capacity and 2 sorting bands by 15 m each. There are sorted paper, cardboard, glass, plastic, metals which are sent for recycling; biodegradable waste are sent to the composting station and street and mixed waste are sent to landfilling.

Table 1

Emissions from burning diesel fuel used for waste transportation

Emissions	2008 (kg)	2013 (kg)
CO_2	121211	146167
CO	513	619
NO_x	1428	1723
N_2O	3.05	3.6
PM10	65.8	79.3
CH_4	6.7	8.1
SO_2	192	232
Hydrocarbons	136	164

Consumption or resources used for sorting and pre-cleaning of recyclable materials are given by [21]. The composting station from Tutora covers an area of 2,100 m^2 and has a capacity of 95,000 tons/year. The emission factors for composting are provided by [21].

The inputs for landfilling process consists of the amounts of waste fractions landfilled and fuel consumption, while the outputs are: emissions from fuel consumption, landfill gas and leachate. Most of them are calculated based on the equations presented by [21]. The data related with leachate from Tomesti landfill are provided by [22].

3.3. Impact assessment and interpretation

The overall goal of impact assessment phase is to connect each life cycle inventory results to the corresponding environmental impacts [23-24]. The impact categories such as: *abiotic depletion potential* (**ADP**), *acidification potential* (**AP**), – *eutrophication potential* (**EP**), *global warming potential* (**GWP**), *ozone depletion potential* (**ODP**), *photochemical ozone creation potential* (**POCP**) and others can be evaluated in the life cycle impact assessment phase [7, 9, 21, 25]. In our case we have applied GaBi software to obtain the environmental impacts of the municipal solid waste management systems from 2008 and 2013 in Iasi, Romania. In this paper we presented the results obtained by considering two LCA methods ReciPe (Figs. 5-6) and CML 2001 (Figs. 7-10), which are included among others in GaBi software. The values obtained for each category of impact in different measurement units are normalized (PE – person equivalents) so that the environmental impact categories to be compared and illustrated on a single graphic. All impact categories determined showed positive values which mean negative impacts on the environment.

According to the ReCiPe method all the impacts categories (*agricultural land occupation* **- ALO**; *climate change Ecosystems* **- CCE**; *climate change human health* **- CCHh**; *fossil depletion* **- FD**; *particulate matter formation* **- PMF)** have positive values for both MSWM systems (negative impacts on the environment) decreasing in the following order: for 2008 - FD>CCHh>PMF>CCE>ALO and for 2013 - FD>PMF>CCHh>CCE>ALO (Figs. 5-6). It can be observed that fossil depletion (FD) has the highest value for both systems, followed by climate change human health (CCHh) in the case of MSWM system from 2008 and particulate matter formation (PMF) impact category for MSWM system from 2013. Fossil fuel depletion (FD) refers to a group of resources that contain hydrocarbons such as methane or non-volatile materials like anthracite coal [26]. In our case this indicator has highest value due to the use of diesel (that contains hydrocarbons with 12-20 carbon atoms) which is used both in collection and transportation of solid waste and in waste treatment processes. Climate change – damage to human health (CCHh) has direct effects (heat waves, air pollution and aeroallergens) and some infectious diseases, malnutrition and others as indirect effects. In 2008 the MSWM system included only landfilling of solid waste as treatment/elimination process. The CCHh impact category has high value because all the amount of waste was landfilled in a non - compliant landfill at Tomesti, without leachate (a gas-liquid-solid phase which may contain unwanted and toxic chemicals) collection and treatment and also without biogas (which contains mainly CH_4 and CO_2, both greenhouse gases) collection. Analysis of leachate composition at Tomesti landfill and the environmental components quality indicators are presented by [22]. In the case of MSWM system from 2013 the CCHh has a lower value compared to 2008 because of the decreased amount of waste landfilled and the fact that landfilling of waste is performed in a compliant landfill at Tutora (with leachate collection and treatment).

Particulate matter formation (PMF) - particulate matter with a diameter of less than 10 μm (PM 10) causes health problems, they can be formed in air from emissions of sulphur dioxide (SO_2), ammonia (NH_3), and nitrogen oxides (NO_x) among others [26]. In this case the PMF impact category has highest value due to the combustion of diesel used but also because of other emissions. Another indicator that has positive value (Fig. 5) is climate change - damage to ecosystem diversity (CCE). Species loss is related to climate change, an important role in the extinction of species plays the temperature. In the calculation of this indicator temperature factor and a damage factor are combined [26].

According to the CML 2001 method both MSWM systems negative impacts on the environment (impacts categories have positive values) decreasing in the following order: for 2008 - GWP>ADP>AP> POCP>EP>ODP and for 2013 - AP>GWP>EP>ADP>POCP>ODP (Figs. 7-8).

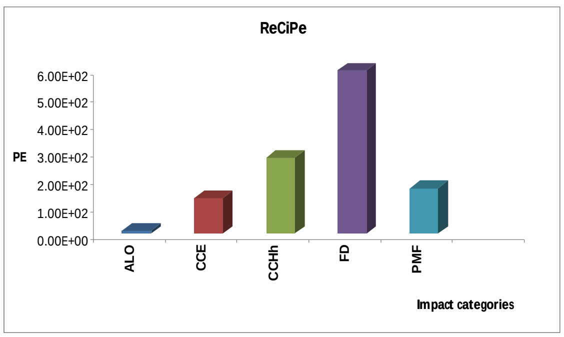

Fig. 5. Environmental impacts of MSWM system in 2008 (ReCiPe method)

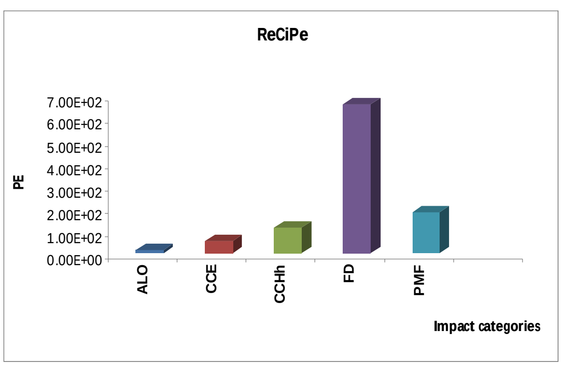

Fig. 6. Environmental impacts of MSWM system in 2013 (ReCiPe method)

For the comparison there were chosen global warming potential expressed in kg CO_2 -eq. and abiotic depletion potential (kg Sb-eq.).

Abiotic depletion covers all natural resources, while the "depletion" depends on ultimate reserves and rates of extraction of a given resource. Depletion of abiotic resources occurs by the decrease of availability of the total reserve of potential functions of resources [27].

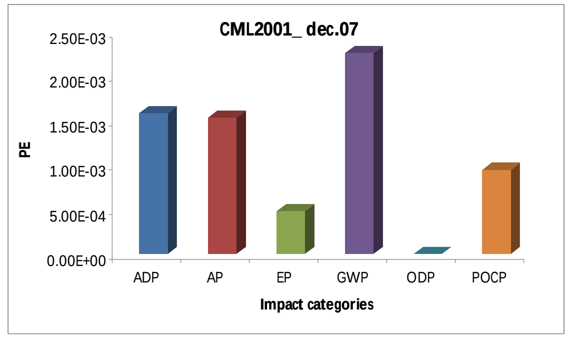

Fig. 7. Environmental impact of MSWM system in 2008 (CML method)

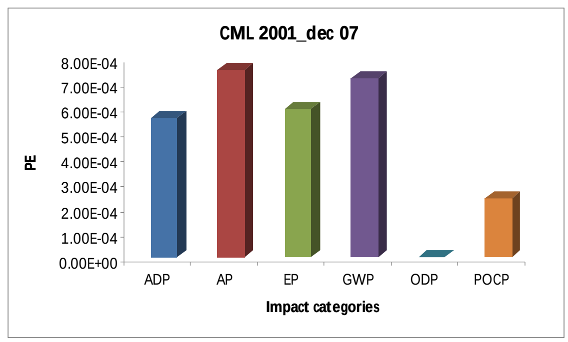

Fig. 8. Environmental impact of MSWM system in 2013 (CML method)

This impact category applied to waste management assessment allows for accounting positive aspects of the recovery/recycling of waste [13, 20, 28].

Climate change involves environmental mechanisms that affect both the human health and the environment [28]. Climate change is caused by the emission of greenhouse gases like CH_4, CO_2, halocarbons, nitrogen oxides, non-methane volatile organic compounds which are substances with the ability to absorb infrared radiation from the Earth [28]. Some of the greenhouse gases (GHG), such as water vapour, CO_2, O_3, CH_4 and N_2O, besides being emitted through human activities occur naturally [29]. Some gases like the fluorinated gases only occur due to human activities [29]. A greenhouse gas can be more or less potent regarding to how much contributes to global warming and affects climate change. The contribution to the global warming depends on greenhouse gas properties such as atmospheric lifetime, the degree of infrared absorption and the spectral location of its absorbing wavelengths [29].

According with Kyoto Protocol emissions of four greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and sulphur hexaflouride (SF6), and two groups of GHG: hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) must be reduced [29].

The Global Warming Potential (GWP) represents a comparative index based on the radiative forcing of a unit mass of a given greenhouse gas. The relative capacity of each greenhouse gas to absorb heat is compared by GWP [29].

GHG emissions from the municipal solid waste management system may be divided into the following categories:

- direct emissions, which originate from waste management activities such as methane from landfills and CO_2 emissions from transport, incineration and recycling plants;
- avoided emissions, which represent the life-cycle benefits from resource recovery (using waste as a secondary material or energy source) and replacing the use of virgin materials or fuels [30].

When the waste management practices are analyzed, the following particular aspects can be found:

- the GHG emission, especially CO_2 from waste collection and transport result from the use of fuel by the vehicles;
- recycling can produce substantial GHG emission savings;
- composting is an aerobic process with energy consuming and implies CO_2 emission and carbon storage in soil by the application of compost;
- anaerobic treatment of solid waste generates significant quantities of biogas, as well as CH_4 and N_2O emission;
- incineration is mainly used to minimize the volume of solid waste to be disposed in landfills and to obtain energy;
- nitrous oxide (N_2O) and carbon dioxide (CO_2) are the main emissions from incineration that contributes to climate change;
- biogas produced from landfilling of solid waste contains mainly methane and carbon dioxide, but it is considered that only CH_4 emission is relevant to the global warming [31- 35].

Global warming potential has high values because of the higher content of organic waste that were landfilled. The organic wastes are degraded through a series of consecutive reactions, which take place in the body of landfill, as follows:

- the large molecules (biopolymers like carbohydrates, proteins, fats) are broken down into simpler molecules;
- the simpler molecules (monomers like sugars, amino acids etc.) are biodegraded in intermediates such as fatty acids, alcohols;
- the intermediate compounds are degraded under anaerobic conditions in acetates and hydrogen;
- the acetates and hydrogen will then form biogas (CH_4 and CO_2) [36].

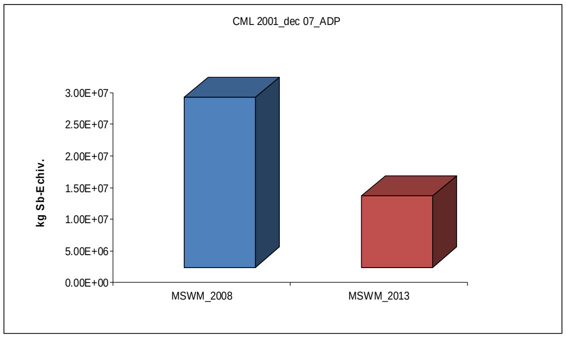

Fig. 9. Abiotic depletion potential – comparison 2008 and 2013

CH_4 and CO_2 are the main constituents of the biogas. Because the biogas is not collected in the non-compliant landfill (Fig. 10, MSWM_2008), it will reach the atmosphere as a contributor to global warming potential.

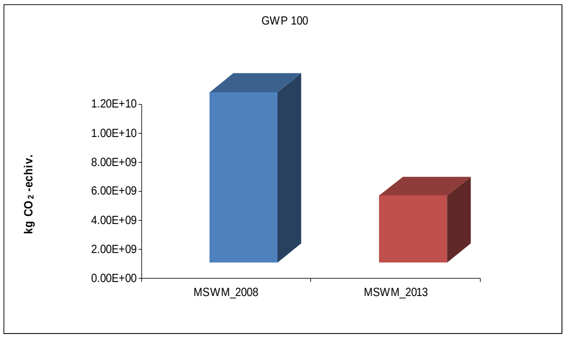

Fig. 10. Global warming potential or climate change – comparison 2008 and 2013

4. Conclusions

In this paper two MSWM systems were evaluated from the environmental point of view with two methods (ReCiPe and CML2001) included in LCA software. After the assessment it can be concluded that both MSWM systems have negative impacts on the environment, mentioning that MSWM system from 2008 has higher impacts as compared to the system existenting in 2013. The impacts categories with higher values are *fossil depletion* (values obtained by applying ReCiPe) *global warming potential* from the assessments of MSWM system existent in 2008 and *acidification potential* obtained by evaluating MSWM system from 2013 with CML2001 method. It can be concluded that an improvement of MSWM system is urgently required; it can be considered implementation of other treatment methods given the amount of waste generated and its composition. Also a better separate waste collection on waste fractions followed by the recycling may lead considerably to a decrease in environmental impacts.

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6. References

[1]. GHINEA C., GAVRILESCU M., Models for sustainable waste management, *The Bulletin of the Polytechnic Institute from Iasi*, *Chemistry and Chemical Engineering Section*, LVI (LX): 21-36, (2010)
[2]. RATHI S., Alternative approaches for better municipal solid waste management in Mumbai, India, *Waste Management*, 26: 1192-1200, (2006)
[3]. SCHIOPU A.M., GAVRILESCU M., Options for the treatment and management of municipal landfill leachate: common and specific issues, *CLEAN – Soil, Air, Water*, 38: 1101-1110 (2010)
[4]. SCHIOPU A.M., GAVRILESCU M., Municipal solid waste landfilling and treatment of resulting liquid effluents, *Environmental Engineering and Management Journal*, 9: 993-1019, (2010)
[5]. EKVALL T., ASSEFA G., BJORKLUND A., ERIKSSON O., FINNVEDEN G., What life-cycle assessment does and does not do in assessments of waste management, *Waste Management*, 27: 989-996, (2007)
[6]. GLAVIC P., LUKMAN R., Review of sustainability terms and their definitions, *Journal of Cleaner Production*, 15: 1875-1885, (2007)
[7]. BANAR M., COKAYGIL Z., OZKAN A., Life cycle assessment of solid waste management options for Eskisehir, Turkey, *Waste Management*, 29: 54-62, (2009)
[8]. FRIORIKSSON G.B., JOHNSEN L.T., BAJARNADOTTIR H.J., SLETNES L.H., *Guidelines for the use of LCA in the waste management sector*, Technical report, Nordtest Project no. 1537-01 (2002)

[9]. GHINEA C., GAVRILESCU M., Decision support models for solid waste management – an overview, *Environmental Engineering and Management Journal*, 9: 869-880, (2010)

[10]. TSILEMOU K., PANAGIOTAKOPOULOS D., Solid waste management systems assessment: the municipality's point-of-view, *Environmental Engineering and Management Journal*, 6: 51-57, (2007)

[11]. WINKLER J., BILITEWSKI B., Comparative evaluation of life cycle assessment models for solid waste management, *Waste Management*, 27: 1021-1031 (2007)

[12]. McDOUGALL F., WHITE P., FRANKE M., HINDLE P., *Integrated Solid Waste Management: a Life Cycle Inventory*, 2nd Edition, Blackwell Science (2001)

[13]. PE INTERNATIONAL, *Handbook for Life Cycle Assessment (LCA) Using the GaBi Education Software Package*, Germany, (2009)

[14]. DOBA A., NISTORESCU M., PASTRAVANU L., PETRUC I., SIMIONESCU I., *Strategic plan for integrated waste management in Iasi County*, (in Romanian), online at: http://www.scribd.com/doc/13769639/Planul-Judetean-de-Gestionare-al-Deseurilor, (2008)

[15]. IASI COUNTY COUNCIL, *Long-term investment plan for the period 2008-2038 on integrated waste management*, online at: http://www.icc.ro/activitate/mediu/MasterP/Master Plan.pdf, (2009)

[16]. INS IASI COUNTY STATISTICS, *County statistics*, online at: http://www.iasi.insse.ro /main.php?id=373, (2011)

[17]. RWMP - NE, *Regional Waste Management Plan, Region 1 NE*, Ministry of Environment and Water Management, Bucharest, Romania, (2006)

[18]. NWMP, *National Waste Management Plan*, Ministry of Environment and Water Management, Bucharest, Romania, (2004)

[19]. ECOFRIENDS, Waste containers, online at: http://www.ecofriends.ro/, (2013)

[20]. den BOER (Szpadt) E., den BOER J., JAGER J., RODRIGO J., MENESES M., CASTELLS F., SCHANNE L., *The Use of Life Cycle Assessment Tool for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapid Growing Economies LCA-IWM*, Deliverable report on D3.1 and D3.2: Environmental Sustainability Criteria and Indicators for Waste Management (Work Package 3), Technische Universitaet Darmstadt (TUD), Darmstadt, (2005)

[21]. GHINEA C., PETRARU M., BRESSERS H., GAVRILESCU M., Environmental Evaluation of Waste Management Scenarios – Significance of the Boundaries, *Journal of Environmental Engineering and Landscape Management*, 20: 76-85, (2012)

[22]. SCHIOPU A.M., GHINEA C., Municipal solid waste management and treatment of effluents resulting from their landfilling, *Environmental Engineering and Management Journal*, 12: 1699-1719, (2013)

[23]. ISO, Environmental management – Life cycle assessment – Principles and framework (ISO 14040: 2006). European Standard EN ISO 14040. The International Organization for Standardization, Geneva, Switzerland, (2006)

[24]. JOLLIET O., MARGNI M., CHARLES R., HUMBERT S., PAYET J., REBITZER G., ROSENBAUM R., IMPACT 2002+: A New Life Cycle Impact Assessment Methodology, *International Journal of Life Cycle Assessment*, 8: 324-330, (2003)

[25]. GHINEA C., PETRARU M., SIMION I., SOBARIU D., BRESSERS H.Th.A, GAVRILESCU M., Life Cycle Assessment of waste management and recycled paper systems, *Environmental Engineering and Management Journal*, 13: 2073-2085, (2014)

[26]. GOEDKOOP M., HEIJUNGS R., HUIJBREGTS M., De SCHRYVER A., STRUIJS J., van ZELM R., ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level, First Edition, Ministerie van VROM, Den Haag, (2013)

[27]. van OERS L., de KONING A., GUINEE J.B., HUPPES G., *Abiotic resource depletion in LCA*, Road and Hydraulic Engineering Institute, Netherlands, (2002)

[28]. JRC EUROPEAN COMMISSION, *Framework and requirements for LCIA models and indicators*, Joint Research Centre Institute for Environment and Sustainability, ILCD Handbook, (2010)

[29]. AGS, *The complexity of climate change mechanisms - aspects to be considered in abatement strategy planning*, AGS Pathways Report, Göteborg, Sweden, (2010)

[30]. EEA, *Waste opportunities Past and future climate benefits from better municipal waste management in Europe*, European Environmental Agency Report, Copenhagen, ISSN 1725-9177, (2011)

[31]. CALBRO P.S., Greenhouse gases emission from municipal waste management: The role of separate collection, *Waste Management*, 29: 2178-2187, (2009)

[32]. CHEN T.C., LIN C.-F., Greenhouse gases emissions from waste management practices using Life Cycle Inventory model, *Journal of Hazardous Materials*, 155: 23-31, (2008)

[33]. GHINEA C., PETRARU M., GAVRILESCU M., BRESSERS H., Waste management and recovery of fibres – the impact on climate change, IGS-SENSE Conference Resilient Societies - Governing Risk and Vulnerability for Water, Energy and Climate Change, 19 - 21 Octombrie 2011, Universitatea Twente, Enschede, Olanda, online at: http://www.utwente.nl/igs/conference/2011_resilient_societies/Papers%20and%20presentations%20CLIMATE%20CHANGE/Postersession_Paper%20Ghinea_IGS_Conference.pdf, (2011)

[34]. ISWA, *Waste and Climate Change* ISWA WHITE PAPER AKA, International Solid Waste Association, AKA Print, Aarhus, Denmark, (2009)

[35]. US EPA, *Solid Waste Management and Greenhouse Gases, A Life-Cycle Assessment of Emissions and Sinks*, 3rd Edition, United States Environmental Protection Agency, online at: http://www.epa.gov/climatechange/wycd/waste/downloads/fullreport.pdf, (2006)

[36]. SUNDQVIST J.O., *Life cycles assessments and solid waste–Guidelines for solid waste treatment and disposal in LCA*, Final Report, Swedish Environmental Protection Agency, (1999).