Greenhouse Gas Emissions (CO_2-CH_4) from Municipal Solid Waste Management Using Life Cycle Assessment (LCA) in Mahdsht City (IRAN)

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ABSTRACT

Waste production is inevitable in any society and consequently waste management is one of the main roles of any municipality. Therefore, it is necessary to evaluate different waste management scenarios. According to the amount and composition of the generated waste, considering environmental, economic and technical issues, several options are existed. Life Cycle Assessment (LCA) as a decision support tool has been used in several cases to select the most appropriate option. In this paper, production of greenhouse gases (CO2-CH4) in different waste management options in Mahdasht city (Iran) has been studied using IWM software and LCA application. Two scenarios has been defined, the first includes direct and complete transferring of waste to the landfill, and the second includes transferring of 76% of total waste to the landfill and recycling 20% and composting 4%. The questionnaires were fulfilled by the staffs and field surveying. The life cycle inventory cataloging was done using the IWM-1model according to environmental point of view. The amount of produced greenhouse gases in the first scenario is about 9,218 tons and in the second scenario is about 6,801 tons. Results indicate that implementing recycling and composting operation can lead to the 26% reduction in greenhouse gas emissions and energy consumption reduction of a waste management system.

Key word: LCA, IWM, Greenhouse Gas Emissions, Solid Waste, Mahdasht.

INTRODUCTION

By the urbanism expansion and population increases, one of the most important topics is the optimum management of produced residue. Today, in addition to the rapid growth of urbanism, increasing in income level and welfare of the society and rapid economic and social growth in countries, which cause quantity changes in waste production, changes in consumption patterns has led to quality changes.

Integrated solid waste management (ISWM) is a term that is used for all of the activities that related with waste management of a society; the main aim of integrated solid waste management is to organize the society waste in a manner that supplies general health and environmental aspects and people's demands for reuse of wastes and recycling.

A life cycle assessment (LCA) is a technique to assess environmental impacts associated with all stages of a product's life from-cradle-to-grave (i.e. from raw material extraction through materials processing manufacture, distribution, use, repair and maintenance and disposal or recycling) LCA's can help avoid a narrow outlook on environmental concerns by:

- Compiling an inventory of relevant energy and material inputs and environmental releases;
- Evaluating the potential impacts associated with identified inputs and releases;
- Interpreting the results to help you make a more informed decision.

There are four linked components of LCA:

Goal definition and scoping

Identifying the LCA's purpose and the expected products of the study, and determining the boundaries (what is and is not included in the study) and assumptions based upon the goal definition;

Table. 1: Municipal waste generation rate (per individual) in Iran and other neighboring and developed countries

Country	MSW generation (kg/person/day)
Austria	0.89
Bahrain	1.3
Belgium	0.93
Egypt	0.81
France	0.89
India	0.45
Iran	0.61
Italy	0.95
Japan	1.12
Jordan	0.60
Kuwait	1.4
Oman	0.70
Portugal	0.70
Qatar	1.3
Spain	0.88
Tunisia	0.41
Turkey	0.95
UAE	1.2
UK	0.95
US	2.0

Life-cycle inventory

Quantifying the energy and raw material inputs and environmental releases associated with each stage of production;

Impact analysis

Assessing the impacts on human health and the environment associated with energy and raw material inputs and environmental releases quantified by the inventory;

Improvement analysis

Evaluating opportunities to reduce energy, material inputs, or environmental impacts at each stage of the product life-cycle.

The goal of LCA is to compare the foul range of environmental effects an assignable to products and services (such as waste management) in order to improve processes, support policy and provide a sound basis for informed decisions (US EPA, 2010).

The choice of selected indicators for LCA can provide options for the improvement of the existing systems. Such a damage assessment based on the existing life cycle of natural gas combustion district heating system at a rural location in British Columbia was conducted by Pa *et al*(2006,2012)

Table. 2: Physical composition of MSW of Mahdasht City

Component	Content in Kerman (wt. %)	Amount (ton/year)
Organic material	74.1	6215
Hard plastic	1.1	92
Low plastic	6.3	530
PET	0.2	17
PS	0.5	42
PP	1.8	152
Mixed paper	3.0	252
Boxboard	3.8	320
Ferrous metal	0.5	42
Aluminum	0.0	0
Glass	0.5	42
Yard waste	0.7	59
Other	7.5	630

Source: Data gathered in current research

Fig. 1: Mahdasht city

Table. 3: Number of equipment and fuel consumption according to scenarios

Scenario	Stage	Waste (Ton)	Number of Equipment	Fuel Consumption (Ltr)
Scenario1	Collection	8393	6	17782.1
	Transport	8393	5	16060
	Landfill	8393	2	2555
Scenario2	Transport	8393	6	12848
	Landfill	6378.7	1	1941.8
	Recycle	335.7	1	2574.4
	Compost	1678.6	5	10297.6

Source: Data gathered in current research

Table. 4: Emission factors for the production and delivery of fuels (kg/GJ)

	Natural gas	Diesel	Fuel oil
CO2	4.94E+00	1.08E+01	4.78E+02
CH4	6.90E-02	1.01E-01	0.00E+00
NOX	2.07E-02	6.59E-02	2.93E+00
SOX	1.90E-02	6.85E-02	3.04E+00
HCl	7.22E-05	4.18E-04	1.86E-02
PM-10	1.26E-02	3.43E-02	1.52E+00
VOCs	1.10E-02	1.96E-01	7.59E-03
Air_Pb	1.25E-06	3.60E-06	1.60E-04
Ari_Hg	3.72E-07	1.19E-07	5.30E-06
Ari_Cd	5.91E-08	8.55E-07	3.80E-05
Ari_PCCD/F(TEQ)	2.85E-14	1.10E-16	4.90E-12
Water_Pb	6.57E-06	1.33E-05	5.90E-04
Water_Hg	1.07E-07	1.37E-08	5.90E-04
Water_Cd	8.54E-08	1.44E-06	6.40E-05
Water_BOD	3.94E-06	1.12E-04	5.00E-03
Water_PCCD/F(TEQ)	n/a	n/a	n/a

Source: Derived from Pira International, 1996 recently. Similar region-specific LCA studies for woodchip-based 'green electricity generation' in Austria (Siegl, S and *et al*,2012).

Municipal solid waste (MSW) generally includes degradable (paper, textiles, food waste, straw and yard waste),partially degradable(wood, disposal napkins and sludge) and non-degradable materials (leather, plastics, rubbers, metals, glass, ash from fuel burning like coal, briquettes or woods ,dust and electronic waste).Generally MSW is managed as collection from streets and disposal at landfills (ArvindK.Jha and *et al*,2007).

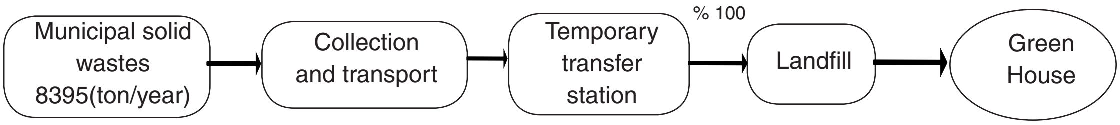


Fig. 2: Scenario 1

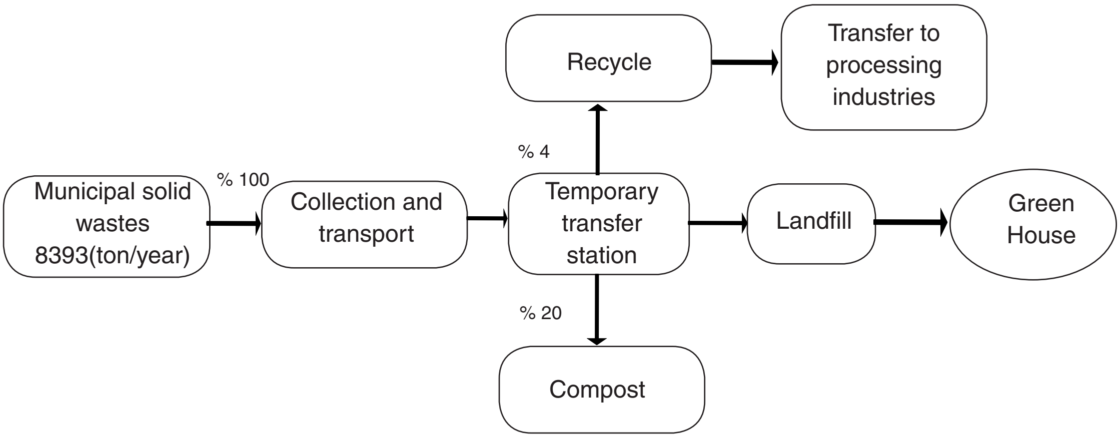


Fig. 3: Scenario 2

Table. 5: Emission factors for the combustion of fuels (kg/GJ)

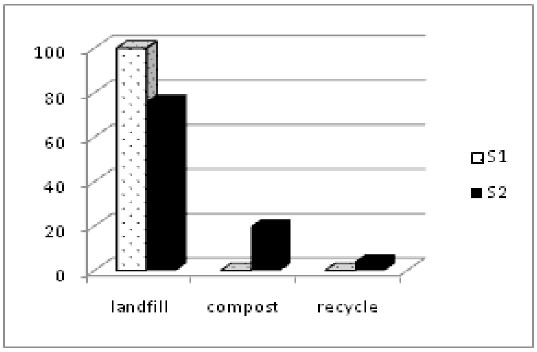
Source	Natural gas	source	Fuel oil	Source	D i e s e l	
CO2	48.77E+01	(3)	7.311E+01	(3)	7.058E+01	(3)
CH4	1.181E-01	(3)	2.40E-03	(3)	0.00E+00	(3)
NOX	5.00E-04	(1)	1.10E-02	(1)	2.15E-02	(2)
SOX	2.58E-04	(1)	4.55E-01	(1)	1.12E-01	(2)
HCl	n/a		n/a		n/a	
PM-10	5.89E-03	(1)	3.57E-02	(1)	9.31E-02	(2)
VOCs	n/a		8.00E-04	(1)	1.18E-01	(2)
Air_Pb	n/a		n/a		n/a	
Ari_Hg	n/a		n/a		n/a	
Ari_Cd	n/a		n/a		n/a	
Ari_PCCD/F(TEQ)	n/a		n/a		n/a	
Water_Pb	n/a		n/a		n/a	
Water_Hg	n/a		n/a		n/a	
Water_Cd	n/a		n/a		n/a	
Water_BOD	n/a	n/a	n/a		n/a	
Water_PCCD/F(TEQ)	n/a		n/a		n/a	

Life cycle assessment (LCA) is a process of evaluating environmental burdens or benefits associated with the total life cycle of a product. This is conducted by identifying and quantifying the energy and materials used and waste products released into the environment (Siegl, S and *et al*,2012).

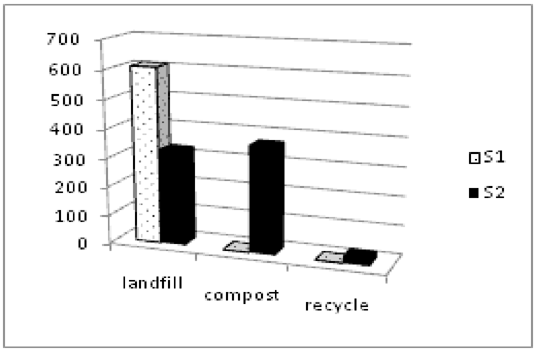
The significance of LCA lies in the fact that it equips the policy makers and decision makers for adoption of suitable and sustainable energy supply systems. Increasing global concern due to air pollution and to limited oil reserves has generated much interest in environmental friendly alternatives to petroleum-based fuels (Merola, SS and *et al*, 2012).

LCA (Life Cycle Assessment) has been used as an effective environmental management tool in much different kind of studies. For example, A number of studies in the literature used LCA as a comparative tool for different MSWM schemes (Su *et al*., 2007; Ahluwalia and Nema, 2007; Liamsanguan and Gheewala,2008; Villeneuve *et al*., 2009; Manfredi and Christensen, 2009; Banar *et al*., 2009).Some of the models conduct the Life Cycle Analysis (LCA) of the waste disposal system while other only focus on different environmental elements such as noise or traffic (Chang *et al*, 1996) or on CO2 emissions from vehicles (Wang at all, 1988).A group of computer models apply the concept of Life Cycle Analysis (LCA). The example of such models are: the US-EPA (Barlaz*et al*, 1995), Integrated Waste Model IWM (White *et al*, 1997), MIMES/Waste (Sundberg, 1995), ORWARE (Eriksson *et al*, 2002).

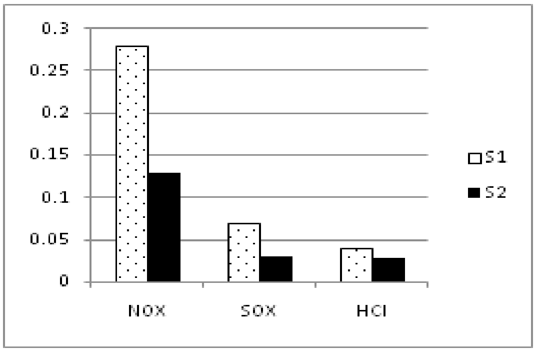
An LCA study on alternatives for residual municipal solid waste management presented Umberto Arena Susan Thorneloe presented a paper on the US EPA landfill life cycle inventory. also we have several studies in different cases such as in order to lower the VOC content of paint in the paint industry (Dobson ,1996), to reduce the environmental burdens of the used automotive batteries (Robertson *et al*.,1997), to compare different forestry operations



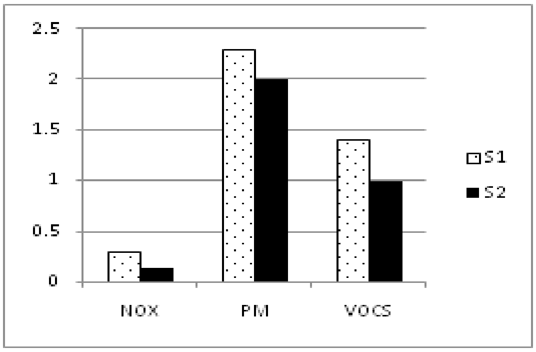
Graph. 1: Comparing elements of two scenarios



Graph. 2: Comparing the two scenarios of energy consumption (GJ)



Graph. 3: Comparing the two scenarios of acid gases emission (tones)



Graph. 4: Comparing the two scenarios of smog gases emission (tones)

of clear cutting and shelter wood cutting in forest management systems (Berg,1997), to compare three degreasing processes in the metal-processing industry and to optimize each process, both environmentally and economically (Finkbeiner *et al.*,1997), to assess different scenarios of treatment of municipal wastewater (Roeleveld *et al.*,1997), etc.

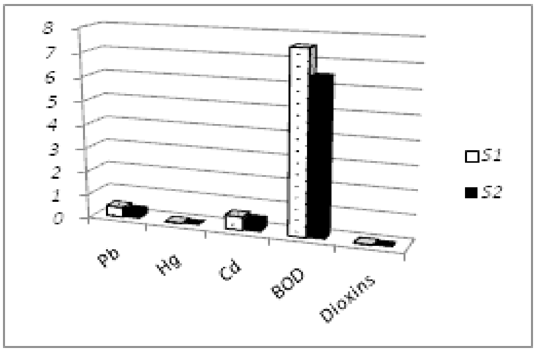
MATERIALS AND METHODS

Mahdasht city with a population of about 55'000 and a square of 6116/1 hectare is situated in the south-west of Karaj city (capital of Alborz province) with a distance of 18km from Karaj. This city with agricultural lands with a square of 2700 hectare is one of agricultural centers of Alborz province. The amount of waste production of this city is about 8400 ton per year (74.1% of wastes are wet and 25.9% solid).

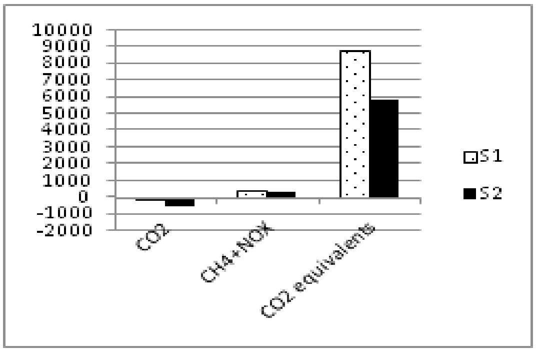
In this paper production of greenhouse gases (CO2-CH4) in different waste management options in Mahdasht city by using Life Cycle Assessment (LCA) method had been studied using IWM3 software. Two scenarios of integrated waste management in the Mahdasht city were compared using the LCA methodology. The scenarios were described using data extrapolation on the basis of data collection referring to 2013. In scenario1 considered that all of the wastes sent to the landfill (100% equivalent with 8395ton) and in scenario2 considered that 20% of produced wastes (equivalent with 1679 ton) transform to compost and 4% of produced wastes (equivalent with 336 ton) are recycled and remained as produced wastes (76% equivalent with 6380 ton) sent to a landfill.

RESULTS

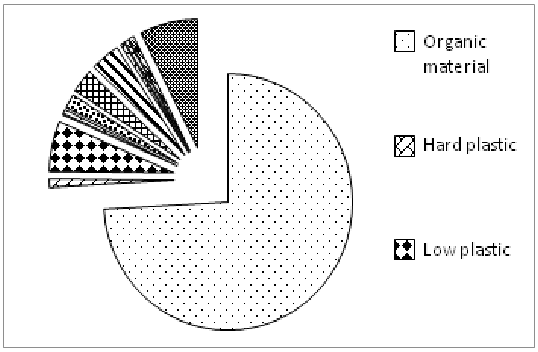
The broad perspective offered by LCA makes it a powerful tool for environmental comparison of different options for waste management in Mahdasht



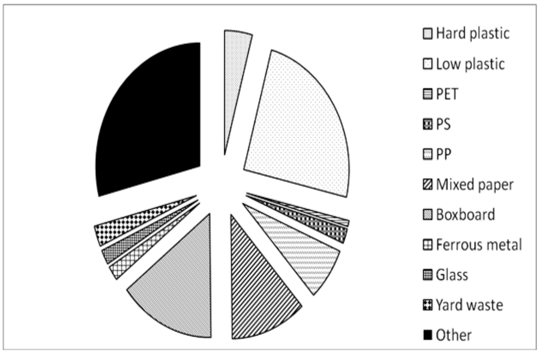
Graph. 5: Comparing the two scenarios of heavy metals emission (kg)



Graph. 6: Comparing the two scenarios of greenhouse gas emission (tones)



Graph. 7: Physical analysis of wastes (wet & dry)



Graph. 8: Physical analysis of wastes (dry waste only)

city in 2011, considering the intricate complexities of material and energy flows. By means of this technique results has been shown in the tables below.

CONCLUSION

The present study estimates production of greenhouse gas emissions (CO2-CH4) in the waste management system in Mahdasht city in IRAN. Two scenarios are assessed: scenario 1 direct and complete transfer of waste to the landfill and scenario 2 transferring 76% of the waste to the landfill (20% recycled, compostable and 4%). The life cycle inventory cataloging was done using the IWM-1model environmental point of view, the results of this study showed that composting and recycling operations have an important role in reducing the burden of pollutants and energy consumption of a waste management system. In this study, the data entered into the software (IWM), and the results provided by the software approach to Life Cycle Assessment (LCA) had been studied and were compared with each other. Given the amount of greenhouse gases in the second scenario (combination of recycling, composting and landfill) produce about 6,801 tons compared to the first scenario (only landfill) which produced about 9218 tons, the results indicates a significant reduction in the amount of harmful gasses. It is concluded that if the combined method (scenario 2) is used, it can lead to reduction in greenhouse gas emissions by as much as 26 percent.

REFERENCES

1. Ahluwalia, P.K.. and Nema, A.K.. 'A life cycle based multi-objective optimization model for the management of computer waste'. Resources, *Conservation and Recycling,* **51**: 792-826. (2007).
2. Arvind K.Jha,C.Sharma, Nahar Singh, R.Ramesh, R.Purvaja, Prabhat K.Gupta. Greenhouse gas emissions from municipal solid waste management in Indian mega-cities: A case study of Chennai landfill(2007). sites,www.elsevier.com\locate\chemosphere.
3. Banar, M., Cokaygil, Z., Ozkan, A.'Life cycle assessment of solid waste management options for Eskisehir, Turkey'. *Waste Management,* **29**: 54-62. (2009).
4. Barlaz, M.A., Ranjithan, R., Weitz, K.A. and Nishtala, S.R. Life-Cycle Study of Municipal Solid Waste Management, System Description. US Environmental Protection Agency, USA. (1995).
5. Berg S. Some aspects of LCA in the analysis of forestry operations. *j clean Prod;* **5**: 211-7. (1997).
6. Chang, N.B., Shoemaker, C.A. and Schuler, R.E. Solid Waste Management System Analysis with Air Pollution and Leachate Impact Limitations. *Waste Management and Research,* **14**: 463-481. (1996).
7. Dobson ID.Life cycle assessment for painting processes: putting the VOC issue in perspective. *Prog Org Coat;* **27**: 55-8. (1996).
8. Eriksson, O., Frostell, B., Bjorklund, A., Assefa, G., Sundqvist, J.O., Granath, J., Carlsson, M., Baky, A., Thyselius, L. ORWARE-a simulation tool for waste management. Resources, *Conservation and Recycling,* **36**: 287-307 (2002).
9. Finkbeiner M., Haffmann E. and kreisel G. Environmental auditing: the functional unit in the life cycle inventory analysis of degreasing processes in the metal processing industry. *Environ Manage:* **21**: 635-42 (1997).
10. Gunilla,J. LCA — A Tool for Measuring Environmental Performance: PIRA International, 190p.
11. Haight.M.(2004).Technical Report: Integrated Solid Waste Management Model, School of Planning University of waterloo, March9. (1996).
12. "Life Cycle Assessment (LCA). US Environmental Protection Agency. 6 Aug. (2010). Web.<http://www.epa.gov/nrmrl/lcaccess
13. Liamsanguan, C. and Gheewala, S.H. LCA: A decision support tool for environmental assessment of MSW management systems. *Journal of Environmental Management,* **87**: 132-138 (2008).
14. Manfredi, S. and Christensen, T.H. Environmental assessment of solid waste

landfilling technologies by means of LCA-modeling. *Waste Management,* **29**: 32-43 (2009).

15. Merola, SS, Tornatore, C, Marchitto, L, Valenteno, G. and Corcoine, FE. Experimental investigations of butanol-gasoline blends effects on the combustion process in a SI engine. *Int. J. Energy Environ. Eng* **3**: 6(2012).
16. Pa, A, Bi, XT. And Sokhansanj, S. A life cycle evaluation wood pellet gasification for district heating in British Columbia. *Biores. Tech* **102**: 6167–6177(2006).
17. Pa, A, Jill, C, Bi, XT, Staffan, M. and Sokhansanj, S. Environmental footprints of British Columbia wood pellets from a simplified life cycle analysis. *Int. J. of Life Cycle Asses* **17**: 220–231(2012).
18. Robertson JGS, Wood JR, Ralph B. and Fenn R. Analysis of lead\acid battery life cycle factors: their impact on society and the lead industry. *J Power Sources*; **67**: 225-36(1997).
19. Roeleveld PJ , Klapwijk A. Eggels PG, Rulkens WH, Starkenburg W. Sustainability W.S. Ustainability of Municipal Wastewater Treatment. Water Sci Technol1997:35:2218. Page CA, Diamond ML, Campbell M. McKenna S. Life-cycle framework for assessment of site remediation options: case study. *Environ toxicol and chem.,* **18**: USA'SETAC..p.801-10. (1996).
20. Villeneuve, J.; Michel, P.; Fournet, D.; Lafon, C.; Ménard, Y.; Wavrer, P.and Guyonnet, D. 'Process-based analysis of waste management systems: A case study'. *Waste Management,* **29**: 2-11.(2009).
21. Siegl, S, Laaber, M. and Holubar, P. Green electricity from biomass, Part 1: environmental impacts of direct life cycle emissions. *Waste Biomass,* **2**: 267–284(2011).
22. Su, J., Chiueh, P., Hung, M. and Ma, H. Analyzing policy impact potential for municipal solid waste management decision-making: A case study of Taiwan. Resources, *Conservation and Recycling,* **51**: 418-434. (2007).
23. Sundberg, J. Municipal solid waste management with the MIMES/waste model. A complementary approach to LCA studies for evaluating waste management options. Workshop on LCA and treatment of solid waste. Stockholm, Sweden, 28-29 Sept. 1995, pp. 252-258. (1995).
24. Wang, F.S., Richardson, A.J. and Roddick, F.A. SWIM – A Computer Model for Solid Waste Integrated Management. Computers, *Environment and Urban Systems* **20**(4/5), pp. 233-246. (1988).
25. White, P.R., Franke, M. and Hindle, P. Integrated Solid Waste Management - a Life cycle Inventory. Blackie Academic & Professional. (1997).