APPLICATION OF THE INTEGRATED SOLID WASTE MANAGEMENT MODEL FOR THE KRAKOW AREA – PREPARATION FOR THE CASE STUDY

T. Stypka and K. Kopacz

Institute of Heat Engineering and Air Protection, Cracow University of Technology
ul.Warszawska 24, 31-155 Cracow, Poland
(E-mail: stypka@s52pk.wis.pk.edu.pl)

ABSTRACT
The article presents the application for the Krakow area of the White's model to calculate the integrated environmental impact of the waste disposal systems. Based on the collected real date the model estimates emission of many pollutant both to the air and soil. The amounts of disposed waste, as well as the basic statistical data about the existing system are also estimated. The presented example shows the potential of the model and the methodology as well as the practical problems with its application.

KEYWORDS
Integrated solid waste management; Krakow; solid waste

INTRODUCTION

One of the keystones of the common environmental policy is the concept of sustainable development. According to the World Commission on Environment and Development (WCED) sustainable development was defined as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This general concept causes many problems for the practitioners. Several simplified rules are developed such as Polluters Pays Principle (PPP) or the Best Available Technology (BAT) to help the decisions makes. At present it is accepted that the sustainable development is possible only if carried out in three dimensions: ecological, social and economic (Munasinghe, 1993) (Fig. 1).

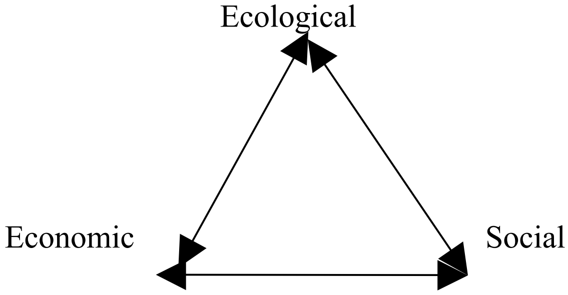

Figure 1. Interaction among different dimensions of the sustainable development.

An economic approach to sustainable development concentrates on maximizing the profit while keeping a constant level of the resources (Maler,1990). This approach focuses on the optimization of decisions making and solves the problem of the value of natural resources.

The socio-cultural approach concentrates on the stability of the social structure and tries to minimize the potential of conflict. The idea of intergenerational or social justice is in the center of interest of this approach. This approach stresses the fact that it is difficult to talk about sustainable development if man's activity causes long lasting conflicts. Such conflicts very often develop into military conflicts that bring economic and environmental collapse. The problems of famine, poverty, cultural diversity, democracy, and public participation dominate the research in this area.

An ecological approach to sustainable development focuses on stability of the biological and physical systems, which are the most crucial for the human being. These are: the cycles of water and carbon, biodiversity, ozone depletion etc. Urban development and system balance are also of interest.

SUSTAINABLE DEVELOPMENT IN MUNICIPAL SOLID WASTE MANAGEMENT

The traditional approach to waste management is very often limited to the question: to have or not to have the incinerator in the city, or where to locate the new landfill. Such an approach has two main flaws. Firstly, it assumes that the waste management should focus only on the techniques of waste disposal and not the ways of the waste avoidance or minimization. In other words, it assumes that waste disposal is "an end of the pipe technology" only. Secondly, such discussions assume that the options in waste handling are very limited: landfilling or incineration.

The concept of sustainable development in solid waste management requires the use of the following hierarchy in waste handling (Hultman in preparation):

- avoidance
- minimization
- reuse
- recycling
- treatment with energy recovery
- safe disposal

This hierarchy of action, which has to be soon as a rule of thumb more than as a binding standard, clearly requires, avoiding or minimizing the waste generation. This has to be done before any other action and that means the intervention in the production process even at the design stage. Such an approach to waste management by the waste avoidance is very distant from the "traditional" one which concentrates on waste disposal technology.

Unfortunately, the hierarchy of action is also challenged as non-efficient.(Stypka in preparation) In many situations waste reuse is possible from technical point of view, but totally ridicules from economic or social perspectives. For example, the waste in artic regions or in deserts can be reused or incinerated, but such solution does not make sense from the economical point of view. Because the problem of choosing the best waste management method requires more knowledge than the simple hierarchy can offer, more advanced methods are needed. One of the methods is the integrated waste management approach.

The integrated waste management looks at the problem far more broadly. It looks locally at the all types of generated wastes (recyclable and non-recyclable) and simultaneously their disposal, hoping that this can bring some economical, environmental or social profits. These benefits are also looked for by integrating different sources of wastes (commercial, household, industrial), and the different technical options of waste disposal.

The total impact on the environment society and economy is calculated. It is a sum of the impacts that take place on each stage of waste disposal from "cradle to grave."

Generally, the process consists of collection, central sorting, biological, and thermal treatments and landfilling. Each of these elements has specific environmental, economical and social impacts, but the final decision about the structure of system is made on the objective how to minimize the integrated impact of the whole process. The components of the integrated waste management system and their interlinks presents Fig. 2 White (1997).

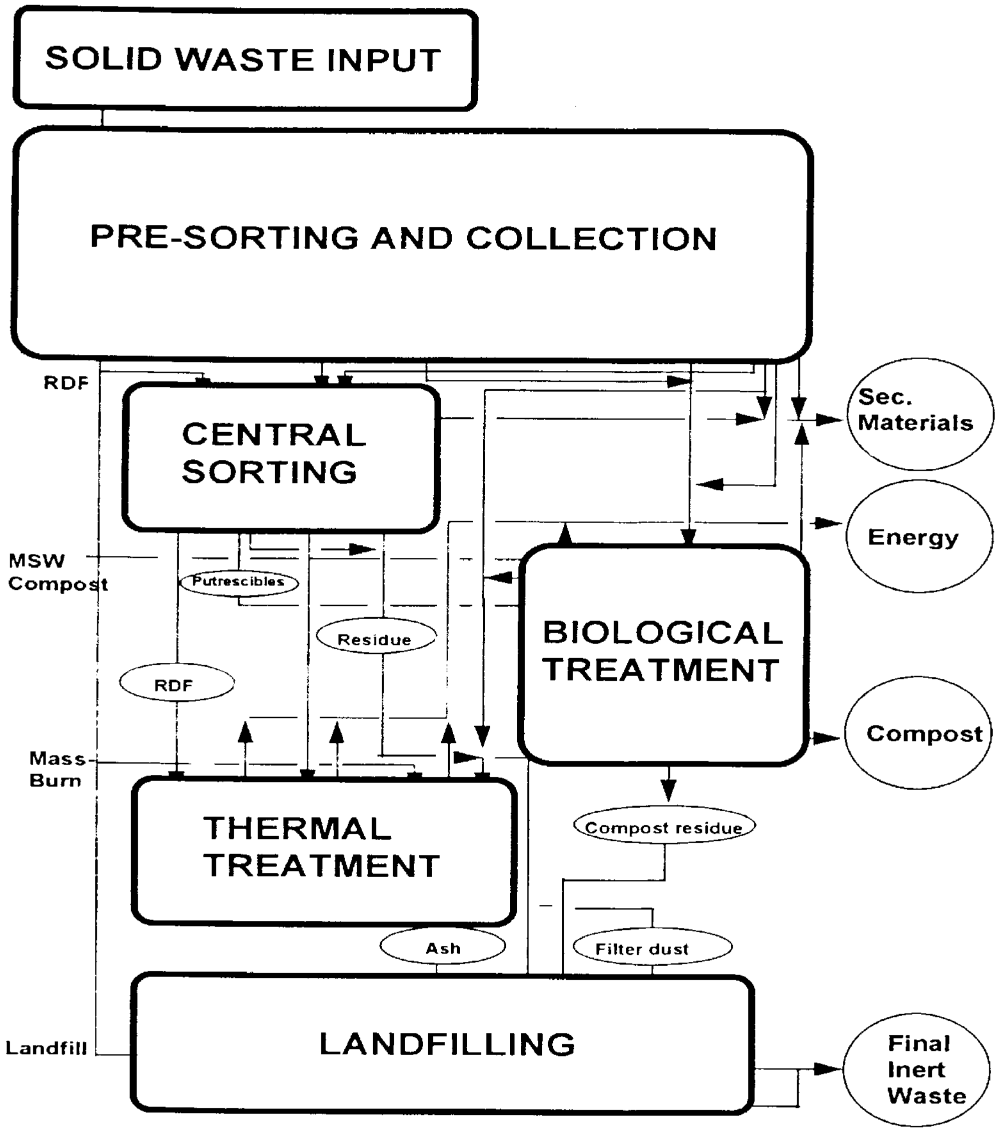

Figure 2. Components of an integrated waste management system (White, 1997).

The detailed structure of this system is far more complicated. For example, what is presented on the scheme as a "thermal treatment" in detail scheme means Refuse-Derived Fuel (RDF) burning or mass-burning incinerator of solid waste or burning as fuel source-separated paper and plastic. Each of these facilities has different impact on the environment, society and economy. Additionally choosing one of these options predetermines, to some extent, the selection of the biological treatment as well as the selection system. The whole system is very much inter linked and has to be seen as a unit. The detail scheme of the system presents Fig. 3 (White, 1997).

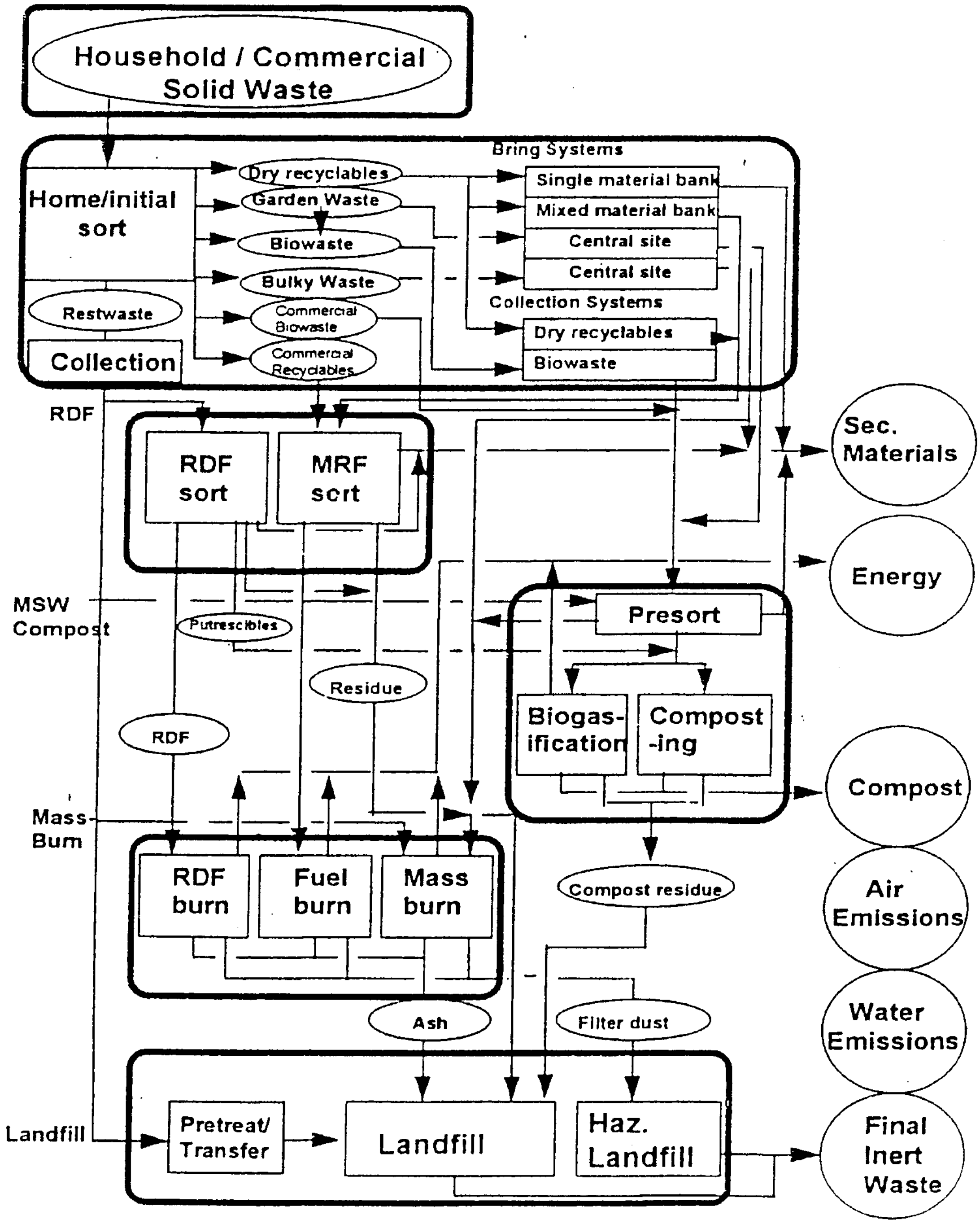

Figure 3. Detailed structure of an integrated waste management system (White et al., 1997).

White et al. (1997) presented not only the model on the conceptual level, but the spreadsheet to calculate the environmental and economic impacts of the different waste strategies. The spreadsheet is based on the average flow data. The presented example shows the potential and drawbacks of the model.

THE EXISTING SYSTEM OF SOLID WASTE DISPOSAL IN KRAKOW

Krakow intensively develops its solid waste disposal system in accordance with the plan accepted by the City Council (Act No CXX/1074/98 from June 10, 1998). This law called "Program for the Municipal Solid Waste Disposal System" is being implemented step by step. The main assumptions and goals of the program are:

- organise source separated system of recyclables collection
- develop composting facility for the organic fraction of the MSW
- building a Material Recovery Facility (MRF)
- application of the thermal treatment of the restwaste
- development and expansion of the existing landfill "Barycz"

To implement this policy the city introduced in 1994 the recycling program. The program is designed as the bring system with the igloo containers scattered around the town in selected districts. At the beginning only paper, glass and metal were collected and in year 2000 the PET bottles containers were also introduced. At present there are 150 deposit banks in the city. The amount of collected recyclables presents Table 1 (IOS, 2002)

Table 1. Amount of collected recyclables in years 1999 to 2001

Year	Paper kg	Glass kg	Metal kg	PET bottles kg
1999	153 072	187 440	30 260	-
2000	190 543	270 750	25 782	-
2001	208 605	349 628	41 336	17 347,5
Total	552 220	807 818	97 378	17 347,5

The system is operated by the city and is co financed by the county Ecofund (PFOSiGW). The problem of hazardous municipal solid waste is marginalized and only the old and unused drugs are collected during a few months long campaigns in selected pharmacies. In year 2001 the total amount of collected household hazardous waste (HHW) was 977,5 kg. (IOS, 2002)

The composting of the green fraction of the MSW was implemented in year 2000. The composting plant utilizes the technology MUT "Kyberferm" and is designed for the source separated grass clippings and garden waste. The total amount of so far processed waste is 10 500 tons of green waste (IOS 2001). The composting facility works on commercial bases charging 70% of the solid waste disposal price charged at the landfill.

The Material Recovery Facility (MRF) is in the conceptual stage, and at present there is a discussions about its location. Two MRFs are planned. One, with the throughput 20 000 tons per year, is planned at the landfill site "Barycz." The second facility is planned at the location of the "Sedzimira" Steelworks.

The city plans to build also the second composting facility at the landfill site with the throughput 6000 tons per year.

So far the main method of waste disposal remains landfilling. The main municipal landfill “Barycz” is located in eastern part of town in the old salt mine query. The landfill’s area is 37 hectares. It is the only landfill within the city limits, but it is not the only one that serves the city. The private companies, who sometimes use the other landfills located in the Krakow vicinity, collect some amount of waste and do not report that to anybody. The “Barycz” landfill has the landfill gas collection system, and burns that gas in the two co-generation engines 280 KWelectic each. The produced electricity is sold to the grid and the produced heat used in small fraction at the landfill site for heating and car washing.

THE MODEL INPUT DATA

To conduct the analysis the extensive data set is necessary. It includes not only the data about the MSW system of disposal, but also the prices and the parameters about the served community and waste composition. Each of these vales turns to be difficult to obtain. One of the elementary parameter is the waste composition and the number of waste generated. The amount of served people is also unknown with high precision, because at present there are very many private companies collecting MSW and not reporting the throughput to anybody. They not always dispose the waste at the Krakow landfill choo sing the cheaper solutions. Also the existing in Krakow dual system of collection of recyclables is not included in the official statistics. The estimated composition of the municipal solid waste in Krakow presents the Fig. 4.

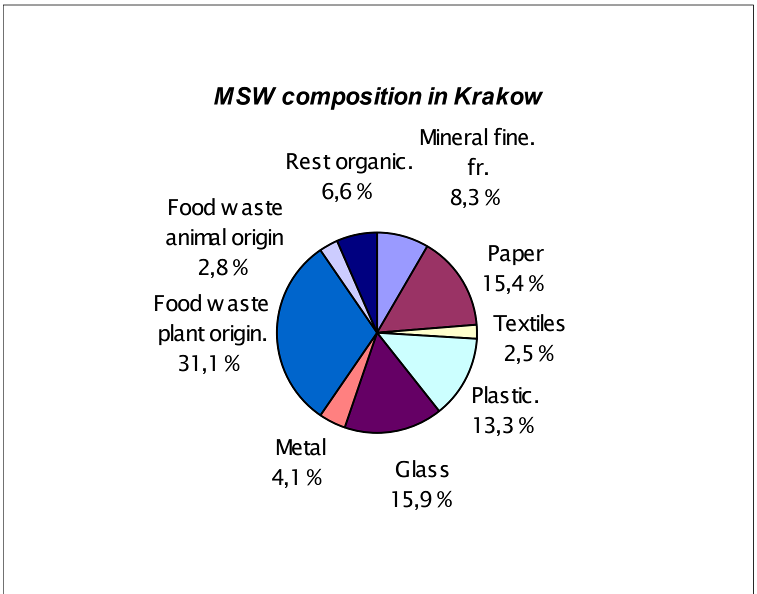

Figure 4. The estimated composition of the municipal solid waste in Krakow.

All together the model needs 69 parameters about the waste, collection, transportation and disposal systems, to estimate the air and water emissions, cost of disposal and statistics. These parameters were estimated from information gathered from the Municipal Cleaning Office (MPO) from the composting company (Ecokoncsorcjum “Efekt”), private recyclers and from the official municipal and national raports.

OBTAINED RESULTS AND CONCLUSIONS

The table of results prepared by the model is very extensive. It covers both emissions to air, and water. Thermal energy consumption of the proposed system is also calculated as well as the amount of remaining waste. Total emission to air of 22 compounds additionally with the information of the origin of the pollution (collection, sorting, biological treatment, thermal treatment and landfilling) is presented. Also the avoided emission of each compound due to material recovery is calculated.

The water emission includes the list of 23 compounds and indicators. The statistics about the recovery rates is also calculated. The calculated costs are presented in Fig 5

	COLLECTION	SORTING	BIOLOGICAL TREATMENT	THERMAL TREATMENT	LANDFILL	IWM MODEL TOTAL	RECYCLING SAVINGS	OVERALL TOTAL
(a) COST								
Overall (000 ecu)	13095,22	0,00	427,49	0,00	6977,24	20499,95	-910,41	21410,36
per tonne waste managed(ecu)						90,32		94,33
per household serviced(ecu)	52,96	0,00	1,73	0,00	28,22	82,91	-3,68	86,59

Figure 5. Some economic parameters about the Krakow MSW disposal system.

The total cost of waste disposal is divided into stages of waste processing and later compared with the avoided cost from the collection of recyclable. The total cost of the existing system is calculated in the last column.

The pollution of the MSW system to the air presents Fig. 6.

EMISSIONS AIR EMISSIONS(kg)	COLLECTION	SORTING	BIOLOGICAL TREATMENT	THERMAL TREATMENT	LANDFILL	IWM MODEL TOTAL	RECYCLING SAVINGS	OVERALL TOTAL
Particulates	8,12E+03	0,00E+00	5,58E+01	0,00E+00	-3,45E+03	4,73E+03	4,12E+04	-3,65E+04
CO	5,35E+04	0,00E+00	9,89E+01	0,00E+00	3,50E+03	5,71E+04	1,41E+04	4,30E+04
CO2	7,67E+06	0,00E+00	3,16E+06	0,00E+00	3,11E+07	4,20E+07	5,45E+04	4,19E+07
CH4	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,98E+06	6,98E+06	0,00E+00	6,98E+06
NOx	7,97E+04	0,00E+00	3,50E+02	0,00E+00	-2,08E+04	5,93E+04	1,62E+04	4,30E+04
N2O	2,01E+02	0,00E+00	1,98E+01	0,00E+00	-1,24E+03	-1,02E+03	5,13E+02	-1,54E+03
SOx	3,59E+04	0,00E+00	7,09E+02	0,00E+00	-4,42E+04	-7,58E+03	2,89E+04	-3,64E+04
HCl	1,23E+02	0,00E+00	0,00E+00	0,00E+00	1,30E+03	1,42E+03	2,00E+01	1,40E+03
HF	7,59E+01	0,00E+00	2,84E-03	0,00E+00	2,31E+02	3,07E+02	1,08E+00	3,06E+02
H2S	1,17E+01	0,00E+00	0,00E+00	0,00E+00	3,56E+03	3,57E+03	7,03E+01	3,50E+03
HC	3,99E+04	0,00E+00	5,99E+02	0,00E+00	-1,28E+03	3,92E+04	1,89E+04	2,03E+04
Chlor. HC	0,00E+00	0,00E+00	0,00E+00	0,00E+00	7,41E+02	7,41E+02	0,00E+00	7,41E+02
s/Furans (TEQ)	0,00E+00	0,00E+00	0,00E+00	0,00E+00	9,48E-06	9,48E-06	0,00E+00	9,48E-06
Ammonia	9,66E-01	0,00E+00	1,39E-01	0,00E+00	-8,71E+00	-7,60E+00	3,34E+01	-4,10E+01
Arsenic	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Cadmium	0,00E+00	0,00E+00	0,00E+00	0,00E+00	9,96E-02	9,96E-02	0,00E+00	9,96E-02
Chromium	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,17E-02	1,17E-02	0,00E+00	1,17E-02
Copper	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Lead	0,00E+00	0,00E+00	0,00E+00	0,00E+00	9,07E-02	9,07E-02	-8,71E+00	8,81E+00
Mercury	4,95E-04	0,00E+00	0,00E+00	0,00E+00	7,29E-04	1,22E-03	1,76E-02	-1,63E-02
Nickel	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Zinc	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,33E+00	1,33E+00	0,00E+00	1,33E+00

Figure 6. Air pollution from the Krakow MSW disposal system.

The interesting fact is that sometimes according to the model the emissions from the system are negative. This is due to the avoided emission from the energy generation. If there is energy generated at the landfill site. (in case of Krakow it is) this electricity substitutes the electricity which would have to be generated at the power station. The not emitted emissions from these sources is called the avoided emission.

The water pollution presents Fig. 7.

WATER EMISSIONS(kg)	COLLECTION	SORTING	BIOLOGICAL TREATMENT	THERMAL TREATMENT	LANDFILL	IWM MODEL TOTAL	RECYCLING SAVINGS	OVERALL TOTAL
BOD	5,20E+02	0,00E+00	7,68E+02	0,00E+00	1,70E+04	1,83E+04	1,38E+04	4,44E+03
COD	3,80E+03	0,00E+00	1,30E+03	0,00E+00	1,70E+04	2,21E+04	1,23E+05	-1,01E+05
spended Solids	3,34E+02	0,00E+00	4,25E-02	0,00E+00	9,63E+02	1,30E+03	7,25E+00	1,29E+03
rg. Compounds	1,47E+03	0,00E+00	1,33E+00	0,00E+00	-6,44E+01	1,41E+03	3,32E+01	1,38E+03
AOX	3,71E-01	0,00E+00	0,00E+00	0,00E+00	1,92E+01	1,95E+01	1,46E+01	4,89E+00
hlorinated HCs	0,00E+00	0,00E+00	0,00E+00	0,00E+00	9,84E+00	9,84E+00	0,00E+00	9,84E+00
s/Furans (TEQ)	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,07E-06	3,07E-06	0,00E+00	3,07E-06
Phenol	7,43E+01	0,00E+00	0,00E+00	0,00E+00	3,63E+00	7,79E+01	6,69E-02	7,79E+01
Ammonia	1,13E+01	0,00E+00	1,33E+02	0,00E+00	1,99E+03	2,14E+03	5,00E+00	2,13E+03
Toatal Metals	4,02E+02	0,00E+00	0,00E+00	0,00E+00	9,16E+02	1,32E+03	-5,64E-02	1,32E+03
Arsenic	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,34E-01	1,34E-01	0,00E+00	1,34E-01
Cadmium	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,34E-01	1,34E-01	0,00E+00	1,34E-01
Chromium	0,00E+00	0,00E+00	0,00E+00	0,00E+00	5,78E-01	5,78E-01	0,00E+00	5,78E-01
Copper	0,00E+00	0,00E+00	0,00E+00	0,00E+00	5,20E-01	5,20E-01	0,00E+00	5,20E-01
Iron	3,34E-03	0,00E+00	8,51E-04	0,00E+00	9,05E+02	9,05E+02	0,00E+00	9,05E+02
Lead	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,02E-01	6,02E-01	5,19E-02	5,50E-01
Mercury	0,00E+00	0,00E+00	0,00E+00	0,00E+00	5,72E-03	5,72E-03	0,00E+00	5,72E-03
Nickel	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,63E+00	1,63E+00	0,00E+00	1,63E+00
Zinc	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,52E+00	6,52E+00	0,00E+00	6,52E+00
Chloride	8,84E+02	0,00E+00	5,67E-03	0,00E+00	5,63E+03	6,52E+03	1,35E+02	6,38E+03
Fluoride	7,60E+01	0,00E+00	3,78E-01	0,00E+00	-2,00E+01	5,64E+01	1,05E+01	4,59E+01
Nitrate	2,19E+01	0,00E+00	3,74E-01	0,00E+00	-2,35E+01	-1,22E+00	-3,96E-02	-1,18E+00
Sulphide	8,65E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	8,65E-01	3,52E+01	-3,44E+01

Figure 7. Water pollution from the MSW system in Krakow.

The last result table is the waste statistics. It is presented in Fig. 8.

(c) STATISTICS	AVERAGE	Paper	Glass	Metal-Fe	Metal non-Fe	Plastic-film	Plastic-rigid	Textiles	Organic
Materials Recovery rate	0.6%	1.7%	0.2%	0.7%	0.2%	0.0%	0.1%	0.0%	
Organic Recovery Rate									0.2%
Overall Recovery Rate	0.4%								
Diversion from Landfill	0.5%								
	Total	Paper	Glass	Metal-Fe	Metal non-Fe	Plastic-film	Plastic-rigid	Textiles	Compost
Sec. materials (Kt/yr):	0.009	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.002

Figure 8. Waste statistics of Krakow MSW disposal system.

The statistics indicate that in the Krakow case only about 0.6% of waste is recovered. Most of it is paper (1.7%). This is a very poor statistics particularly in comparison with the legal requirements. Only 0.2% of organic fraction is recovered and the EU requires the recovery rate of 25% by year

2006 and 50% by year 2009 and finally 65% recovery of the organic waste by year 2016 the country to recover 35%. (EEA, Council Directive 1999/31/EC) This means also incinerating but this technology is not applied in Krakow at present and will not be very soon. The farther evaluation of the obtained date is likely to change this picture.

Generally, the lifecycle inventory is a useful tool for the decision makers and the presented model gives broader picture of the used system. There is a lack of reliable date and its need for the correct analysis cannot be underestimated. The presented case study is in the working stage and the presented results are subject to change, but the integrated method of system identification is attractive.. Further integration of the obtained data and application of the multicriteria techniques is necessary. This will allow the comparison of the different scenarios of waste disposal. Extension of the model to incorporate the social data and time factor will make the model more precise for the decision makers.

REFERENCES

Hultman B., Stypka T.,Stypka A. (in preparation). Concept of Sustainable Development and Tools of its Implementation. In *Municipal Solid Waste and Sludge Handling-Sustainability and Trends* Royal Institute of Technology, Stockholm.

Maler, K.G. (1990). Economic Theory and Environmental Degradation: A Survay of Some Problems, *Rexista de Analisis Economico*, **5**,2, 7-17.

Munasinghe, M. (1993). Environmental Economics and Sustainable Development, World Bank, Wahington D.C., US.

Stypka T. (in preparation). Economic Tools of Evaluations of the Solid Waste and Sludge Handling Policies In *Municipal Solid Waste and Sludge Handling-Sustainability and Trends* Royal Institute of Technology, Stockholm.

White P.R., Franke M., Hindle P. (1997). Integrated Solid Waste Management - a Lifecycle Inventory Blackie Academic & Professional.

Inspekcja Ochrony Srodowiska (2002). Raport o stanie srodowiska miasta Krakowa za lata 1999-2001 Bibilioteka Monitoringu Srodowiska