ANALYSIS OF SOLID WASTE MANAGEMENT SYSTEM IN GDAŃSK

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ABSTRACT
The article presents the application of the White's model in the city of Gdańsk in order to evaluate the environmental impact of the integrated solid waste management system. There are different information obtained. The model estimates exploitation costs of the waste management system, total energy use and also emissions of different pollutants to water body and to the atmosphere. The case study, based on Gdańsk city, shows the potential of the model.

KEYWORDS
Municipal solid waste, solid waste management, White's model

INTRODUCTION

Gdańsk lies in the northern part of Poland, at the Baltic Sea. This city lies at the mouth of Vistula, the largest Polish river. Gdańsk, together with Sopot and Gdynia, is a part of a tri–city complex. The Gdańsk city covers the area of about 26 300 ha. Buildings area cover about 4 400 ha. The forests take the area of about 4 600 ha, there are more than 10 200 ha for agricultural use. The area for communication covers almost 2 700 ha (Zarząd Miasta Gdańska, 2002). The city is divided into six main districts. The districts differ from each other. It differs with area, the type of buildings, the number of people living there. This means that there are different waste amounts generated, having different composition. In Gdańsk, there are more tenant–houses in the centre of the city, the buildings are close and densely situated. Moving from the city centre towards peripheries we can notice that there are more one–family buildings, which are not that dense as in the middle of the city.

SOURCES OF SOLID WASTE

The amount of wastes generated in Gdańsk were calculated taking into consideration the number of inhabitants and the average amount of wastes produced by a person annually in Gdańsk, which is 394 kg according to Waste Management Plan (OBREM, 2001). In the summer time, during holidays, many tourists come to visit Gdańsk. In the year 2000 more than 300 000 tourists came to Gdańsk. They also take part in waste production. Assuming that one person produces about 300 kg of solid waste during a year we can obtain general amount of the solid wastes produced during a day which is about 0.82 kg/day. Considering the fact that in the year 2000 there was 891393 accommodations provided, we can calculate the amount of solid waste generated during one year which is equal to about 731 tones.

In the last few years there was an increase in large shopping centers development observed. These complexes play a very important role in the local trade but also in waste production. Assuming that from the shopping center which is about 15 000 m^2 large we obtain about 1 500 tones of municipal solid waste (Alpha Centrum, 2003), we can calculate the estimated value taking into consideration all huge shopping centers. This value will be equal to about 14620 tones of the solid waste generated.

According to the Waste Catalogue (Ustawa o odpadach, 2001) wastes from the market places also belong to municipal wastes. There are five large markets in the city of Gdańsk, covering the area of about 118 300 m^2. The wastes coming from the markets have a quite high organic fraction. Its amount depends on the seasons. During spring and summer it could be even twice as much as in the rest of the year. It's because a lot of vegetable and fruits is being sold in this part of the year. Generally, taking into account the information from the company CLEAN-BUD which said that form a market about 4000 m^2 large there is about 260 tones of solid wastes collected every year (Clean-Bud, 2003), we can compute the possible amount of solid wastes from all the market places. Assuming that from 1m^2 we get about 0.065 tones annually, from the total area 118300 m^2 we will have about 7690 tones per year.

In Gdańsk there is different kind of greenery. The area of the greenery in the city is about 301.81 ha. If we assume that from one hectare there is 5 thousand tones of green mass obtained annually (Clean-Bud, 2003), we could easily calculate the mean value of green mass produced in Gdańsk which is about 1510 tones.

The estimated amount of the municipal solid waste generated in Gdańsk annually is presented in table 1.

Table 1. The estimated amount of the municipal solid wastes produced in the city of Gdańsk

SOURCE OF WASTES	**AMOUNT [Mg]**
Inhabitants + tourists	175 763+ 731 = 176 494
Trade	14 620
Markets	7 690
Greenery	1 510
TOTAL	**200 314**

POLICY AND STRATEGY IN WASTE MANAGEMENT

The environmental policy of Gdańsk was generally based on the resolution of the City Council from 20th of July 1993 No. LXVI/493/93 (Uchwała Rady Miasta, 1993). Additionally, in the year 1999, a 'Sustainable Development Plan in Gdańsk Municipality' was elaborated. It contained a schedule of activities to the year 2010.

The environmental policy and sustainable development assumptions, from the waste management point of view, results in the following tasks:

a) waste segregation in the whole city;
b) hazardous waste collection (like: batteries, fluorescent lamps, accumulators, medicines, etc.);
c) three ways of wastes management:
   - raw material and 'dry' wastes – contamination removal and division into parts that could be used again;
   - 'biotone' (kitchen wastes and green wastes suitable for composting) – removal of contamination in order to obtain compost for commercial purposes;
   - mixed wastes – division into wet and dry fractions; the dry one can be used as alternative fuel.

When taking into consideration the waste management there are following priorities established:

a) short–term to the year 2003 – waste management improvement:
   - selective waste collection in the whole city;
   - pro-ecological education promoting selective waste collection, implementation of organizational and technical methods concerning transport of the selected wastes to the landfill;
   - transformation of the Szadółki landfill into a modern system for municipal waste utilization;
   - safe utilization of the hazardous wastes;
b) medium–term – to the year 2006 – further waste management modernization:
   - building of a sorting plant at the Szadółki landfill;
   - organic wastes composting development;
   - creation of ballast wastes storage area;
c) long–term to the year 2010 – there are no new actions planned in the waste management; the present solutions should be constantly improved.

CHARACTERISTICS OF SOLID WASTE IN GDAŃSK

The figure 1 shows the morphology of the municipal solid wastes in Gdańsk (in the year 2000).

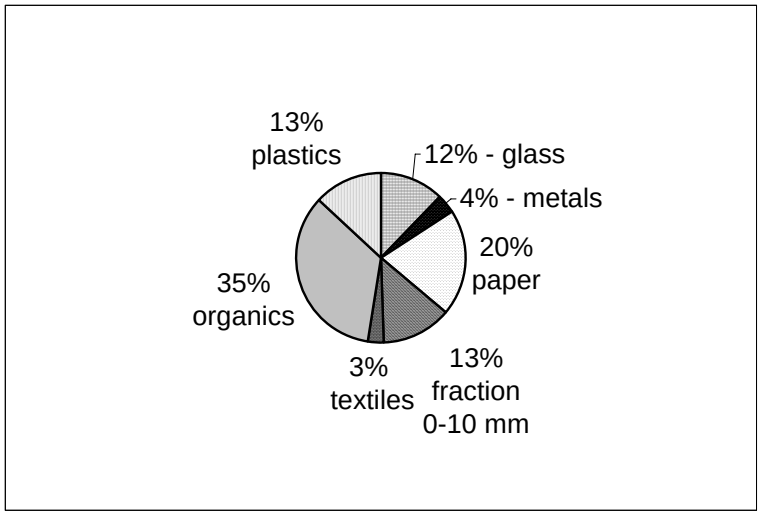

Figure 1. Morphology of municipal solid waste in Gdańsk in 2000 year.

Segregation of solid wastes in the city of Gdańsk has been carried out since 1993. The company that is engaged in solid waste segregation is PRSP S.A. This is performed with the use of system of container sets. There are 429 container sets in use:

a. 409 three container sets for paper, glass and plastics;
b. 20 two container sets for paper and glass only;

Aluminum cans are collected separately and for this purpose there are 219 special containers.
The local authorities also try to eliminate the hazardous materials from the municipal solid wastes – used batteries, overdue medicines and fluorescent lamps (Zarząd Miasta Gdańska, 2002).

The table 2 shows the amount of selected solid wastes collected in the containers in Gdańsk within the period 1997 – 2001.

Table 2. The results of selective collection of solid wastes in Gdańsk

WASTE TYPE [Mg]	1997	1998	1999	2000	2001
Paper	15	30	43	150	310
Glass	300	252	1800	400	490
Plastics [m^3]	600	1800	150	190	170
Used Batteries	0.1	no data	no data	no data	no data
Overdue medicines	3.0	3.0	2.2	2.5	3.8
Fluorescent lamps	-	-	5200	3477	7733

The main source for secondary materials recovery in Poland is its buying by special companies. The secondary materials suppliers are the inhabitants, different firms and all the other which generate solid wastes directly. Scavengers and the companies which deal with transport of the wastes also supply it to the purchasing points.
In the city of Gdańsk there is a few secondary materials purchasing points and they have collected a big amount of material. In summary, in the year 2000 in Gdańsk the total amount of secondary materials accumulated after selective collection and gathered by the purchasing points was 34.5 thousand tones (Tab. 3).

Table 3. The amount of secondary materials gathered by the purchasing points in Gdańsk

SECONDARY MATERIAL	AMOUNT [Mg]
Paper	7 814
Glass	400
Plastics	170
PE foils	22
Aluminum cans	310
Steel scrap	25 346
Accumulators	428
Bottles	0.8
TOTAL	**34 490.8**

The recent research show that in the present time it is possible to recover and manage about 20% of paper, 20% of glass and 20% of plastics. This fact, considering the solid waste morphology (Fig. 1), causes a decrease in the total municipal waste mass by about 9%. The rest usually is deposited onto landfill. Landfill in Szadółki is located about 8 km from the city center, in the south-eastern part of the city and it covers the area of about 65.95 ha from which 42.76 is for garbage disposal. The volume of about 810 000 m^3 has been used so far. It is assumed that the whole volume will be used by the year 2015. The price for a deposition of one tone of non-segregated solid wastes is about 57.50 zł which is 13.70 Euro.
As we have found there is a general increasing tendency in the amount of wastes which is deposited in the landfill. In 1991 it was about 200 Mtons and in 2001 about 256 Mtons. But we can also notice that in the year 1994 there is a significant decrease in the solid waste mass deposited on the landfill (from 297 Mtons in 1993 to 175 Mtons in 1994). This is because in 1993 there has been selective collection system introduced in the city of Gdańsk.

There are different ways of solid wastes utilization in the Szadółki landfill. These are:

- Organic wastes composting (with the maximum composting ability of 3000 tones annually);

- Green wastes composting;
- Tyres collection point;
- Pyrolysis of hazardous wastes;
- Debris crushing;
- Treatment of the soil contaminated with oily substances by biodegradation;

ANALYSIS ACCORDING TO WHITE'S MODEL

The analysis of the solid waste management for the city of Gdańsk was performed with the use of White's model (White et. All., 1996). This model is based on a life cycle of solid waste from the point it is produced to the moment it is utilized. The White's model has been constructed using Excel program and in details it was presented elsewhere (Stypka, Kopacz, 2003). Every data which were collected and recalculated were introduced to the model to different Excel boxes. The data which are used were taken from different sources: the City Council, PRSP S.A., secondary materials purchasing points and other institutions that are engaged in solid waste management. However, some of the data had to be estimated because there were no data available.

There are different scenarios of waste management in Gdańsk analyzed using the White's model. The first scenario reflects the present situation in the waste management in the city of Gdańsk. Here we took into consideration the following:

- selective collection of secondary materials (paper, glass and plastic);
- secondary materials purchasing;
- collection of non segregated wastes;
- green wastes composting (garden waste);
- deposition of the solid wastes at the landfill;

The second scenario assumes further development of the present solutions (doubling the number of selective collection containers and introduction of two container sets for collection of wet and dry fractions) and additionally, building of a composting plant and a material recovery facility. The third scenario assumes further development of the segregation system, utilization of hazardous waste from the household waste stream and additionally building of an incineration plant.

ANALYSIS OF THE RESULTS

The results obtained after putting all the data in the model are very wide. We get different information connected with the waste management system – both directly and indirectly. We learn about the costs of the selected system, about energy consumption. We also know the scale of emissions of various toxic substances to the atmosphere and to water environment.

The emissions to the air of the following substances can be computed in the model: CO, CO_2, CH_4, NO_X, N_2O, SO_X, HCl, HF, H_2S, HC, Dioxins/Furans, Ammonia, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel and Zinc.

When considering the emissions to the water body we obtain the information of the following: BOD, COD, Suspended Solids, Total Organic Compounds, AO_X, Chlorinated Hydrocarbons, Dioxins/Furans, Phenol, Ammonia, Total Metals, Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, Zinc, Chloride, Fluoride, Nitrate and Sulphide.

In this work there are only some of results presented. There were chosen results considering economical part and some emissions to the atmosphere.

The results obtained are presented in figures 2-5 in the form of graphs, where the numbers on the horizontal axis relate to the following stages of the waste management system:

1 – solid waste collection;
2 – sorting process;
3 – composting process;
4 – incineration;
5 – solid waste deposition;
6 – overall total;

The exploitation costs at different stages of the solid waste management system are presented in the figure 2.

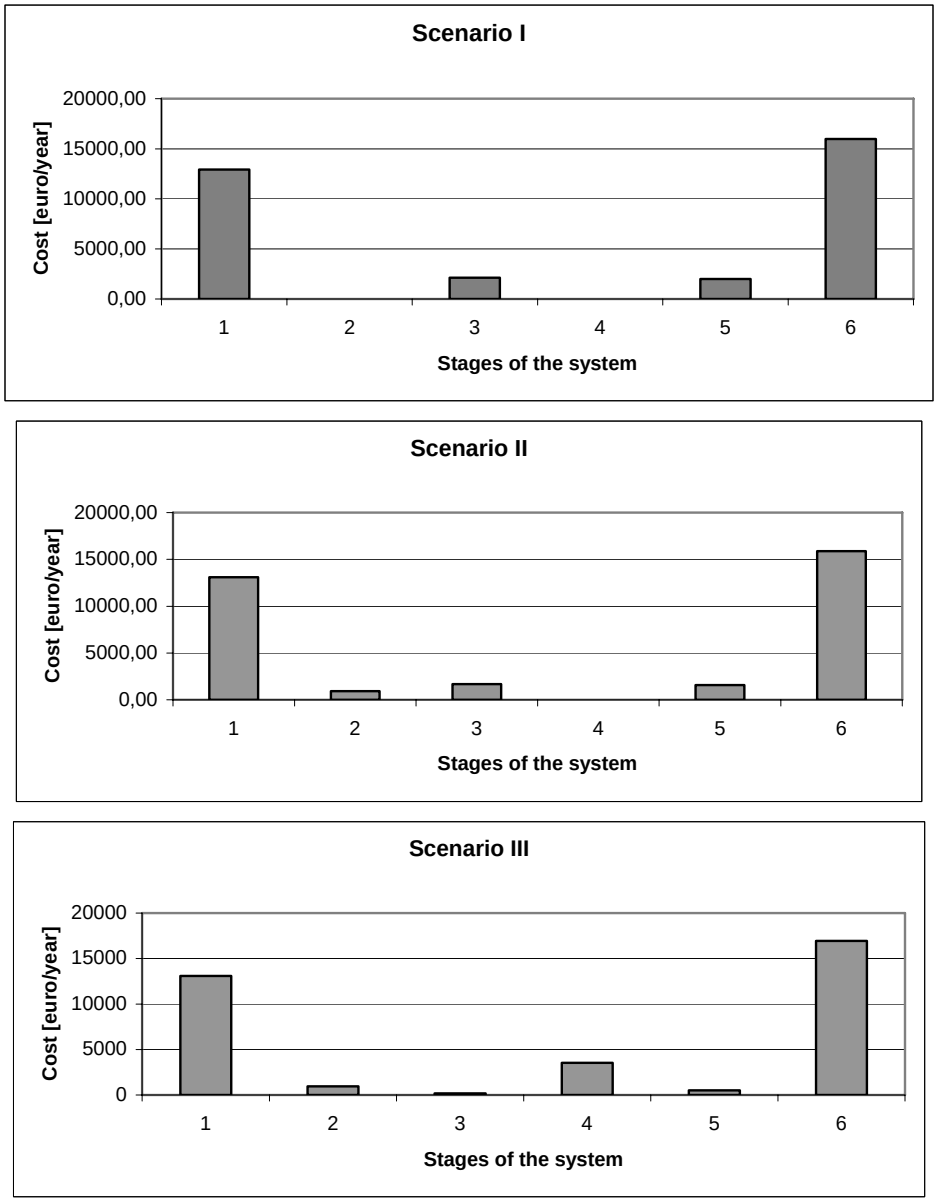

Figure 2. The exploitation costs in different stages of the waste management system

As we can see on the graphs solid waste collection is the most expensive process in the solid waste management system. If the collection system is more developed it costs more money. We can also notice that there are cheaper (composting) and more expensive ways (incineration) connected with

dealing with the solid wastes. The scenarios which include more advanced technology implementation (MRF facility, incineration plant) need more money. Unfortunately, the model does not take into account investment cost. If so, the costs in some stages would be much greater (for instance: the cost of building of incineration plant).
Finally, one can state that the total costs are quite similar, independently on the scenario.

The energy consumption at different stages in solid waste management system is presented in the figure 3.

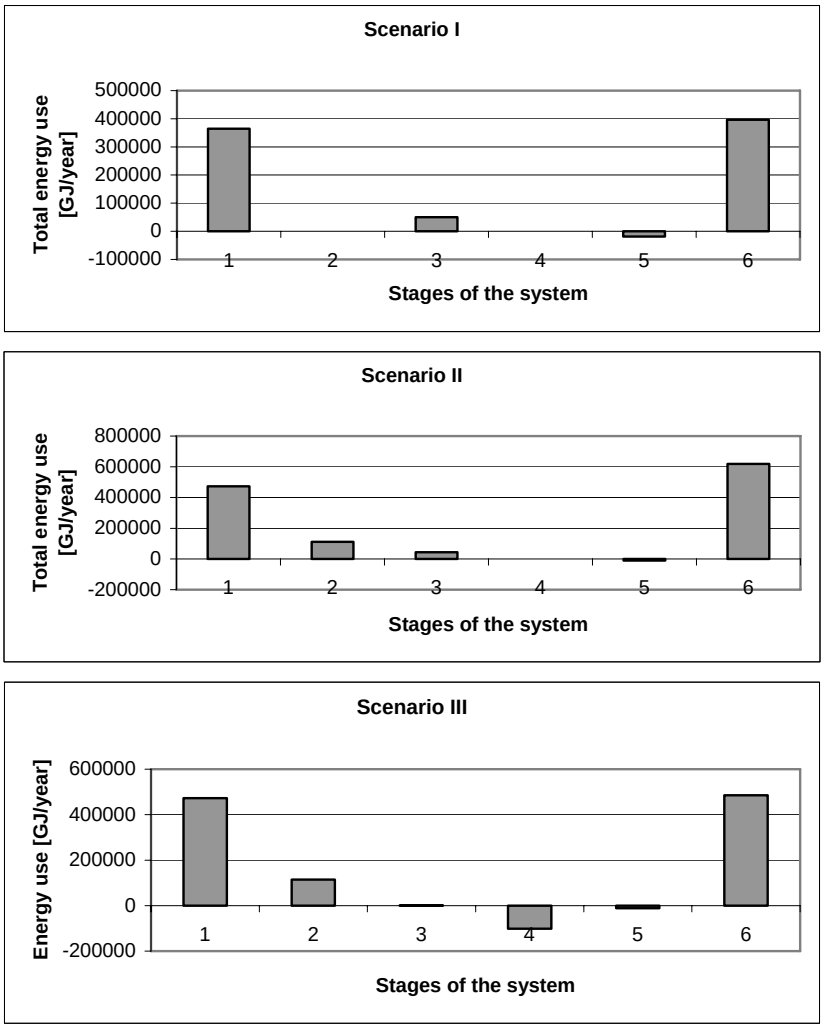

Figure 3. The energy consumption in different stages of the waste management system

The energy consumption is very high in all cases taking into account the first step of solid waste management which is its collection. The development of the collection systems in the scenarios II and III results in costs rise – this is well shown on the graphs. Sorting technology also consumes some energy, and very little of energy is used during composting processes. When considering incineration process we can see that there is energy gained. In the solid waste deposition, the observed negative value is an effect of biogas collection which means that there is also a gain of energy.

The carbon dioxide emissions at different stages in solid waste management system are presented in the figure 4.

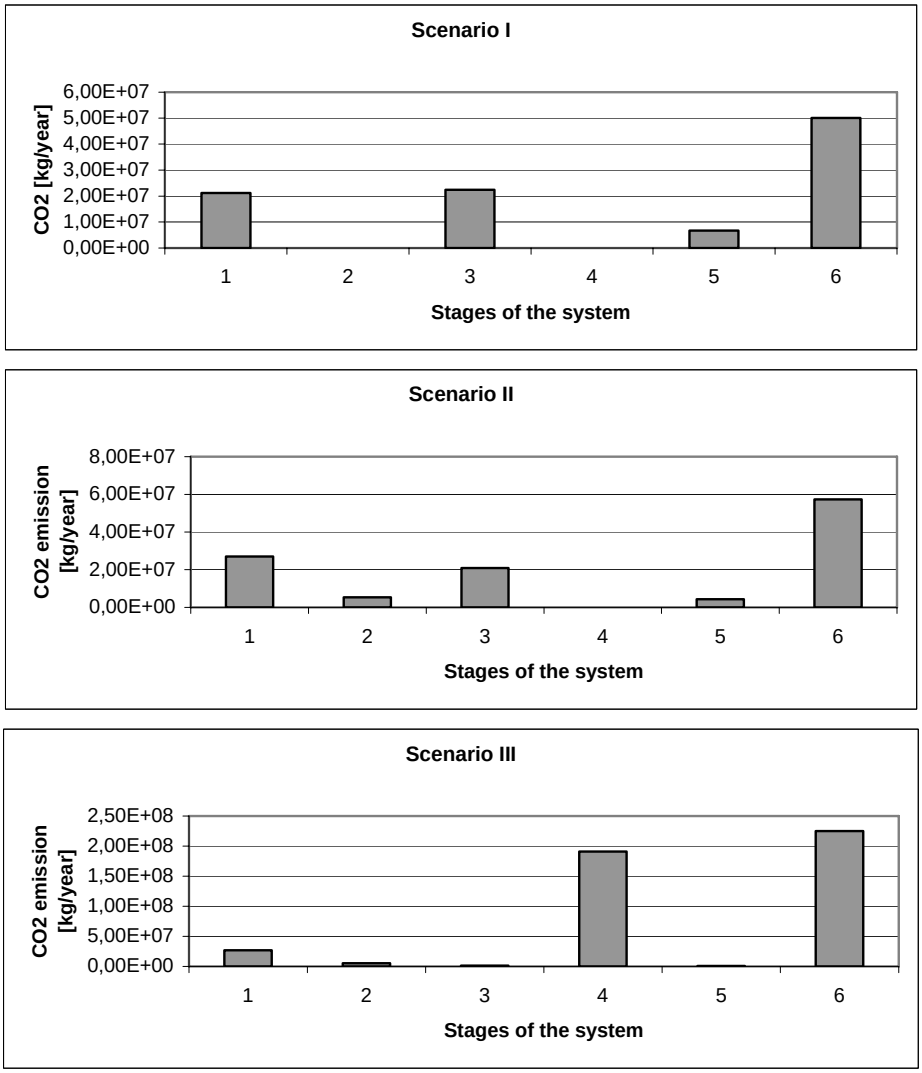

Figure 4. The carbon dioxide emissions in different stages of the waste management system

The carbon dioxide emission is well presented. Without any hesitation one can say that the highest CO_2 emissions are connected with the solid waste incineration. This is connected with the fact that during incineration of the solid waste carbon dioxide is produced. In scenarios I and II, where there is no incineration, the biggest amount of carbon dioxide is emitted during landfilling. It is because CO_2 forms during biogas generation inside the dump.
There is also some CO_2 gas emitted in the composting processes due to decomposition of organic matter, as well as during waste collection (mainly with exhaust gases from vehicles during transport). The total CO_2 emission is the lowest in the scenario I and the highest in the scenario III.

The nitrogen oxides emissions to the air at different stages in solid waste management system is presented on the figure 5.

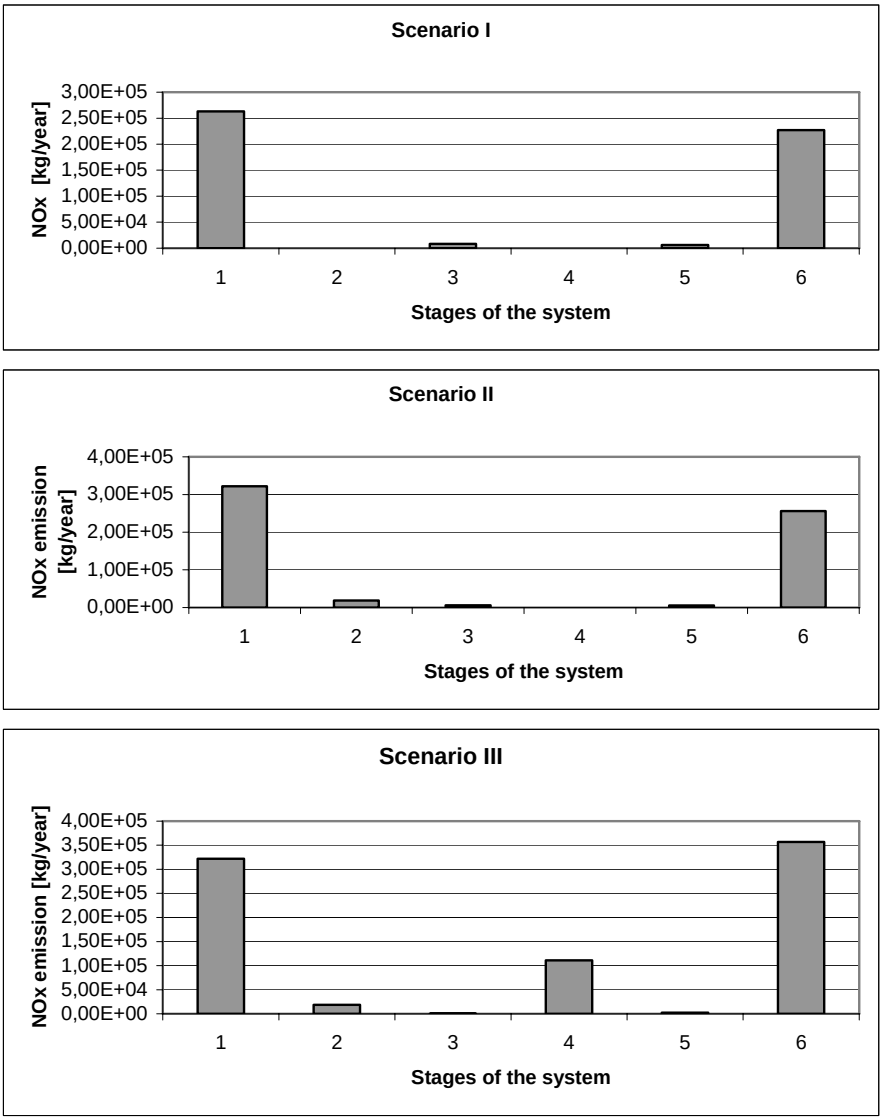

Figure 5. The nitrogen oxides emissions in different stages of the waste management system

When analyzing the nitrogen oxides emissions to the atmosphere we can also notice that the highest emissions are recorded in the first step of waste management – solid waste collection. The values are larger if the collection system is more advanced. In the other stages NO_X emissions are not significant except the incineration in the scenario III where the emissions are greater.

CONCLUSIONS

The results obtained in the analysis give us information about the costs, the energy consumption and possible emissions of different substances. Gaining of reliable information is strictly dependent on the data we use, which are sometimes difficult to possess. But the more detailed data we have the better results we get. The model takes into account all the stages which are present in the solid waste management, starting with the point of solid waste production and finishing at the point of its utilization. This model can give us very valuable information when considering different scenarios of waste management. This can be very useful in choosing the most advantageous system.

When considering the results obtained in the analysis, we can notice that every new scenario, which consider the development of the waste management system is related with financial expenditures. Selective collection of the solid waste is much more expensive than collection of the mixed solid wastes. Building of a material recovery facility or an incineration plant is very expensive as well, however, it was not shown on this model (investment costs were not included). On the other side, the emission to the environment can be minimized or increased when new technologies are implemented.

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