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Importance of Municipal Waste Data Reliability in Decision Making Process Using LCA Model- Case Study Conducted in Timok County (Serbia)

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Abstract

This paper presents the consequences of using various waste management data for the municipal waste management planning process in the Timok County (Serbia) using life cycle analysis. Life cycle analysis was performed using the integrated waste management model which is designed to analyze different waste management options for the implementation of integrated waste management system. The results of this model are presented through two indicators: global warming potential and costs of selected waste management system. The aim of this paper is to examine and to discuss contribution of life cycle analysis in decision making process in waste management sector and to emphasize importance of waste data in waste management planning as well as prediction of the environmental performance and economic cost of an integrated waste management system. The application of data analysis on the evaluation of life cycle solid waste management system in the Timok County (Serbia) is an innovative approach to this problem, necessary to make the right, professional decisions in the field of waste management not only in the Republic of Serbia, but also in European union candidate, potential candidate countries as well as any other countries in the world. Results indicate significant differences in global warming values, respectively the impact of waste disposal options on global warming and the costs of such system, depending on the data source that was used. Bearing in mind the implications of waste data can play in a variety of sectors and decision making process, this research refers to the need for reliable data.

Introduction

Municipal waste management is one of the priorities of environmental management [1] in all countries that are members of the EU as well as in the Republic of Serbia, which started the EU Accession Negotiations Process. In the Republic of Serbia, environmental protection, especially municipal waste management, is acknowledged as one of the most demanding and the most complex chapters when it comes to approximation of legislation, investments needed and adopting technologies necessary to reach the EU standards [2]. The long term environmental strategy of the Republic of Serbia, based on principles of sustainable development, is practically unachievable without considering the problems of planning and resolving inadequate waste management [3]. The Law on Waste Management (LWM) [4] and by-laws introduced the obligation of waste generators report on the quantities and composition of generated waste. Furthermore, the LWM stipulates that each municipality develop a municipal waste management plan; subsequently, municipalities must then organize themselves into regions and prepare regional waste management plans based on the local plans [5] and accurate data on the quantities and composition of waste. The importance of planning in municipal waste management is reflected in the fact that the management plans have to integrate the most appropriate option for the environment, taking into account economic, technical, social and environmental factors [6]. Analysis of a different waste management options allows decision makers to use different instruments to consider more acceptable options and make decisions about the optimal option to satisfy their specific needs. The bases for decision-making process are waste generation and waste composition data in a given territory within a certain time.

The National Waste Management Strategy (NWMS, 2003) in Serbia [7] has identified the lack of data on composition and quantities of municipal waste generated across the country. In most municipalities in the Republic of Serbia there is a lack of information of waste qualitative and quantitative analysis, i.e. data base of quantities, characteristics, especially content and classification of waste. Most companies which have the duty of waste collection and its transport to the disposal site do not perform measuring procedure of waste quantities, nor do they have proper equipment for performing this procedure.

For this reason in the Republic of Serbia there are no quality baseline data for making professional decisions for the implementation of integrated waste management. The sources of data on the waste can be found in various national, regional and local documents and databases (Statistical Office of the Republic of Serbia, Serbian Environmental Protection Agency, regional and local waste management plans, local strategies). The diversity of data on the quantity and composition of municipal solid waste generated in local governments or regions, which are located in different documents, refer to different sizing of necessary infrastructure capacity for implementation of modern waste management system in their territories. In the final instance, this fact has a financial implication. This paper presents the consequences of using various data in the municipal waste management planning process in municipalities of

the Timok County through the application of LCA (LCA-Life Cycle Assessment) study. The application of data analysis on the evaluation of life cycle solid waste management system in the municipalities Zajecar, Boljevac, Knjazevac, Majdanpek, Kladovo, Negotin and Bor (Timok County, Serbia) is an innovative approach to this problem, necessary to make the right, professional decisions in the field of waste management. The aim of this paper is to examine and to discuss contribution of LCA analysis in decision making process in waste management sector and importance of waste data in prediction of the environmental performance and economic cost of an integrated waste system.

Life cycle assessment model as a tool for planning solid waste management

Life cycle assessment is an analytical tool for evaluating environmental impacts. This tool can be used in decision-making process during the selection of appropriate options for municipal solid waste management [8]. Framework for Life Cycle Assessment (LCA) is described in ISO 14040 standard. LCA study is conducted through: the development of an inventory of relevant inputs and outputs of a given product system; evaluation of potential impacts on the environment given the inputs and outputs and interpretation of the results of inventory analysis and impact of assessment phases in relation to the objectives of the study placed [9]. LCA was initially developed for evaluating the whole life cycle of products, including extraction of resources, production, distribution, use and disposal [10].

In the waste management sector, LCA can be applied to compare the environmental performance of alternative waste treatment systems and identify focus areas for system performance improvement. All life cycle is seen through approach "from cradle to grave." The cycle begins ("the cradle") from the moment when some product is identified as a waste in households, and it is usually the dustbin. The "grave" is the final disposal of the product; often back into the earth (as emissions to water, air, soil) as landfill. Waste is inevitable "product" of society. Analysis based on the application of LCA studies on waste management claim that the waste management should be conducted so that the risk to human health is minimized and on recognition that the waste is actually a resource [8]. A prerequisite to create LCA studies for product or waste is good input data [11]. The requirements in terms of data quality are defined by the standard ISO 14044 and should include the following [9]:

- time-related coverage: age of data and the minimum length of time over which data should be collected;
- geographical coverage: geographical area from which data for unit processes should be collected to satisfy the goal of the study;
- technology coverage: specific technology or technology mix;
- precision: measure of the variability of the data values for each data expressed (e.g. variance);
- completeness: percentage of flow that is measured or estimated;
- representativeness: qualitative assessment of the degree to which the data set reflects the true population of interest (i.e. geographical coverage, time period and technology coverage);
- consistency: qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis;
- reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow

an independent practitioner to reproduce the results reported in the study;
- sources of the data;
- uncertainty of information (e.g. data, models and assumptions).

Therefore, the efficacy of LCA studies on waste management system depends on the quality of data that need to be characterized by quantitative and qualitative aspects, as well as the methods used to collect and merge these data.

Waste management system in municipalities of the Timok county

Timok County includes municipalities of: Zajecar, Boljevac, Knjazevac, Majdanpek, Kladovo, Negotin and Bor. This County belongs to parts of the mountain range Carpatho-Balkanides [12]. The specified area of Eastern Serbia occupies an area of over 3.000 km2, which corresponds to 30% of the area of the massif of the Carpatho-Balkanides [13].

Existing environmental problem of the Timok County is the fact that the total waste (municipal, industrial and hazardous), is dumped without pretreatment. The only method of waste management in the region is disposal. Waste is disposed on the municipal disposal sites, which are more or less neglected [6]. This non-systematic disposal has caused great pollution not only in municipal landfills, but also on the whole territory of the region. In addition, the city dump presents a risk to human health and the environment because they do not meet the basic measures of protection in accordance with the sanitary and technical standards. Therefore, almost all local landfills consider that unsanitary [12].

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According to the National Waste Management Strategy [2] the Waste Management Act [5], as the optimal solution for the disposal of waste is proposed to set up a regional waste management, which includes the construction of regional sanitary landfills. In accordance with these requirements, the municipality of Zajecar is expressed as a leader in the regional organization of municipalities of the Timok County. Taking into account its central position, Zajecar joined the preliminary analysis of potential locations for the regional sanitary landfill on its territory where it showed an appropriate location "Halovo" [14].

Experimental Section

As a starting point for this paper are used data on quantities and composition of waste resulting in the municipality of Zajecar, Boljevac, Knjazevac, Majdanpek, Kladovo, Negotin and Bor which are potential members of the waste management region. The total population of the County is about 260.000 inhabitants. Data are taken from the following documents:

Waste Management Strategy for the period 2010-2019 [2] (further on: the Strategy)

Regional Waste Management Plan for municipalities ZajecarBoljevac, Bor, Kladovo, Majdanapek, Negotin, and Knjazevac [13], (further on: Regional Plan)

Data from the Statistical Office of the Republic of Serbia - Census of Population and Housing in the Republic of Serbia in 2011 [14] and Statistics of waste and waste management in the Republic of Serbia [15,16] (further on: the Statistics)

Determining the composition of the waste and the amount of the assessment in order to define the strategy of secondary raw materials as part of the sustainable development of the Republic of Serbia [17]. (further on: a Project)

The data are shown in Table 1 and processed using IWM-2 model-Integrated Waste Management model. From Table 1 it is evident that the present data shows considerable variability between different data sources in all categories, i.e., in terms of population, the amount and composition of MSW-Municipal Solid Waste, and to all municipalities.

The model IWM-2 is designed for use in the development of LCA studies, specifically intended to handle issues related to waste. LCA analysis performs using the IWM-2 model and provides an understanding of the life cycle of waste and its impact on the environment. The model is intended for researchers, waste managers and policy makers as a useful tool that will help in analyzing the different options for the introduction of integrated waste management. IWM-2 model requires input data relating to the quantity and composition of waste [18]. The results of this model are presented in the form of emissions to environmental media, generated during the life cycle of waste and resource consumption for different waste management options, including collecting, sorting, biological waste treatment, thermal treatment of waste, recycling and disposal. The functional unit is the total amount of waste generated by the residents of each municipality in tonnes per year.

City / Data sources	1	2	3	4
Kladovo				
Population	22.640	23.613	20.635	23.613
Average number of person per household	2,8	2,8	2,8	2,8
Amount of generated (kg/person/year)	317	183	360	114
Composition (% by weight) :	12,6	20	15,8	14,4
paper	5,4	20	5,3	4,6
glass	2,4	5	2,7	2,8
metal	12,8	30	15	15,1
plastic	5,6	5	5,6	7,5
textiles	49,7	20	42,9	42,1
organics	11,5	/	12,7	13,5
other				
Total diesel fuel consumption for transport 38.571 litres/year				
Negotin				
Population	41.380	43.418	36.879	43.418

Average number of person per household	2,8	2,8	2,4	2,8
Amount of generated (kg/person/year)	317	208	360	114
Composition (% by weight) :	12,6	3,5	15,8	14,4
paper	5,4	6	5,3	4,6
glass	2,4	1,5	2,7	2,8
metal	12,8	5	15	15,1
plastic	5,6	6	5,6	7,5
textiles	49,7	31	42,9	42,1
organics	11,5	47	12,7	13,5
other				
Total diesel fuel consumption for transport 43.200 litres/year				
Majdanpek				
Population	21.691	23.703	18.179	23.703
Average number of person per household	2,8	2,8	2,5	2,8
Amount of generated (kg/person/year)	317	311	360	114
Composition (% by weight) :	12,6	37,5	15,8	14,4
paper	5,4	7,5	5,3	4,6
glass	2,4	6	2,7	2,8
metal	12,8	12,5	15	15,1
plastic	5,6	4	5,6	7,5
textiles	49,7	17,5	42,9	42,1
organics	11,5	15	12,7	13,5
other				
Total diesel fuel consumption for transport 30.720 litres/year				
Bor				
Population	55.817	55.817	48.155	55.817
Average number of person per household	2,9	2,9	2,9	2,9
Amount of generated (kg/person/year)	317	183	360	114
Composition (% by weight) :	12,6	9,6	15,8	14,4
paper	5,4	2,5	5,3	4,6
glass	2,4	2	2,7	2,8
metal	12,8	11,5	15	15,1
plastic	5,6	4,5	5,6	7,5
textiles	49,7	55,5	42,9	42,1
organics	11,5	14,4	12,7	13,5
other				
Total diesel fuel consumption for transport 18.023 litres/year				
Zaječar				
Population	63.398	65.969	58.547	65.969
Average number of person per household	2,9	2,9	2,7	2,9
Amount of generated (kg/person/year)	317	333	360	114

Composition (% by weight) :	12,6	9	15,8	14,4
paper	5,4	5	5,3	4,6
glass	2,4	2	2,7	2,8
metal	12,8	12	15	15,1
plastic	5,6	3	5,6	7,5
textiles	49,7	30	42,9	42,1
organics	11,5	39	12,7	13,5
other				
Total diesel fuel consumption for transport 8.135 litres/year				
Boljevac				
Population	14.610	15.849	12.865	15.849
Average number of person per household	3	3	2,7	3
Amount of generated (kg/person/year)	317	370	360	114
Composition (% by weight) :	12,6	1	15,8	14,4
paper	5,4	3	5,3	4,6
glass	2,4	5	2,7	2,8
metal	12,8	3	15	15,1
plastic	5,6	1	5,6	7,5
textiles	49,7	4	42,9	42,1
organics	11,5	83	12,7	13,5
other				
Total diesel fuel consumption for transport 6.933 litres/god				
Knjaževac				
Population	34.435	37.172	30.902	37.172
Average number of person per household	2,8	2,8	2,6	2,8
Amount of generated (kg/person/year)	317	598	360	105
Composition (% by weight) :	12,6	10	15,8	9,5
paper	5,4	5	5,3	2,9
glass	2,4	6	2,7	1,9
metal	12,8	15	15	12,3
plastic	5,6	5	5,6	4,9
textiles	49,7	30	42,9	52,5
organics	11,5	29	12,7	16
other				
Total diesel fuel consumption for transport 36.000 litres/year				

Table 1: Presentation of data and data sources that are used when creating LCA studies for the Timok County.

For the purposes of this research, and in order to discuss the role of data reliability in the process of decision-making on integrated waste management, two indicators are shown in studies, using the IWM-2 model that was used for its analysis:

GWP-Global Warming Potential based on the calculation of the amount of air emissions (emissions that contribute to global warming, CO_2, CH_4 and N_2O) and

- costs of selected waste management system (collection, transport and disposal) that a resident of the municipality paid annually
- The indicators are calculated on the basis of data from these different data sources. Comparative analysis was performed for three waste management options, including:
- disposal of mixed materials/waste to local unsanitary landfill (landfill without landfill gas collection or leachate collection)
- disposal of mixed waste to local sanitary landfill (landfill with landfill gas collection and energy recovery and leachate collection and treatment)
- disposal of mixed waste from all municipalities to the regional sanitary landfill (landfill with landfill gas collection and energy recovery and leachate collection and treatment).

Data on the amount of diesel fuel needed for waste transport (to a local landfill, as well as to the future regional sanitary landfills) were obtained from the records of the municipal utilities, responsible for the collection and transportation of waste.

Distances regional landfill "Halovo" from local landfills were calculated according to regional waste management plans for the Timok County.

Results

Based on the basic data for the municipality, using the IWM-2 model, analyzed indicators were specified as:

- GWP calculated according to the model of the IPCC-Intergovernmental Panel on Climate Change, and
- information about the level of costs per capita, required for the implementation of a waste management system that includes disposal of mixed materials/waste to local unsanitary landfill, local sanitary landfill and the regional sanitary landfill.

As global warming is a priority criterion in policy, this indicator should always be included in any decision-supporting assessment of the environmental impacts of waste management options [19]. GWP values for waste management in each municipality in Timok County for two different scenarios: disposal of mixed waste to local unsanitary landfill (landfill without landfill gas collection or leachate collection) and disposal of mixed waste to local sanitary landfill (landfill with landfill gas collection and energy recovery and leachate collection and treatment) were shown in Figure 1. It can be seen that the GWP varies depending on the data source and deviations were also up to 96%.

Table 2 presents the differences (%) in the GWP values between a minimum and maximum value of the municipalities, depending on the source of the initial data for two options: sanitary and unsanitary waste disposal. The data presented in Table 2 for GWP, calculated for waste disposal at the regional sanitary landfill "Halovo", showed that GWP varies up to 65% according to different sources.

For the purpose of this research, waste disposal fees were calculated using the IWM-2. Waste disposal fees present fees which inhabitants pay for the waste disposal on the local unsanitary and sanitary landfill. The results are shown in Figure 2.

Table 3 presents differences in waste management fees per person per year (%) between the minimum and maximum amount of a fee, according to data from various sources and in the case of waste disposal to the local unsanitary and sanitary landfill.
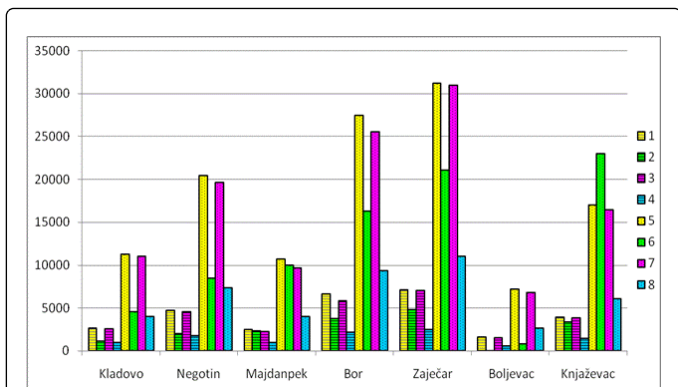
Figure 1: GWP values (tonnes) for Timok municipalities in case of waste disposal to sanitary (1-4) and unsanitary local landfill (5-8) (Data processed according to the results of IWM-2 model).
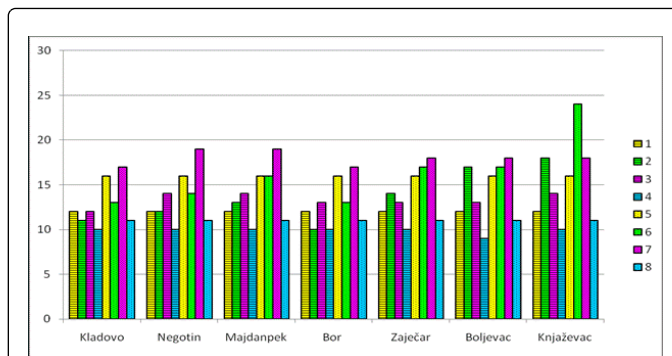

Figure 2: Waste management fees per capita in municipalities of the Timok County in the case of waste landfilling on sanitary (1-4) and unsanitary landfill (5-8) (eur/capita/year) (Data processed according to the results of IWM-2 model).

City	Kladovo	Negotin	Majdanpek	Bor	Zaječar	Boljevac	Knjaževac
Unsanitary landfill							
GWP	4/11,26	7,3/20,4	4/10,7	0,9/27	11,1/31,7	0,8/7,2	6,6/22,9
%	65	64	63	96	65	89	71
Sanitary landfill							
GWP	1,1/2,6	1,8/4,8	0,9/2,5	2,1/6,6	2,5/7,5	0.2/1,6	1,4/5,3
%	58	62	64	68	67	87	74
Regional sanitary landfill							
GWP	10,1-29						
%	65						

Table 2: Differences in GWP values (103 tons) per municipalities of the Timok County in the case of waste disposal on sanitary and non-sanitary landfill (%).

City	Kladovo	Negotin	Majdanpek	Bor	Zaječar	Boljevac	Knjaževac
Unsanitary landfill							
Fees	17-Nov	19-Nov	19-Nov	17-Nov	18-Nov	18-Nov	24-Nov
Increase %	35	42	42	35	39	39	54
Sanitary landfill							
Fees	12-Oct	14-Oct	14-Oct	13-Oct	14-Oct	17-Sep	18-Oct
Increase %	17	29	29	23	29	47	44
Regional sanitary landfill							
Fees	14-Oct						
Increase %	29						

Table 3: Shows differences in the amount of waste management fees (minimum/maximum value, eur) per person, per year in municipalities of the Timok County for waste disposal to the local unsanitary and sanitary landfill (%).

According to data presented in the Table 3, it can be concluded that differences in the amount of waste management fees per capita are up to 54% in some municipalities of the Timok County, taking into account various data sources.

This can be represented as follows: According to data from one source, an inhabitant of the municipality of Knjazevac would pay for waste landfilling on unsanitary landfill 54% more than for the used data from other sources for the calculation.

GWP values, calculated for waste landfilling on regional sanitary landfill "Halovo" for all municipalities of the Timok County, using different data sources, are shown in Figure 3.

Fees paid by inhabitants of the Timok County for collection, transport and waste disposal on sanitary landfill "Halovo", calculated according to different data sources are presented in Figure 4.

Discussion

From the results of GWP (Figure 1 and Table 2), it can be seen that the GWP value count, based on data from various sources, differ drastically, even up to 96% (e.g. the Municipality of Bor) for both waste disposal options (waste disposal on local sanitary and unsanitary landfills) and up to 65% for waste disposal on regional sanitary landfill "Halovo." Several studies also shown that the sources used for the inventory analysis varied [21-23]. These differences affect the reliability and validity of used data and direct potential data for customers' evaluation [21]. This indicates the need for updating and uniforming data about waste amount in Serbia and other developing countries. Figure 1 present that sanitary waste disposal method, with technical measures that it includes, is a better solution from the point of *greenhouse gas* (GHG) emission (e.g. the Municipality of Zajacar

77%). It is also evident that GWP values may vary depending on methods of waste treatment as well [23-25].

The municipal cost for waste collection and treatment depends on collection schemes and reprocessing operation [26]. IWM-2 software provides an opportunity to assess waste management fees (using transportation and waste disposal costs typical for EU countries), so Figure 2 and Table 3 show fees value for the collection and waste disposal on local unsanitary and sanitary landfill for inhabitants of the Timok County, according to the data from different data sources. On the basis of the present data, it should be noted that there are significant differences in waste management fees per capita, depending on the waste disposal method and used data sources. According to various data sources, differences in waste management fees per capita can be up to 54% as shown in the Table 3. It is important to conclude that sanitary waste disposal requires lower waste management fees per capita, taking into account all technical requirements for sanitary waste landfilling (using landfill gas etc.). The economics of energy recovery from landfill gas associated with CO_2 reductions are shown to be significantly better than other alternative energy forms [27]. All of this is very important in decision-making process, because waste management fee is one of the most critical parameters for decision on the establishment of a waste management system in the municipality. Using waste management data from various sources indicates that there is an inconsistency, which is reflected in the results for GWP and waste management fees per capita and have to be taken into account when decisions are made on the implementation of adequate waste management system.
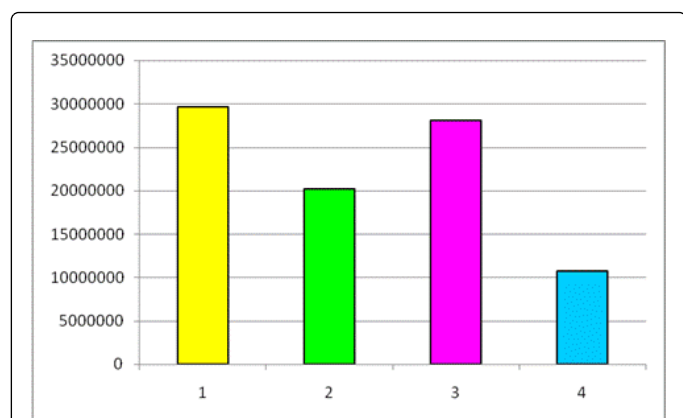

Figure 3: GWP values for the entire Timok County in the case of waste disposal on the regional sanitary landfill "Halovo" (tons) (Data processed according to the results of IWM-2 model).

Conclusions

From the above analysis, it is clear that prerequisite for the implementation of a waste management system is reliability data on a national and local level. The analysis was conducted using the IWM-2 model, and it showed significant differences in GWP values, respectively the impact of waste disposal options on global warming and the costs of such system per capita, depending on the data source that was used. The establishment of valid data on waste is a prerequisite for making decisions as follows:
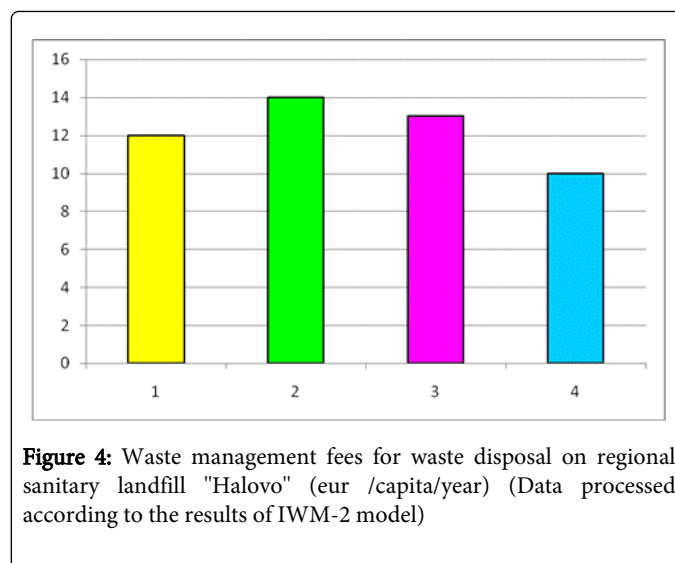

Figure 4: Waste management fees for waste disposal on regional sanitary landfill "Halovo" (eur /capita/year) (Data processed according to the results of IWM-2 model)

- designer to design the optimal and efficient facility,
- decision-makers to make timely and proper decision,
- state authorities to report on the state of the environment and waste management practices in their territories, and
- inhabitants to establish waste management fees.

At this point, the Republic of Serbia has to make significant efforts to establish a valid database on waste at national, regional and local level.

The aim of the study is not to assess the reliability of data from various sources, but to draw attention to the need for reliable data, bearing in mind the implications of these data can play in a variety of sectors.

Acknowledgement

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