

# **COMPARATIVE ANALYSIS OF THE WASTE MANAGEMENT POSSIBILITY ON THE TERRITORIES OF SERBIA AND CROATIA**

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**Abstract:** On their way of joining the European Union, Serbia and Croatia have, as one of their tasks, to fulfill the standards in the area of the environment protection and improve their citizens' life qualities. Managing solid waste is one of the problems whose resolving requires substantial analysis having in mind not only the legal regulations but also the sustainable development of the two states – especially the economic and the social aspects. Such an analysis requires an overview of the current state of the waste management, the potentials and the possible directions. This paper presents the section of the waste management state on the territories of Serbia and Croatia along with the adopted laws, accepted technological procedures, good practice, but the problems that the two states have encountered so far as well. With the aim of realizing the best waste management methods on the territories mentioned, two cities were observed, one on the territory of Serbia (Nis) and one in Croatia (Zagreb). Four models of waste management, all of which include single methods: recycling, waste incineration, composting and depositing, were taken into consideration. In accordance with the data for the amount and the composition of the solid waste, all four models were processed by the Life Cycle Assessment (LCA) method and their influence on the environment was presented. Based on the gained data, analysis of each model was executed and their advantages and disadvantages were shown. In the end, the models were compared and their applicability in the stated cities was analyzed.

**Sažetak:** Na putu priključenja Evropskoj Uniji Srbija i Hrvatska imaju zadatak da ispune standarde u oblasti zaštite životne sredine i unaprede kvalitet života svojih građana. Upravljanje čvrstim otpadom je jedan od problema čije rešavanje zahteva dosta analize imajući u vidu ne samo postavljene zakonske norme, nego i održivi razvoj država posebno ekonomski i društveni aspekt. Za takvu analizu potrebno je sagledavanje trenutnog stanja upravljanja otpadom, potencijala i mogućih pravaca. U radu je dat presek stanja upravljanja otpadom na teritoriji Srbije i Hrvatske sa analizom usvojenih zakona, prihvaćenih tehnoloških postupaka, dobre prakse, ali i problema sa kojima su se države dosad susretale. U cilju sagledavanja najboljih metoda za upravljanje otpadom na pomenutim teritorijama, posmatrana su dva izabrana grada: jedan na teritoriji Srbije (Niš) i jedan u Hrvatskoj (Zagreb). U razmatranje su uzeta četiri modela upravljanja otpadom koji uključuju pojedine metode: reciklažu, spaljivanje otpada, kompostiranje i deponovanje. U skladu sa podacima za količinu i sastav čvrstog otpada, metodom Life Cycle Assessment (LCA) obrađena su sva četiri modela i prikazan njihov uticaj na životnu sredinu. Na osnovu dobijenih rezultata izvršena je analiza svakog modela i pokazane njihove prednosti i nedostaci. Na kraju su upoređeni modeli i analizirana njihova primenljivost u navedenim gradovima.

**Key words:** LCA, municipal solid waste, recycling, incenatation, composting

## **Introduction**

Waste management has, a long time ago, stopped to be only taking care of waste and has more been becoming part of the sustainable development of the society. In order to reach the best possible solution for waste management from the aspect of sustainable development a lot of factors need to be considered. Some of them are of economic nature, of course, some of social but what is of great importance are the further influences of waste management on the environment.

The amount of waste generated by the citizens of the European Union varies from country to country, while the average amount for the 27 countries, members of the EU for 2008, is 524 kg per person per year [1]. Over the period of eight years (2000-2008) the amount of waste per capita in individual countries did not change significantly, but the waste treatment did. Table 1 presents the amounts of deposited and incinerated waste. It also shows that, in countries like Germany, Switzerland, Denmark and Holland, waste is less deposited and more thermally processed [1].

**Table 1:** Municipal waste generation, landfilling and incinerated in EU countries

**Tabela 1:** Komunalni odpad na teritoriji zemalja EU, produkcija, deponovanje I inseneracija

Geo/Time	Municipal waste, kg per person per year					
	2000.			2008.		
	Generated	Landfilled	Insinerated	Generated	Landfilled	Insinerated
EU (27 count.)	523	288	79	524	207	102
Bulgaria	516	399	0	467	440	0
Czech Rep.	334	282	31	306	218	34
Denmark	665	67	352	802	35	433 <sup>s</sup>
Germany	643	165	133	581	3 <sup>e</sup>	193 <sup>e</sup>
Greece	408	372	0	453	347	0
Spain	662	339	37 <sup>e</sup>	575	327 <sup>e</sup>	53 <sup>e</sup>
France	516	220	169	543	193 <sup>e</sup>	172 <sup>e</sup>
Netherlands	616	57	190	622	7 <sup>e</sup>	203 <sup>e</sup>
Slovenia	513	402	0	459	341	7

Switzerland	657	40	320	741	0	371
Norway	615	336	90	490	88	184

e=Estimated value s=Eurostat estimate

The Republic of Serbia and the Republic of Croatia, as potential EU candidate countries, are in the process of harmonization with the laws and the principles of the European Union, along with those considering the waste management. Both countries have adjusted their legal regulations to the EU's; their implementation is what is left to be done. They have also adopted state strategies for waste management. Serbia has recently adopted a new waste management strategy for the period of 2010-2019 [2]. Croatia has adopted the waste management strategy for the period of 2007-2015 [3]. In Serbia, the only way of waste management at this point is disposal on local landfills that, with minor exceptions, does not satisfy the criteria of sanitary landfills. In 2009 the Law of waste was adopted which, as a consequence, has a set of regulations that define managing certain waste flows. These regulations provide the possibility of introducing order to the sphere of waste management and provides making of businesses that will give a swing to this branch of economy.

For the territory of Serbia, as well as for the states encircling it, the lack of exact data about the amounts and the composition is characteristic. According to the last data provided by the Ministry for environmental protection and physical planning [4] the amount of the generated waste for 2009 is 4.49 million tons, out of which 2.63 million tons is communal waste. 1.58 million ton out of this amount goes to the landfills and about 1 million tons to wild dumps. The average amount of waste that is generated by one citizen per year is 360kg, which is below the European average. The amount of the industrial waste generated that year was 1.86 million ton out of which 1.21 was non-hazardous, and 0.65 million ton hazardous waste.

Based on the last available data from the Croatian Environmental Protection Agency [5], during 2006 3.7 million tons of waste were produced, out of which 1.7 million ton was communal waste (not including separately collected waste from MSW), which corresponds to 393 kg per capita. Despite the fact that great efforts are placed to introduce the system of priary sorting with the aim of recycling and return, the greatest part of the waste is still deposited on landfills (96-98% out of the total amount MSW) [6]. The Waste Management Plan foresees the reduction of the biodegradable content in teh deposited waste: 75% of the amount of biodegradable waste produced in 1997, 50% in 2015, and 35% in 2020. The proposed strategy in the Plan for fulfilling these goals comprises a system of integral waste management, whose backbone would be waste management centers. The waste management centers (WMC) are facilities in which waste would be processed in sustainable manner (with material and energy recovery), in order to reduce the quantity of waste that is disposed on landfills and decrease its reactivity. The thermal treatment of waste with energy recovery is included as the last step in the system of integral waste management. [6]

Regarding the waste management and sustainable development, the European Commission Communication suggests integrating the basic objectives of the European Union waste hierarchy (preventing waste and promoting reuse, recycling and recovery) [7] by a new impact-based approach in which Life cycle assessment (LCA) is used for measuring environmental impacts and identifying priorities. LCA has been acknowledged as tool enabling researchers to analyze the full life cycle of MSW management system, and the holistic information provided by it has been used for decision support in MSW management planning [8,9]. The life cycle of waste starts when a material is discarded into the waste stream and ends when the waste material has either been converted into a resource (such as recycled material or recovered energy) or when it has been finally disposed [10]. LCA can be useful and conveniently applied only to the life cycle related to the collection, transfer, treatment and landfill disposal of solid waste. In this particular

case, the reference flux is given by the amount of waste produced by a community, while the output is represented by the emission of pollutants due to the several parts of the MSW management system.

The aim of this study is the application of the LCA procedure to MSW management in the two chosen cities (Nis and Zagreb) in order to choose the best management system from the aspect of environment protection.

## **2. Description of experimental research**

### ***2.1. Study area and reference data***

The study areas are 'City of Zagreb', the capital of Croatia and 'City of Nis', the third biggest city in Serbia.

#### **City of Zagreb**

The city of Zagreb has a surface area of 641 000m<sup>2</sup> and a population of 779,145 inhabitants (National Institute of Statistics). The total MSW production was 405,001 tons, while the MSW composition was presented in (Table 2). Most waste (353 000 tons) is to date, sent to the landfill of Jakuševac where a partial landfill gas recovery takes place, and 51,001 tons of waste are recycled. All the data necessary for the construction of the analysed scenarios were deduced from the database of the competent authorities: Waste management plan of the city of Zagreb for the period up to 2015 year; Local waste management company "Čistoća Zagreb"; Ministry of Environmental Protection, Physical Planning and Construction; Waste management strategy of the Republic of Croatia, Meteorological and hydrological service and other previously published work on MSW status in Zagreb [11].

**Table 2:** MSW composition in Zagreb and Nis

**Tabela 2:** Sastav komunalnog otpada u Zagrebu I Nisu

	Zagreb		Nis	
<b>Fraction</b>	Percentage (%)	Production (t/year)	Percentage (%)	Production (t/year)
Food waste	30.6	108 018	33.7	24 298
Yard waste	5.3	18 709	10.4	7 494
Paper	25.3	89 309	15.3	11 031
Plastics	14.9	57 534	17.7	12 762
Glass	5.1	31 809	5.1	3 677
Metals	3.4	12 337	1.9	1 370
Other	15.4	54 362	15.9	11 464
Total	100	405 001	100	72 100

#### City of Nis

According to the data from May 2009, Nis has 253,077 inhabitants. The city covers an area of about 597 square kilometers, including the urban area, Niška Banja (the Spa of Nis) and 68 suburbs. The total MSW production per year is about 72 000 tons, while the MSW composition was presented in (Table 2) [4]. The whole territory of the City of Nis is completely covered by the services of waste removal.

Most waste (72 000 tons) is to date sent to the landfill of Bubanj, 6 km from the city's center. All capacities of the existing location are almost completely depleted and the waste can be deposited on the location, with the application of technically-technological solutions, for a very short time (not longer than three years). At this point 5% of the communal waste is recycled.

The method that is to be chosen for waste management on the territory of the City of Nis will be affected by the decision of the Ministry for environmental protection and physical planning that recycling is an imperative. According to the National strategy for waste treatment, waste incineration is allowed.

## **2.2. The IWM procedure**

Integrated Waste Management (IWM) model [12], applied in this paper, uses life cycle methodology to quantify the consumed energy and the released emissions from a specified waste management system. The specific evaluated indicator parameters are: total consumed energy, greenhouse gases, acid gases, smog precursors, heavy metals, trace organics, biochemical oxygen demand, residual solid waste.

The model evaluates the environmental burdens associated with waste management from the point at which a material is discarded into the waste stream to the point at which it is either converted into a useful material or it is finally disposed. Details of the IWM procedure with its assumptions and restrictions are described in the paper [13].

## **2.3. The MSW management scenarios**

This study uses the results based on the data about waste amounts produced on the yearly level of both cities respectfully. Reference years are 2009 for Nis and 2006 for Zagreb. Based on the previously stated overviews four scenarios were made.

The first scenario represents the current status in Zagreb and Nis undertaken by the waste management company (WMC). Scenarios 2, 3 and 4 were fed to the model in order to assess the possibility of improving the current MSWMS that exist in Zagreb and Nis.

*Scenario 1:* (Base scenario): Most waste is sent to landfill without any further treatment. A fraction of the waste collected by WMC is recovered for reprocessing, which was also considered.

*Scenario 2:* Plastics, glass, paper, metal are recycled. Organic waste is composted. Other waste is sent to landfill. Flow chart of MSW scenario 2 is shown on Figure 1.

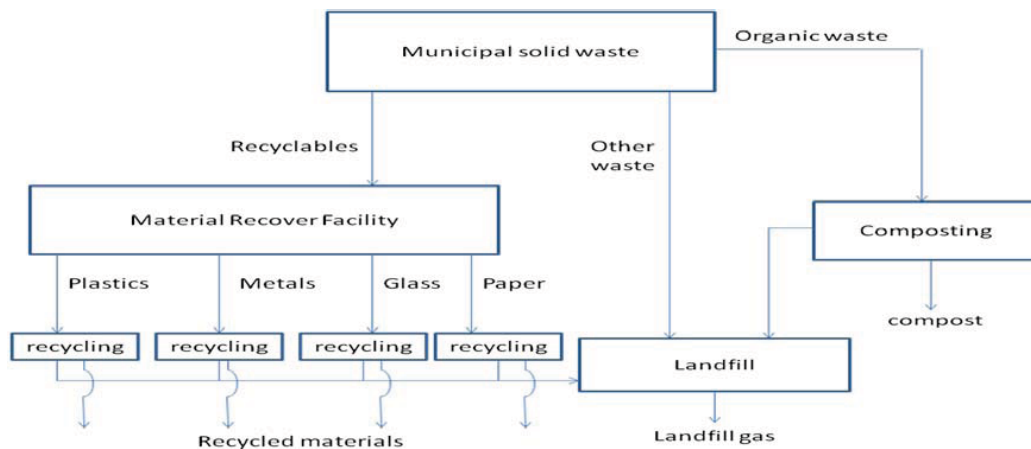


Figure 1. Flow chart of MSW scenario 2.

Slika 1. Blok sema scenarija 2

*Scenario 3:* Glass and metal are recycled. The other waste is sent to a cogeneration incineration plant.

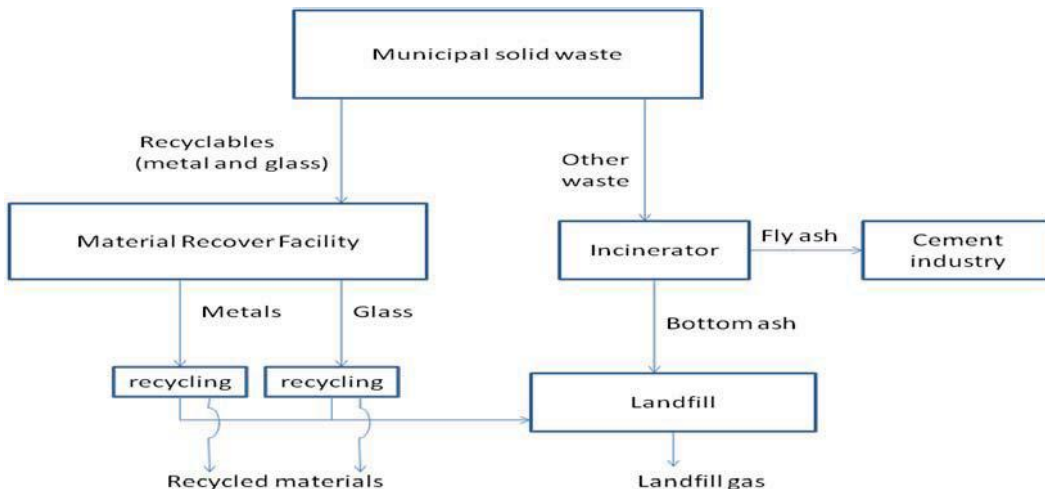


Figure 2. Flow chart of MSW scenario 3.  
Slika 2. Blok sema scenarija 3

Scenario 4: Glass, metal and plastic are recycled. The other waste is sent to anaerobic digestion plant to produce electricity (Fig.3).

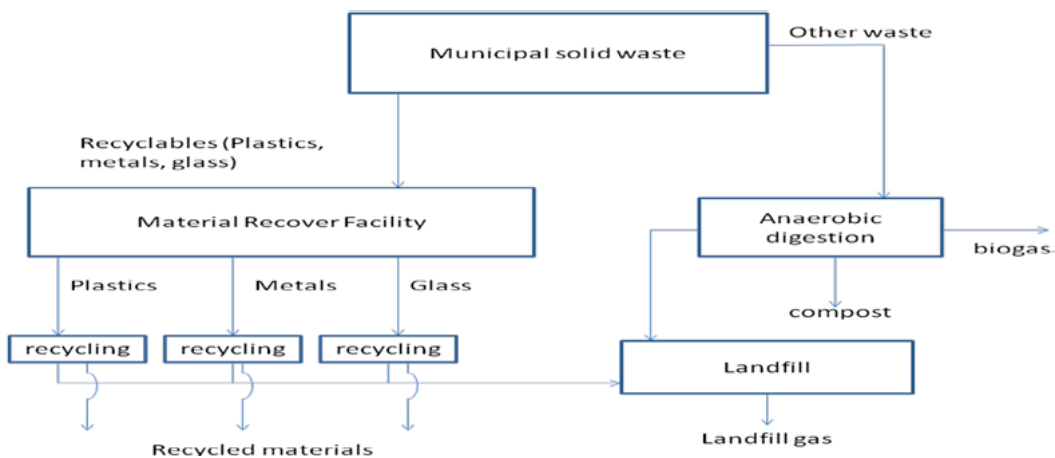


Figure 3. Flow chart of MSW scenario 4.  
Slika 3. Blok sema scenarija 4

### 3. Results and discussion

Based on the gathered data for each of the waste management phases, IWM for each scenario was made. Gained data depict an excellent picture of each scenario on the environment. Table 3 shows comparative results of the different scenarios influence on the environment, energy spent (saved) and the amount of the residual waste for both Zagreb and Nis.

The recycling process in the life cycle causes the highest impact in all scenarios. Taking into account virgin material displacement credit, net life cycle inventory of each scenario is obtained. Regarding scenario 3 and 4, electrical energy can be generated from incineration as well as, anaerobic digestion process. Subtracting the emissions obtained by waste or biogas combustion from emissions obtained by mix of methods used to produce the electricity that is used by the waste management processes analyzed by the model, resultant emissions is calculated. In some cases emissions have negative values. It means that emissions generated in scenario 2 and 3 for producing the electrical energy are less than emissions generated by electricity grid, for the same amount of electrical energy generated. The main findings of the study can be summarized as follows:

- Scenario 2 is the most environmentally sound option, in terms of global warming potential (GWP), acidification potential and smog formation.
- Scenario 3 is the most environmentally sound option, in terms of water pollution.
- Minimum amount of final MSW disposed was obtained from scenario 4.
- Considering thermal treatment of MSW in Zagreb, the waste treated in scenario 3 will reduce the demand of energy from fossil fuel, but, if virgin material displacement credit is taken into account, i.e. complete net life cycle inventory, scenario 2 is the best, in terms of energy saved.

- Having in mind the plan of installing a waste recycling plant in Nis, scenario 2 would be most suitable to the set demands.
- As the minimal amount of waste for depositing is gained in scenario 4, this scenario is also of importance for Nis having in mind the capacity of the existing landfill.

**Table 3:** Comparison of the scenarios

**Tabela 3:** Upoređenje scenarija

	CITY OF ZAGREB				CITY OF NIŠ			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<b>Tonnes Managed (***)</b>	405,001	405,001	405,001	405,001	72,100	72,100	72,100	72,100
<b>Energy Consumed (GJ)</b>	-882,220	-6,041,866	-4,755,340	-4,575,553	-11,908	-1,042,126	-684,559	-1,043,542
<b>Greenhouse Gases</b>								
- CO2 Equiv. (tonnes)	224,939	-499,462	49,494	-302,797	51,507	-85,273	17,830	-69,592
<b>Acid Gases</b>								
- NOx (tonnes)	-102.0	-795.0	26.8	-486.5	-2.5	-129.1	24.2	-111.6
- SOx (tonnes)	-148.1	-1073.2	-303.7	-773.6	-3.4	-174.4	-6.5	-142.7
- HCl (tonnes)	-1004.2	-5331.7	-2633.5	-4677.2	-196	-859.3	-291.4	-752.2
<b>Smog Precursors</b>								
- NOx (tonnes)	-102.0	-795.0	26.8	-486.5	-2.5	-129.1	24.2	-111.6
- PM (tonnes)	34.8	-342.2	-80.4	-185.1	17.5	-51.8	-1.7	-43.5
- VOCs (tonnes)	-66.5	-586.6	-22.7	-370.9	7.8	-98.8	-1.2	-77.9
<b>Heavy Metals &amp; Organics</b>								
- Air								
Pb (kg)	-2.6	-20.4	240.1	-21.4	0.0	-2.6	47.1	-3.1
Hg (kg)	-0.11	-1.37	90.02	-1.72	0.0	-0.28	18.23	-0.58
Cd (kg)	-0.06	-0.85	17.10	-1.92	-0.01	-0.20	4.71	-0.23
Dioxins (TEQ)(g)	0.012	0.001	0.184	0.035	0.001	0.0	0.048	0.006

- Water									
Pb (kg)	19.38	-56.24	-85.85	-100.45	0.81	-6.33	4.97	-42.52	
Hg (kg)	0.520	0.352	-0.408	0.222	0.0	0.072	-0.068	0.075	
Cd (kg)	29,350	7.740	-0.052	-0.219	-0.242	1.601	0.349	1.973	
BOD (kg)	245,398	121,567	2,442	49,708	-6	19.043	277	26,354	
Dioxins (TEQ)(g)	0.00234	0.00068	0.00025	0.00010	0.0	0.00012	0.0004	0.00017	
<b>Residual Waste (tonnes)</b>	<b>355,981</b>	<b>71,266</b>	<b>38,920</b>	<b>17,600</b>	<b>68,652</b>	<b>13,977</b>	<b>6,853</b>	<b>3,100</b>	

#### 4. Conclusion

The amount of waste generated on the territories of Serbia and Croatia and its composition is rather similar. Compared to the countries of the European Union, the amount of waste in both countries per capita is on the lower line. Greater part of the total amount is deposited, while only 5% is recycled. Both states are in search of contemporary models of waste management having in mind the sustainable development and the best available technologies.

LCA is a very powerful tool for assessing the potential environmental impacts of different waste management strategies.

The paper presents four different alternative scenarios for the MSW management of the cities of Zagreb and Nis. The results shown demonstrate that, if the system is modeled in sufficient detail, LCA can identify not only the best scenario, but also the analytical contribution of single operations to the overall environmental performance of the system.

In accordance with the results obtained from this study, scenario 2 has the least influence on the environment, while scenario 3 is the most environmentally sound option, in terms of water pollution. The minimum amount of final MSW disposed was obtained from scenario 4.

Considering thermal treatment of MSW in Zagreb, the waste treated in scenario 3 will reduce the demand of energy from fossil fuel, but if we take into account virgin material displacement credit, i.e. complete net life cycle inventory, scenario 2 is the best, in terms of the energy saved.

Having in mind the plan of installing a waste recycling plant in Nis, scenario 2 fits best to the set demands. Also scenario 4, which generates the least possible waste, can be of a great importance for Nis, having in mind the capacity of the existing landfill.

Results obtained from this study also support the conclusion that LCA, as an environmental tool, can be successfully applied in an Integrated Solid Waste Management System (ISWMS) as a decision support tool.

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