Application of MFA as a decision support tool for waste management in small municipalities – case study of Serbia

N. Stanisavljevic, S. Jokanovic, M. Živančev, B. Batinic, B. Tot, D. Ubavin

Department of Environmental Engineering, Faculty of Technical Sciences, University of Novi Sad, Novi Sad, 21000, Serbia

nemanjastanisavljevic@uns.ac.rs

Abstract:

Developing countries all over the world are facing the transition period of waste management. This transition predominantly mean the transformation from uncontrolled landfilling towards improved waste management systems, of controlled sanitary disposal, recycling, and some small scale attempts for waste to energy. However despite the large number of existing methods for decision support in waste management, new decisions in transition and developing countries are usually made without any application of existing models.

This study aims at generation of adequate decision support data for solid waste management especially biodegradable waste in small municipalities in Serbia. Five small undeveloped municipalities in Serbia were taken as representative case study examples for similar municipalities in Serbia, as well as in other countries with similar socio-economic condition. Like every small municipality in Serbia, five municipalities are part of administrative regions for waste management, where centralized waste treatment and disposal units will be constructed. Hence these municipalities will have to transport and dispose the generated waste to regional centers where appropriate fees must be paid. In order to reduce the costs for each municipality appropriate treatment solutions, which have potential to reduce the waste mass and volume on a local level are considered.

Key words: MFA, transition country, biological treatments, small municipalities

1. Introduction

Similar to other developing and transition countries landfilling is predominant solution in the waste management in Serbia (Stanisavljevic et.al 2012). Majority of these landfills are uncontrolled. Like in every transition country, waste management in municipalities in Serbia have to be improved, in order to fulfill legislation aims, and to reach the main goals of modern waste management: to protect human beings and the environment, and to converse resources, at affordable costs (Brunner and Fellner 2007). Slow development progress of waste management sectors in Serbia is to large extent due to inadequate solutions generated within relevant planning documents. Solutions proposed in different local plans very often do not reflect the field situation of the specific municipality, and do not promote sustainable and affordable solutions in long term. This comes from the insufficient data and adequate knowledge base, which are crucial input for solid waste management planning and development, and from the widely spread "copy-paste" practices, taken from other municipalities and applied without looking into specificity of a single cases.

This research was performed by applying the Material Flow Analysis as basis for evaluation of status quo, and for further scenario, evaluation and simulation of different alternatives of local waste management. As an input data for material flow analysis, data about municipal waste generation and composition, waste from the industry and agriculture are used. Data about MSW are obtained by field analysis of quantities and composition in four different seasons during one year. Industry waste by questionnaires and quantities of agricultural waste are assessed based on the field crops and farm structure. Since the main problem in this municipalities is very small budget for waste management, and high share of biodegradable waste, solutions for waste treatment especially biodegradable waste on a local level were developed, compared and evaluated. Criteria for evaluation and comparison of developed scenarios with status quo were indicators in accordance to the goals of waste management, and economic parameters.

Objectives of this paper is to support waste management development in five small municipalities in Serbia, by providing sufficient data which will serve as a basis for further decision making. In addition this study should help in defining the local policies and unified solution on a state level directed at supporting the role of small municipalities in waste management regionalization in Serbia.

2. METHODOLOGY AND DATA

Based on considered criteria's (up to 30.000 inhabitants; level of development belonging to the second, third and fourth group; lack of private operator to provide services in waste management) following municipalities are selected: Aleksandrovac, Bela Crkva, Krupanj, Kuršumlija and Svilajnac,. Their location and territorial distribution of municipalities under the case study are presented on the picture below.

Picture 1: Map of Serbia with selected municipalities (municipalities in red color)

Methodology applied for the analysis consists from:

- Analysis of municipal waste generation and composition
- Collection of data about agriculture waste generation
- Collection of data about industrial waste generation
- Modeling of status quo and development of waste management scenario by MFA
- Evaluation and comparison of the scenarios

Analysis of MSW generation and composition, was performed by applying the existing methodology (Vujic et.al 2010). Over a seven-day period in four different seasons (summer, autumn, winter and spring), which complies with municipal waste-collection cycle in all representative municipalities. Mass of every empty vehicle was recorded only once. Further measurements of full vehicles were conducted after each collection route, and the above procedure was repeated for each waste collection vehicle with a designated route for that day. Data obtained by measuring include residents under the waste collection system. In order to get more comprehensive data about average waste generation rate, projection on the entire municipality population was made.

Data about quantity of industrial and agricultural waste data are obtained through questionnaires and of official statistics data. Each municipality has provided data on existing companies and quantities and its generated waste. Based on data on the number of livestock and areas with certain crops, and on the basis of literary data (Brkic and Janic 2011; Batzias et.al 2005) amount of agricultural waste is estimated.

Methodology used for modeling and evaluation in this study is based on the Material flow analysis – MFA (Brunner and Rechberger 2004) and methodology represented by Brunner and Fellner 2006. With MFA, the materials flowing into a given system, the stocks and flows within this system, and the resulting outputs from this system can be examined (Obernosterer et al., 1998). Based on the status quo of waste management in selected municipality's four scenario are developed evaluated and compared.

For comparative and evaluation purposes of developed scenarios, appropriate indicators related to the objectives of waste management: protection of men and environment, conservation of resources and sustainable waste management (after care free landfill) are chosen. Selected indicators is presented below.

1. Emissions of greenhouse gases
2. Recycling rate
3. Required volume of landfill
4. Mass flows
5. Mass of biodegradable waste landfilled
6. Nitrogen emissions to hydrosphere
7. Energy consumption and production

In this paper detailed results of material flow analysis performed, are presented for a case study in municipality of Bela Crkva. The same scenarios are developed for each municipalities under assessment. Hence the evaluation results presented includes all five municipalities.

3. RESULTS AND DISCUSSION

3.1. Description of scenarios

Status quo

Bela Crkva municipality annually generates around 5634 tons of municipal solid waste. Current situation in municipal waste management of Bela Crkva municipality involves only partly collection of generated waste. 60 % of the total population in the municipality is covered by waste collection and disposal system. 3400 tons of waste per year is collected within this system. Collected waste is then disposed on landfill that does not meet the standards of sanitary waste disposal. Remaining waste generated in the municipality (2300 tons per year) is not in the system of municipal waste management and it is usually disposed on illegal dumps. Primary separation of recyclable materials is on a very low level. Only 3 tons of PET per year are separately collected as potential recyclables. Industrial waste generated in the municipality is 5236 tons per year .. Estimated amount of generated agricultural waste per year is around 12000 tons per year. Status quo of waste management in municipality Bela Crkva is presented in Figure 1.

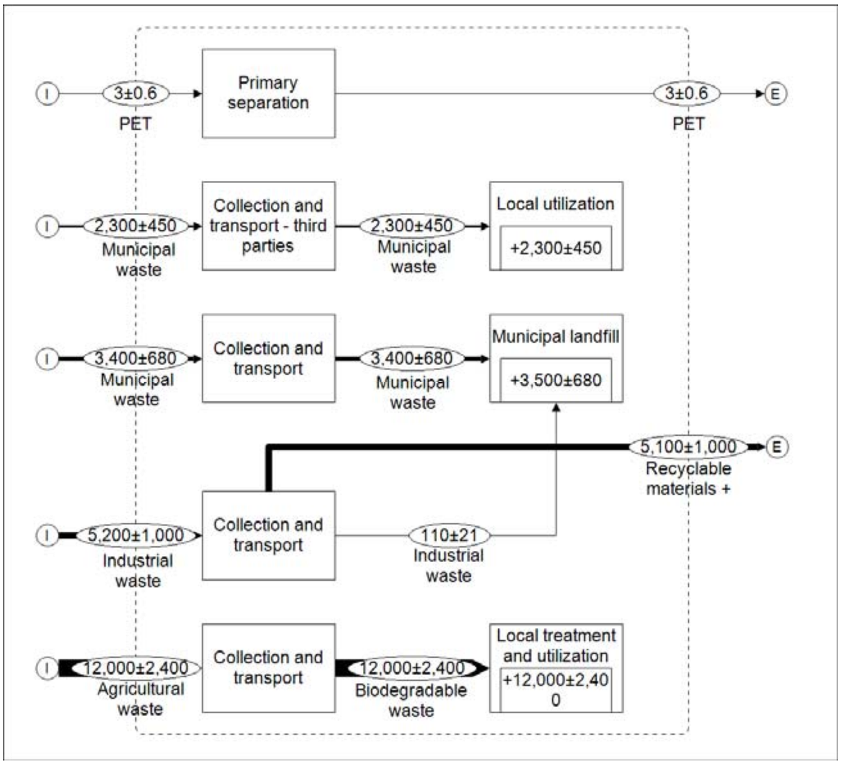
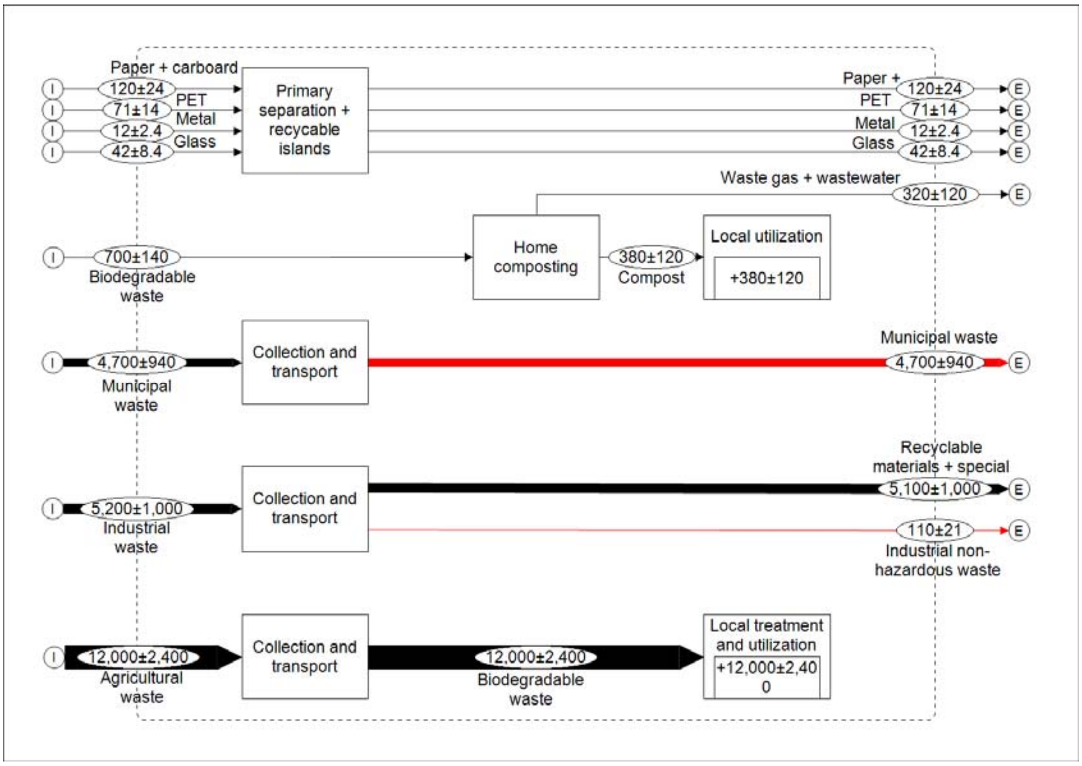


Figure 1: Status quo, t/yr

Scenario I

Waste management in the municipality of Bela Crkva in scenario 1 primarily involves increasing of coverage by organized municipal waste collection system up to 100 % of the population.. It is expected that 25 % of recyclables factions (paper/cardboard, PET, glass, metal) will be separated at organized collection point. "Home composting" is provided only for households with individual type of housing outside urban settlements. Around 700 tons of garden and kitchen waste will be treated in home composting units. Generated compost will be used within the municipality (depending on produced compost quality). . Mixed MSW will be collected and transported directly to a regional center for further management. Inert industrial waste (106 tons per year) will be also transported to a regional center for further management. Scenario II for the municipality of Bela Crkva is given on the figure II.

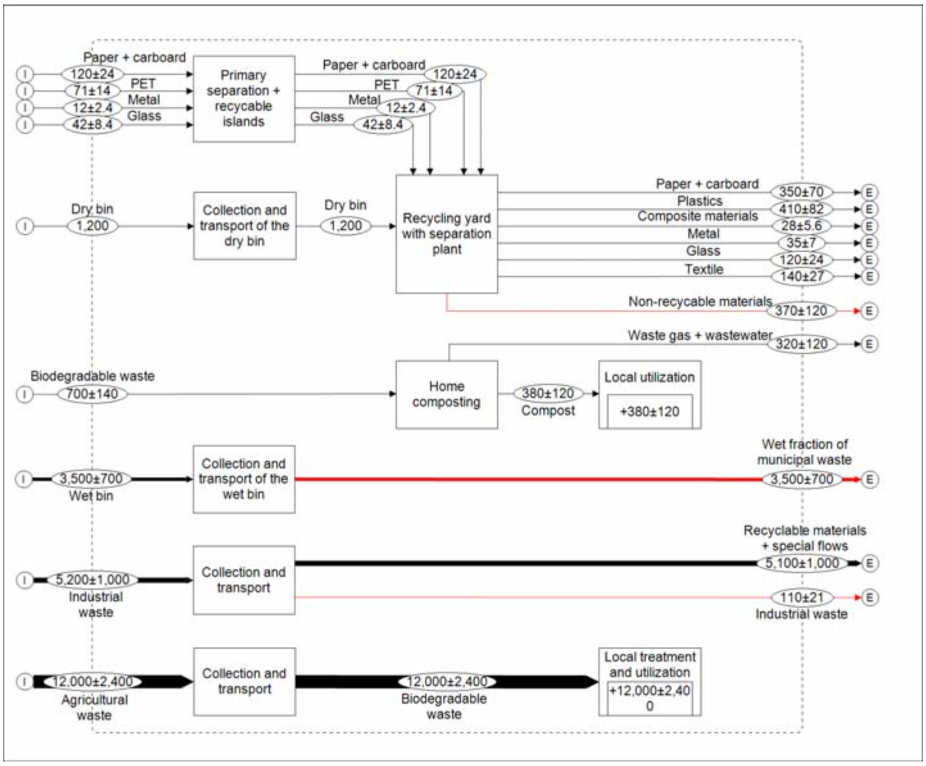


* Red export flow is transported to the waste management regional center

Figure 2: Scenario I, t/yr

Scenario II

In scenario II municipal solid waste will be collected in two bins. In a dry bin, and wet bin 1200 tons and 3500 tons of recyclable materials will be collected respectively. Waste collected in dry bin will be transported to the waste separation plant (located in municipality) where the different categories of waste will be separated. Waste collected in a wet bin will be without pre-treatment transported directly to the regional center for further management. Scenario II is presented in figure 3.



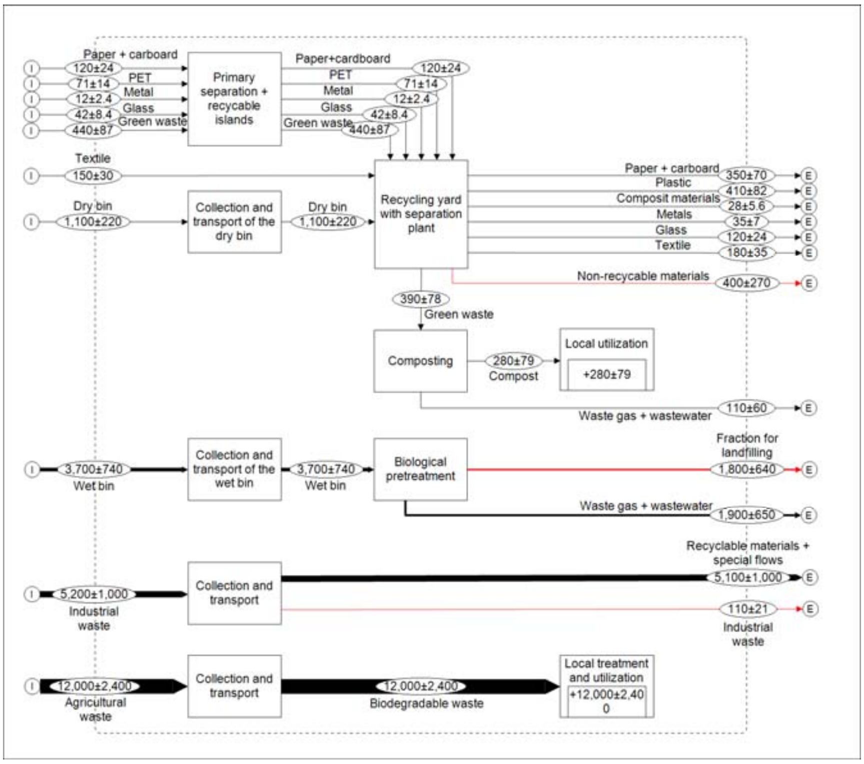
*Red export flow is transported to the waste management regional center

Figure 3: Scenario II, t/yr

*

Scenario III

In scenario III in addition to home composting of garden and kitchen waste, the primary separation of 440 tons of green garden waste is introduced. This fraction will be composted in central composting plant and compost will be utilized within the municipality. Municipal solid waste will be collected in two bins. In dry bin recyclable materials will be collected and transported to the separation plant where the different categories of waste will be separated. In wet bin residual waste will be collected and transported to a biological pre-treatment in the municipality. After treatment, stabilized waste will be transported to a regional center for further management. Scenario III is presented in figure 4.

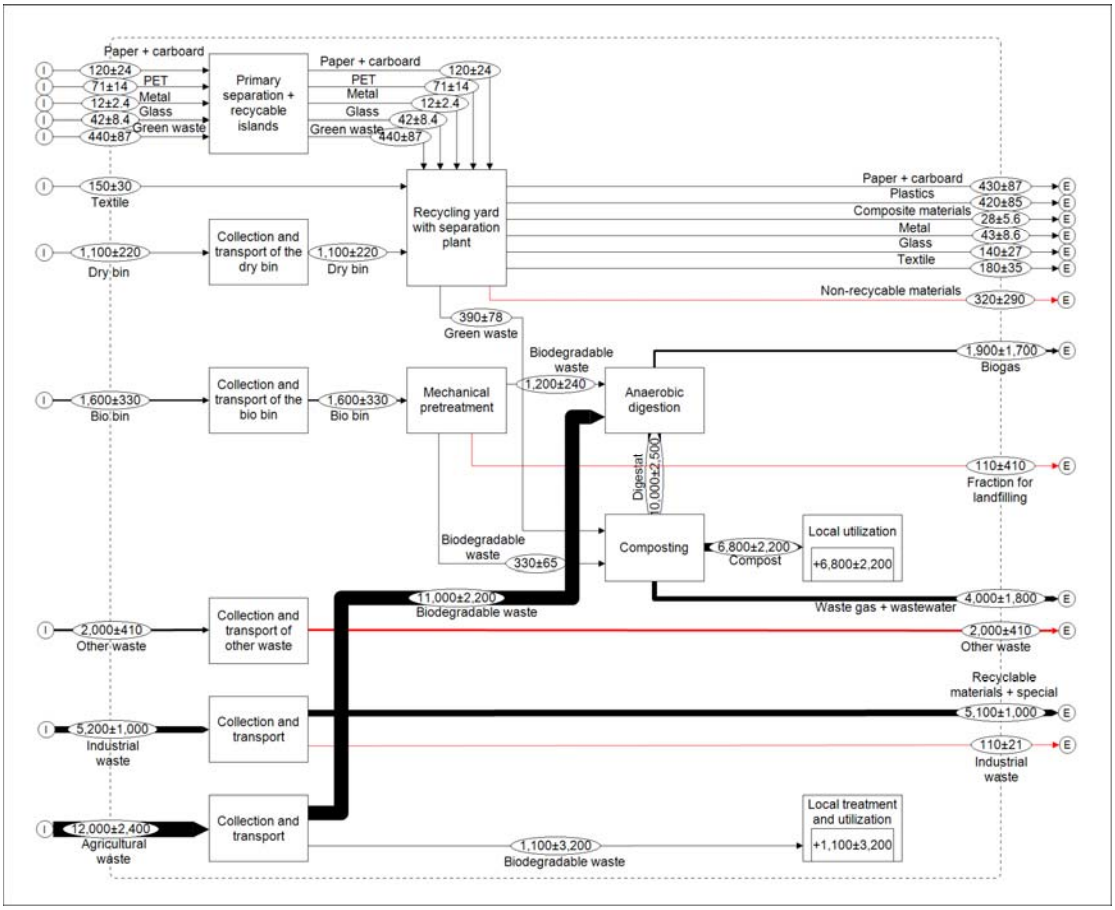


*Red export flow is transported to the waste management regional center

Figure 4: Scenario III, t/god

Scenario IV

In this scenario MSW will be collected in three bins. Recyclable materials collected in the dry bin will be transported to the separation plant where the separation of recyclables will take place. Biodegradable waste collected in bio bin will be transported to anaerobic digestion plant consisted of anaerobic unit mechanical pre-treatment and composting unit. Together with biodegradable municipal waste, suitable agriculture waste will be treated. In third bin residual waste will be collected. This fraction will be without treatment transported directly to the regional center for further management. Scenario 4 is presented in figure 5.



*Red export flow is transported to the waste management regional center

Figure 5: Scenario IV, t/yr

3.2. Evaluation of results

This section, the results of the scenario modeling of solid waste management are presented. In table 3.1 calculated values of indicator for all five municipalities are given.

Table 3.1: Calculated indicator for developed scenarios for five municipalities in Serbia

Scenarios	Municipalities	GHG Emissions, $CO_{2ekviv}\cdot(c\cdot yr)^{-1}$	Recycling rate, %	Separated recyclables, $kg\cdot(c\cdot yr)^{-1}$	Landfill volume, $10^{-3}\cdot m^3\cdot(c\cdot yr)^{-1}$	Percentage of landfilled waste, %	Landfilled waste, $kg\cdot(c\cdot yr)^{-1}$	Percentage of lanfilled biodegradable waste without treatment, %	Biodegradable landfilled waste, $kg\cdot(c\cdot yr)^{-1}$	Nitrogen emitted in hydrosphere, $g\cdot(c\cdot yr)^{-1}$	Energy consumption, $kWh\cdot(c\cdot yr)^{-1}$	Energy production, $kWh\cdot(c\cdot yr)^{-1}$
Status quo	Aleksandrovac	180	0.4	1.2	243	100	297	100	158	297	23	0
	Bela crkva	165	0.05	0.2	278	100	324	100	154	324	28	0
	Krupanj	206	0.05	0.2	142	100	373	100	189	373	17	0
	Kuršumlija	121	2.8	6.9	237	100	245	100	115	245	26	0
	Svilajnac	179	2	6.6	405	100	284	100	178	284	32	0
Scenario 1	Aleksandrovac	147	5	14	217	73	173	50	69	145	37	0
	Bela crkva	155	4	14	337	83	270	64	107	121	53	0
	Krupanj	147	4	16	238	73	191	50	72	205	59	0
	Kuršumlija	89	2.9	7	216	88	173	74	72	106	40	0

	Svilajnac	134	4	12	256	72	205	57	103	129	34	0
Scenario 2	Aleksandrovac	89	20	60	160	54	128	40	56	134	41	0
	Bela crkva	95	19	62	277	68	222	56	92	91	60	0
	Krupanj	93	17	64	177	54	142	42	61	193	63	0
	Kuršumlija	55	13	32	185	75	148	67	65	100	44	0
	Svilajnac	73	18	50	208	59	166	48	86	100	37	0
Scenario 3	Aleksandrovac	41	21	62	128	43	102	7	10	166	38	0
	Bela crkva	52	20	64	190	47	152	8	13	159	54	0
	Krupanj	44	18	67	140	43	112	8	11	230	47	0
	Kuršumlija	32	14	33	117	48	94	8	8	149	39	0
	Svilajnac	41	18	52	153	43	122	6	10	149	35	0
Scenario 4	Aleksandrovac	41	23	69	98	33	78	9	12	161	77	314
	Bela crkva	45	22	71	171	42	136	9	16	139	74	171
	Krupanj	43	20	75	116	35	93	9	14	224	127	562
	Kuršumlija	27	15	37	108	44	87	10	9	136	70	231
	Svilajnac	28	21	58	118	33	94	8	15	143	71	283

Emission of GHG gases is significantly lower in all scenarios compared to the status quo. Decrease of indicator value in all scenarios is result of waste disposal at sanitary landfills with installed systems for landfill gas and leachate control. Furthermore, in scenarios 3 and 4, direct disposal biodegradable solid waste or in other words disposal without is not present.

The calculated values for recycling show that the degree of municipal solid waste reuse in all scenarios of waste management higher than the status quo. In scenario 1, organized primary separation is present, while in other scenarios the secondary recyclable materials separation is introduced. In scenario 4, this rate is the highest due to waste collection system in three bins where the highest level of recyclable materials separation is expected.

Regarding the required landfill volume, in some municipalities in scenario 1 larger volume for waste disposal site comparing to status quo is needed due to due to higher level of collected waste.. In other scenarios, the required landfill volume is lower due to separation of recyclable materials, home composting and / or biological treatment.

In status quo, all generated waste is disposed on municipal and uncontrolled landfills. Decreasing of landfilled waste is result of an increase in the level of the primary separation of recyclable materials, which is present in all developed scenarios. In scenario 2, secondary separation of recyclable materials and home composting of biodegradable waste influence on the amount of disposed waste. In scenario 3 this amount is additionally reduced due to biological stabilization treatment. In scenario 4, the smallest amount of waste is disposed since produced compost has potential for utilization. .

In all scenarios, the amount of biodegradable waste landfilled directly without any pretreatment is reduced. In the status quo no biodegradable waste treatment exist, and the entire amount of generated biodegradable waste is disposed to an uncontrolled landfill. Reduction of landfilled biodegradable waste is the result of biological treatment of municipal waste and separation of some biodegradable MSW fraction (paper and cardboard).

The results indicates that significant decrease of the amount of nitrogen which is emitted through leachate in all developed scenarios compared to status quo. This decrease is the result of a sanitary waste disposal system and leachate management. In scenarios with biological treatment these emission are slightly higher as a consequence of large amounts of waste which is directed to biological treatment.

Unlike the other indicators, energy consumption in all scenarios is higher compared to the status quo of waste management due to collection, transport, treatment and disposal of higher quantities of MSW. Increased energy consumption for waste collection is a result of higher number of citizens under organized waste collection and transportation of the waste to regional centers for further management. In addition waste collection in two or three bins is more energy demanded. On the other hand, the production of energy in the status quo is not present, as in scenarios 1, 2 and 3. Only scenario 4 provides energy production. In this scenario, the anaerobic waste treatment generates biogas which can be used for energy production. Hence, only scenario 4 has a positive energy balance.

4. CONCLUSION

Based on the presented analysis of the developed waste management scenarios and comparison of the calculated indicators values it can be concluded that all developed waste management systems better full fill the goals of waste management comparing to status quo. Each next scenario brings significant improvements comparing to existing situation in the municipality. Based on these findings, final results are focused in the development of waste management systems in the municipalities from Scenario 1 to Scenario 4. The objectives related to environmental issues are fulfilled already in the simplest scenario 1 and from the economic point of view it is the easiest feasible scenario. After the implementation of this scenario, it will be easier to introduce improvements presented in Scenario 2 what can be followed with the solutions given in scenario 3. Scenario 4 is the most demanding scenario. However this scenario represents state of the art solution for given waste management in representative municipalities. Scenario 4 has a potential to be the most demanding in terms of economic feasibility. Additional research should focus on financial assessment of all developed scenarios and assessment of economic capacity of selected municipalities to introduce suggested solutions.

Acknowledgments

This research is performed under financial support by GIZ, in the framework of „IMPACT“ project in Serbia.

REFERENCE

Belevi, H. & Baccini, P. (1989): Long-term behavior of municipal solid waste landfills. Waste Management & Research, 7, 43–56.

Brunner P.H., Fellner J., (2006) “Setting priorities for waste management strategies in developing countries,” Waste Management & Research 25, 234-240

Brunner P.H., Recheberger H., (2004) Practical Handbook of Material Flow Analysis, Lewis Publishers, USA.

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Obernosterer et al., “Urban Metabolism - The City of Vienna”, Institute for Water Quality and Waste Management Vienna University of Technology Austria, 1998

Stanisavljevic, N., Ubavin, D., Batinic, B., Fellner, J., & Vujic, G. (2012). Methane emissions from landfills in Serbia and potential mitigation strategies: a case study. Waste management & research: The journal of the International Solid Wastes and Public Cleansing Association, ISWA, 30(10), 1095–103. doi:10.1177/0734242X12451867

Vujić G., Jovičić N., Redžić N., Jovičič G, Batinić B., Stanisavljević N., Omran A., A fast method for the analysis of municipal solid waste in developing countries - case study of Serbia, Environmental Engineering and Management Journal, August 2010, Vol.9, No. 8, 1021-1029

Brkić M., Janić T., Potential amounts of biomass for production of energy in Serbia, Journal of Contemporary Agricultural Engineering, November 2011, Vol.37, No. 3, 225-234

Batzias, F. a., Sidiras, D. K., & Spyrou, E. K. (2005). Evaluating livestock manures for biogas production: a GIS based method. *Renewable Energy*, *30*(8), 1161–1176. doi:10.1016/j.renene.2004.10.001