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Waste management strategies effects on GHG emission: Case study of Serbia

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Abstract. Landfilling is a dominant method of waste management in most developing countries. Moreover, a significant quantity of waste has been disposed on open dumps and unmanaged disposal sites. Landfill gas (LFG) can be considerable source of GHG emissions, as it consists of 50 % methane and 50 % carbon dioxide. Republic of Serbia is a developing country. Its waste management legislation is based on EU legislation. In the first decade of 2000s a set of laws was passed in this area. Unfortunately, the majority of goals were not fulfilled. An updated version of Waste management program is active since 2022. In Serbia, 2.95 million tons of waste is generated every year. It is estimated that 15-20 % is disposed on dumps, while 80 % is collected and disposed on the landfills. Waste treatment does not exist. Recycling rate is a very low, around 15%. Different waste management scenarios of impact on GHG emissions have been analysed. The analysis was performed using the software "Tool for Calculating Greenhouse Gases (GHG) in Solid Waste Management (SWM-GHG calculator)" developed by the German IFEU (ger. Institut für Energie- und Umweltforschung Heidelberg). The base scenario describes the current situation. Scenarios 1 and 2 describe goals set for 2025 and 2030 by Waste management program in the Republic of Serbia for the period 2022 - 2031. Scenario 3 describes best case scenario, with fully functional modern waste management system. The analysis includes several parameters, such as landfill type, recycling rate, LFG collection efficiency and use of waste incineration technology.

1. Introduction

Landfills are significant source of greenhouse gasses (GHG), accounting for approximately 5% of global overall GHG emissions, according to IPCC Climate Change for 2013 [1, 2]. Decomposition of biodegradable waste releases landfill gas (LFG) which contains cca 50% methane and 50% carbon dioxide. These gases are released in the atmosphere. Methane is significant as GHG because it has 21 time higher global warming potential than carbon dioxide [3]. Recent study shows that in some cases emissions from waste sector can be reduced for 70.82% [4]. In developing countries, municipal solid waste (MSW) often contains more than 60% of biodegradable waste. Dominant method of waste management is landfilling.

Many strategies have been developed aiming to mitigate the GHG emission from waste sector. Different techniques are developed and investigated, such as waste separation, recycling technologies, incineration, anaerobic digestion etc. Moreover, many countries have set a legal framework in waste sector. Serbia, as EU candidate, is obliged to transpose EU laws into local regulations. EU Directive on the landfill of waste 99/31/EC is transposed in the Regulation on the Disposal of Wastes to Landfills in 2010 [5, 6, 7]. In 2022, Serbia adopted Waste management program of the Republic of

Serbia for the period 2022-2031 (hereinafter: the Program) [8]. Some of the main specific objectives are increased recycling rate, significant reduction of biodegradable waste disposed in landfills and reduced disposal of waste in unsanitary landfills. Kitchen and park/garden waste should be composted at home in rural and semi-rural areas. However, goals set in previous period were not achieved: recycling rate is very low, only 8 regional landfills have been built, there is none LFG treatment and only one flare was installed. Previous work showed that in developing countries environmental policies should be carefully chosen and implemented. If appropriate measures are not applied GHG emissions from sanitary landfills may be even bigger then emissions from dumpsites [9].

In the Western Balkans region, Serbia and Montenegro are main producers of CO_2, accounting for almost 60% of emissions. Main source of GHG is energy sector, while waste sector is contributing for 6.5% [10]. According to World Bank data, Serbia emitted 61.86 $MtCO_2eq$ all GHG and 11.55 $MtCO_2eq$ methane in 2019. In the waste sector, those quantities were 5.80 $MtCO_2eq$ all GHG and 5.56 $MtCO_2e$ methane [11]. Several papers deal with quantities of LFG emitted from landfills in Balkan region [12, 13, 14].

2. Study method

Republic of Serbia is located in Western Balkan region and its population is 7.2 mil. Average waste generation is 1.2 kg/capita/day, which is under EU average value. In 2020, 2.95 million tons of MSW was generated. The average coverage of waste collection is 86.4%. Collected waste is disposed on 120 municipal landfills and 12 sanitary landfills that meet EU standards. Municipal landfills are often obsolete, and they are not built in accordance with EU Directive. Often, its management includes only organised collection of waste. It is estimated that 20% of MSW is disposed on 3,500 existing dumpsites and unmanaged landfills. Average waste composition is presented in table 1 [8].

Table 1. Waste composition in Serbia.

Waste component	Share, %
Food waste	25.0
Garden and park waste	15.0
Paper, cardboard	13.0
Plastics	12.1
Glass	4.1
Ferrous Metals	2.7
Aluminium	2.5
Textiles	2.8
Rubber, leather	0.6
Nappies (disposable diapers)	4.0
Wood	3.4
Mineral waste	0.0
Others	14.8
Sum	100.0

Calculations are done by using SWM-GHG calculator developed by the German IFEU (ger. Institut für Energie- und Umweltforschung Heidelberg). SWM-GHG Calculator is based on the Life Cycle Assessment (LCA) method. In LCA methodology environmental impact analyses of a product (or process or service) is done over all stages of a product's life, from cradle to grave. As such, SWM-GHG Calculator compares calculated emissions with respect to avoided or newly generated emissions.

For example, emissions originating from recycling incorporate effects of substitution of primary raw materials or fossil fuels. Since secondary raw material is used, emissions decreased and their value is shown as credits. This methodology neglected emissions from waste collection. The calculation method used in the SWM-GHG Calculator is described in Manual [15].

The case study is based on four representative scenarios: baseline (Status quo), Scenario 1 (S1), Scenario 2 (S2) and Scenario 3 (S3). MSW quantity is the same in all scenarios, corresponding to the 2022 quantity. This way effect of different measures can be quantified, without effect of waste quantity change. Figure 1 shows different waste management categories in representative scenarios. Abbreviations at the picture are: MBS/MPS: Mechanical-biological stabilisation / mechanical-physical stabilisation and BS: Biological stabilisation.

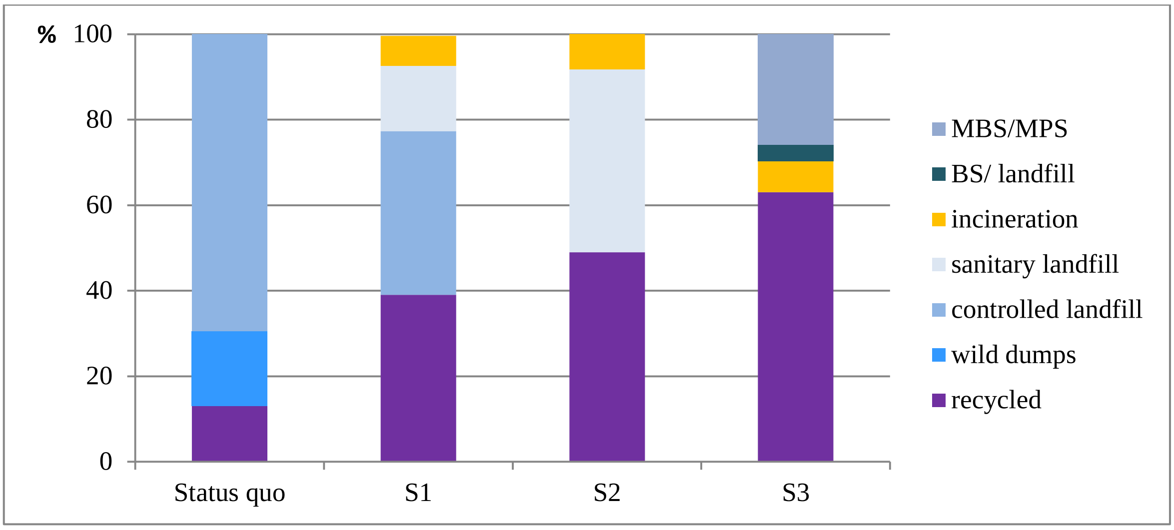

Figure 1. Waste disposal and recycling rates.

Baseline: This scenario describes the current situation. All generated waste is disposed on regional or municipal landfills or wild dumps. There is not any LFG collection or treatment. Recycling rate is low.

S1: Scenario 1 represents goals from the Program planned for 2025. All generated waste will be disposed on controlled landfills with or without gas collection system and 340.000 t of waste will be incinerated. At landfills with gas collection there is not any gas treatment system, only 5% of collected gas is burnt on flare. 10% of gas will be used to generate electricity. Recycling rate is increased to 40%.

S2: Scenario 2 represents goals from the Program planned for 2030. In this scenario, all waste is either disposed on sanitary landfills with gas collection system or incinerated. Treatments of LFG include flare (50% of all generated LFG) and electricity generation (10%). Recycling rate is increased to 50%.

S3: Scenario 3 represents the modern system. Majority of generated waste is disposed on landfills with advanced technologies, 3.7% is disposed on sanitary landfills, and 7.4% of waste is incinerated. Efficiency of LFG collection is 50% and 90% is used to generate electricity while 10% is burnt on flare. Recycling rate is high.

3. Results and discussion

The obtained results are presented in figure 2. Debits represent GHG emissions caused by recycling or waste disposal. Credits represent GHG emission savings by recycling or waste disposal, thus it has negative value. This negative value or credits occurs as a consequence of the LCA methodology. It takes into account that recycling reduces overall GHG emissions from certain production in future. Net is the difference between debits and credits [15].

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Baseline scenario shows that in recent years about 730,000 tonne CO_2-eq/year has been avoided, as a result of existing recycling. Aluminium and paper/cardboard recycling has the biggest impact on avoided emissions. In scenario 2, which presents 2025 goals, avoided emission due to recycling amounts cca 1.2 million tonne CO_2-eq/year. The biggest contributors are aluminium, paper/cardboard and plastics recycling. Incineration effect is 53,800 tonne CO_2-eq/year less.

Scenario 2 shows similar results compared to scenario 1. As a result of gas collection, GHG emissions are reduced significantly. According to this scenario all landfilled waste is disposed on landfills with gas collection, 50% of collected LFG is burnt on flare and 10% is used for electricity generation.

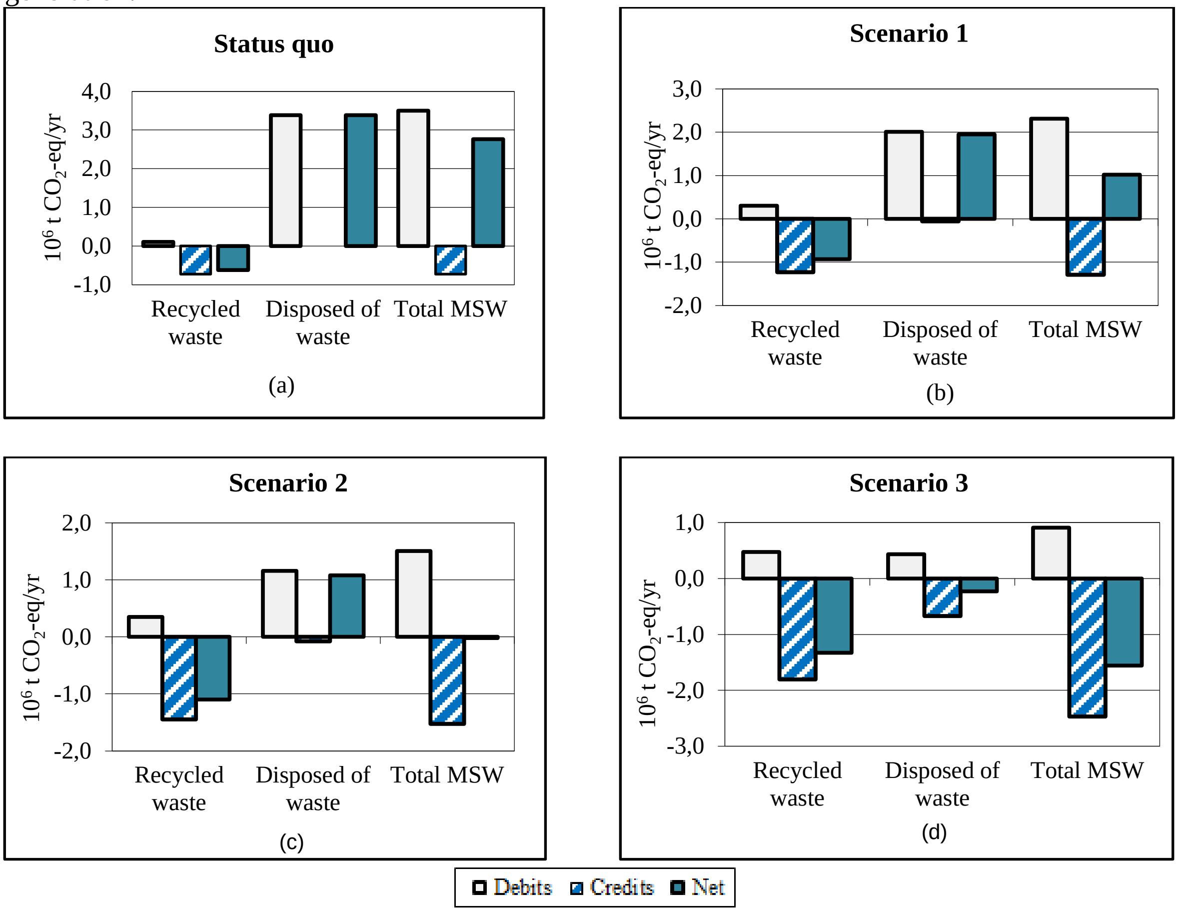

Figure 2. Structure of GHG emissions for (a) status quo, (b) scenario 1, (c) scenario 2 and (d) scenario 3.

The best case scenario, scenario 3 shows significant reduction in overall GHG emissions. Net value is -1.556.426 tonne CO_2-eq/year. High recycling rate contributes about 85%, while remaining 15% is a consequence of advanced landfilling technologies. Obtained results show that in developing countries, where incineration is too expensive option, modern landfilling and high recycling rate may lead to substantial GHG reduction.

Figure 3shows results of overall GHG emissions for all four scenarios.

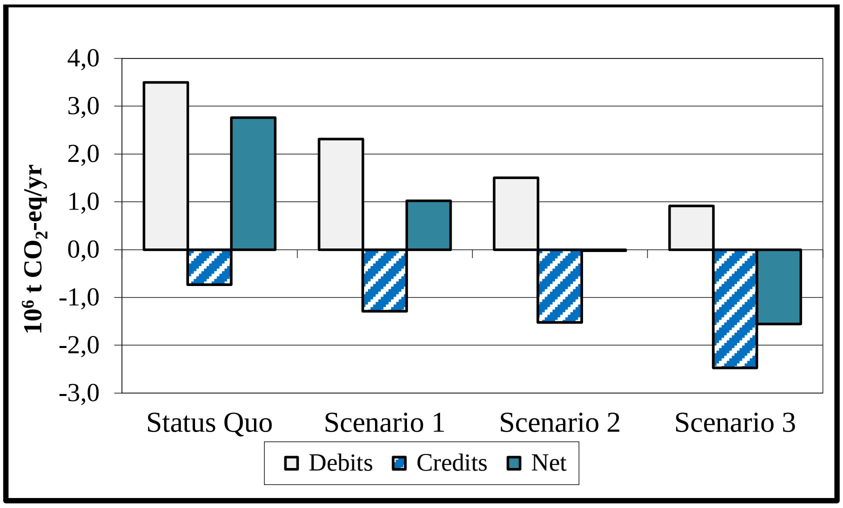

Figure 3. Debits, credits and net value of GHG emissions for all scenarios.

When generated emissions are compared, GHG emission in S1, S2 and S3 decreased 34%, 57% and 74% compared to baseline, respectively. But, net emissions have negative values just in scenario 2 and 3.

Structure of net emissions is presented in figure 4.

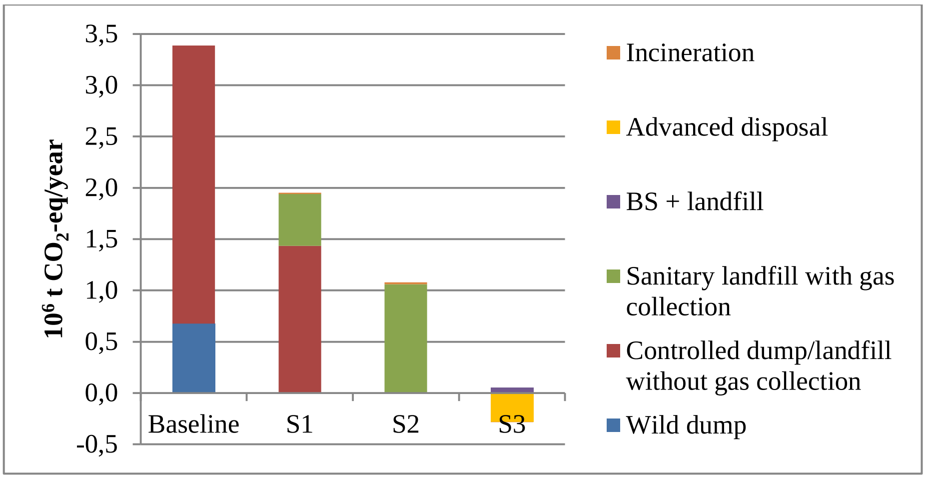

Figure 4. Net emissions for different disposal methods in all scenarios.

It may be concluded that disposal on landfills without gas collection has the biggest impact on GHG emissions. Incineration as a disposal method has positive net value for scenario 1 and 2 (average GHG emissions increased for 15,000 tCO_2-eq/year). Negative value of net emissions can be observed only for scenario 3 (GHG emission decreased for 4,000 tCO_2-eq/year). Significant reduction may be achieved if advanced disposal techniques are applied. These techniques include mechanical-biological stabilisation and/or mechanical-physical stabilisation, as well as use of waste residues in cement kiln or similar. For developing countries, where a small probability of widely applied expensive advanced technique exists, a good solution may be encouragement of landfill operators to collect and treat LFG, along with biological stabilisation.

4. Conclusion

Landfills can be significant source of GHG emissions, contributing to climate change. Analyses of four different scenarios showed that overall GHG emissions from waste sector in Serbia may decrease after 2030. The reduction is possible if objectives from Waste management program of the Republic of Serbia for the period 2022-2031 are fulfilled. Net GHG emissions for Status quo, S1, S2 and S3 are 2.7 mil t, 1.0 mil t, -0.02 mil t and -1.6 mil t CO_2-eq/year, respectively. The obtained results show that in developing countries, where incineration is too expensive option, modern landfilling and high recycling rate may lead to substantial GHG reduction.

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