Conceivable Environmental And Energy Benefits Of The Solid Municipal Waste Utilization For Energy Production In Bulgaria

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***Abstract* — The main treatment method of municipal solid waste (MSW) in Bulgaria is disposal in open landfills without hermetic lining membrane and leachate collecting system – the most aggressive to the environment. Free atmospheric methane from MSW intensifies the greenhouse effect, the leachate pollutes the soil and water, and the waste itself destroys the natural terrain and disrupts the ecosystem's balance in the area. Spontaneous fires in depots happens and leads to large-scale gassing and dusting in settlements and natural sites. To estimate the energy potential of the generated MSW in Bulgaria, the approximate composition of the waste was determined as a potential biofuel for energy production. Based on official data, the quantities, structure and composition of the generated gas emissions from landfills in Bulgaria have been analyzed. The potential environmental benefits and energy benefits by replacing landfilling with thermal treatment were assessed with the main technologies implemented – direct burning in steam boiler or gasification and burning in integrated gasification combined cycle (IGCC).**

Keywords — municipal solid waste, landfill gas, methane, greenhouse effect, infiltrate pollutes, waste processing, energy potential, environmental benefits.

I. Introduction

Landfills have a complex and multi-directional negative impact on all environmental components. Natural decomposition of solid municipal waste (MSW) is a long process, with the intensity and the ratio of the emitted emissions changing over time. The impact on the environment is cumulative and long lasting. Industrial processing would reduce the environmental impact and turn MSW from an environmental threat into a useful energy resource.

II. Biodegradable Waste Decomposition Mechanism

Studies of the contained gases in the deposited waste layer show the dynamics of emission of gaseous fractions depending on the duration of the decomposition, with the time scale being dynamic according to temperature, humidity, degree of compaction and thickness of the material layer, etc. The process is described in details in [3] and [5]. Initially, the decomposition is aerobic, gradually turning into anaerobic, which continues until the biodegradable ingredients are almost completely exhausted, Fig. 1, [3]. The natural compaction of the waste layer and the intensively released CO_2 during aerobic degradation (oxidation) gradually expels the air and isolates the access of oxygen - stages II and I.

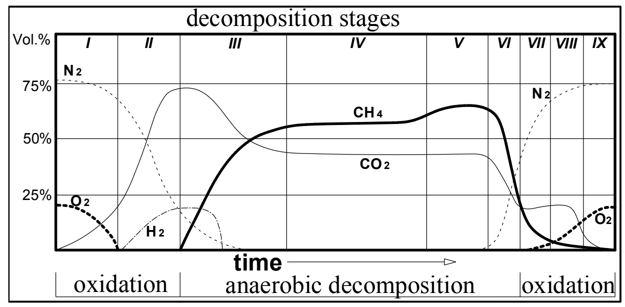

Fig. 1

Around middle of stage III, fermentation (anaerobic digestion) is intense enough and creates excess pressure from methane and carbon dioxide in the volume of waste, completely isolating access to atmospheric air - nitrogen and oxygen are not present. At the beginning of Stage VI, the intensity of CO_2 and CH_4 emissions decreases due to a decrease in biodegradable constituents and atmospheric air begins to seep into the waste layer. From step VII until the biodegradable material is completely exhausted, aerobic decomposition is reactivated – methane sharply declines and carbon dioxide is released, nitrogen and oxygen are present at stages VI - IX.

III. Treatment Of MSW In Bulgaria

Landfilling with continuous addition of new waste and mechanical mixing with the older one, which is characteristic of basic MSW treatment in Bulgaria, enhances aerobic digestion and suppresses anaerobic, i.e. the ratio of carbon dioxide to methane is very likely to differ from that shown in Fig. 1, with more CO_2 released at the expense of CH_4. Accurate estimation of the ratio of greenhouse gases emitted in this case is difficult to achieve due to the variable conditions - variable flow and waste composition, uncertain ratio and degree of mixing between old and new waste, random nature of mechanical mixing, variable waste thickness and layer density, etc. Local experiments or emissions modeling would be highly uncertain and low representative of the results, and large-scale coverage of most landfills is difficult to achieve.

IV. Quantity And Composition Of MSW In Bulgaria

The demographic and socio-economic conditions in the different territorial units of the Republic of Bulgaria determine the different composition of the waste.

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The natural tendency of urbanization and depopulation of rural areas implies an increase in the share of urban waste at the decrease of rural.

Not so long time ago, the population in Bulgaria was predominantly rural and there was no organized waste management. Practical Bulgarians have processed the waste on the principle of cyclic household – almost complete recycling:

- food and plant waste have been digested by domestic animals and birds or partially incinerated in stoves;
- paper, wood and textile waste have been incinerated for heating in stoves.
- metals and glass have been recycled;
- plastics and tires, if any, have been burned or temporarily disposed of;
- the coal and briquette scoria have been permanently landfilled;
- wood ash has been used for soap made or as fertilizer due to its high potassium content;
- excrements and sewage sludge have been used as natural fertilizer due to the high nitrogen content.

In practice, insignificant quantities of tires, plastics and plant waste have been temporarily disposed of, which have been periodically burned by open combustion. Only inert scoria has been permanently deposited. Thus, methane emissions from waste decomposition were minimal and carbon emissions inevitable. Methane emissions from domestic animals are significant, but not considered here. In the last few decades, the lifestyle and share of the rural population has changed dramatically and now relies entirely on centralized waste management. The principle of the cyclic household is forgotten and centralized waste management approaches 100% [1], with consequent logistical, economic and environmental consequences.

Results of research in period of 2012 – 2015 [8] determine the MSW composition according to scale of the settlements population Table 1.

Based on information on population number and distribution by settlements size for 2018 [2], Fig. 2 and Table 1, annual total amount of MSW generated by type for 2018 is calculated, Fig. 3.

For above calculation, the following assumptions are made:

• the villages are referred to the group with a population of less than 3000 inhabitants;

• the composition and quantities of waste generated per capita in 2018 are identical to those in the period 2012 - 2015, as it is not expected that the purchasing power and habits of the population will change significantly over several years.

TABLE I. MSW DECOMPOSITION MIXTURE

Average annual generated MSW for the period 2012-2015, kilograms per capita						
MSW for the period	2012-2015	Populated place, citizens				
		> 150 thousand	50 - 150 thousand	25-50 thousand	3-25 thousand	< 3 thousand
Biodegradable	Food waste	118,7	107	93,8	68,7	37,7
	Garden	44,7	38,2	44,2	64	74,6
Total biodegradable		163,4	145,2	138	132,7	112,3
Recyclable as material	Cellulose	85,5	61,7	50,1	41,3	24,4
	Plastics	46,4	54	42,9	29,7	25
	Glass	37,8	27,4	23,6	18	5,7
	Metals	7,8	7	6,6	5,8	4,7
Total recyclable material		177,5	150,1	123,2	94,8	59,8
Non-recyclable combustible	Textiles	11,5	10,3	9,7	11	4,8
	Rubber	3,8	3,4	3,2	2,8	2,3
	Leather	3,8	3,4	3,2	2,8	2,3
	Wood	8,1	7,2	9,7	6	7,1
Total non-recyclable combustible		27,2	24,3	25,8	22,6	16,5
Others	Inert	39,8	27,8	45,9	43,6	51,6
	Hazardous	2,4	2,2	2	1,8	1,5
Total others		42,2	30	47,9	45,4	53,1

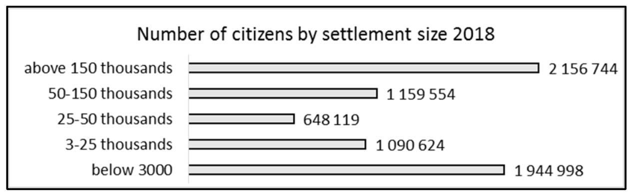

Fig. 2

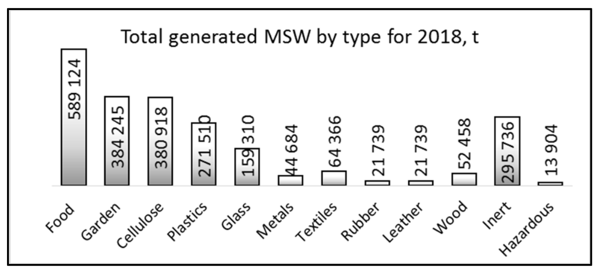

Fig. 3

The estimated total amount of MSW for 2018 is 2 299 733t, and according to the latest official Eurostat data for 2016 [1], it is 2 440 719, i.e. the deviation is about (6%). Taking in account the downward trend of the generated MSW in the last 10 years, Fig. 4, [1], the actual deviation is expected to be less.

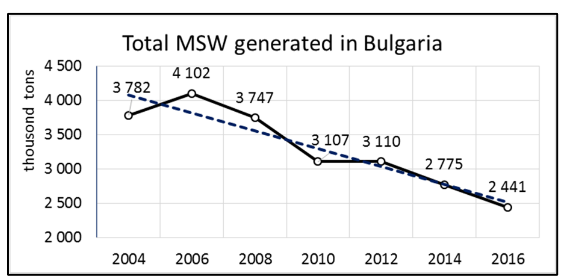

Fig. 4

Relative share of any type of MSW for 2018 is estimated Fig. 5. If group the types MSW according to Table 1, Fig. 6 results. Summarized finally, Fig. 7 results.

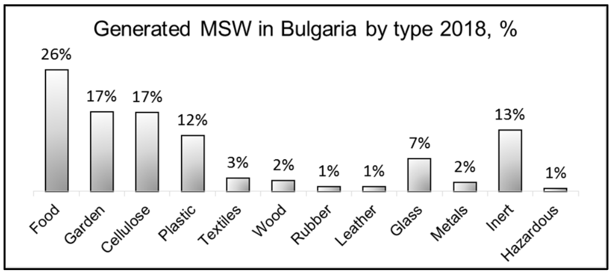

Fig. 5

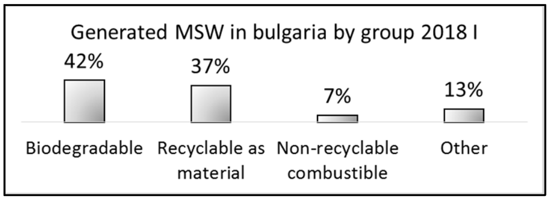

Fig. 6

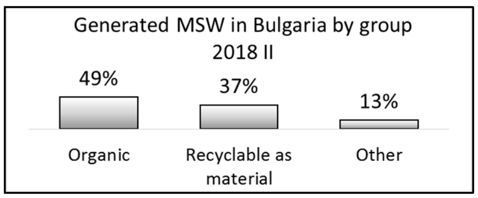

Fig. 7

In terms of gas emissions and potential for energy production, biodegradable and combustible MSW are essential. Organic recyclable materials - cellulose and plastics, in line with EU cyclical economy concepts, should be fully recyclable as material and should not be considered as pollutants and energy resources in the near future.

It can be concluded that about 49% of the total generated MSW in Bulgaria is a source of greenhouse and odorous landfill gas and a potential bio-fuel.

V. Gas Emissions From MSW

Carbon dioxide emissions can only be limited by reducing the amount of organic waste generated as all processing technologies, including processing and recycling, result in carbon emissions. The quantities of greenhouse gases as CO_2 equivalent generated by landfills in the territory of Bulgaria for the period 2007 - 2017 have steadily decreased by about 21% for the period [1], Fig. 8.

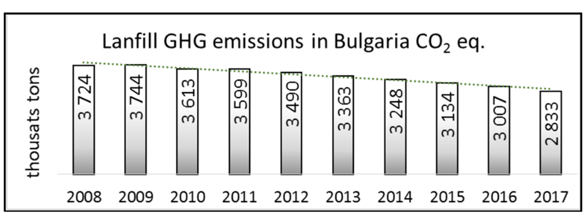

Fig. 8

The trend can be explained by the demographic collapse, migration, educational campaigns, entry into operation the MSW processing facilities etc. Despite the downward trend, when comparing per capita GHG emissions per year in Bulgaria and the EU average, the amounts for Bulgaria are about twice as high [1], Fig. 9.

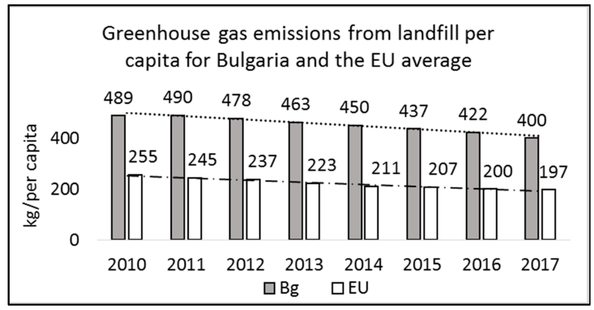

Fig. 9

From the point of view of the possibilities for natural compensation of the emitted MSW GHG emissions by photosynthesis, the comparison with the EU average [1] shows a significantly higher forest load in Bulgaria, Fig. 10.

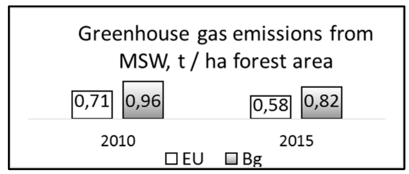

Fig. 10

The changes in the main gas emissions from landfill in Bulgaria for the period 2011 - 2017, [2] are shown in Fig. 11. The main pollutant - methane, steadily decreased by about 21% over the period.

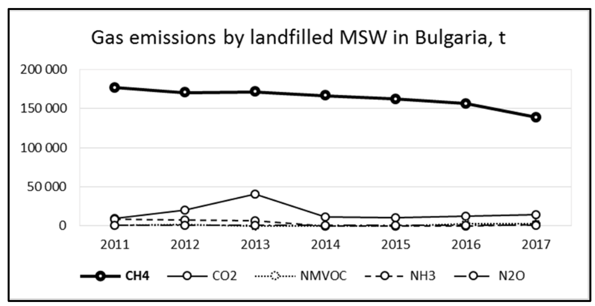

Fig. 11

Amount of emissions for 2017 is shown in Fig. 12, [2]. The main contaminants for disposal are CH_4, CO_2, C_XH_Y, NH_3 and odorous gases. Methane, which obtains about 25 times stronger greenhouse effect then carbon dioxide, accounts about 88% of emissions. One CH_4 molecule on combustion generates one CO_2 molecule (1) therefore, thermal processing would reduce the greenhouse effect of the MSW emissions dozens of times.

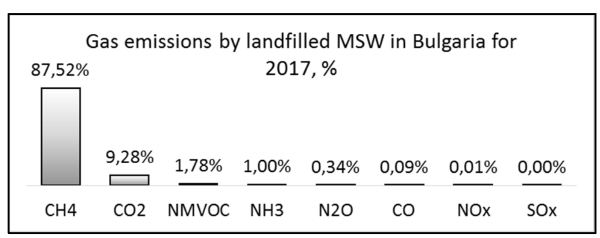

Fig. 12

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \tag{1}$$

Hydrogen sulphide and other odorous gases produced by decay are low in volume and have a local effect but greatly affect the air quality in the landfill area. When burned, they break down.

Open combustion of MSW in Bulgaria is not practiced, but spontaneous landfill fires lead to heavy and prolonged gassing of vast areas with the release of toxic gases, aerosols, fly ash (PM) etc.

VI. Breakdown Of Territories

The direct impact on the lithosphere is primarily the transformation of natural terrains into landfill sites. The occupied areas [2] for the permanent disposal of MSW in Bulgaria for the period 2007 - 2017 are steadily decreasing Fig. 13. Expressed as a percentage of the total area of the country, the occupied landfill area for 2017 amounts to about 0.0025%.

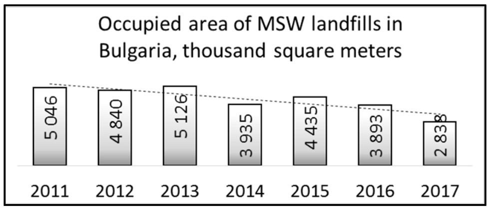

Fig. 13

Landfill free capacity has been steadily increasing over the last 7 years, Fig. 14, which can be explained with a view to reducing the amount of MSW generated, but this trend implies that landfill is considered a major waste management practice in Bulgaria in the future as well. No official data were found on recovered landfills in Bulgaria.

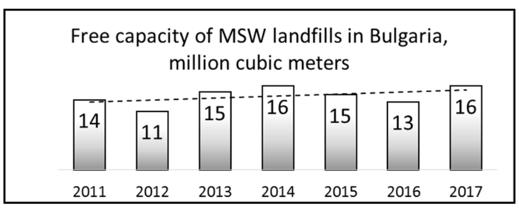

Fig. 14

VII. Potential Environmental Benefits

The relative share of greenhouse gas emissions from landfills has been steadily declining over the last 10 years [1], Fig. 15, with an average relative share of total GHG emissions in Bulgaria of about 6.5%. Replacing landfills with thermal processing for energy production ignores methane emissions and total greenhouse gas emissions by about 6%, neutralize odorous gases and significantly reduce the risk of spontaneous fires in landfills.

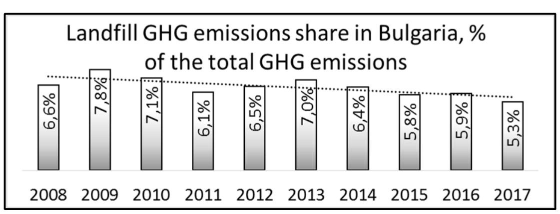

Fig. 15

The construction of modern facilities for the pre-treatment, temporary storage and thermal treatment of MSW in energy would reduce the in times occupied landfills and would minimize infiltration of leachate in soil, exclude the spread of zoonoses and parasites, and minimize the negative effect on ecosystems balance. It creates conditions for recultivation of a large part of the damaged terrains.

VIII. Potential Energy Benefits

According to Fig. 7, 49% of the MSW generated in Bulgaria is non-recyclable organic and a potential energy source. The composition and caloric content of the mix, the moisture content, the selected processing energy generation technology, etc. are determining for energy benefits. In the most primitive processing - composting of organic MSW with natural conversion to methane, maximum annual yield can be assumed below the annual methane deposited in the atmosphere [1], Fig. 16.

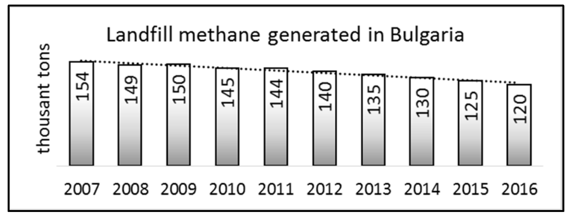

Fig. 16

Based on the annual consumption of natural gas (methane) in Bulgaria [1] for 2016, Fig. 17, when composted, the landfill methane production would cover less than 5%, Fig. 18 of the natural gas needs.

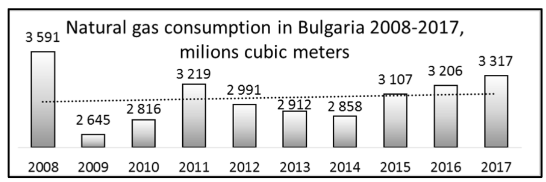

Fig. 17

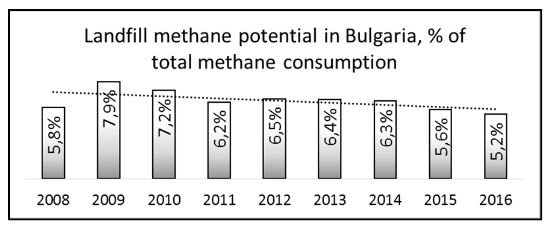

Fig. 18

In the centralized processing of sustainable MSW flows from major cities, more productive methods could be applied - thermal gasification or co-gasification with mineral fuel with the production of syngas and subsequent combustion in an integrated combined cycle system (gas and steam turbine) or the production of synthetic liquid fuels and chemical products.

Another applicable technology is direct combustion or co-firing of fossil fuels, with the production of electricity via condensing steam cycle or co-generation of electricity and heat, in which case a lower moisture content of the fuel is required, which requires preliminary preparation (drying).

The choice of the optimum processing technology also depends on investment opportunities, operating costs, the ability to ensure safe operation and compliance with environmental requirements, availability of qualified personnel, etc.

IX. CONCLUSIONS

The widely used technology for the disposal of mixed MSW in open landfills in Bulgaria without a system for catching and purifying the leachate is an archaic technology with severe environmental consequences. It is advisable to apply pre-treatment and separation of recyclable materials, and inorganic waste from organic waste. Treated safe organic waste should be processed by advanced industrial energy production technologies that would reduce greenhouse gas and other gas emissions, the number and area of landfills, soil and water pollution, and disturbance of ecological balance around landfill areas

The raw material potential is significant - almost 50% of the generated MSW or 1 220 000t as of 2016. The implementation of modern technologies for the production of energy from biomass would provide additional energy resource and partial diversification of energy sources in Bulgaria.

Serious investment in processing facilities could be provided through different sources - environmental protection funds, banks, government, insurance companies, GHG trading, preferential prices of generated energy etc.

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