

Original Scientific paper
UDK 628.1/.3:502/504(497.6 Brijesnica)
DOI: 10.7251/afts.2019.1120.073K
COBISS.RS-ID 8101400

AIR POLLUTION-PRESENT AND FUTURE CHALLENGES, CASE STUDY SANITARY LANDFILL BRIJESNICA IN BIJELJINA

Knežević Danijela¹, Knežević Nebojša²

¹University Singidunum, Faculty of Applied Ecology-Futura, Belgrade, Serbia, e. mail:
danijelabl28@yahoo.com

²Civil Engineering Institute "IG" Ltd. Banja Luka, Republic of Srpska, Bosnia and Herzegovina,

ABSTRACT

The management of air quality at landfills has, among other things, the objective of controlling of waste management efficiency at the landfill. Modern landfills, although built in accordance with domestic and European regulations, affect the quality of the air in the area where they are located. The challenges faced by sanitary landfills are the safe disposal of waste, the possibility of waste recovery and environmental protection (air and wastewater pollution).

This paper analyses the problems of air quality management at the location of the Brijesnica landfill in Bijeljina and the assessment of the sanitary waste disposal method efficiency based on the analysis of the results of the air quality measurement at the landfill site.

Keywords: *air pollution, sanitary landfill, air quality, challenges, Greenhouse gases*

INTRODUCTION

Any change in the composition of air in relation to natural conditions due to the presence of other gases, vapour, particles in concentrations affecting human health or affecting the biosphere is considered air pollution. Air pollution can sometimes be the result of natural phenomena (volcanic eruptions, dust storms and forest fires) and anthropogenic activities (combustion of fossil fuels, industrial emissions, agricultural activities and waste production). The world recognises air pollution as a problem that has a significant impact on human health, about which numerous studies were conducted around the world [1,2,3].

According to the database of the WHO that regularly monitors and assesses air pollution, the BiH region has a historical problem with air quality in several urban areas of BiH, with Tuzla as the second most polluted city in Europe after Tetovoin 2017 [4]. The consequences to health due to increased air pollution are closely monitored by the WHO, whose data show that 3535 inhabitants died of diseases related to air pollution in BiH in 2012 [5]. But air pollution not only provokes the toxicological effects on human health, it has also significantly degraded the environment in recent years [6,7]. For this reason, the European Environment Agency (EEA) and the European Commission (EC) have published a new air quality index in Europe, which allows users to check the current quality of air in cities and

regions throughout Europe [9]. The index consists of an interactive map showing local air quality at the level of measuring stations based on the measurement of five key pollutants that damage human health and the environment: PM_{2.5} and PM₁₀, O₃, NO₂ and SO₂.

Brijesnica regional sanitary landfill was established in 2010. Non-hazardous communal waste is disposed of at the landfill into sanitary cells that have been built in accordance with the valid European waste management directives. The challenges faced by the landfill management are related to the provision of safe conditions for waste disposal, raising the level of reuse of waste and the implementation of the environmental protection measures.

The construction of sanitary cells lined with all the necessary multibarrier layers and protective membranes successfully responded to challenge of sanitary and safe disposal of waste.

The implementation of raising awareness on the benefits of selective disposal of waste at the site of waste generation, but not by introducing monetary incentives therefor, partially managed to respond to the challenges of reuse and recycling of waste. Further activities in this direction went towards the formation of recycling islands in the city zone and the central recycling yard at the location of the landfill itself. The results of these activities are still at an early stage, but positive experiences from the region give a positive incentive. [10,11].

Environmental protection means a long lastingly safe environment, both from the impact of deposited waste and from external impacts (weathering, floods, etc.). About two-thirds of the landfill waste contains biodegradable organic substances from households, economy and industry. When organic substances such as food remains and green waste are placed on the landfill, it is generally compacted and covered. In this way, the oxygen is removed and causes its decay in the anaerobic process. This process produces landfill gas, which is about 50% methane and 50% carbon dioxide with small amounts of other gases.

Although the production of these gases generally peaks in five to seven years, the landfill can continue to produce gas for more than 50 years. A gas collection system was installed at the site of the landfill. It consists of blowers which are connected through a vacuum pipeline to a series of wells that are drilled and built inside the waste. This gas, once collected, can either be burned or used for energy. At study landfill, the landfill gas is collected and burnt on the torch, due to the lack of funds for the construction of a plant for the utilization of landfill gas.

Given that methane is a greenhouse gas 25 times stronger than carbon dioxide, the implications for global warming and climate change are enormous. Methane as a powerful greenhouse gas captures up to 20 times more heat in the atmosphere compared to carbon dioxide, thus directly contributing to the reduction in the production of GHS gases [12,13,14]. The IPCC modelled roads [15] that limit global warming to 1.5 °C without any or limited overruns, which include a deep reduction in methane and black carbon emissions (35% or more from both by 2050 compared to 2010). Reducing GHS emissions will be crucial to limiting the impact of climate change.

MATERIAL AND WORK METHODS

The monitoring of air quality at the location of the Brijesnica landfill has been carried out for 5 years [16,17] in order to monitor the state of the quality at the site's location and the effects of sanitary waste disposal at the landfill. The law-prescribed methodology [18] for monitoring the concentrations of certain pollutants in ambient air is in accordance with EU directives [19]:

- The reference method for the analysis of nitrogen dioxide and nitrogen oxides is chemiluminescence (CLD), the principle of measurement: a modulating type of cross-flow with reduced pressure (according to the standard BAS EN 14211).
- The reference method for analysis and the principle of measurement of sulphur dioxide is ultraviolet fluorescence (standard: BAS EN 14212).

- Monitoring carbon monoxide concentration is conducted by the method of non-dispersive infrared absorption (NDIR-CFM), and the principle of measurement: modulation of the cross-flow (standard BAS EN 14626).
- Monitoring the concentration of PM suspended particulate matter is done by the method of beta radiation absorption (standard: BAS EN 12341-1).
- Monitoring the concentration of ozone by the method of non-dispersive ultraviolet absorption (NDUV) (standard: BAS EN 14625).
- Monitoring of methane concentration is carried out by the flame ionization method.

Air quality measurements were conducted from August 2017 to July 2018 at the location of the regional sanitary landfill "Brijesnica" in Bijeljina. Measurements were carried out continuously by the authorised institution "Technical Ecological Institute" Ltd. Banja Luka, using a mobile ecological laboratory.

The measuring station is a container type, within the equipment for analysis, collection and sending of data to the central unit, is located. Communication between the station for measuring air quality and the central unit is established via GPRS. The central unit is equipped with computer and software support that allows processing and display of data in accordance with domestic and EU legislation.

RESULTS AND DISCUSSION

The measured values of the conducted continuous monitoring of the emission concentrations of pollutants were processed using a standard statistical method, calculation of the arithmetic mean. The results obtained are shown in Table 1.

Table 1. Monthly average values of measurement of air quality parameters at the location of the Brijesnica sanitary landfill – Bijeljina in the period from 01.08.2017 to 31.07.2018

MONTH	SO ₂	PM	NO ₂	NO	NO _x	CH ₄	O ₃	CO
	(24 hours µg/m ³)	(24 hours µg/m ³)	(24 hours µg/m ³)	(24 hours µg/m ³)	(24 hours µg/m ³)	(24 hours µg/m ³)	(8 hours)	(8hours)
	Limit value– 125 µg/m ³	Limit value– 50µg/m ³	Limit value– 85 µg/m ³	Limit value– 30 µg/m ³	Limit value– 30 µg/m ³	Target value -	Limit value- 120µg/m ³	Limit value 5.000 µg/m ³
August	30.2223	0.0151	10.9595	5.3710	16.3077	5.6022	55.8648	613.0906
September	33.028	0.014	11.398	6.316	17.714	5.031	44.088	598.094
October	36.1077	0.0128	12.6470	7.0219	19.6904	4.6022	35.3406	625.8506
November	42.978	0.0103	11.7317	6.8321	18.564	4.0292	31.04267	700.2535
December	43.7732	0.0091	13.6815	8.1435	21.8355	4.7736	25.0484	830.1761
January	45.0552	0.0081	14.3146	8.5211	22.8336	4.2100	21.1725	941.4642
February	48.7357	0.0052	14.2548	7.4521	21.7068	4.0691	20.7964	1041.289
March	40.8484	0.0057	14.4054	7.0455	21.4524	4.5056	27.7934	986.8990
April	31.2993	0.0121	13.2610	6.0820	19.3683	4.2102	33.4597	843.8383
May	25.5035	0.0095	12.2917	5.3685	17.6721	4.3753	43.2000	748.5859
June	20.8750	0.0054	11.3289	4.3971	15.7301	4.1186	53.9267	632.3723
July	19.3071	0.0100	9.8169	5.0731	14.8900	4.4310	61.2081	599.0241

Graphics in the figures (Figure 1 and Figure 2) shows that the values of a majority of parameters (SO₂, NO₂, NO, NO_x and CH₄, O₃,) were in a narrow interval range whereas the values of CO and PM were variable during the monitoring period.

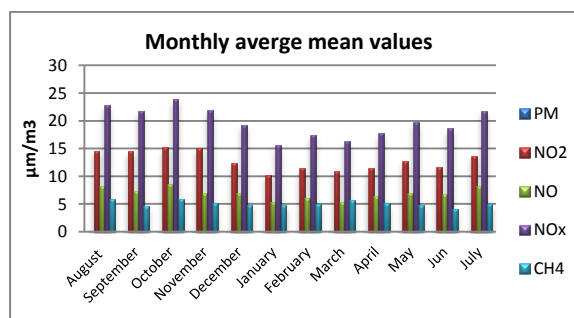


Figure 1. Monthly averages mean values for parameters PM, NO₂, No, NO_x, CH₄

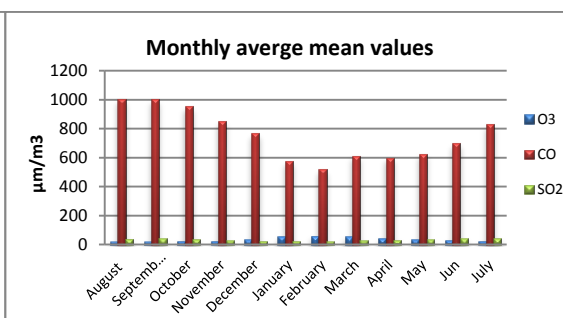


Figure 2. Monthly averages mean values for parameters O₃, CO and SO₂

Analysing the collected results shown in Table 2 in accordance with legally defined criteria shown in Table 3, the following results were obtained:

- The measured annual mean concentration of PM₁₀ particles amounts to 10 µg/m³, which is below the prescribed limit value of 40µg/m³ and a tolerance value of 48µg/m³, which categorised the air is categorized as the first category in terms of PM₁₀ particles. The PM₁₀ hourly values over the calendar year exceeded the threshold value of 35µg/m³ by 13 times, which is less than the permissible frequency of exceeding, which is 35 times.
- The measuring of ozone, a secondary pollutant in the troposphere resulting from a complex photochemical reaction with the emission of precursor gases, resulted in an average annual concentration of O₃ is 37.74µg/m³. The maximum daily 8-hour mean value of ozone calculated from concentrations measured hourly exceeded the prescribed allowable tolerance of 120 µg/m³ for 7 times, which is below the permitted frequency which is 25 times, thereby air is categorized into the first category.
- The concentrations of NO, an ozone precursor, measured at the location of the sanitary landfill, are low, especially in the summer months, which exclude ozone formation at the micro-location of measurements. The annual mean NO concentration calculated from the measured hourly concentrations is 6.46µg/m³, which is below the prescribed annual limit value of 40µg/m³. During the measurement, no exceeding of hourly limit values of 150 µg/m³ was established, on the basis of which it can be declare that in regard to NO, air is categorized into the first category.
- The prescribed annual NO₂ limit is 32µg/m³, and the annual average value calculated from the measured hourly NO₂ concentration for the measurement period is 14.86µg/m³. During the calendar year, no exceedance of hourly limit values of 105µg/m³ was established, on the basis of which we find that with regard to NO₂, air is categorized into the first category.
- The limit value of 24-hour (125µg/m³) and hourly (350µg/m³) concentration of SO₂ was exceeded 14 times during the monitoring period. The annual mean SO₂ concentration calculated on the basis of the measured hourly concentrations is 34.81µg/m³, which is less than the permitted limit value of 50µg/m³, based on which we estimate that with regard to SO₂ air is categorized into the first category.
- The annual mean value of measured concentrations of CO particles is 763.41 µg/m³, which is well below the prescribed annual limit value of 3000 µg/m³ and at the same time represents a tolerance value, based on which the air is categorized into the first category.

Based on the analysis of the measured data, the air quality at the location of the Brijesnica sanitary landfill was assessed and categorised in accordance with Article 21 of the applicable Regulations shown in Table 4. Air quality at the location of the sanitary landfill was categorized into the first category, with regard all measured parameters during the 2017/2018 monitoring period.

The obtained data were processed by additional statistical methods, using the statistical program SPSS. Table 5 shows the results of descriptive statistics for each measured parameter, presented by the statistical program SPSS.

Table 2. Percentage of data available for assessment

Pollutant	24-hour values of concentrations - number of data	24-hour values of concentrations – % of available data	Hourly values of concentrations - number of data	Hourly values of concentrations - % of available data
SO ₂	365	100	8585	98
NO	365	100	8498	97
NO ₂	365	100	8498	97
PM ₁₀	365	100	8585	98
CO	365	100	8585	98
O ₃	365	100	8410	96
CH ₄	365	100	8585	98

Table 3. Criteria for assessment of the concentrations of some parameters

Pollutant	Assessment limit	Monitoring period	Time of averaging	Assessment limit value	Frequency of allowed exceeding
SO ₂	upper	calendar year	24 hours	75 µg m ³ (60 % of LV)	8
	lower	calendar year	24 hours	50 µg m ³ (40 % of LV)	6
NO ₂	upper	calendar year	1 hour	105 µg m ³ (70 % of LV)	9
			1 year	32 µg m ³ (80 % of LV)	5
	lower	calendar year	1 sat	75 µg m ³ (50 % of LV)	12
			1 year	26 µg m ³ (65 % of LV)	8
PM ₁₀	upper	calendar year	1 year	35 µg m ³ (70 % of LV)	13
	lower	calendar year	1 year	25 µg m ³ (50 % of LV)	14
CO	upper	calendar year	8 hours	7 mg m ³ (70 % of LV)	17
	lower	calendar year	8 hours	5 mg m ³ (50 % of LV)	8
O ₃	-	-	1 hour	120 µg m ³	7

Table 4. Categorisation of air at the location of the Brijesnica landfill during 2017/2018

Pollutant	Annual average	Limit value (for a calendar year)	Tolerance value (for a calendar year)	Air category
SO ₂	34.81	50	50	I category
NO	6.46	30	-	I category
NO ₂	12.50	20	60	I category
TSP	10	40	48	I category
CO	763.41	3000	3000	I category
O ₃	37.74	120	-	I category
CH ₄	4.49	-	-	I category

The figures 3, 4 and 5 shows statistical indicators that describe a set of measured data, i.e. the position of the central tendency: the median (the value above and below which shows 50% of all measured data), the 25th, 75th and 95th percentiles.

Table 5. Results of the descriptive statistics for the measured data

		SO ₂	PM	NO ₂	NO	NO _x	CH ₄	O ₃	CO
N	Valid	365	365	365	365	365	365	365	365
	Missing	20	20	20	20	20	20	20	20
Mean		34.7270	.0098	12.5028	6.4731	18.9760	4.5050	37.8735	761.8596
Median		35.6400	.0090	12.5028	6.4128	18.9239	4.3292	35.1400	728.5400
Mode		38.64(a)	.00	14.30	6.41(a)	12.51(a)	4.20	28.64(a)	563.28(a)
Std. Deviation		10.12687	.00676	1.58042	1.30562	2.63486	.62491	13.86050	157.47378
Range		43.88	.02	7.15	6.05	11.68	3.80	52.97	631.54
Minimum		14.28	.00	8.34	3.40	12.51	3.02	16.28	522.31
Maximum		58.16	.03	15.49	9.45	24.18	6.82	69.25	1153.85
Sum		12675.36	3.57	4563.54	2362.69	6926.22	1644.32	13823.84	278078.75
Percentiles	25	26.2950	.0030	11.2559	5.3343	16.7974	4.0272	26.2250	615.7650
	50	35.6400	.0090	12.5028	6.4128	18.9239	4.3292	35.1400	728.5400
	75	42.8500	.0150	13.8580	7.5090	21.4042	4.9038	50.2100	900.7800
	95	50.2570	.0210	14.7900	8.5916	22.8336	5.7627	61.2800	1028.5670
	98	52.2780	.0240	15.0262	8.8510	23.2363	6.0234	65.0064	1067.4820

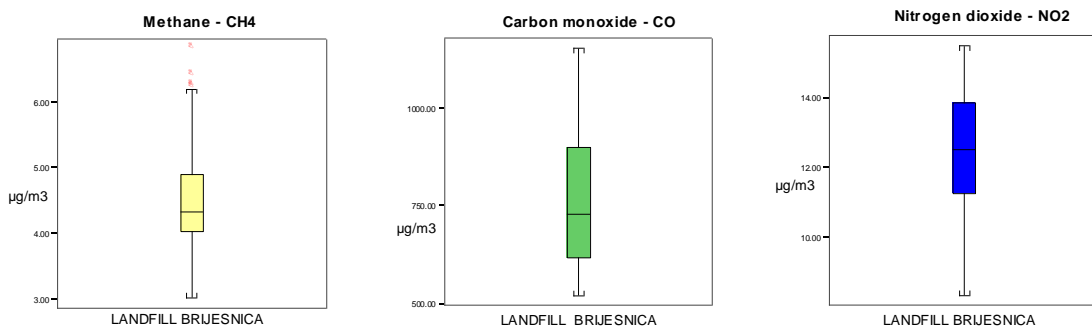


Figure 3. Box & Whiskers chart for CH₄, CO and NO₂

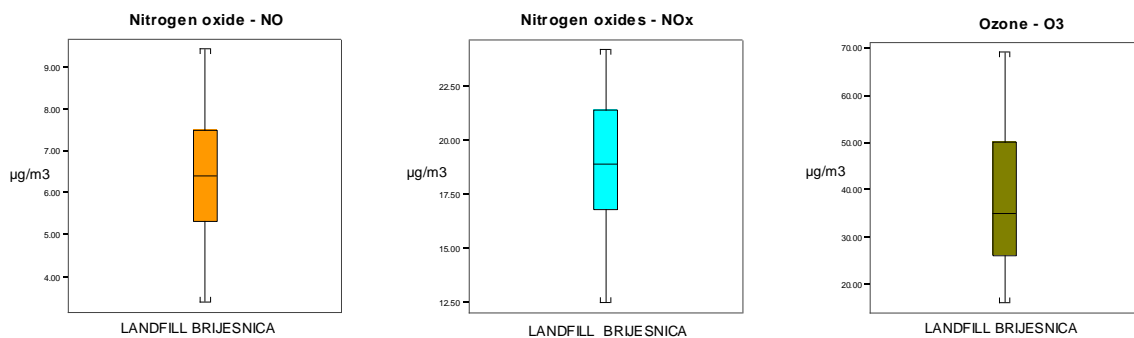


Figure 4. Box & Whiskers chart for NO, NO_x and O₃

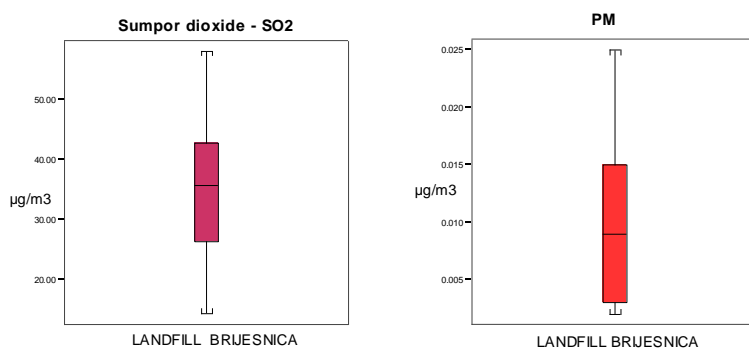


Figure 5. Box & Whiskers chart for SO₂ and PM

Based on the Box&Whiskers charts, it can be noted that all the measured values for the CO, NO, NO₂, NO_x, O₃, PM and SO₂ parameters are within the Box&Whiskers chart, which means that the measures of central tendency, the arithmetic mean and the median are in the correlation. That is, there are no outliers within the measured values, which could significantly affect the mathematically calculated values of the central tendency. On the other hand, the determined position of the central tendency-median does not deviate from the determined values of the arithmetic mean, which indicates that this is a homogeneous data set.

For the CH₄ parameter, multiple outliers were identified, whose values were not significantly high to affect the occurrence of differences in the obtained values of the arithmetic mean and the median. The value of the arithmetic mean is 4.50 while the value of the median is 6.32 which confirm the above.

CONCLUSION

Challenges faced by sanitary landfills are complex, but they are successfully handled at the Brijesnica landfill. The sanitary way of waste disposal in sanitary cells, with the planned overlapping layers of deposited waste and built-in multibarrier layers provided with drainage pipes for the leachate, is the best technical solution, thus the challenge of safe disposal of waste has been successfully accomplished.

Continuous education of the population and raising public awareness regarding the advantages of selective waste separation and the planned construction of the recycling yard have created good prerequisites for handling the challenges of increasing the percentage of waste reuse and reducing the amount of waste that will permanently be disposed of at the landfill.

The construction of a system for the collection of landfill gas from the sanitary landfills and the discharge to the torch for gas incineration greatly contributed to one of the challenges of environmental protection. Methane incineration positively affects the reduction of GHS generation. However, the future challenge would be the construction of a methane utilisation plant, for the energy needs of heating facilities at the site of the landfill. This challenge is theoretically very possible to achieve, using funds from the European funds.

Through regular monitoring and air quality control for several years, another segment of the environmental protection has been successfully implemented, which has minimised air pollution from waste disposal activities.

On the basis of the conducted research, analysis and interpretation of the obtained air quality results, a conclusion can be drawn that the current and future challenges relating to air pollution from the sanitary waste management method at the Brijesnica landfill have been successfully identified and positively resolved, and it is recommended to continue in the same way, responsibly to the environment.

(Received March 2019, accepted April 2019)

REFERENCES

- [1] Akinjare, O.A., (2011). Impact of sanitary landfills on urban residential property values in Lagos State, Nigeria. *Journal of Sustainable Development*, 4(2), p. 48-60, access: March, 2019.
- [2] Aljaradin M., Persson, K. M. (2012), Environmental Impact of Municipal Solid Waste Landfills in Semi-Arid, Climates - Case Study – Jordan, *The Open Waste Management Journal* 5, p. 28-39, access: March, 2019.
- [3] Kelly, F.J, Fussell J.C. (2015). Air pollution and public health: emerging hazards and improved understanding of risk. *Environ Geochem Health* 37: 631-649, access: March, 2019.
- [4] UNDP, (2018). Informative sheet on air quality in Bosnia and Herzegovina (translation of: Informativni list okvalitetu vazduha u Bosni I Hercegovini), <https://www.unicef.org/bih/media/1206/file>, access: March, 2019.
- [5] WHO, (2012). Global assessment of ambient air pollution exposure and the resulting burden of disease, p. 65, access: March, 2019.

- [6] Genc, S, Zadeoglulari, Z, Fuss, S.H, Genc.K.(2012).The Adverse Effects of Air Pollution on the Nervous System. *J Toxicol* 2012: 1-23, access: March, 2019.
- [7] Chen, W. Y. Kao,J. J. (2008). Air Pollution Directional Risk Assessment for Siting a Landfill, *Journal of the Air & Waste Management Association*, , 1539-1545, DOI: 10.3155/1047-3289.58.12.1539, access: March, 2019.
- [8] Weichenthal, S., Rijswijk, D.- V., Kulka, R., You, H., Ryswyk, K.V., Willey, J., Dugandzic, R., Sutcliff, R., Moulton, J., Baike, M., , White, L., Charland, JP., Jessiman, B., (2015). The impact of a landfill fire on ambient air quality in the north: A case study in Iqaluit, Canada, *Environmental Research*, Volume 142, p. 46-50.
- [9] EEA, Air Quality Index, http://airindex.eea.europa.eu/#_blank, access: March,2019.
- [10] Gudelj I. 2015.Sustainable waste management, Collection, Separate collection and storage of waste (translation of: Održivo gospodarenje otpadom, Sakupljanje, odvojeno sakupljanje i skladištenje otpada) Zagrebačko učilište, Zagreb. 3:91-114. access: March, 2019.
- [11] Nodoushani, O., Stewart, C., & Kaur, M. (2016).Recycling and its effects on the environment. *Target journal: Competitive Forum*, Volume 14, p 65-69. access: March, 2019.
- [12] Uisung L. J., Han, H.,M., (2017). Evaluation of landfill gas emissions from municipal solid waste landfills for the life-cycle analysis of waste-to-energy pathways, *Journal of Cleaner Production*, Volume 166, Pages 335-342, access: February, 2019.
- [13] Turner, A: D., Williams, D., I., Kemp,S. (2015). Greenhouse gas emission factors for recycling of source-segregated waste materials, *Resources, Conservation and Recycling*, Volume, 105, Pages 186-197, <https://doi.org/10.1016/j.resconrec.2015.10.026>, access: March, 2019.
- [14] Kashyap, R.K., Chugh, P, Nandakumar, T. (2016). Opportunities & Challenges in Capturing Landfill Gas from an Active and Un-scientificly Managed Land Fill Site – A Case Study, *Procedia Environmental Sciences*, Volume 35, 2016, Pages 348-367, <https://doi.org/10.1016/j.proenv.2016.07.015>, access: March, 2019.
- [15] IPCC, (2018).Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, p. 32. access: March, 2019.
- [16] Knežević, D. Radun, M. (2012)."Air quality monitoring at the regional sanitary landfill" Brijesnica "Bijeljina." *International Conference XIV • YUCORR*, Proceedings: 509-523. access: March, 2019.
- [17] Knezevic, D. Pavlovic; S., Kuzman-Katica, J., Bojic, M. (2014)."Environmental impact assessment of sanitary landfills on air quality."International scientific conference "X consulting chemists, technologists and ecologists Serbian Republic". Proceedings: Faculty of Technology Banja Luka, p. 650-658.
- [18] Regulation of air quality limit values, 124. (2012). Banja Luka: Official Gazette of Republic of Srpska
- [19] Air Quality (Framework) Directive – 96/62/EC, access: February, 2019.
- [20] Unpublished article: Annual report on air quality measurements at the location of the sanitary landfill "Brijesnica" Bijeljina, no. 61-09-EK / 13, "Technical Environmental Institute" Ltd. Banja Luka, 2013.