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Air quality measurement on the location of the highway section on corridor Vc, Johovac - FBIH border

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A R T I C L E I N F O

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A B S T R A C T

Corridor Vc connects the middle part of the Adriatic coast and the port of Ploče, with Corridor X on the Zagreb-Belgrade stretch and ends at the hub in Budapest. The goal of the construction of the corridor Vc Johovac - Border of FBiH is to improve the traffic capacity of this road, as well as to improve the entire segment of accompanying effects, of which the effects on the environment are one of the most significant. The start of the section is located in the town of Johovac, where a loop is planned to connect the highway Banja Luka - Doboj with corridor Vc, and the end of the section is located in the area of the Makljenovac settlement, i.e. to the border with FBiH. The observed coverage of the site is a combination of flat and hilly terrain that is mainly used as agricultural land. The route of the planned highway mainly follows the course of the Bosna River, which is the most dominant watercourse in the section. The total length of this section is 10.65 km. This paper presents the results of air pollution measurements that will be the basis for further assessment of air quality when the highway is put into operation. Air pollution represents the concentration of harmful substances over the tolerance limit (maximum permissible concentration - MPC), however, this concentration will depend not only on the intensity of the source of pollution, but also on local conditions in terms of air currents, precipitation, terrain configuration, etc. The effect of air pollution on the population can be direct or indirect. Air pollution directly damages and worsens people's health, while its indirect effect manifests itself through a harmful effect on domestic animals, vegetation, material and cultural assets.

1. Introduction

The construction of a large structure such as the corridor Vc is a major construction project with the involvement of a "heavy" construction machinery and a large number of construction workers. Used machinery increases local air pollution with exhaust gases. Diesel engine exhaust gases mainly contain carbon, nitrogen and sulphur oxides, aldehydes, unburned hydrocarbons and soot particles [1,2]. The percentage representation of certain hazardous substances in the exhaust gases depends on the fuel quality, operating mode and engine load [3,4].

Air pollution is a consequence of the operation of construction machinery, which, bearing in mind the locality in question, is more significant in terms of the parameters of suspended solid particles than in terms of exhaust gases (NO_x, CO, SO_2, etc.) due to the proximity of major roads, as well as dust created by trucks and other mechanisation on the construction site [5,6,7].

Suspended matter and particulate pollution may contain hydrocarbon compounds of importance for human health: H_xC_y, HCHO, etc., including aromatic hydrocarbons, compounds with carcinogenic potential such as benzo(a)pyrene [8,9,10]. The emission of sulphur compounds directly depends on the sulphur content in fossil fuels [11,12,13].

The behaviour of dust in the air is primarily a function of the ability to settle, which depends on the density and diameter of the particle itself and is subject to Stokes' law [14,15]. Particles smaller than 0.1 µm have low speeds <10 m/s. Basic deviations from this law occur primarily due to the irregular shape of the particles, random movement in the air current and meteorological conditions [16,17]. Considering the mentioned characteristics of the particles, it is possible to expect that: dust particles larger than 10 microns sediment spontaneously, particles from 1 to 10 microns sediment according to Stokes' law, at a constant speed and float longer in the air, and particles from 0.1 to 1 micron do not sediment but float in air according to the law of Brownian motion and have a diffusion capacity similar to gases [18,19].

Based on previous experience at similar construction sites and literature data, it is possible to expect that particles with a diameter greater than 50 microns will sediment at close distances of up to 50 m, particles of 20 microns up to a distance of 200 m, particles of 10 microns will sediment at distances of up to 500 m, and smaller particles (<10 µm) can also appear at greater distances (< 800 m) [20,21].

The aforementioned hazardous effects must be prevented by proper handling of construction machinery, the use of technically valid machines, and by pouring fuel only in the designated place [22,23].

2. Methodology

The measuring instruments and measurement methods that were used when determining the air quality at the concerned location are as follows:

No	Name of measuring/testing equipment	Manufacturer	Type	Measuring range	Method of measurement
1	Analyser SO2	HORIBA, JAPAN	APSA-370	0-1000 µg/m³	BAS EN 14212:2013 ultraviolet fluorescence*
2	Analyser NO/NO2/NOx	HORIBA, JAPAN	APNA-370	NO: 0- 1200 µg/m³ (0- 960 ppb) NO2: 0- 500 µg/m³ (0- 260 ppb)	BAS EN 14211:2013 chemiluminescence*
3	Analyser CO	HORIBA, JAPAN	APMA-370	0- 100 mg/m³	BAS EN 14626:2013 non-dispersive infrared spectroscopy*
4	Analyser O3	HORIBA, JAPAN	APOA-370	0- 500 µg/m³	BAS EN 14625:2013 ultraviolet photometry*
5	Gravimetric sampler of solid particles TSP, PM10 и PM2.5	Digitel AG Hegnau, Switzerland	DPA14	-	BAS EN 12341:2015 standard gravimetric method*
6	Electronic scales METTLER TOLEDO	Mettler Toledo GmbH, Switzerland	XPR206DR/M	0,01mg/0,005 mg-220gr	-

Figure 1. Gravimetric sampler of solid particles TSP, PM10 and PM2.5

Figure 2. Electronic scales METTLER TOLEDO

Figure 3. Analysers SO2, NO/NO2/NOx, CO, O3 HORIBA JAPAN

The Regulation on Air Quality Values (Republika Srpska Official Gazette, 124/12) establishes the limit and tolerance values of air quality in order to protect the health of people, vegetation and natural ecosystems, as well as the maximum allowed concentration of pollutants in the air in dedicated measurements [24,25,26].

Table 1. Limit, tolerance values and limits for the protection of human health

Sampling period	Limit value	Tolerance limit	Tolerance value
Sulphur dioxide			
One hour	350 µg/m^3	150 µg/m^3	500 µg/m^3
One day	125 µg/m^3	-	125 µg/m^3
Calendar year	50 µg/m^3	-	50 µg/m^3
Nitrogen dioxide			
One hour	150 µg/m^3	75 µg/m^3	225 µg/m^3
One day	85 µg/m^3	40 µg/m^3	125 µg/m^3
Calendar year	40 µg/m^3	20 µg/m^3	60 µg/m^3
Suspended particles PM_{10}			
One day	50 µg/m^3	25 µg/m^3	75 µg/m^3
Calendar year	40 µg/m^3	8 µg/m^3	48 µg/m^3
Carbon monoxide			
Maximum daily eight-hour value	10 мг/м^3 (10000 µg /m^3)	6 mg/m^3 (6000 µg /m^3)	16 mg/m^3 (16000 µg/m^3)
One day	5 мг/м^3 (5 000 µg/m^3)	5 mg/m^3 (5000 µg/m^3)	10 mg/m^3 (100 00 µg/m^3)
Calendar year	3 мг/м^3 (3 000 µg/m^3)	-	3 мг/м^3 (3000 µg/m^3)

Table 2. Target value for ground-level ozone

Target value for ground-level ozone		
Target	Average value calculation period	Target value
Human health protection	Maximum daily eight-hour average value	120 µg/m^3

The air quality values according to the aforementioned regulation represent the numerical values of limit values of the level of pollutants in the air, notably the bottom and upper limits of air quality assessment, critical levels, tolerance limits and tolerance values, target values and long-term goals of pollutants in the air, concentrations hazardous to human health and concentrations reported to the public. The level of air pollutants is monitored by measuring concentrations of sulphur dioxide, nitrogen dioxide and nitrogen oxides, suspended particles (PM_{10}, $PM_{2,5}$), lead, benzene, carbon monoxide, ground ozone, arsenic, cadmium, mercury, nickel, benzo(a)pyrene and soot in the air with instruments for automatic measurement and/or taking samples for analysis.

Limit and tolerance values and tolerance limits for sulphur dioxide, nitrogen dioxide and carbon monoxide are given in the following table:

In the zone and agglomerations in which the level of the concerned pollutants is below the limit values determined by the above tables, it is necessary to keep pollutant concentration at a level below the limit values.

For pollutants for which no tolerance limit is prescribed, their limit value is taken as the tolerance value [27].

Limit and tolerance values are the basis for:

- assessment of air quality,
- division of zones and agglomerations in the category based on the level of air pollution and
- air quality management.

Limit values of the air pollutant level prescribed by this Regulation must not be exceeded once they have been reached.
Concentrations dangerous to human health for sulphur dioxide, nitrogen dioxide and ground ozone in the air are given in the following table:

Table 3. Concentrations of sulphur dioxide and nitrogen dioxide dangerous to human health

Pollutant	Concentration dangerous to human health
Sulphur dioxide	500 µg/m^3
Nitrogen dioxide	400 µg/m^3

Table 4. Concentrations of ground-level ozone dangerous to human health and concentrations reported to the public

Purpose	Averaging period	Limit
Notice	1 hour	180 µg/m^3
Warning	1 hour*	240 µg/m^3

** In a zone or agglomeration, the exceedance of limit is determined or predicted during three consecutive hours, with the aim of adopting short-term action plans for the protection of human health or the environment as necessary.*

Concentrations dangerous to human health are measured during three consecutive hours at locations representative of air quality in a zone whose area is not less than 100 km^2, or in a zone or agglomerations, if their area is smaller [28].

3. Degree of air pollution with basic and specific pollutants

To assess the air quality at two locations of the planned motorway on the Vc corridor, Johovac interchange - Rudanka interchange, 24-hour air emission concentrations were measured at two measuring points, in the period from 2019 to 2022. The measurements were carried out by the Civil Engineering Institute "IG" LLC Banja Luka using a mobile station equipped with appropriate measuring analysers and a sampler for air quality.

Figure 4. Satellite image of the location (Source: Google Earth)

Coordinates of measuring point no.1:

- 44°48'9.58"N
- 18° 3'27.45"E

Coordinates of measuring point no.2:

- 44°45'38.25"N
- 18° 3'26.20"E

Air quality measurement included the following parameters:

- Carbon monoxide CO
- Nitrogen oxides NO, NO_2, NO_X
- Ozone O_3
- Sulphur dioxide SO_2
- Suspended particles PM_{10}

4. Results of laboratory tests

In order to determine the content of air pollutants on the planned motorway section, MM1-Johovac Interchange, in the period from 2019 to 2022, immission concentrations of carbon monoxide (CO), sulphur dioxide (SO_2), ozone (O_3), and nitrogen oxides (NO, NO_2, NO_x) and suspended particles (PM_{10}) were measured.

The content of the mentioned air pollutants was measured using a mobile station equipped with appropriate analysers and a sampler.

The average concentration of carbon monoxide (CO) in the air during the measurement period was 0.43 mg/m^3 at the observed location and did not exceed the prescribed limit value of 5 mg/m^3. The average value of O_3 concentration was 43.66 µg/m^3. The average concentration of CO_2 in the air during the measurement period was 31.67 µg/m^3 and did not exceed the prescribed limit value of 125 µg/m^3. The average concentration of NO in the air during the measurement period was 13.94 µg/m^3, the average concentration of NO_2 was 18.95 µg/m^3 and did not exceed the prescribed limit value of 85 µg/m^3 a NO_X 32.90 µg/m^3. The average concentration of PM_{10} during the measurement was 33.81 µg/m^3.

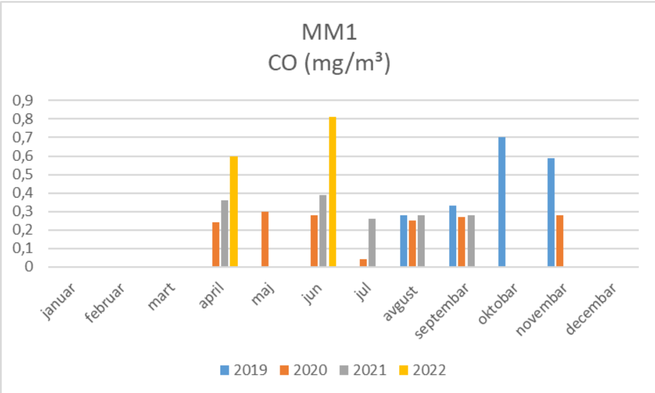

Figure 5. Graphic representation of the multi-year trend of average immission concentrations of CO at MM-1 motorway location for the measurement period from 2019 to 2022

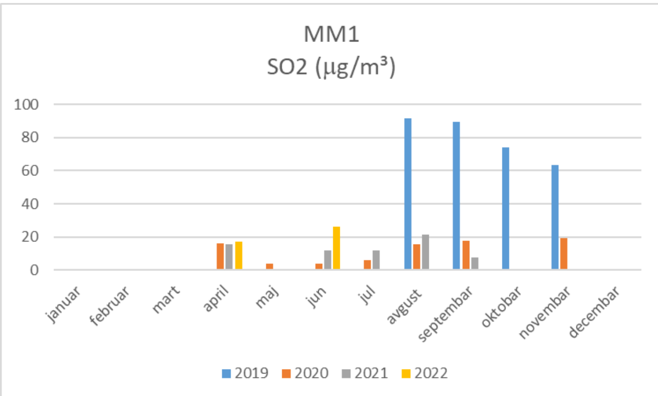

Figure 6. Graphic representation of the multi-year trend of average immission concentrations of SO_2 at MM-1 motorway location for the measurement period from 2019 to 2022

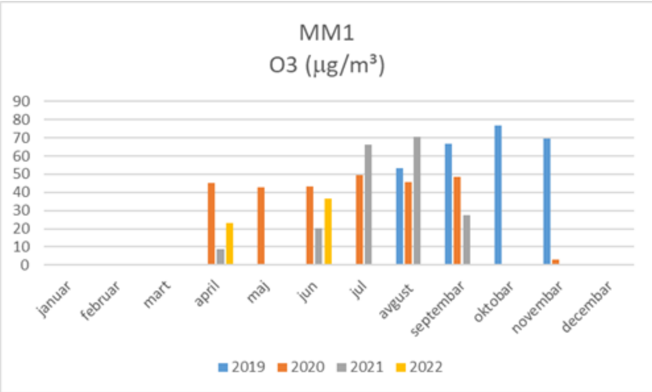

Figure 7. Graphic representation of the multi-year trend of average immission concentrations of O_3 at MM-1 motorway location for the measurement period from 2019 to 2022 године

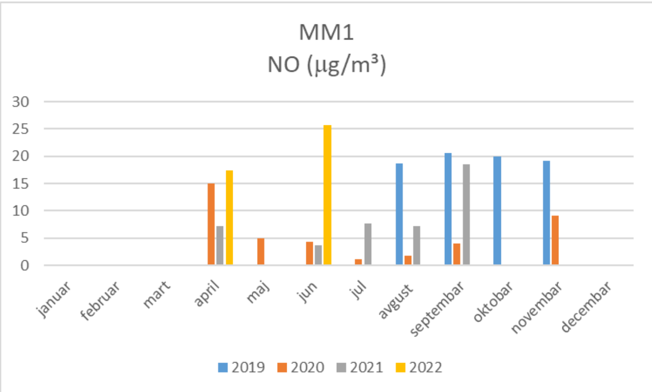

Figure 8. Graphic representation of the multi-year trend of average immission concentrations of NO at MM-1 motorway location for the measurement period from 2019 to 2022

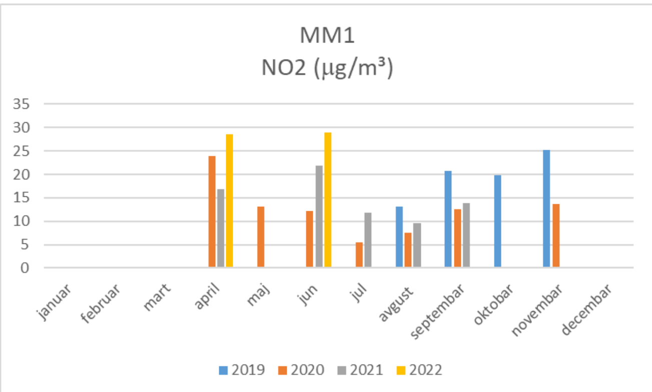

Figure 9. Graphic representation of the multi-year trend of average immission concentrations of NO_2 at MM-1 motorway location for the measurement period from 2019 to 2022

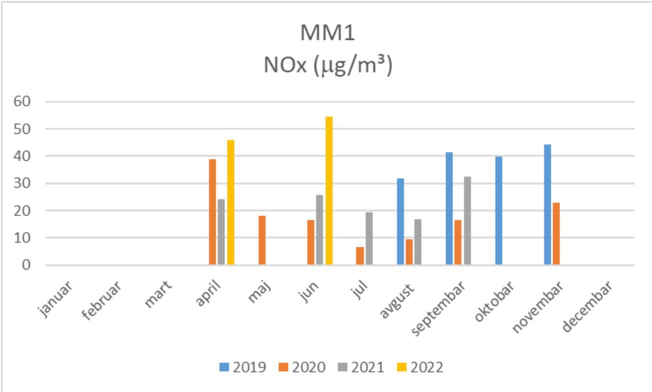

Figure 10. Graphic representation of the multi-year trend of average immission concentrations of NO_x at MM-1 motorway location for the measurement period from 2019 to 2022

At the MM2-Rudanka interchange measuring point, in the same period from 2019 to 2022, the same immission concentrations were measured as at the location MM1-Johovac Interchange.

The average concentration of carbon monoxide (CO) in the air during the measurement period was 0.51 mg/m^3 at the observed location and did not exceed the prescribed limit value of 5 mg/m^3. The average value of O_3 concentration was 49.19 µg/m^3.

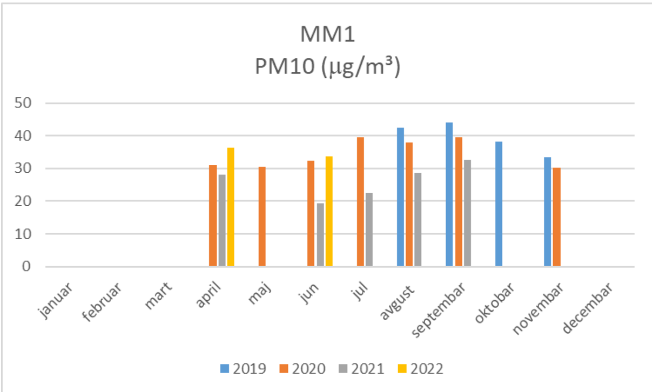

Figure 11. Graphic representation of the multi-year trend of average immission concentrations of PM_{10} at MM-1 motorway location for the measurement period from 2019 to 2022

The average concentration of SO_2 in the air during the measurement period was 37.39 µg/m^3 and did not exceed the prescribed limit value of 125 µg/m^3. The average concentration of NO in the air during the measurement period was 12.62 µg/m^3, the average concentration of NO_2 was 17.73 µg/m^3 and did not exceed the prescribed limit value of 85 µg/m^3, a NO_X 30.44 µg/m^3. The average concentration of PM_{10} during the measurement was 34.96 µg/m^3.

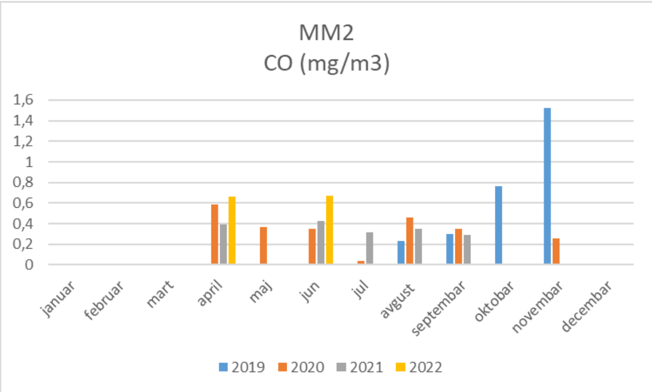

Figure 12. Graphic representation of the multi-year trend of average immission concentrations of CO at MM-2 motorway location for the measurement period from 2019 to 2022

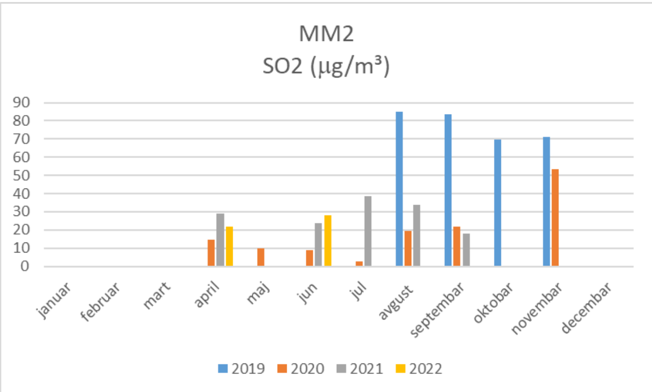

Figure 13. Graphic representation of the multi-year trend of average immission concentrations of SO_2 at MM-2 motorway location for the measurement period from 2019 to 2022

The obtained values do not exceed the limit values prescribed by the Regulation on Air Quality Values (Republika Srpska Official Gazette, 124/12).

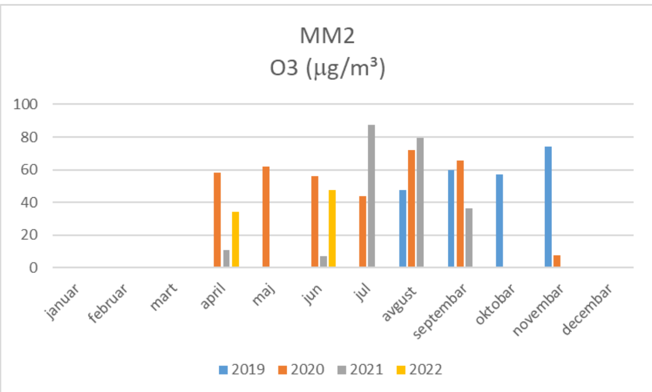

Figure 14. Graphic representation of the multi-year trend of average immission concentrations of O_3 at MM-2 motorway location for the measurement period from 2019 to 2022

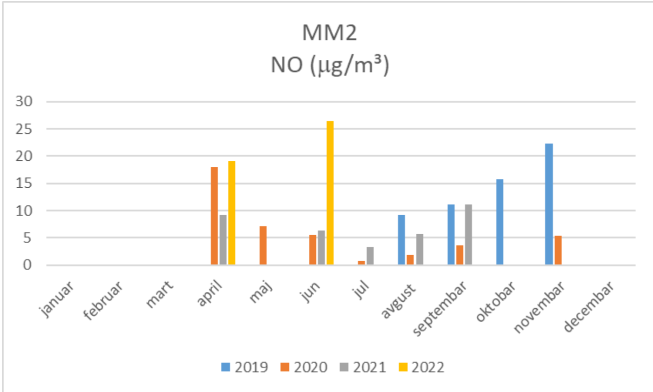

Figure 15. Graphic representation of the multi-year trend of average immission concentrations of NO at MM-2 motorway location for the measurement period from 2019 to 2022

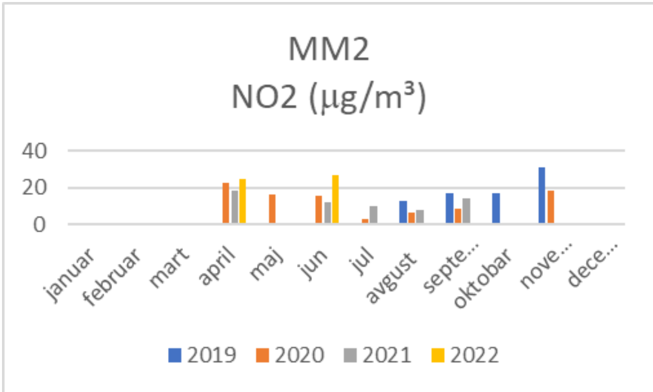

Figure 16. Graphic representation of the multi-year trend of average immission concentrations of NO_2 at MM-2 motorway location for the measurement period from 2019 to 2022

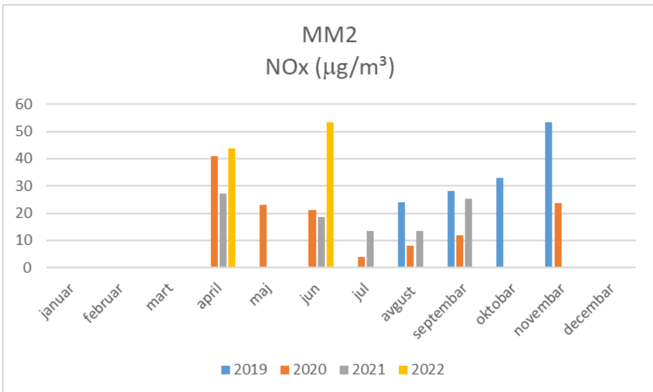

Figure 17. Graphic representation of the multi-year trend of average immission concentrations of NO_x at MM-2 motorway location for the measurement period from 2019 to 2022

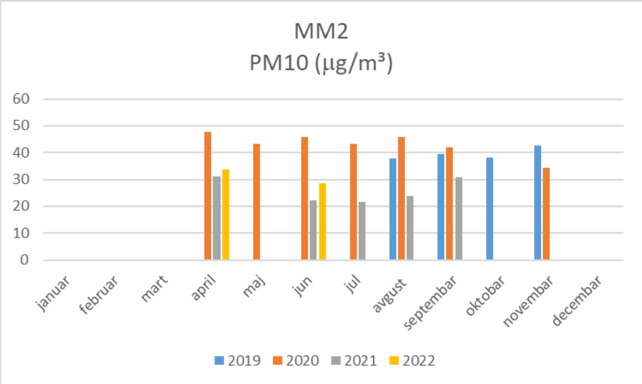

Figure 18. Graphic representation of the multi-year trend of average immission concentrations of PM_{10} at MM-2 motorway location for the measurement period from 2019 to 2022

5. Conclusion

Based on the measurement of air pollutant concentrations and the results obtained in the area of MM1 and MM2 measuring points, a conclusion can be drawn that the air quality is satisfactory, that is, that the obtained values do not exceed the limit values prescribed by the Regulation on Air Quality Values (Republika Srpska Official Gazette, 124 /12).

Adequate organisation and undertaking of preparatory works for the corridor construction can achieve control over activities that can harm the environment, and it is possible to prevent and reduce the expected environmental impact. Among the air protection measures that should be taken during the construction of the corridor, the most important are:

- Perform misting and wetting of access roads in order to reduce dust emissions.
- Dispersion of suspended particles as a result of construction works (excavation, loading and unloading of materials), is to be mitigated by protective measures that bring suspended particles to limit values (optimal humidity of materials, wetting and misting of materials).
- Cover trucks transporting construction material, i.e. wet the material with water.
- The speed of vehicle movement on unpaved (access) roads should be limited and adapted to road conditions.
- Cargo vehicles and trucks that will take away/deliver construction materials, before entering the roads must be cleaned of soil deposits that can be found on the vehicle's wheels.
- If there is a need for blasting, the regulations that are provided as a form of protection for the execution of that type of work must be applied.

Of the air protection measures that should be taken during the operation of the corridor, the most important are [29]:

- Plant protective green belts along the corridor to prevent the spread of pollution, according to the Landscaping design.
- Sound barriers also prevent the spread of pollutants, and their effectiveness depends on the height,
- The belt inside the fence is to be horticulturally arranged and grass planted in order to reduce the impact of exhaust gas emissions.

Literature

[1] B. Arsenović: „Hemija i biohemija životne sredine“ Nezavisni univerzitet Banja Luka, , 2013. *(B. Arsenović: "Environmental Chemistry and Biochemistry" Independent University of Banja Luka, 2013.)*

[2] Baldauf R.W., E. Thoma, A. Khlystov, V. Isakov, G.E. Bowker, T. Long, R. Snow, 2008b. Impacts of Noise Barriers on Near-Road Air Quality, Atmospheric Environment (in press).

[3] Baldauf, R.W., W. Crews, R. Snow, and P. Gabele, 2005. Criteria and Air Toxic Emissions from In-Use, Low Emission Vehicles, Jounal of the Air & Waste Management Association, 55:1263- 1268.

[4] Brunekreef, B.; Janssen, N.A.H.; de Hartog, J.; Harssema, H.; Knape, M.; van Vliet, P. Air Pollution from Truck Traffic and Lung Function in Children Living near Motorways; Epidemiol. 1997, 8, 298-303.

[5] Baldauf, R.W., E. Thoma, M. Hays, R. Shores, J. Kinsey, B. Gullett, S. Kimbrough, V. Isakov, T. Long, R. Snow, A. Khlystov, J. Weinstein, F. Chen, R. Seila, D. Olson, I. Gilmour, S. Cho, N. Watkins, P. Rowley, J. Bang, 2008a. Traffic and Meteorological Impacts on Near Road Air Quality: Summary of Methods and Trends from the Raleigh Near Road Study, J. Air & Waste Manage Assoc. 58:865–878.

[6] California Environment Protection Agency, Air Resource Board, 2000. Public meeting to consider approval of revisions to the state’s on-road motor vehicle emissions inventory. Technical Support Document.

[7] Đuković J, Bojanić V. Aerozagađenje, Institut zaštite i ekologije, Banja Luka,2000. *(Đuković J, Bojanić V. Air pollution, Institute of Protection and Ecology, Banja Luka, 2000.)*

[8] Gaćeša, D.: „Bezbjedonosni aspekti zaštite životne sredine u RS-rizici i prijetnje, Bezbjednost i zaštita u Republici Srpskoj i Bosni i Hercegovini, stanje i perspektive. *(Gaćeša, D.: "Security aspects of environmental protection in the RS - risks and threats, Security and protection in Republika Srpska and Bosnia and Herzegovina, situation and perspectives.")*

[9] Ilić, P. (2015): Zagađenje i kontrola kvaliteta vazduha u funkciji zaštite životne sredine. Nezavisni univerzitet, Banja Luka. *(Ilić,*

P. (2015): Pollution and air quality control in the function of environmental protection. Independent University, Banja Luka.)

[10] Jokanović I, Knežević N. (2006): Pokazatelji stanja životne sredine u toku rehabilitacije puteva u RS, Međunarodna konferencija „Put i životna sredina“, Institut za puteve a.d Beograd, Tara, jun 2006. pp. 297-302. *(Jokanović I, Knežević N. (2006): Indicators of the environmental state during road rehabilitation in the RS, "Road and Environment" International Conference, Institut za puteve a.d. Belgrade, Tara, June 2006, pp. 297-302.)*

[11] Jokananović I, Knežević N. (2006): Organizacija i izvršenje monitoringa životne sredine tokom radova rehabilitacije puteva u RS, Međunarodna konferencija „Put i životna sredina“, Institut za puteve a.d Beograd, Tara, jun 2006. pp. 291-296. *(Jokananović I, Knežević N. (2006): Organisation and execution of environmental monitoring during road rehabilitation works in RS, "Road and Environment" International Conference, Institut za puteve a.d. Belgrade, Tara, June 2006, pp. 291-296.)*

[12] Jordan Aleksić, M. Adžemović: skripta Sistem ekološke bezbjednosti. *(Jordan Aleksić, M. Adžemović: System of ecological security script.)*

[13] Knežević N, Cukut S, Dunović S, Knežević D. (2016): Procjena o uticaju na životnu sredinu prilikom izgradnje i modernizacije regionalnog puta R435, Nevesinje - Berkovići u dužini od 19,14 km, Drugi srpski kongres o putevima, Srpsko društvo za puteve „Via Vita“, Beograd, jun 2016. *(Knežević N, Cukut S, Dunović S, Knežević D. (2016): Environmental impact assessment during the construction and modernisation of R435 regional road, Nevesinje - Berkovići in the length of 19.14 km, Second Serbian Road Congress, "Via Vita" Serbian Road Society, Belgrade, June 2016.)*

[14] Kim, J.J., Smorodinsky, S., Lipsett, M., Singer, B.C., Hogdson, A.T., Ostro, B., 2004. Trafficrelated Air Pollution Near Busy Roads: The East Bay Children's Respiratory Health Study. American Journal of Respiratory and Critical Care Medicine 170(5), 520-526.

[15] Lolić, B. (1989): Uticaj onečišćenja atmosfere na funkcionalne promjene pluća i učestalost respiratornih bolesti kod djece- Magistarski rad, Zagreb. *(Lolić, B. (1989): The influence of atmospheric pollution on functional lung changes and frequency of respiratory diseases in children - Master's thesis, Zagreb.)*

[16] N.Bozić: „Kvalitet vazduha u regionu SI BiH i značaj informisanja o kvalitetu“; Studija o kvalitetu vazduha u SI BiH; Centar za ekologiju i energiju, Tuzla 2009. *(N. Bozić: "Air quality in the NE BiH region and the importance of quality information"; Study on air quality in NE BiH; Centre for Ecology and Energy, Tuzla 2009.)*

[17] N.Đurić, N.Božić, R.Babić, B.Stojanović, M.Vidaković: „Monitoring ukupnih azotnih oksida u vazduhu grada Bijeljine“; UDC 504.3.054.(497.6 Bijeljina); Tehnički institut Bijeljina; Arhiv za tehničke nauke, G III, N0 3. *(N.Đurić, N.Božić, R.Babić, B.Stojanović, M.Vidaković: "Monitoring of total nitrogen oxides in the air in Bijeljina City"; UDC 504.3.054.(497.6 Bijeljina); Bijeljina Technical Institute; Archive for technical sciences, G III, N0 3.)*

[18] Platt, U. In Air Monitoring by Spectroscopic Techniques; Sigrist, M, Ed.; Wiley: New York, 1994; pp 27-84.

[19] Pešević, D, Knežević, N. (2018): Uticaj gradilišta dijela autoputa Banja Luka - Doboj na kvalitet životne sredine *(Pešević, D, Knežević, N. (2018): Impact of the construction site of the Banja Luka - Doboj motorway section on the environmental quality)*, 1st International Conference "The Holistic Approach to Environment", Association for Promotion of Holistic Approach to Environment, Sisak, September 2018, pp. 590-601

[20] Radić, R, Knežević, N, Lazić, V, Arsenović, B. (2006): Uticaj lebdećih čestica na kvalitet vazduha u gradu Banjaluci, XX Simpozijum o koroziji i zaštiti materijala, Crnogorsko društvo za zaštitu materijala i životne sredine, Podgorica, decembar 2006. pp. 129-134. *(Radić, R, Knežević, N, Lazić, V, Arsenović, B. (2006): Impact of suspended particles on air quality in Banja Luka City, XX Symposium on Corrosion and Protection of Materials, Montenegrin Society for Material and the Environmental Protection, Podgorica, December 2006. pp. 129-134.)*

[21] Roorda-Knape, M., Janssen, N., De Harthog, J., Van Vliet, P., Harssema, H., Brunekreef, B., 1998a. Air pollution from traffic in city districts near major motorways. Atmospheric Environment 32, 1921–1930.

[22] Roorda-Knape, M., Janssen, N., De Harthog, J., VanVliet, P., Harssema, H., Brunekreef, B., 1998b. Air pollution from traffic in city districts near major motorways. Atmospheric Environment 32, 1921–1930.

[23] Russwurm, G.M. Compendium Method T0-16 Long-Path Fourier Transform Infrared Monitoring of Atmospheric Gases; EPA/625/R-96/010b; U.S. Environmental Protection Agency: Center for Environmental Research Information, Office of Research and Development: Cincinnati, OH, 1999.

[24] Reponen, T., Grinshpun, S.A., Trakumas, S., Martuzevicius, D., Wang, Z.M., LeMasters, G., Lockey, J.E., Biswas, P., 2003. Concentration gradient patterns of aerosol particles near interstate highways in the Greater Cincinnati airshed. Journal of Environmental Monitoring 5(4), 557-562.

[25] Standard Guide for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air. 2002 ASTM Standard Designation E 1865-97; American Society for Testing and Materials: West Conshohocken, PA, 2002.

[26] Regulation on Air Quality Values (RS Official Gazette, 124/12).

[27] Law on Air Protection (RS Official Gazette, 124/11 и 46/17).

[28] Zhu, Y., Hinds, W.C., Kim, S.K., Shen, S., Sioutas, C., 2002. Study of ultrafine particles near a major highway with heavy-duty diesel traffic. Atmospheric Environment 36, 4323-4335.

[29] Zhu, Y., Hinds, W.C., Kim, S., Sioutas, C., 2002. Concentration and size distribution of ultrafine particles near a major highway. Journal of the Air and Waste Management Association, accepted for publication.