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Chapter 10 Air Quality

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Volume 1: Environmental and Social Impact Assessment Report

Chapter 10 Air Quality

October 2023

The Infrastructure Project Facility (IPF) is a technical assistance instrument of the Western Balkans Investment Framework (WBIF) which is a joint initiative of the European Union, International Financial Institutions, bilateral donors and the governments of the Western Balkans which supports socio-economic development and EU accession across the Western Balkans through the provision of finance and technical assistance for strategic infrastructure investments. This technical assistance operation is financed with EU funds.

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10 Air Quality

10.1 Introduction

This chapter reports the findings of the assessment of the baseline conditions and potential impacts on air quality of the Project during the construction and operational phases. For this phase of the Project, the types and sources of air pollution are identified, significance of potential effects are identified using computer simulations based on the Computational Fluid Dynamics (CFD) method, and the measures that will be employed to minimise the impact are described.

This Chapter should be read in conjunction with the following Chapters:

Chapter 1	Introduction
Chapter 2	About the Project
Chapter 3	Detailed Project description
Chapter 4	Policy, legislative and institutional context
Chapter 5	Assessment methodology
Chapter 17	Cumulative impacts
Chapter 18	Residual impacts
Chapter 19	ESMP.

10.2 Baseline Conditions

According to the Rulebook on the Manner of Monitoring Air Quality and Defining the Types of Pollutants, Limit Values and Other Air Quality Standards[1], air quality assessment requires a measurement lasting for one calendar year.

There has not been an operational monitoring station in Konjic since 1990s. The closest station is located on Ivan Sedlo approx. 17 km north of Konjic at 967 m a.s.l. However, Konjic is located approx. 270 m a.s.l. and data from Ivan Sedlo cannot be considered relevant for the project area. Considering the fact that the City of Konjic does not have measuring station for monitoring for the past 30 years, the concentration of SO_2, NO_X, as well as other pollutants, it is not possible to determine the air quality.

The air quality measurements in the City of Mostar are carried out on two monitoring stations. The first monitoring station is operated by the Cantonal Institute of Public Health and the second one is operated by the Faculty of Science and Education of University of Mostar[2]. Unfortunately, the monitoring station operated by the Cantonal Institute of Public Health is not in function, and the latest data are available for the period 2000-2007, while the monitoring

[1] Official Gazette of FBiH, no. 1/12, 50/19, 3/21
[2] Owned by the Federal Ministry of Environment and Tourism, operated by the City of Mostar who transferred the operation rights to the University of Mostar.

station operated by the University of Mostar never made their data publicly available[3].

Hence, the only available data on the air quality in Mostar refer to the period 2000-2007 and are summarised in the table below.

Table 10-1: Status of air quality in the City of Mostar in the period 2000-2007

SO_2 **(measured from 2000 to 2007)**	**PM_{10}** **(measured from 2000 to 2005)**	**NO_X** **(measured in 2000 and in 2001)**
› Not recorded during the spring-summer and summer-autumn transitions. › In the summer period, SO_2 maximum values are approximately constant in the range of 38-68 µg/m³. › During the winter, SO_2 maximum values fluctuate between 54 and 146 µg/m³. › It can be concluded that SO_2 concentrations does not exceed the annual limit values during the year.	› The recorded PM_{10} particles values hit the extreme maximum during the first three months in 2004 (209-414 µg/m³). › In the remaining measurement periods, the maximum values are also recorded during the winter months of January and February (18-148 µg/m³). › If observed on the annual level, it can be concluded that annual average concentrations of PM_{10} are not exceeded however the peaks during the winter months are observed.	› Nitrogen-oxides (NO_X) had only been measured twice, in 2000 and 2001. › During the summer, recorded maximum NO_2 values are constant and are within the range of 28-46 µg/m³. › During the winter, values fluctuate from 32-62 µg/m³. › It can be concluded that NO_X concentrations does not exceed the limit values during the year.

In order to define the air quality baseline for this ESIA, one-time measurement of air quality was performed in the framework of this assignment. The monitoring was carried out along the main motorway route, along South Connection to the Main Road M17 (hereafter referred to as the Konjic Bypass), and along access roads to the Prenj Tunnel.

The 24-hour measurements of concentrations of air pollutants in the ambient air including carbon monoxide (CO), sulphur dioxide (SO_2), ozone (O_3), nitrogen oxides (NO, NO_2, NO_X) and particulate matters (PM_{10}) were carried out. Measurements were made by a mobile air quality monitoring station. The measurement methods used are presented in Table 10-2.

Table 10-2: Measurements methods

Pollutant	Test method
CO	BAS EN 14626 non-dispersive IR spectrometric method
SO_2	BAS EN 14212 ultraviolet fluorescence method
O_3	BAS EN 14625

[3] Federal Hydrometeorological Institute, Annual air quality report for FBiH, 2019

	Method ultraviolet photometry
NO/NO_2/NO_x	BAS EN 14211:2005 Chemiluminescence method
PM_{10}	BAS EN 12341:1998 Manual gravimetric – beta absorption equivalent

Main Motorway Route

Monitoring at five measuring points along the planned motorway route was performed during winter period in early March 2021 and during summer period in July 2021. The location of measurements is presented in Table 10-3 and Figure 10-1 to Figure 10-5.

Table 10-3: Description of measurement points near planned motorway route

Ordinal number	Description	Location
MP 1 – Ovcari	Settlement Ovcari at the beginning of the route, to the left of the M17 before entering the town of Konjic	N: 43° 40' 9,75" E: 17° 58' 36,01"
MP 2 – Polje Bijela	Next to river Neretva, under the Viaduct No. 4 in Polje Bijela	N: 43° 38' 12,12" E: 17° 58' 46,15"
MP 3 – Bijela	Near the motorway alignment in Bijela settlement	N: 43° 35' 35,37" E: 17° 56' 29,97"
MP 4 – Podgorani	Houses closest to the alignment in Podgorani settlement	N: 43° 27' 47,24" E: 17° 53' 23,78"
MP 5 – R435a	Next to the road R435a towards Rujiste near the house closest to the alignment	N: 43° 26' 27,66" E: 17° 54' 34,63"

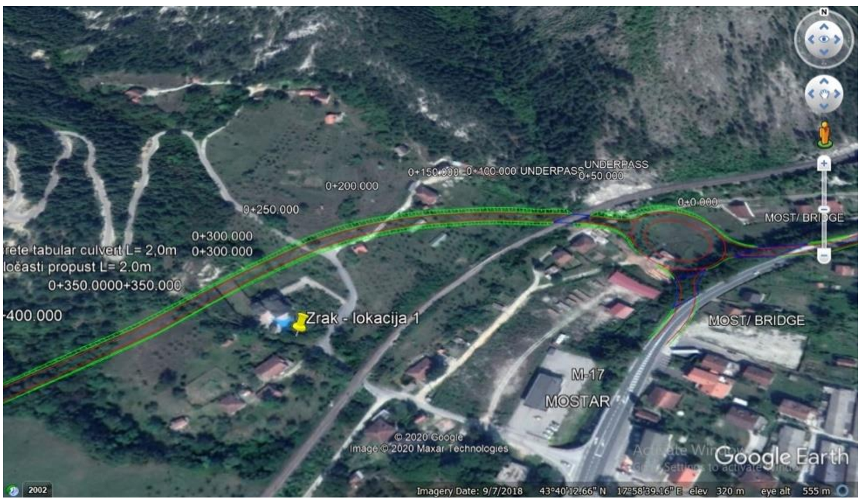

Figure 10-1: Air quality measuring point 1

Figure 10-2: Air quality measuring point 2

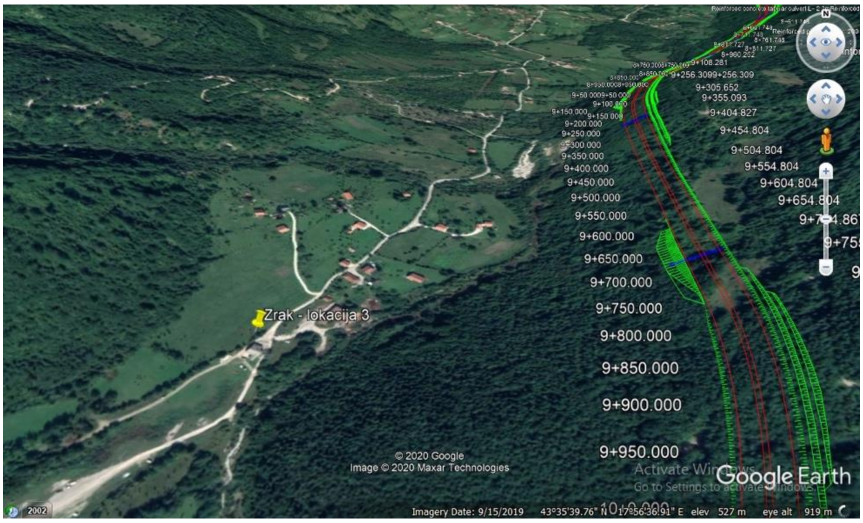

Figure 10-3: Air quality measuring point 3

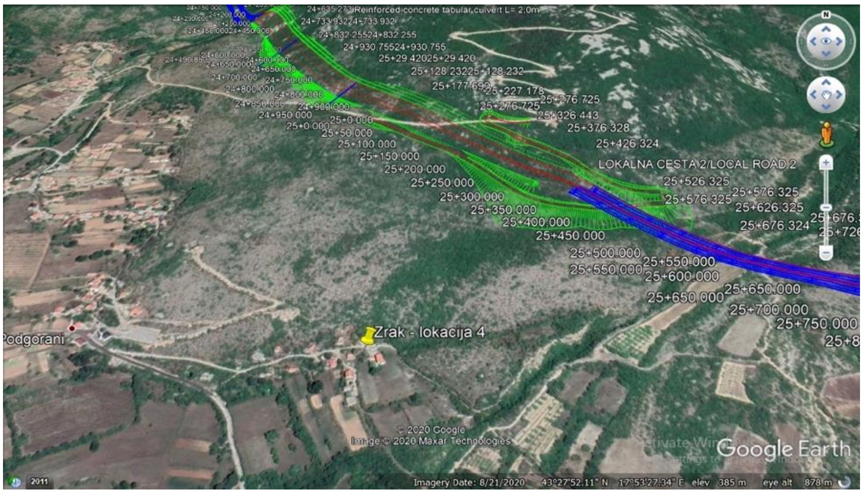

Figure 10-4: Air quality measuring point 4

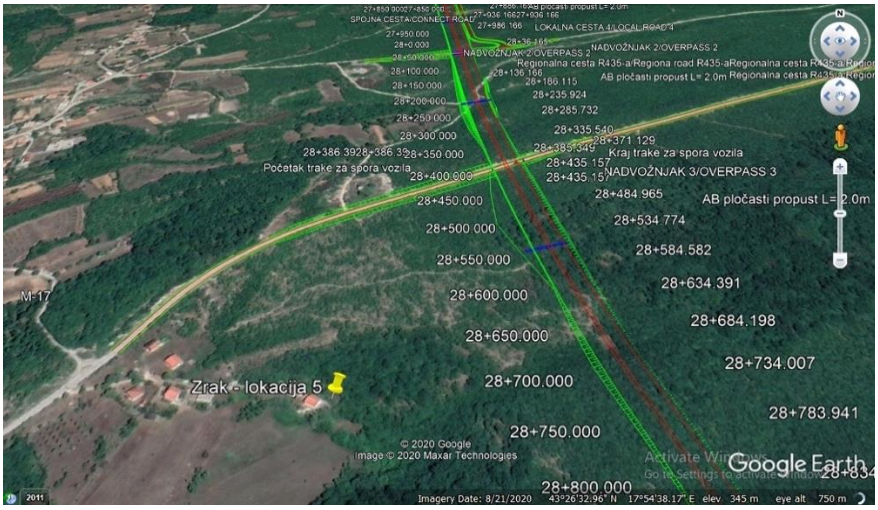

Figure 10-5: Air quality measuring point 5

Measurements of air quality during the winter period in March 2021 showed that **all measured parameters are within the limit values** stipulated by *Rulebook on the Manner of Monitoring Air Quality and Defining the Types of Pollutants, Limit Values and Other Air Quality Standards*[4]. Measurement of air quality at the project location indicates a normal condition and the presence of pollutants is withing legally defined limit values. The results are presented in Table 10-4 to Table 10-9.

Table 10-4: Meteorological parameters during the winter period in March 2021

Measuring point	Date	Temperature (°C)	Humidity (%)	Pressure (hPa)	Wind speed (m/s)
MP 1	15.03.2021. – 16.03.2021.	1-12	37.3-84.3	949.5-992.4	0.42-4.29
MP 2	16.03.2021. – 17.03.2021.	1-13.6	39.7-95.8	948.1-996.2	0.28-4.97
MP 3	17.03.2021. – 18.03.2021.	4-14.2	33.2-97.3	939.1-998.1	0.22-6-01
MP 4	18.03.2021. – 19.03.2021.	2-16.3	41.0-98.9	939.5-998.8	0.31-6.85
MP 5	18.03.2021. – 19.03.2021.	3-17.1	42.0-95.2	941.5-993.4	0.12-5.21

[4] Official Gazette of FBiH, no. 1/12, 50/19, 3/21

Table 10-5: Results of air quality monitoring during the winter period at MP 1

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	12.56	0
NO_2	24h	85	0.94	0
CO	24h	5	0.87	0
O_3	24h	-	23.50	-
PM_{10}	24h	50	18.30	0
$PM_{2.5}$	24h	17	4.21	0
Total PM	24h	-	20.04	-

Table 10-6: Results of air quality monitoring during the winter period at MP 2

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	13.67	0
NO_2	24h	85	1.03	0
CO	24h	5	0.98	0
O_3	24h	-	18.65	-
PM_{10}	24h	50	14.71	0
$PM_{2.5}$	24h	17	3.15	0
Total PM	24h	-	21.86	-

Table 10-7: Results of air quality monitoring during the winter period at MP 3

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	9.82	0
NO_2	24h	85	0.61	0
CO	24h	5	0.59	0
O_3	24h	-	27.63	-
PM_{10}	24h	50	11.02	0
$PM_{2.5}$	24h	17	2.12	0
Total PM	24h	-	14.33	-

Table 10-8: Results of air quality monitoring during the winter period at MP 4

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	9.20	0
NO_2	24h	85	0.72	0
CO	24h	5	0.85	0
O_3	24h	-	22.06	-
PM_{10}	24h	50	11.49	0

$PM_{2.5}$	24h	17	1.98	0
Total PM	24h	-	14.75	-

Table 10-9: Results of air quality monitoring during the winter period at MP 5

Pollutant	Sampling period	Average limit value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	7.51	0
NO_2	24h	85	0.59	0
CO	24h	5	0.63	0
O_3	24h	-	21.52	-
PM_{10}	24h	50	11.12	0
$PM_{2.5}$	24h	17	1.09	0
Total PM	24h	-	12.48	-

Measurements of air quality during the summer period in July 2021 showed that **all measured parameters are within the limit values** stipulated by *Rulebook on the Manner of Monitoring Air Quality and Defining the Types of Pollutants, Limit Values and Other Air Quality Standards*[5]. Measurement of air quality at the project location indicates a normal condition and the presence of pollutants is withing legally defined limit values. The results are presented in Table 10-10 - Table 10-15.

Table 10-10: Meteorological parameters during the summer period in July 2021

Measuring point	Date	Temperature (°C)	Humidity (%)	Pressure (hPa)	Wind speed (m/s)
MP 1	05.07.2021. – 06.07.2021.	1-12	37.3-84.3	949.5-992.4	0.42-4.29
MP 2	06.07.2021. – 07.07.2021.	1-13.6	39.7-95.8	948.1-996.2	0.28-4.97
MP 3	07.07.2021. – 08.07.2021.	4-14.2	33.2-97.3	939.1-998.1	0.22-6-01
MP 4	08.07.2021. – 09.07.2021.	2-16.3	41.0-98.9	939.5-998.8	0.31-6.85
MP 5	09.07.2021. – 10.07.2021.	3-17.1	42.0-95.2	941.5-993.4	0.12-5.21

Table 10-11: Results of air quality monitoring during the summer period at MP 1

Pollutant	Sampling period	Average limit value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	13.96	0
NO_2	24h	85	0.97	0

[5] Official Gazette of FBiH, no. 1/12, 50/19, 3/21

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
CO	24h	5	0.84	0
O_3	24h	-	19.75	-
PM_{10}	24h	50	17.50	0
$PM_{2.5}$	24h	17	4.05	0
Total PM	24h	-	22.63	-

Table 10-12: Results of air quality monitoring during the summer period at MP 2

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	15.61	0
NO_2	24h	85	0.95	0
CO	24h	5	1.03	0
O_3	24h	-	17.04	-
PM_{10}	24h	50	16.93	0
$PM_{2.5}$	24h	17	1.94	0
Total PM	24h	-	19.25	-

Table 10-13: Results of air quality monitoring during the summer period at MP 3

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	6.16	0
NO_2	24h	85	0.45	0
CO	24h	5	0.51	0
O_3	24h	-	29.77	-
PM_{10}	24h	50	10.04	0
$PM_{2.5}$	24h	17	1.98	0
Total PM	24h	-	12.63	-

Table 10-14: Results of air quality monitoring during the summer period at MP 4

Pollutant	Sampling period	Average limit value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	11.44	0
NO_2	24h	85	0.58	0
CO	24h	5	0.61	0
O_3	24h	-	20.53	-
PM_{10}	24h	50	13.33	0
$PM_{2.5}$	24h	17	2.07	0
Total PM	24h	-	15.90	-

Table 10-15: Results of air quality monitoring during the summer period at MP 5

Pollutant	Sampling period	Average limit value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
SO_2	24h	125	9.88	0
NO_2	24h	85	0.61	0
CO	24h	5	0.73	0
O_3	24h	-	18.24	-
PM_{10}	24h	50	12.24	0
$PM_{2.5}$	24h	17	1.77	0
Total PM	24h	-	14.67	-

<u>South Connection to the Main Road M17</u>

Monitoring at two measuring points along the planned Konjic Bypass was performed in June 2022. The location of measurements is presented in Table 10-16 and figures below.

Table 10-16: Description of measurement points near planned Konjic Bypass

Ordinal number	Description	Location
MP 1 – Donje Selo	Settlement Donje Selo, at the end of Konjic Bypass	N: 43°39'43.02" E: 17°56'53.85"
MP 2 – Ovcari	Settlement Ovcari, at the beginning of Konjic Bypass	N: 43°40'13.53" E: 17°58'50.67"

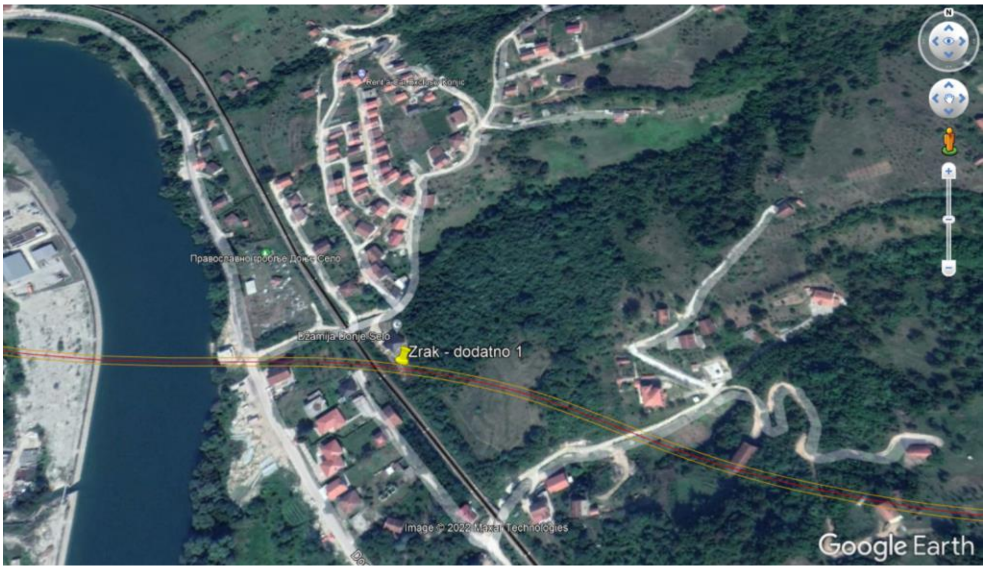

Figure 10-6: Settlement Donje Selo, at the end of Konjic Bypass

Figure 10-7: Settlement Ovcari, at the beginning of Konjic Bypass

Measurements of air quality in June 2022 showed that **all measured parameters are within the limit values** stipulated by Rulebook on the Manner of Monitoring Air Quality and Defining the Types of Pollutants, Limit Values and Other Air Quality Standards[6]. Measurement of air quality at the project location indicates that presence of pollutants is withing the limit values. The results are presented in

Table 10-18 and Table 10-19.

Table 10-17: Meteorological parameters

Measuring point	Date	Temperature (°C)	Humidity (%)	Pressure (hPa)	Wind speed (m/s)
MP 1	June 9th 2022	27.4	49.1	961.2	2.1
MP 2	June 9th 2022	25.4	52.1	964.2	3.1

Table 10-18: Results of air quality monitoring at MP 1

Pollutant	Sampling period	Marginal average value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
SO_2	June 9th 2022	350	11.00	0
NO_2	June 9th 2022	200	0.38	0
CO	June 9th 2022	10*	0.61	0
O_3	June 9th 2022	120*	10.00	0
PM_{10}	June 9th 2022	50*	14.58	0

[6] Official Gazette of FBiH, no. 1/12, 50/19, 3/21

$PM_{2.5}$	June 9th 2022	/	2.52	/
Total PM	June 9th 2022	250*	19.35	0

Table 10-19: Results of air quality monitoring at MP 2

Pollutant	Sampling period	Marginal average value (µg/m³)	Average measured value (µg/m³)	Number of pollutant tolerance values exceeded
SO_2	June 9th 2022	350	15.00	0
NO_2	June 9th 2022	200	0.92	0
CO	June 9th 2022	10*	0.85	0
O_3	June 9th 2022	120*	13.00	0
PM_{10}	June 9th 2022	50*	17.22	0
$PM_{2.5}$	June 9th 2022	/	2.63	/
Total PM	June 9th 2022	250*	12.87	0

Access roads to Prenj Tunnel

Monitoring at three measuring points along the planned access roads to Prenj Tunnel was performed during June 2022. The location of measurements is presented in Table 10-20 and figures below.

Table 10-20: Description of measurement points near planned access roads

Ordinal number	Description	Location
MP 1 – Donje Selo	Settlement Donje Selo	N: 43°37'23.69" E: 17°58'2.75"
MP 2 – HP Investing	Near HP Investing industrial site	N: 43°26'35.79" E: 17°51'42.82"
MP 3 – Prigradjani	Near houses in Prigradjani settlement	N: 43°27'37.65" E: 17°52'22.04"

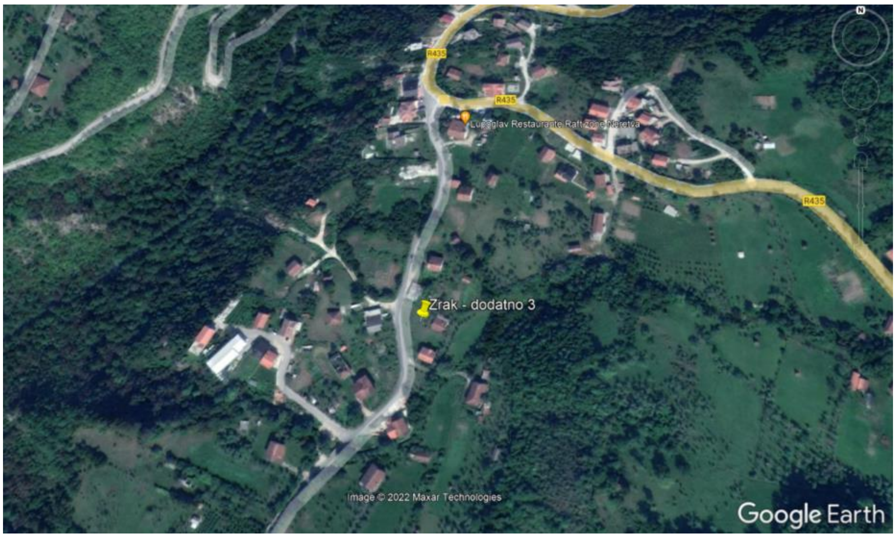

Figure 10-8: Settlement Donje Selo

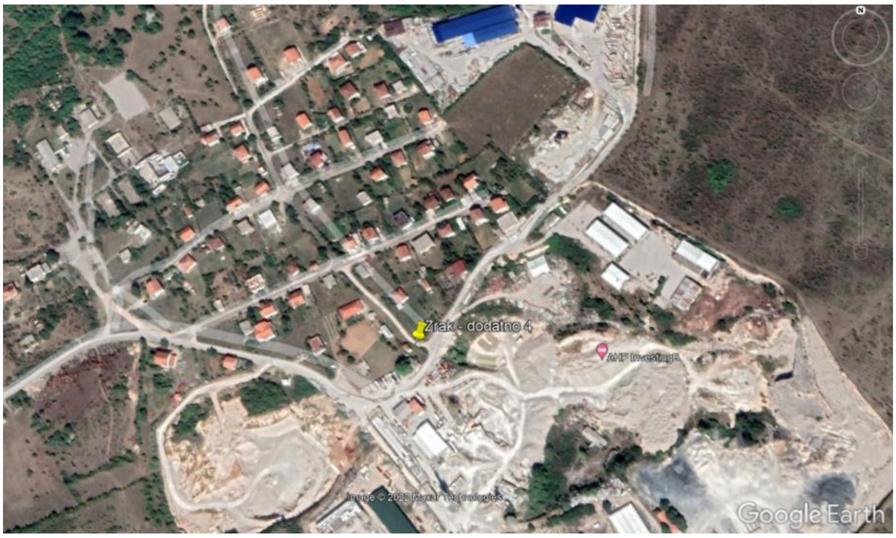

Figure 10-9: Near HP Investing industrial site

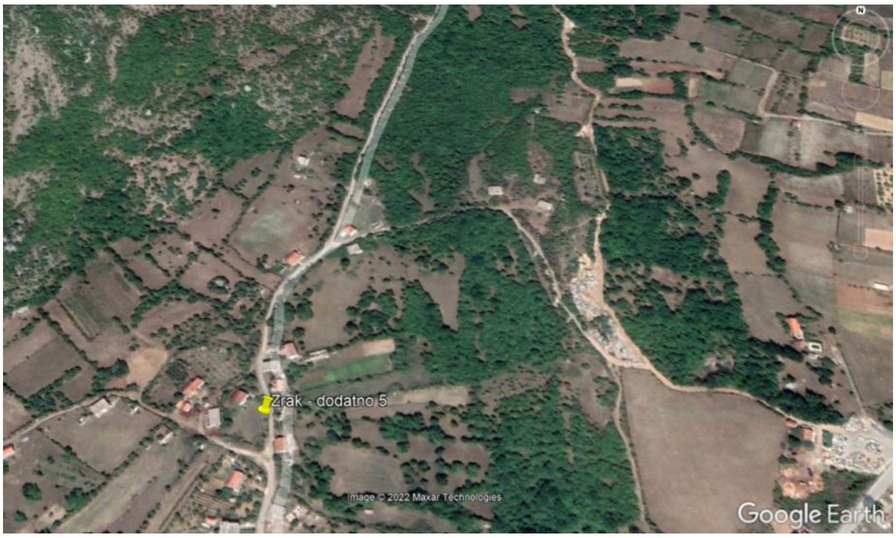

Figure 10-10: Near houses in Prigradjani settlement

Measurements of air quality during June 2022 showed that **all measured parameters are within the limit values** stipulated by Rulebook on the Manner of Monitoring Air Quality and Defining the Types of Pollutants, Limit Values and Other Air Quality Standards[7]. Measurement of air quality at the project location indicates a normal condition and the presence of pollutants is withing legally defined limit values. The results are presented in Table 10-21 - Table 10-23.

Table 10-21: Results of air quality monitoring at MP 1

Pollutant	Sampling period	Marginal average value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
SO_2	June 9th 2022	350	10.00	0
NO_2	June 9th 2022	200	0.34	0
CO	June 9th 2022	10*	0.48	0
O_3	June 9th 2022	120*	12.00	0
PM_{10}	June 9th 2022	50*	11.54	0
$PM_{2.5}$	June 9th 2022	/	2.52	/
Total PM	June 9th 2022	250*	18.85	0

Table 10-22: Results of air quality monitoring at MP 2

Pollutant	Sampling period	Marginal average value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
SO_2	June 9th 2022	350	19.00	0
NO_2	June 9th 2022	200	0.81	0
CO	June 9th 2022	10*	1.14	0
O_3	June 9th 2022	120*	16.00	0
PM_{10}	June 9th 2022	50*	25.04	0
$PM_{2.5}$	June 9th 2022	/	2.87	/
Total PM	June 9th 2022	250*	34.58	0

Table 10-23: Results of air quality monitoring at MP 3

Pollutant	Sampling period	Marginal average value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
SO_2	June 9th 2022	350	19.24	0
NO_2	June 9th 2022	200	0.98	0
CO	June 9th 2022	10*	0.66	0

[7] Official Gazette of FBiH, no. 1/12, 50/19, 3/21

Pollutant	Sampling period	Marginal average value (μg/m³)	Average measured value (μg/m³)	Number of pollutant tolerance values exceeded
O_3	June 9th 2022	120*	19.00	0
PM_{10}	June 9th 2022	50*	19.24	0
$PM_{2.5}$	June 9th 2022	/	2.48	/
Total PM	June 9th 2022	250*	24.01	0

10.3 Air Quality Modelling

10.3.1 Pollution sources and emissions on construction sites

The corridor impact on the air quality is taking place during the construction phase and operational phase. The construction phase is more intensive in terms of pollutant emissions compared to the operational phase where the main source of air pollution are emissions from vehicle traffic on the corridor.

The construction phase impact on air quality is due to:

- work of construction machinery,
- blasting of rock mass,
- laying asphalt and concrete.

The construction machinery generates dust and exhaust gases from propulsion engines during the work on the corridor. Mineral dust particles are emitted by trucks movement on temporal, unpaved roads, as well as by the excavation and loading of soil resulting in significant increase of concentrations of PM_1, $PM_{2.5}$ and PM_{10}. The internal combustion engines of the heavy machinery such as excavators and trucks additionally contribute to the deterioration of the local air quality. The large portion of coarse particles produced during earthworks are due to fugitive dust releases. However, fine particles originate mainly from combustion of fossil fuels (Ketchman and Bilec, 2013). In addition to enhanced concentrations of gases such as CO_2, CO and NO_X, typically coming from the exhaust of diesel engines (Chirico et al., 2011), Faber et al. (2015) observed significant increases in BC, p-PAH and organics (OA) in PM_1 compared to background levels. All these emissions are directly linked to combustion exhaust. The intensity of dust emissions from transport depends on the condition of the roads, the speed of transport, the humidity of the road, i.e. the season and the wind.

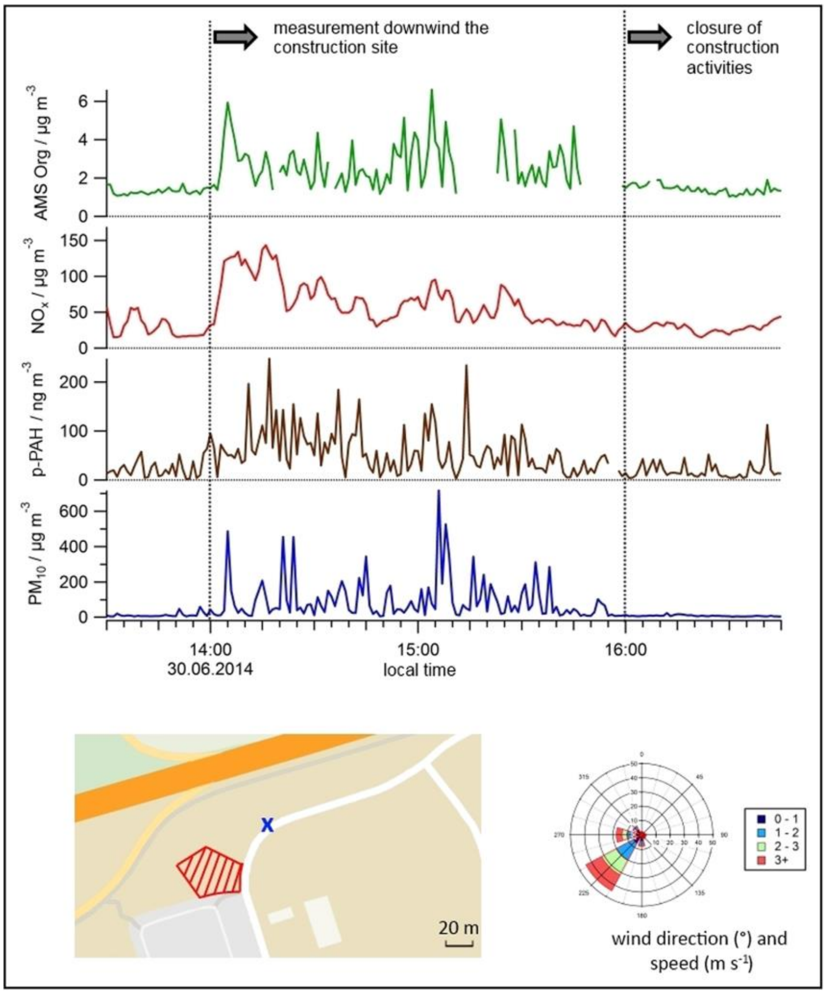

Figure 11: Mass concentrations of PM_{10}, particle-bound PAH, NOx and AMS organics in ambient air measured downwind the construction site in Germany during earthworks and after terminating all construction activities. Measurement location is marked by blue mark and the construction area is red area. Source: Faber et al., 2015.

Muleski et al. (2005) have reported that the earthworks potentially contribute to 70% to 90% of the total PM10 emissions by any single construction site. Table 24 lists the mean concentration increase of various pollutants measured on construction site from different construction activities, reported by Faber et al. The research of Faber et al. (2015) confirmed that different road work activities lead to a significantly increase of PM_1, $PM_{2.5}$ and PM_{10} concentrations compared to background levels. They reported that the highest PM_{10} emissions were measured with a mean concentration of 278µg/m^3 (60-383 µg/m^3) during the use of a plate compactor (see Table 24), while tailpipe emissions from machinery impacted the local air quality in terms of other pollutants.

The trace gases and organic particles, almost entirely emitted from internal combustion engines of heavy machinery as well as from asphalt paving, are the most harmful pollutants produced on the construction site. The submicron particles have a long atmospheric residence time and high penetration efficiency into lung tissue, thus are of particular interest when assessing the effects of air pollutants on human health. This emphasizes the importance of the implementation of mitigation strategies aiming the reduction of emissions from construction activities. These strategies critically depend on the proper understanding of the emissions and dispersions of the pollutants in space and time. It is reported by Faber et al. (2015) that mitigation strategy can reduce emissions of PM_1 by 92 ± 30%, $PM_{2.5}$ by 94 ± 25% and PM_{10} by 95 ± 34%.

Table 24: Mean concentration increases (in parentheses: lower quartile; upper quartile) of various particulate and gaseous pollutants by earthworks, road works, and asphalt paving compared to background levels (Source: Faber et al., 2015).

	PM_1 ($g\ l^{-1}$)	$PM_{2.5}$ ($g\ l^{-1}$)	PM_{10} ($g\ l^{-1}$)	p-PAH ($mg\ l^{-1}$)	BC ($g\ l^{-1}$)	NO_x ($g\ l^{-1}$)
Earthworks						
26.06	0.62 (0.4; 2.9)	3.5 (1.3; 36)	32 (8.7; 272)	8.3 (1.2; 28)	0.3 (0.2; 0.7)	5.8 (1.8; 22)
27.06.	1.9 (0.9; 4.3)	6.0 (1.3; 25)	42 (1.0; 189)	6 (3.3; 9.2)	0.7 (0.4; 1.1)	17 (12; 26)
30.06.	0.2 (0.1; 0.5)	1.6 (0.8; 5.1)	17 (7; 49)	12 (5.3; 22)	0.5 (0.3; 1.1)	10 (5.2; 19)
Road works						
Road roller	0.5 (0.4; 1.6)	0.5 (0.4; 1.6)	0.6 (0.6; 1.7)	38 (4.0; 65)	1.4 (1.1; 2.4)	3.3 (2.0; 7.5)
Road roller/sweeper	2.6 (1.2; 5.0)	2.6 (1.5; 5.5)	8.1 (3.3; 10)	19 (11; 38)	0.8 (0.6; 1.3)	4.5 (2.6; 7.4)
Asphalt sawing	0.7 (0.2; 1.1)	0.8 (0.4; 1.7)	3.7 (1.4; 7.1)	12 (3.7; 24)	1.1 (0.6; 3.0)	1.2 (<LOD; 4.0)
Asphalt smashing	0.3 (<LOD; 0.4)	0.3 (<LOD; 0.4)	0.5 (<LOD; 2.7)	22 (8.5; 39)	0.6 (0.3; 1.4)	5.7 (<LOD; 13)
Plate compactor	2.5 (1.2; 5.4)	8.4 (2.1; 14)	55 (17; 132)	50 (20; 80)	1.7 (1.2; 2.6)	2.8 (0.2; 7.9)
Asphalt paving						
Asphalting	2.9 (1.4; 4.3)	3.1 (1.4; 4.4)	4.0 (2.4; 6.6)	12 (7.8; 15)	0.6 (0.3; 0.7)	11 (6.7; 13)

10.3.2 Methodology

The dispersion of air pollutants emitted from the subsection Corridor Vc Konjic (Ovcari) - Prenj Tunnel - Mostar North is modelled by using Computational Fluid Dynamics (CFD) method. Computer simulations based on CFD methods differ significantly from the currently prevalent methods for computational estimation of pollution levels based on the Gaussian distribution of pollutants from various sources (so-called dispersion models). Dispersion models use a very simplified air flow field (without solving Navier-Stokes's equations) over an imposed predefined external wind field or self-generated thermal and orographic conditions. The main limitation of the dispersion models is the requirement for wind speed as input which limits the use of these software only for situations where there is a wind. But even then, dispersion software cannot reproduce flow phenomena such as separation and recirculation of air flow which has a significant effect on pollutant dispersion. CFD technique has been employed for computing air flow and pollutant dispersion in three-dimensional space. Full set of Navier-Stokes equations that define fluid motion in three-dimensional space and transport equation for pollutant and turbulence properties are numerically solved, resulting in velocity, pressure, temperature, concentration of pollutant fields in three-dimensional space. Computations are of a field type, meaning that air velocity, temperature and pollutant concentration value are computed simultaneously and interactively in time-dependent three-dimensional space on a computational mesh that provides desired time and space resolution to predict time evolution of wind and pollutant concentration over the entire solution domain.

10.3.2.1 Physical model

Turbulence is modelled by Reynolds-Average Navier-Stokes (RANS) approach, namely by *k-ε-ζ-f* model[8] that is successfully tested against a number of benchmark cases. The simulation results provide concentration of pollutant at any time instant and at any point within the solution domain. Any type of averaged information (time, field or space averaging) is possible to extract from the results, thus making it possible to evaluate integral and average data such as local or average ground concentration.

The ground boundary conditions for all variables are defined in the ground-nearest grid cell (well outside the viscous sub-layer) using the semi-empirical wall functions derived by pre-integration of the equations over the ground-adjacent grid cells. More details of the model and boundary conditions are given in the literature[9].

The influence of the surface characteristics is accounted through the roughness model that is commonly used to predict an impact of natural and human-made obstacles on the ground such as buildings, trees, etc. on the flow field. Different terrain zones are defined (low-height private houses, forest, grass fields and parks, river and roads) for which different values of roughness coefficient and heat flux are assigned.

An air pollutant is treated as a passive scalar, meaning that the pollutant particles do not affect the dynamical flow field and no chemical reaction takes place during the simulation. Some of the main pollutants such as NO_x, SO_2, $PM_{2.5}$, PM_5 and PM_{10} are well approximated by this approach.

10.3.2.2 Terrain model

The terrain is modelled by using Geographical Information System (GIS) software where all terrain characteristics are genuinely represented. Since the computation of the whole corridor is not possible in a single run due to the size of the domain, the corridor is divided into six sub-domains which were modelled and computed separately. A typical size of the solution domain is about 4 km x 3 km in the horizontal and 1 km in the vertical direction. The computational mesh resolution in the horizontal plain is between 5-50 meters.

10.3.2.2.1 Sub-domain A

The sub-domain A covers the region of 3.7km x 2.9km. The length of the corridor included in the sub-domain is around 2500 meters, with the additional Konjic Bypass in length of 4400 m, and the connection between the Ovcari roundabout and corridor in length of approximately 1000 m. The orientation is

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[8] Hanjalić, K., Popovac, M., Hadžiabdić, M. (2004). A robust near-wall elliptic-relaxation eddy-viscosity turbulence model for CFD. International Journal of Heat and Fluid Flow. 25. 1047-1051. 10.1016/j.ijheatfluidflow.2004.07.005.
[9] Hanjalić, K., & Hrebtov, M. (2016). Ground boundary conditions for thermal convection over horizontal surfaces at high rayleigh numbers. Boundary-layer meteorology, 160(1), 41-61.

NE–SW. For the most of its part the corridor is parallel to the prevailing wind direction, except the last part of 600 meters which is gently turning towards the South. The corridor starts in the Ovcari settlement at the exit of tunnel Ivan, includes an interchange with the Ovcari roundabout, three viaducts, toll plaza, and ends at the entrance to the tunnel T-1 that enters Zlatar hill.

The sub-domain includes different terrain types, forests, meadows and two residential areas (Ovcari settlement and the City of Konjic). There is a small portion of agriculture land, mainly in the Ovcari settlement. The terrain is predominantly hilly, with flat areas in the Ovcari settlement and in the City of Konjic. The solution domain encompasses a large portion of the urban segment of the City of Konjic. The domain includes Neretva River flowing in the direction perpendicular to the prevailing wind direction. The lowest and highest elevation points are at 257 m and 713 m, respectively.

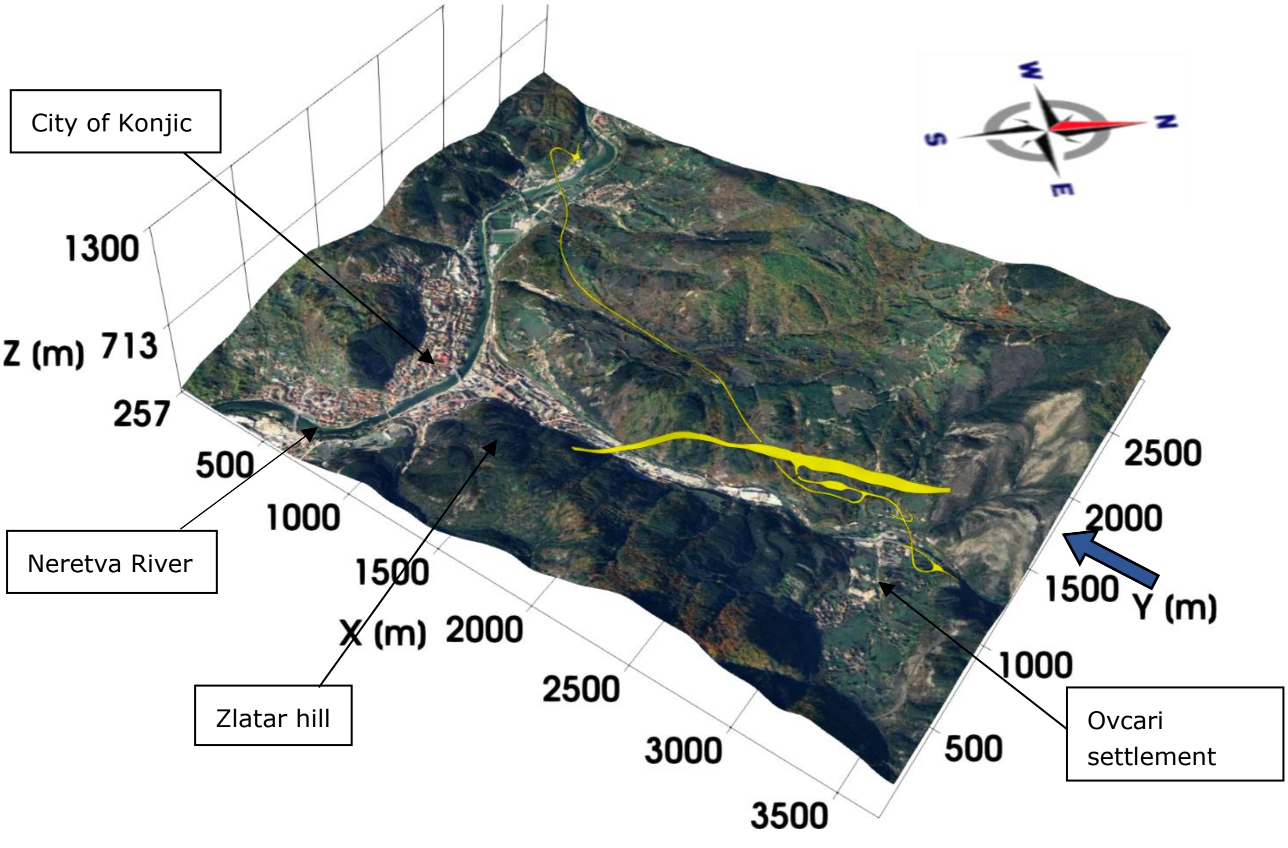

Figure 10-12: Terrain of sub-domain A with main landmarks (source Google Maps).

10.3.2.2.2 Sub-domain B

The sub-domain B covers the region of 4.0 km x 2.6 km. The length of the corridor included in the sub-domain is around 3000 meters. The corridor includes a rest area near the end of the segment. The orientation is NE–SW. The corridor is parallel to the prevailing wind direction along its entire length. The corridor starts with the exit from the tunnel T-2 through Zlatar hill, includes a viaduct V-4 over Neretva River, a viaduct V-5 in Mladeškovići settlement, interchange in the settlement Polje Bijela with connections to local road, a resting area, toll plaza, and ends at point 6+960 km.

Sub-domain B includes different terrain types, forests, meadows and several residential areas. The residential areas include the settlement of Polje Bijela, and several settlements (Prevlje, Mladeškovići, Jošanica). Polje Bijela, with a large number of residential buildings, is located close to the corridor. There is a significant amount of agriculture land, near the second half of the corridor (area of Mladeškovići settlements). The flat areas of Polje Bijela settlement are bounded by hills from eastern and western sides. Therefore, the flat and hilly parts are equally present in the solution domain. The domain includes Neretva River flowing in the direction perpendicular to the prevailing wind direction. The lowest and highest elevation points are at 273 m and 887 meters, respectively.

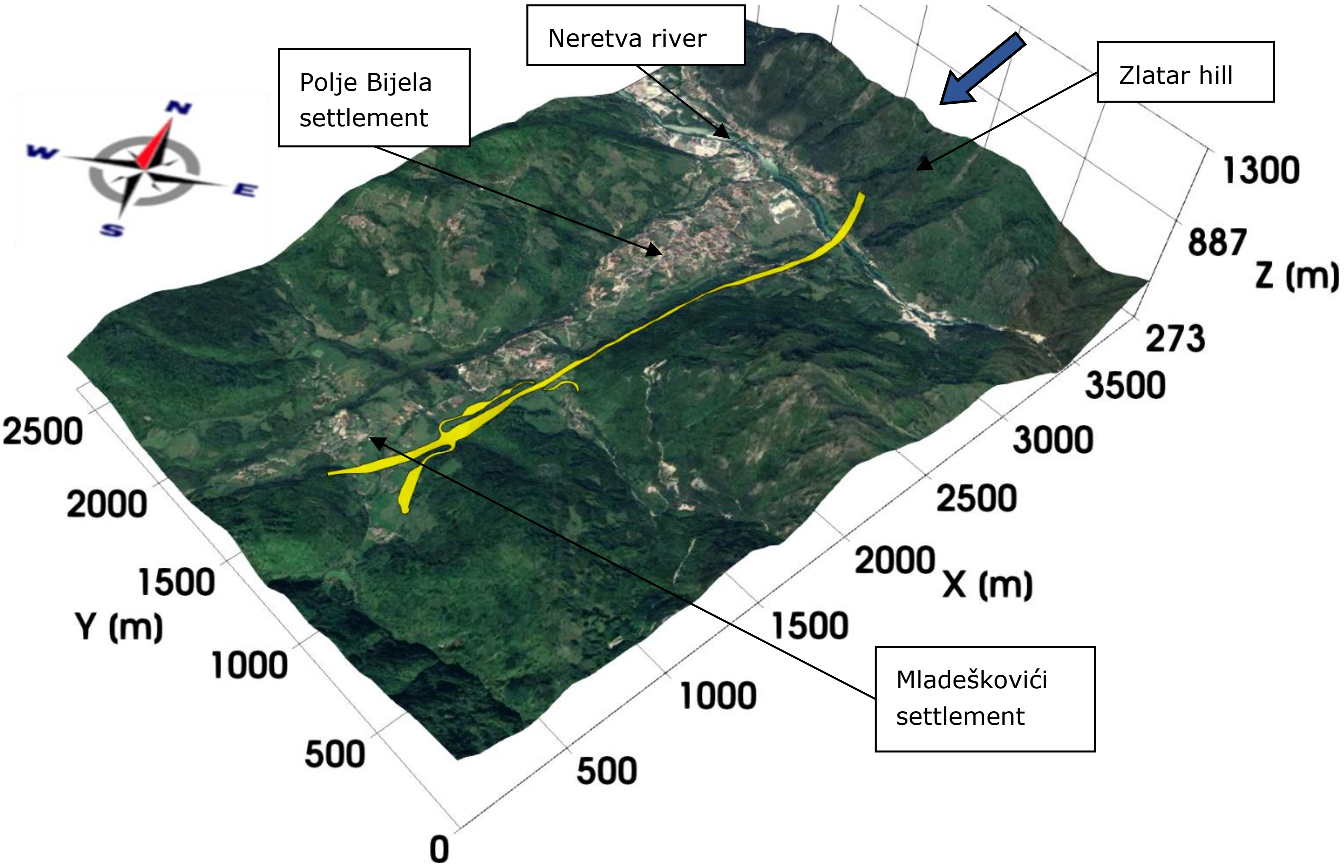

Figure 10-13: Terrain of sub-domain B with main landmarks (source Google Maps)

10.3.2.2.3 Sub-domain C

The sub-domain C covers the region of 6.4 km x 2.8 km. The length of the corridor included in this sub-domain is around 4800 meters. The orientation of the sub-domain is NE – SW. The corridor is nearly parallel to the prevailing wind direction along its entire length. It starts with the point 6+960 km in the Mladeškovići settlement and ends at the entrance of tunnel Prenj.

The area of Sub-domain C is covered mostly by forests and some meadows. The residential areas include the Bijela settlement and a part of the Mladeškovići settlement, with a small number of houses in total. There are no significant parts of agriculture land. The corridor and the settlements are located in the valley between two very steep slopes of mountain Prenj from both sides, making this domain the one with the most extreme elevation difference of all six. The lowest and highest elevation points are at 352 m and 1728 meters, respectively.

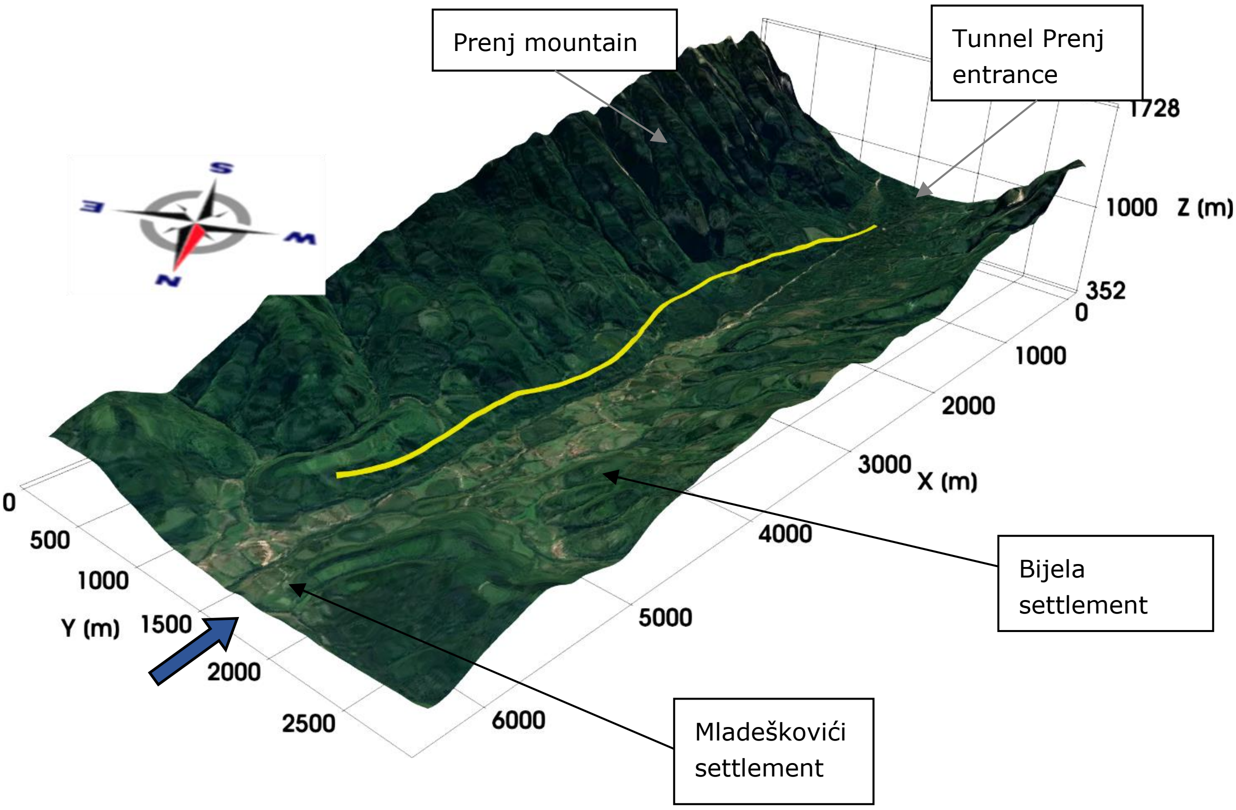

Figure 10-14: Terrain of sub-domain C with main landmarks (source Google Maps)

10.3.2.2.4 Sub-domain D

The sub-domain D covers the region of 4.3 km x 4.6 km. The length of the corridor included in this sub-domain is around 4300 meters. The orientation of the sub-domain is NNE–SSW. For the most of its part the corridor is perpendicular to the prevailing wind direction. The corridor begins with the exit from tunnel T-4, includes two viaducts, a bridge, and ends at the location of road overpass Humilišani.

More than half of the area of the sub-domain D is agriculture land, a third is covered by forests and meadows, while the rest are the residential areas. The residential areas include the settlement of Humilišani, and the Podgorani settlement, which together add up to a significant number of residential objects, mostly located in the vicinity of corridor. The terrain is mostly flat, except for Prenj foothill region north of the corridor, covered by forest. The lowest and highest elevation points are at 146 m and 1185 meters, respectively.

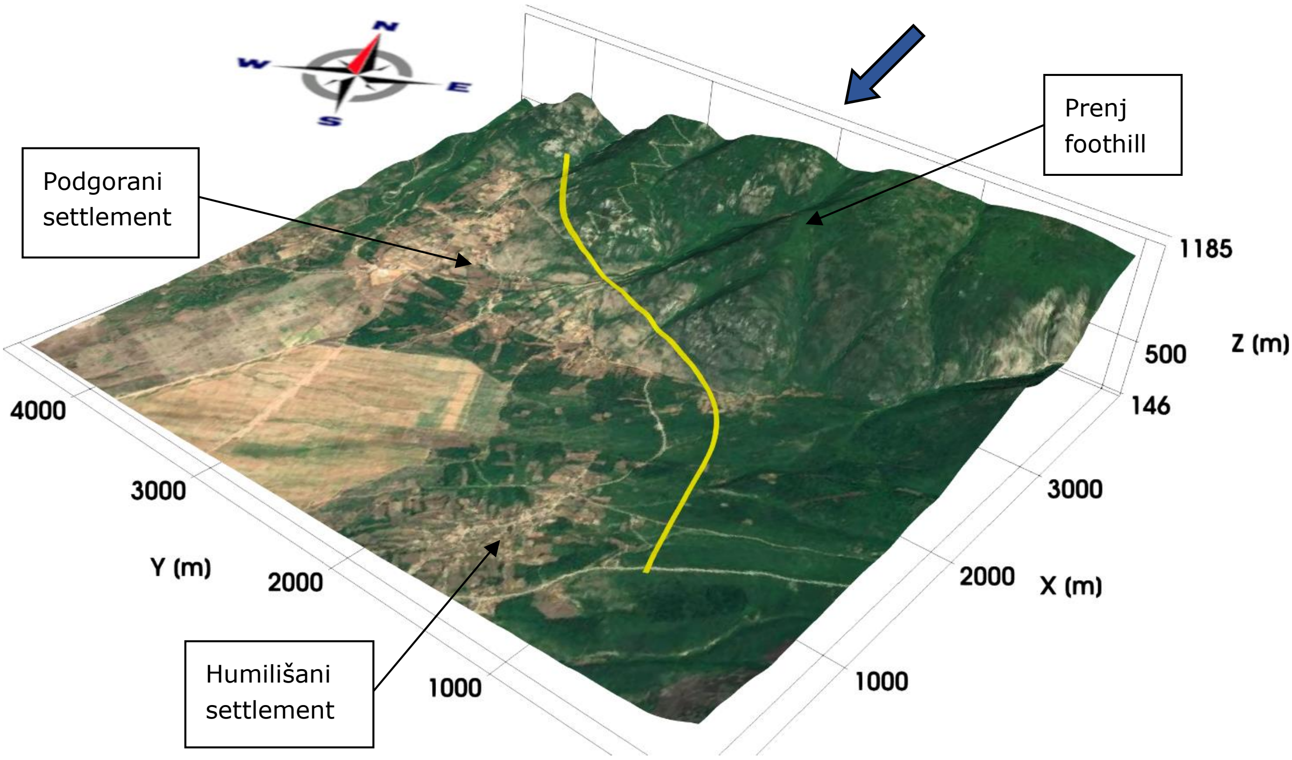

Figure 10-15: Terrain of sub-domain D with main landmarks (source Google Maps)

10.3.2.2.5 Sub-domain E

The sub-domain E covers the region of 4.3 km x 2.7 km. The length of the corridor included in this sub-domain is around 3300 meters. The orientation of the sub-domain is NNE–SSW. The corridor is mostly parallel to the prevailing wind direction. The corridor starts at the location of road overpass Humilišani and ends at the entrance to the tunnel T-5 that passes through the Sljeme hill, which is the last tunnel in this sub-section of the corridor Vc.

Two-thirds of the area of the sub-domain E is covered by forests and meadows, while the rest is covered by agriculture land and a significant number of residential buildings that belong to the settlement of Potoci and the Humilišani settlement. The terrain is mostly flat, with some low-altitude hills eastern of the corridor. The lowest and highest elevation points are at 108 m and 744 meters, respectively.

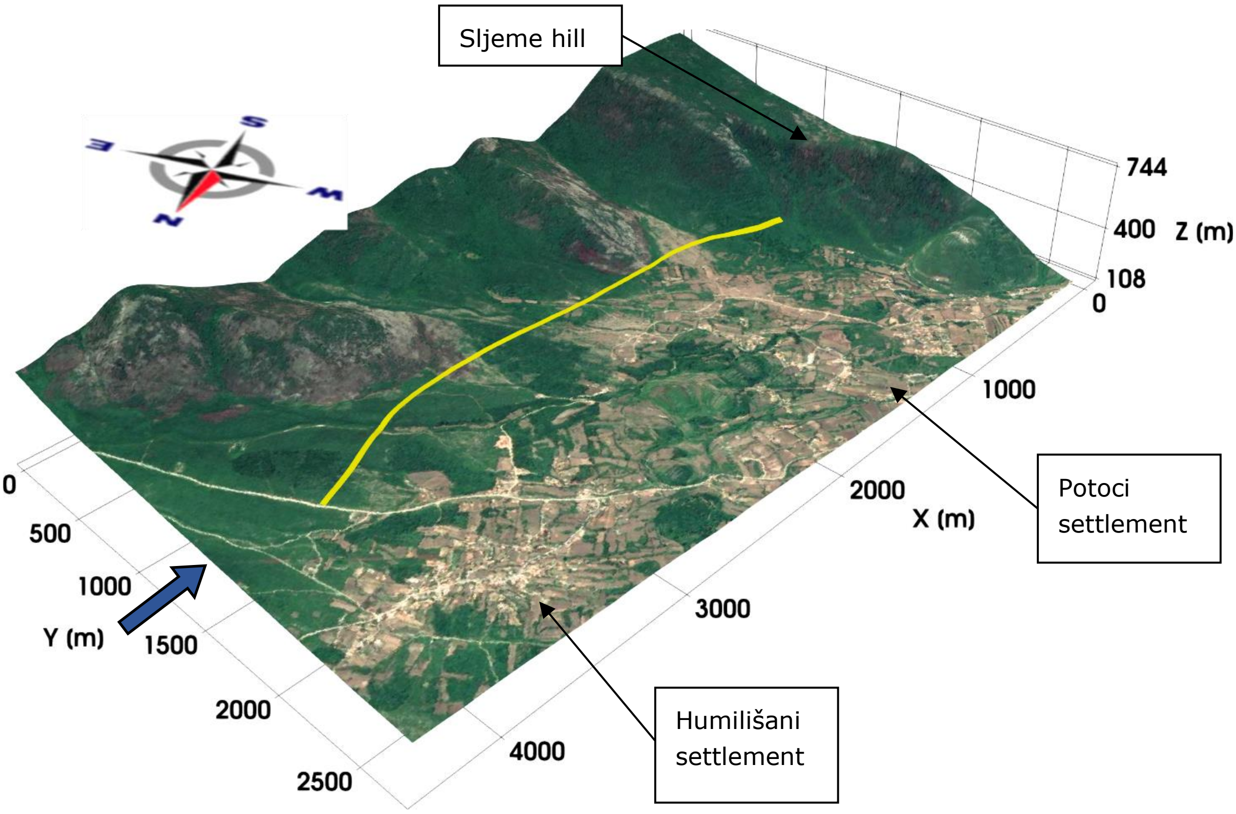

Figure 10-16: Terrain of sub-domain E with main landmarks (source Google Maps)

10.3.2.2.6 Sub-domain F

The sub-domain F covers the region of 1.5 km x 1.3 km. The length of the road included in this sub-domain is around 350 meters. The orientation of the sub-domain is NNE–SSW. The corridor is parallel to the prevailing wind direction. The corridor extends from the exit of the tunnel T-5 through Sljeme hill, and ends in the Kutilivac settlement.

The sub-domain F is characterized by agriculture land and residential areas, while the smaller part is covered by forests. The terrain is prevailingly flat. The lowest and highest elevation points are at 123 m and 430 meters, respectively.

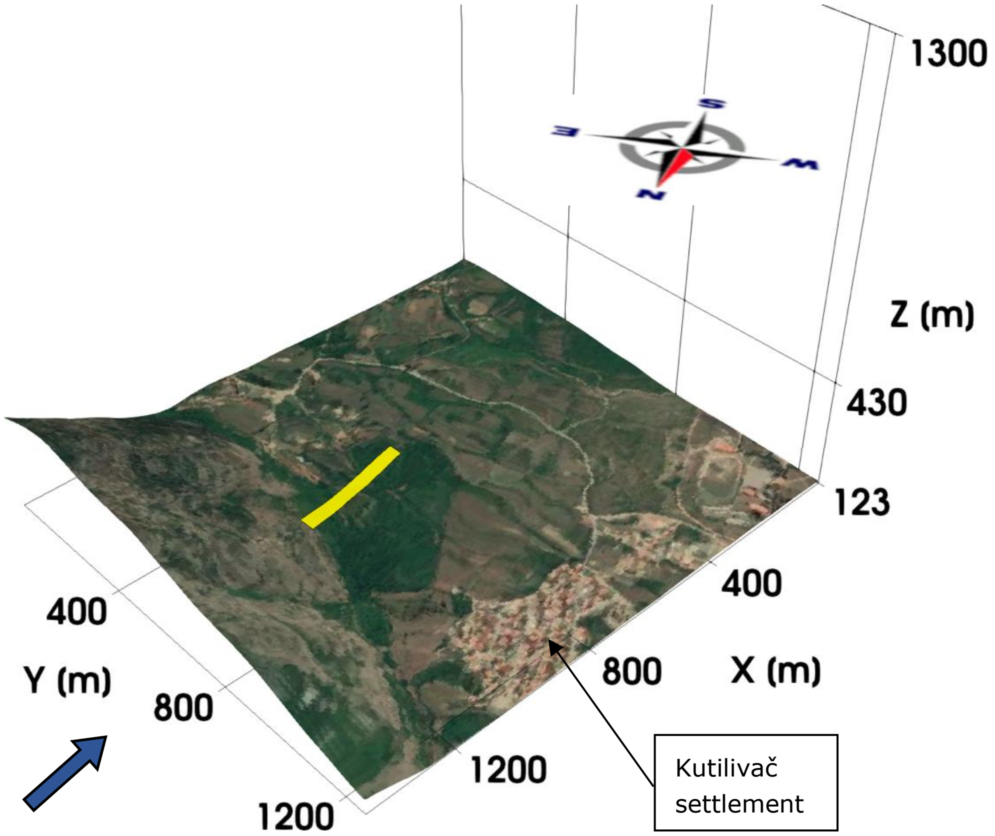

Figure 10-17: Terrain of sub-domain F with main landmarks (source Google Maps)

10.3.2.3 Computational details

The computations were performed using the in-house finite-volume unstructured T-Flows CFD code (TU Delft)[10] [11] that is extensively validated and verified for several benchmark cases relevant for the present configurations. A typical computational mesh is 4km × 3km × 1km meshed with about 4×10^6 grid cells. The grid was clustered towards the ground so that the cell size in the vertical direction changed from around 7 m at the ground to 30 m at the upper boundary of the domain. In the horizontal plane the grid size varied from 2-3m at the corridor to 50 m at the periphery of the computational domain. Symmetry conditions were applied for the side, and the pressure boundary is imposed at the top boundaries. For the windless case, the reference potential temperature was specified with a lapse rate of 4K km^{-1} until it reached the targeted inversion base of 1 km height. To simulate the running river surface, the water surface of $4ms^{-1}$ is imposed, which corresponds roughly to observed value in the winter

[10] Ničeno, B. (2001). An unstructured parallel algorithm for large-eddy and conjugate heat transfer simulations, PhD thesis, Delft University of Technology, Delft, The Netherlands.
[11] Ničeno, B., Hanjalić, K.(2005). Unstructured large-eddy and conjugate heat transfer simulations of wall-bounded flows., n and conjugate heat transfer simulations, In: S. Sunden and M. Faghri (Eds) Modelling and simulation of turbulent heat transfer, WIT Press, USA, pp. 35-76.

period. Typical duration of a single run was around 8 hours for the wind case, and 48 hours for the windless case on 40 processors of modern Dell workstation.

10.3.2.4 Considered scenarios

Two scenarios were considered, a windless scenario that anticipates a meteorological condition in which air movement is due to buoyancy force generated by temperature difference between air and ground, and scenario where a wind is present. In the wind scenario the most frequent wind direction and intensity at the inflow boundary of the computational domain is imposed, assuming neutral stratification in the atmosphere (no influence of buoyancy force). The data from the local meteorological measuring stations is used for determining the wind direction and intensities. The wind scenario computes 1-2 hours of real time, after which a statistically steady flow is established and no changes in the velocity and concentration fields occur.

The windless scenario assumes that air motion is due to a buoyancy force generated by density difference occurring due to different temperature in air. The ground is heated by the Sun. Date of 16 of March with sunrise at around 6am and sunset around 6pm is considered. Based on the equation of the sun's position in the sky throughout the year, the maximum amount of solar insolation on a surface at a particular tilt angle can be calculated as a function of latitude and day of the year. The daily solar insolation and the number of hours the Sun is shining during 16 of March at location of the corridor is shown in Figure 10-18. The cloudy day is assumed with the heat flux from the ground changing in time according to Figure 10-18 but scaled to maximum value of $100W/m^2$. The computation started at 6.30am when ground started to be heated by the Sun. The activities on the corridor are assumed to start at 7.30am. The computations cover approximately 6 hours of real time.

The weak thermal stratification is assumed, capped by an inversion layer that grows as the temperature of the ground is increasing.

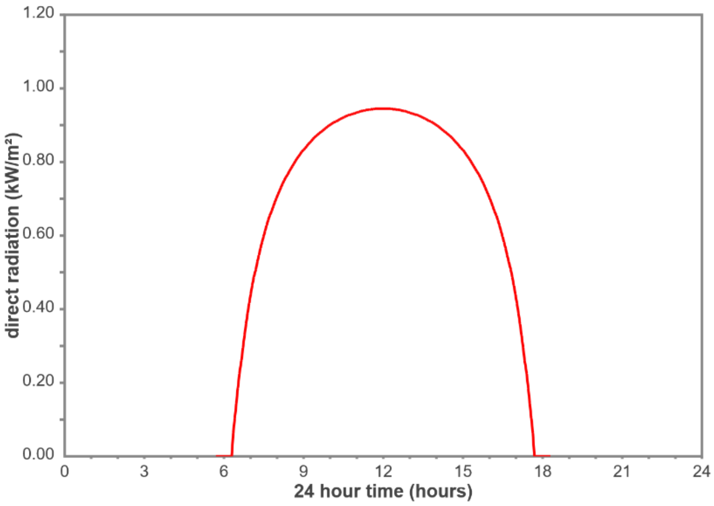

Figure 10-18: The graph shows the intensity of direct radiation in W/m² throughout the day on 16 March for region of Konjic. It is the amount of power that would be received by a tracking concentrator in the absence of cloud. The time is the local solar time.

10.3.3 Modelling Results

The analysis of the impact of the corridor-related emissions on the air quality is divided in the construction and operational phases. The estimation of the impact is based on the computer simulations.

The construction phase is characterized by the emission-intensive activities on the construction site that result in high concentration of pollutants. The most significant increase in concentration is reported for particular matter (PM) of different origin, out of which PM_{10} is expected to have the highest concentration level[12]. High PM emissions in the construction phase can lead to exceeding the European limit level of PM_{10}, as reported in the literature[13] [14], which means a daily mean concentration of 50µg/m^3 that should not be exceeded on more than 35 days per year. Other than PM, NO_x is another pollutant emitted in the construction phase, mainly coming from the combustion exhaust of the machinery used. However, NO_x concentration is not expected to exceed the EU limit of 200µg/m^3 in one hour average. This estimation is based on the fact that the corridor is not located in the urban environment where urban morphology such as street canyons lead to accumulation of the pollutants. As the corridor is not passing through densely populated cities, and since NO_x is coming from the heavy vehicles on the site, it is estimated that NO_x concentration will not have a significant increase due to the corridor-related activities. That is why, the decision is made to analyse dispersion of PM_{10} pollutant, both for the

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[12] Faber, P., Drewnick, F., & Borrmann, S. (2015). Aerosol particle and trace gas emissions from earthworks, road construction, and asphalt paving in Germany: Emission factors and influence on local air quality. Atmospheric Environment, 122, 662-671.
[13] Font, A., Baker, T., Mudway, I. S., Purdie, E., Dunster, C., & Fuller, G. W. (2014). Degradation in urban air quality from construction activity and increased traffic arising from a road widening scheme. Science of the Total Environment, 497, 123-132.
[14] Fuller, G. W., & Green, D. (2004). The impact of local fugitive PM_{10} from building works and road works on the assessment of the European Union Limit Value. Atmospheric Environment, 38(30), 4993-5002.

construction and operational phases, since it is expecting to have the most significant increase in concentration, and it poses a serious threat to health of the population in the corridor vicinity.

While the construction phase is time-limited, meaning that the peaks in pollutants' concentration do not necessarily mean serious threat to health of the people, the operational phase imposes a long-term impact on the air quality in the vicinity of the corridor. Fortunately, the operational phase is much less intensive in terms of emissions of pollutants than the construction phase, especially when it comes to PM emissions.

The dispersion of a generic pollutant that has a maximum concentration on the corridor (100%) is simulated. The result of the computer simulation is the dispersion of generic pollutant in space and time in terms of a percentage of pollutant produced on the corridor. In order to get a concentration of individual pollutants such as PM_{10} or NO_x in space and time, a reference value of that particular pollutant has been defined. The reference value is a value of the pollutant on the corridor in time of simulation. The two reference values of PM_{10} for the construction phase were adopted, 150μg/m^3 and 300μg/m^3, based on the in-situ measurements reported in literature. The reference value of 300μg/m^3 is expected to occur during a dry weather and emission-intensive type of construction work, while 150μg/m^3 is likely to occur when less intensive activities take place and/or favourable weather condition is present on the site. It was much more difficult to set the reference value for the operational phase due to uncertainty of traffic frequency and dependency of the emissions on weather conditions and vehicle types. Based on the measurements of the state Hydrometeorological Institute (HMI) for roads in cities in Bosnia, the reference value for PM_{10} is set to 40μg/m^3. This value is expected to occur when traffic frequency is high and dry weather is prevailing.

The dispersion of the pollutants for six sub-sections of the corridor was analysed, for both construction and operational phase and for the two anticipated scenarios (wind and windless). The dispersion of PM_{10} for two reference values for the construction phase, and a reference value for the operational phase were also analysed.

Figure 10-19 shows limiting values for PM_{10} and NO_2. The colours related to the ranges of the pollutants' concentrations are adopted in the figures that show simulation results.

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*...air quality conditions are:*	*...as symbolized by this color:*
0 - 50	Good	Green
51 - 100	Moderate	Yellow
101 - 150	Unhealthy for Sensitive Groups	Orange
151 - 200	Unhealthy	Red
201 - 300	Very Unhealthy	Purple
301 - 500	Hazardous	Maroon

Figure 10-19: Air quality index for PM_{10} and NO_2 (Image source: AirNow.gov)

10.3.3.1 Construction phase: Wind scenario

10.3.3.1.1 Sub-domain A

Dispersion of the pollutants emitted on the corridor is computed under assumption of wind intensity of 3m/s and direction NE-SW. The terrain of sub-domain A with main landmarks is shown in Figure 10-12. The results are obtained after a statistically steady state is reached. Figure 10-20(a) shows dispersion of the pollutants in the three-dimensional space expressed in relative values (percentage of the reference value of pollutant at the corridor) while Figure 10-20(b) shows the pollutant spreading at the surface due to wind transport. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150µg/m^3) and high-intensity construction activities (300µg/m^3). Figure 10-20(c), (d) show distribution of the pollutant concentration on the surface for two reference pollutant values. The high values of PM_{10} (concentration exceeding 50% of the reference value) occur in the narrow region along the corridor as the prevailing wind is aligned with the direction of the corridor. Relatively high concentration of PM_{10} is also occurring in the small region that is inhabited, see Figure 10-20 (d), which could lead to exceeding EU limits set for PM_{10}. The main residential areas have the concentration below 5% of the reference value and it is not expected to lead to exceeding EU limits set for PM_{10}.

Based on the simulation results the application of mitigation strategy is recommended, such as active wetting of soil on the corridor in sub-section A when the unfavourable weather conditions are present (presence of wind with approximately NE-SW direction, low humidity) and emission-intensive activities are taking place on the corridor. The section of the corridor where mitigation strategies are recommended is defined from km 1+100 (end of viaduct V-2) to km 1+800 (start of the right tunnel tube T-1), with a total length of 700 m, Ovcari Interchange connecting road from km 0+000 to km 0+400, and Konjic bypass road along the first 1 km, i.e. from km 0+000 (roundabout intersection at M17 road) to km 1+000 (400 meters after the end of the bridge).

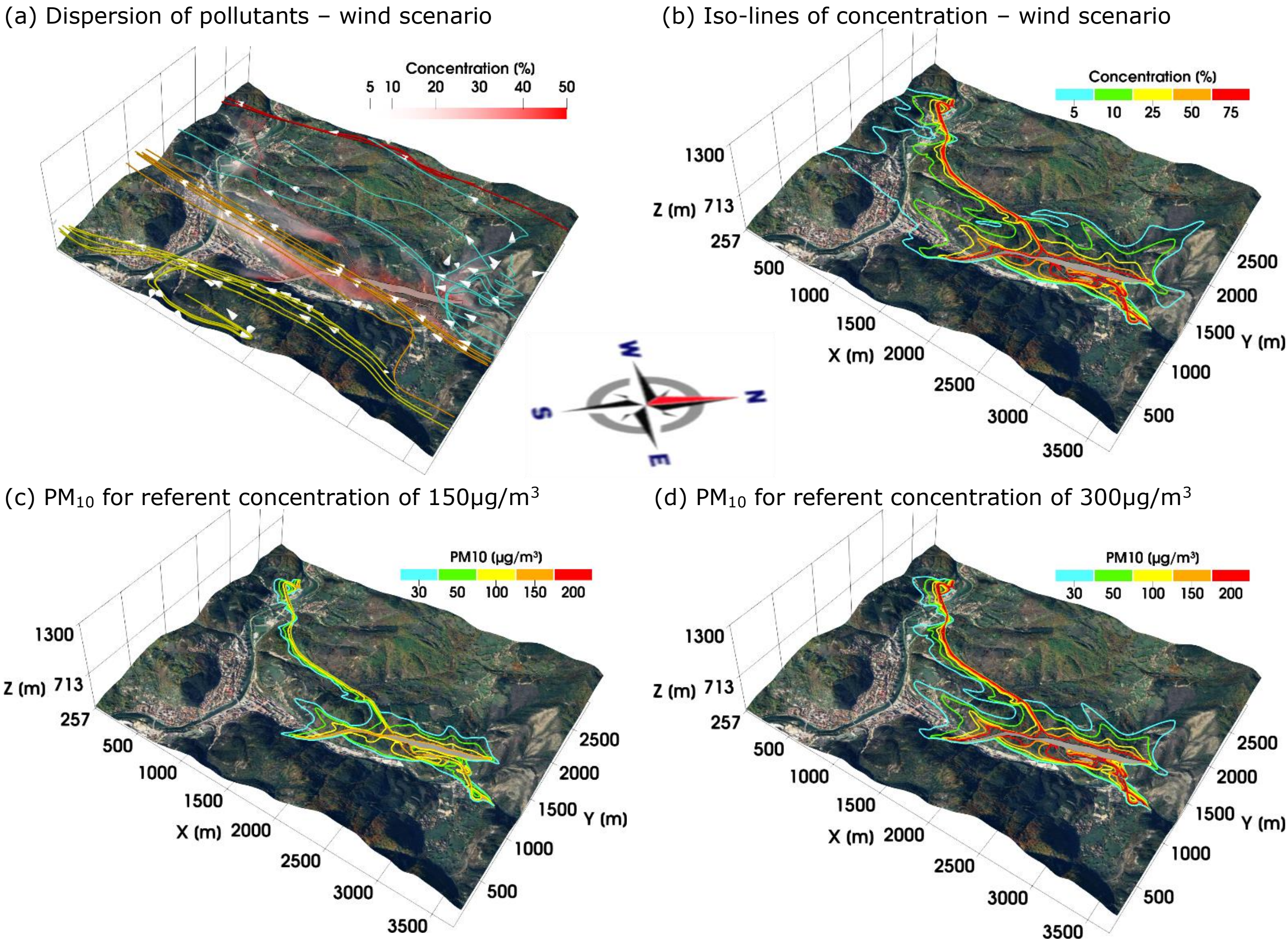


Figure 10-20: (a) Dispersion of pollutants expressed in relative values for wind scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150µg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300µg/m^3

10.3.3.1.2 Sub-domain B

Dispersion of the pollutants emitted on the corridor is computed under assumption of wind intensity of 3 m/s and direction NE-SW. The results are obtained after a statistically steady state is reached. Figure 10-21(a) shows dispersion of the pollutants in the three-dimensional space expressed in relative values (percentage of the reference value of pollutant at the corridor) while Figure 10-21(b) shows the pollutant spreading at the surface due to wind transport. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150µg/m^3) and high-intensity construction activities (300µg/m^3). Figure 10-21(c), (d) present distribution of the pollutant concentration on the surface for two reference pollutant values. The pollutant concentration increases up to 10% (of the value at the source) due to the corridor construction in the strip approximately 450m wide stretching in NE-SW direction along the first 1000 m of the corridor. In this region many residential buildings are present. During the high-intensity construction activities, the increase of PM_{10} in the residential area can go up to 30µg/m^3. This could lead to exceeding EU limits set for PM_{10}.

Based on the simulation results the application of mitigation strategy is recommended such as active wetting of soil on the corridor in sub-section B when the unfavourable weather conditions are present (presence of wind, low humidity) and emission-intensive activities are taking place on the corridor. The section of the corridor where mitigation strategies are recommended is defined from km 3+800 (end of the right tunnel tube T-2) to km 5+400 (Polje Bijela settlement), with a total length of 1600 m.

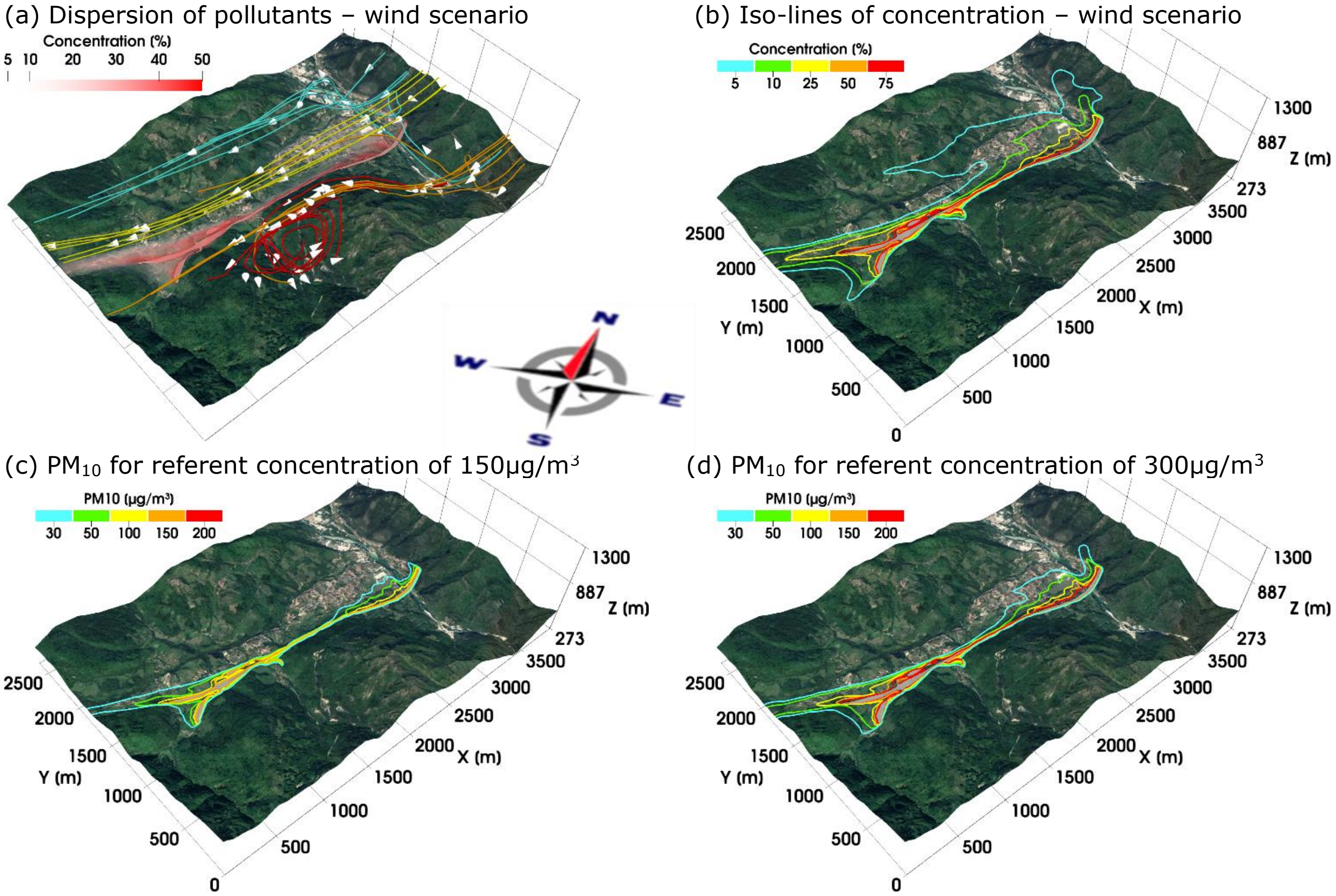


Figure 10-21: (a) Dispersion of pollutants expressed in relative values for wind scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150µg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300µg/m^3

10.3.3.1.3 Sub-domain C

The terrain of sub-domain C with main landmarks is shown in Figure 10-14. The results are obtained after a statistically steady state is reached. Figure 10-22(a) shows dispersion of the pollutants in the three-dimensional space expressed in relative values (percentage of the reference value of pollutant at the corridor) while Figure 10-22(b) shows the pollutant spreading at the surface due to wind transport. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150µg/m3) and high-intensity construction activities (300µg/m3). Figure

10-22(c), (d) present distribution of the pollutant concentration on the surface for two reference pollutant values. Specific orography of the sub-domain C keeps the pollutants concentrated in the elongated area along the corridor which is getting wider as the pollutants are transported downwind. As the pollution affected area is not close to residential areas no mitigation strategies are needed for the sub-domain C when wind scenario is present.

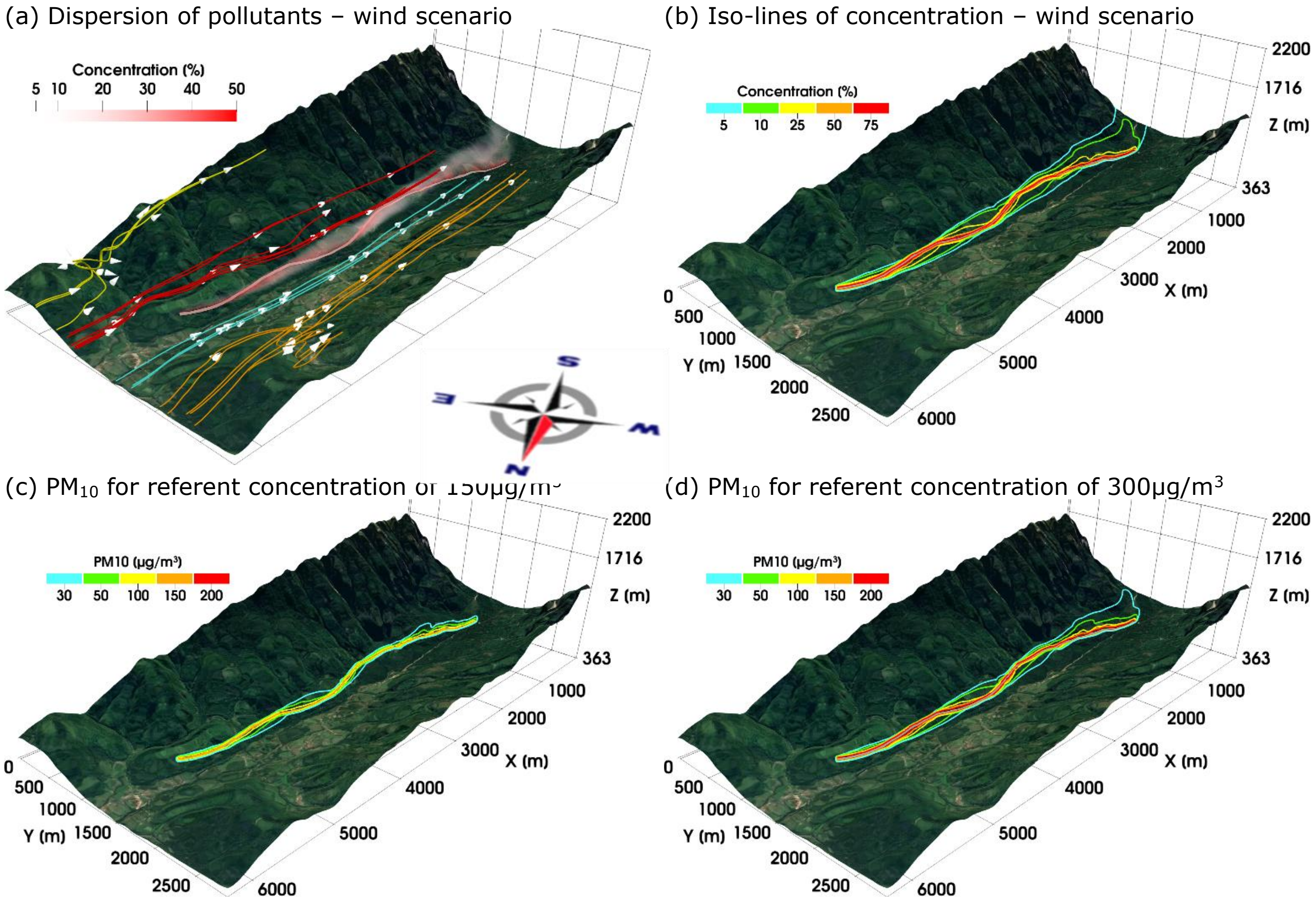


Figure 10-22: (a) Dispersion of pollutants expressed in relative values for wind scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150μg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300μg/m^3

10.3.3.1.4 Sub-domain D

The terrain of sub-domain D with main landmarks is shown in Figure 10-15. The results are obtained after a statistically steady state is reached. Figure 10-23(a) shows dispersion of the pollutants in the three-dimensional space expressed in relative values (percentage of the reference value of pollutant at the corridor) while Figure 10-23(b) shows the pollutant spreading at the surface due to wind transport. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150μg/m^3) and high-intensity construction activities (300μg/m^3). Figure 10-23(c), (d) present distribution of the pollutant concentration on the surface for two reference pollutant values. Relatively high values of pollutant concentration are occurring in the North-West region which is mainly agriculture land. This results in the increase of PM_{10} for minimum 30μg/m^3 for the high-intensive activities on the construction site.

Based on the simulation results the application of mitigation strategy is recommended, such as active wetting of soil in the critical region from km 24+750 (end of the right tunnel tube T-4) to km 25+450 (start of the viaduct), with a total length of 700 m, especially when the unfavourable weather conditions are present (dry, low humidity) and emission-intensive activities are taking place on the corridor. As the construction work is time-limited, it is not expected to have a long-term negative impact on air quality in the sub-section D of the corridor.

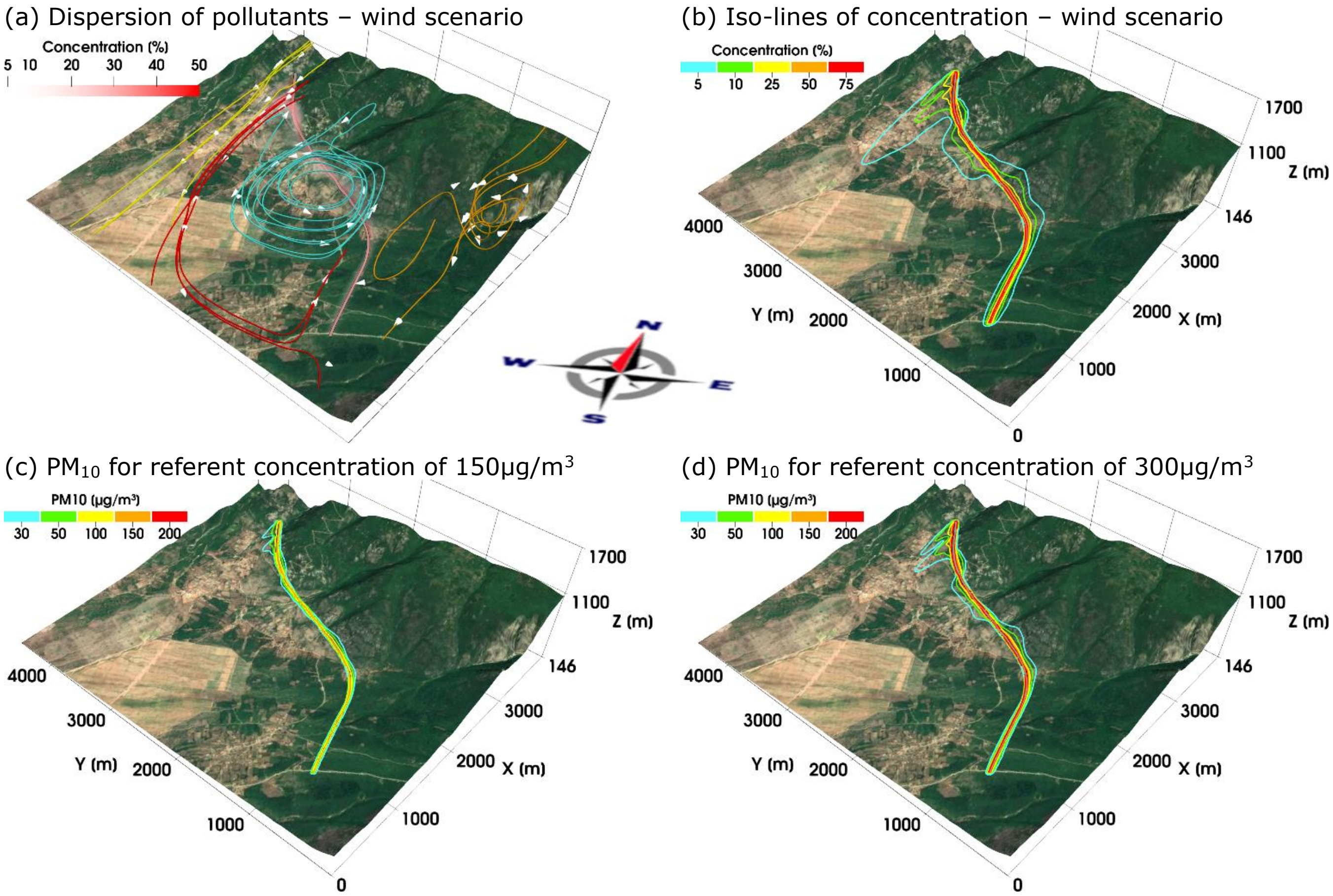


Figure 10-23: (a) Dispersion of pollutants expressed in relative values for wind scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150μg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300μg/m^3

10.3.3.1.5 Sub-domain E

The terrain of sub-domain E with main landmarks is shown in Figure 10-16. The results are obtained after a statistically steady state is reached. Figure 10-24(a) shows dispersion of the pollutants in the three-dimensional space expressed in relative values (percentage of the reference value of pollutant at the corridor) while Figure 10-24(b) shows the pollutant spreading at the surface due to wind transport. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity

(150μg/m³) and high-intensity construction activities (300μg/m³). Figure 10-24(c), (d) present distribution of the pollutant concentration on the surface for two reference pollutant values. Relatively high values of pollutant concentration are occurring in the strip 200m wide that is oriented in NE-SW direction during the high-intensity construction activities. This area includes some agriculture land.

Based on the simulation results the application of mitigation strategy is recommended, such as active wetting of soil from km 29+150 (road overpass) to km 30+000, with a length of 850 m, and from km 30+900 to km 31+900, with a length of 1000 m, especially when the unfavourable weather conditions are present (dry, low humidity) and emission-intensive activities are taking place on the corridor. As the construction work is time-limited, it is not expected to have a long-term negative impact on air quality in the sub-section E of the corridor.

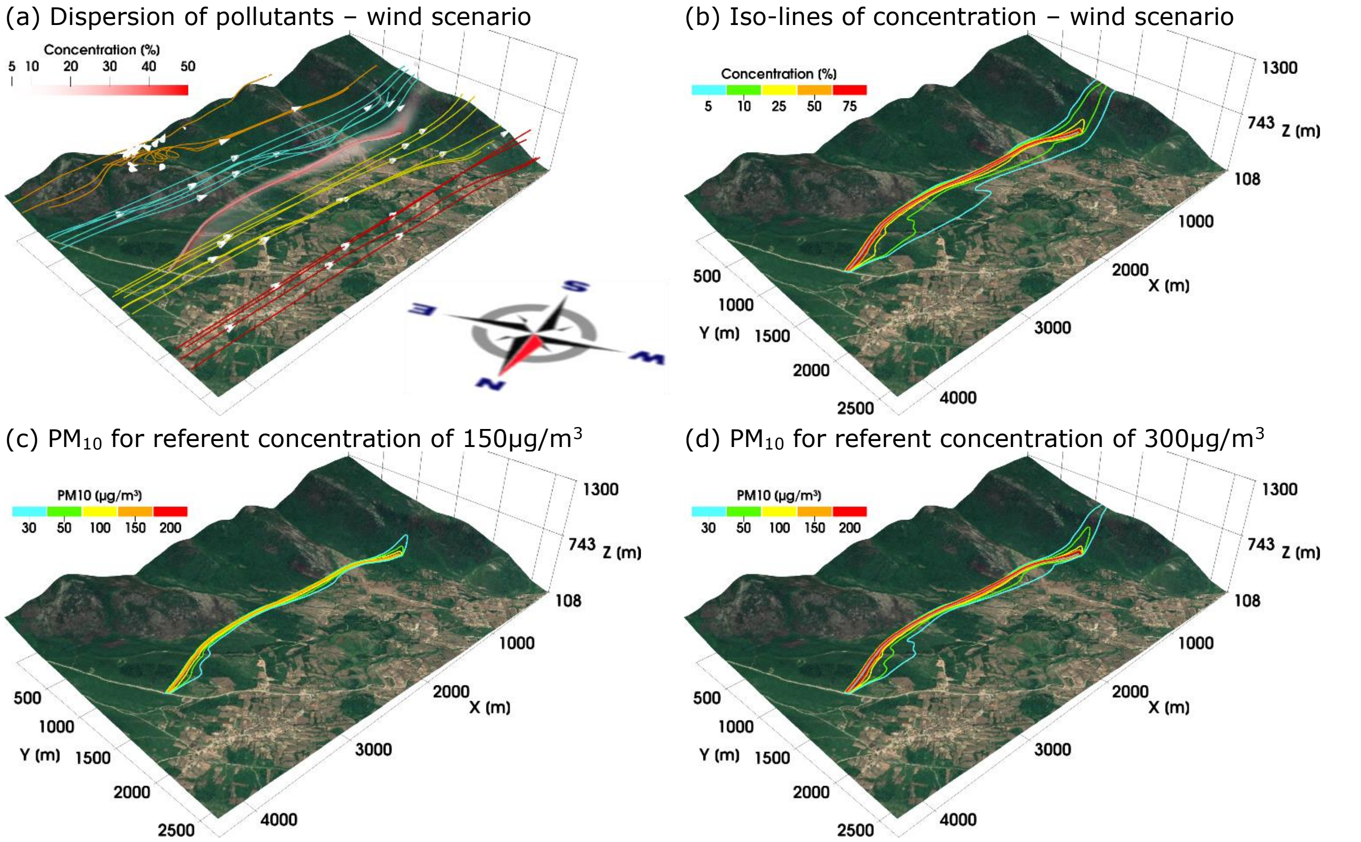


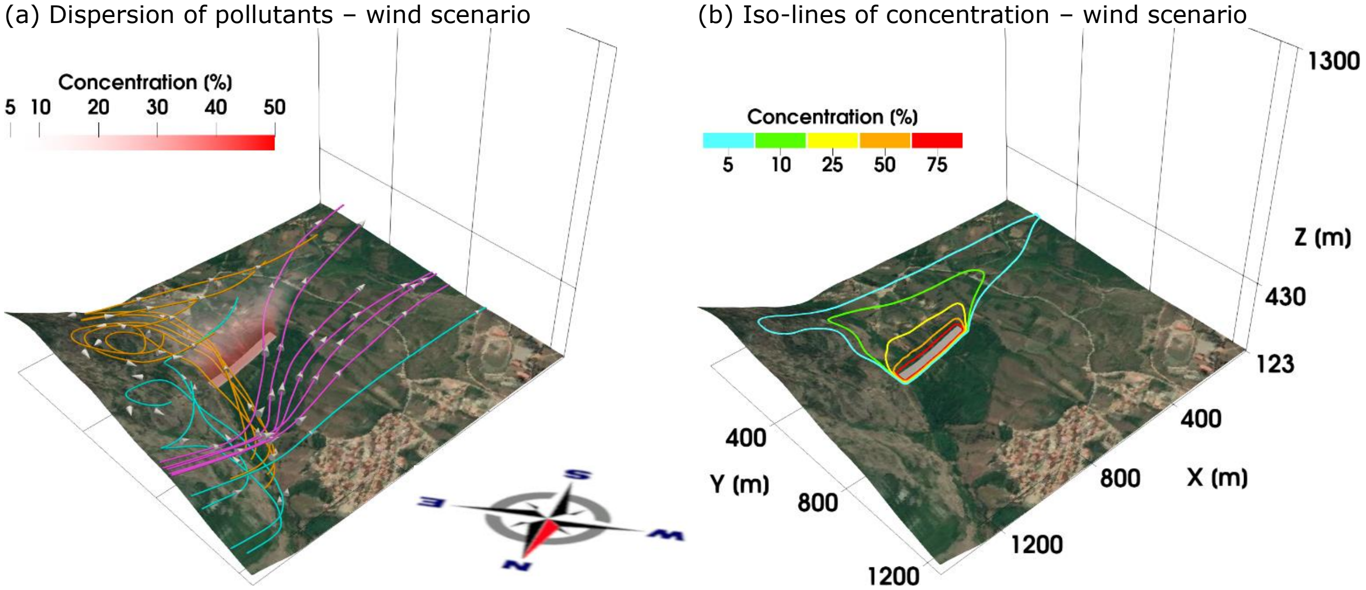
Figure 10-24: (a) Dispersion of pollutants expressed in relative values for wind scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150μg/m³, (d) Iso-surface of PM_{10} values for reference value of 300μg/m³

10.3.3.1.6 Sub-domain F

The terrain of sub-domain F with main landmarks is shown in Figure 10-17. The results are obtained after a statistically steady state is reached. Figure 10-25(a) shows dispersion of the pollutants in the three-dimensional space expressed in relative values (percentage of the reference value of pollutant at the corridor) while Figure 10-25(b) shows the pollutant spreading at the surface due to wind transport. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150μg/m^3) and high-intensity construction activities (300μg/m^3). Figure 10-25(c), (d) present distribution of the pollutant concentration on the surface for two reference pollutant. High values of pollutant concentrations are occurring in the area extending around 700m towards east, south-east, and south from the corridor. This area is all agriculture land and residential buildings. Even medium-intensity construction activities under the wind condition result in a significant increase of the pollution in the area up to 400m from the corridor.

Based on the simulation results the application of mitigation strategy is recommended, such as active wetting of soil along the whole sub-domain F, i.e. from km 34+750 (end of the right tunnel tube T-5) to km 35+100 (start of loop Mostar North), with a total length of 350 m, especially when the unfavourable weather conditions are present (dry, low humidity). As the construction work is time-limited, it is not expected to have a long-term negative impact on air quality in the sub-section F of the corridor.

(a) Dispersion of pollutants – wind scenario (b) Iso-lines of concentration – wind scenario



(c) PM_{10} for referent concentration of 150µg/m^3 (d) PM_{10} for referent concentration of 300µg/m^3

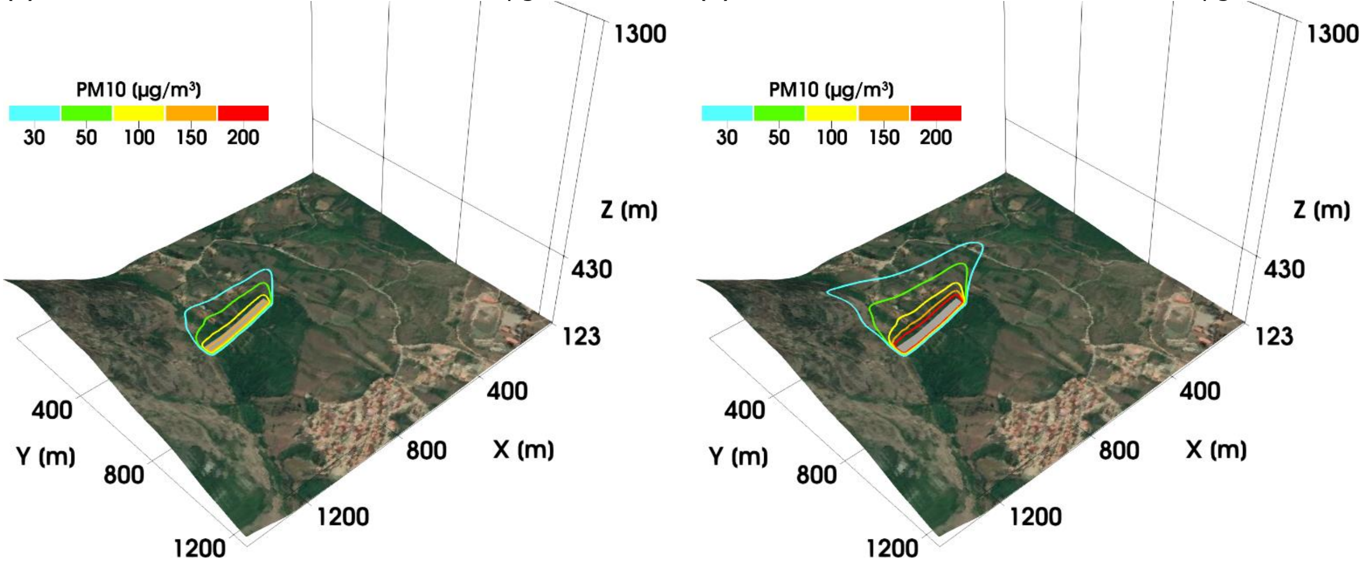


Figure 10-25: (a) Dispersion of pollutants expressed in relative values for wind scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150µg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300µg/m^3

10.3.3.1.7 Conclusions

The dispersion of pollutants during the construction phase in the wind scenario is computed under the assumption of NE-SW wind of intensity 3 m/s. The reference concentrations of 150 µg/m^3 and 300 µg/m^3 are adopted for the medium and high intensity construction activities, respectively.

From the beginning of the corridor (Ovcari Interchange) to the entrance to Prenj Tunnel, most of the residential areas and agriculture land are not affected by the high concentration levels of PM_{10} (more than 30 µg/m^3). The exception is the region of Polje Bijela, where the concentration of PM_{10} is expected to increase for at least 30 µg/m^3 during the high-intensity construction activities. It is estimated that the concentration of PM_{10} particles could lead to the exceeding of the EU limits set for PM_{10}.

In the section from the Prenj Tunnel exit to the loop Mostar North, many residential areas (Humilisani, Podgorani, Potoci) and agriculture land are located close to the corridor, hence are under the direct influence of the activities on the corridor. Based on the simulation results, high values of PM_{10} concentration occur in the area up to 500 m from the corridor, and even medium-intensity construction activities can lead to a significant increase in the PM_{10} concentration in this area (from 30 µg/m^3 up to even 150 µg/m^3).

Based on the simulation results the application of mitigation strategy is recommended especially when the unfavourable weather conditions are present (dry, low humidity with unfavourable wind direction) and emission-intensive activities are taking place on the corridor on the following sections:

- in the sub-domain A from km 1+100 (end of viaduct V-2) to km 1+800 (start of the right tunnel tube T-1), with a total length of 700 m. Along the first 400 m of Ovcari connecting road, and along first 1000 m of Konjic bypass road.
- in the sub-domain B from km 3+800 (end of the right tunnel tube T-2) to km 5+400 (Polje Bijela settlement), with a total length of 1600 m.
- in the sub-domain D from km 24+750 (end of the right tunnel tube T-4) to km 25+450 (start of the viaduct), with a total length of 700 m.
- in the sub-domain E from km 29+150 (road overpass) to km 30+000 (Humilišani), with a total length of 850 m, and from km 30+900 to km 31+900, with a length of 1000 m.
- in the sub-domain F from km 34+750 (end of the right tunnel tube T-5) to km 35+100 (start of loop Mostar North), with a total length of 350 m.

As the construction work is time-limited, the construction activities are not expected to have a long-term negative impact on air quality in the region of the corridor.

10.3.3.2 Construction phase: Windless scenario

10.3.3.2.1 Sub-domain A

Dispersion of pollutants in the windless scenario is unsteady as the mixing layer on the ground is growing in time due to an increase of ground heating from the Sun. The terrain of sub-domain A with main landmarks is shown in Figure 10-12. Figure 10-26 shows instantaneous values of the pollutant three hours after construction works started (four hours of total time). Figure 10-26(a) shows dispersion of the pollutants in the three-dimensional space while Figure 10-26(b) shows the pollutant spreading at the surface. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150μg/m^3) and high-intensity construction activities (300μg/m^3). Figure 10-26 (c), (d) show distribution of the instantaneous pollutant concentration on the surface for two reference pollutant. In the first 3 hours of the construction work, the pollutants emitted on the corridor are transported up to hills located on the NW, see Figure 10-26(a), (b). The high concentration area is limited to the corridor and its vicinity (150 m from both sides of the corridor). 3 hours after the construction work started, the area of 5%-10% concentration expands in the direction of the City of Konjic, see Figure 10-26(c), (d). This results in an increase of the PM_{10} for at least 30μg/m^3 in some parts of the area reference pollution value (300μg/m^3). The lower reference value (150μg/m^3) is adding up extra 30μg/m^3 of PM_{10} in the smaller region, close to the corridor. The region of > 10% of concentration is not static but it is changing in time. Three hours after construction work started, this region is periodically expanding and shrinking into the residential area of Konjic which can result in a significant increase of PM_{10} pollution in the residential area.

Based on the simulation results the application of mitigation strategy in the first 4 hours of the construction work is recommended. This is especially important when the unfavourable weather conditions are present (dry, low humidity) and emission-intensive activities are taking place on the corridor. The section of the corridor where mitigation strategies are recommended is defined from km 0+900 (100 m before viaduct V-2) to km 1+800 (start of tunnel tube T-1), with a total length of 900 m, along the whole connection road to Ovcari Interchange, and along the first 1,000 m of Konjic Bypass road.

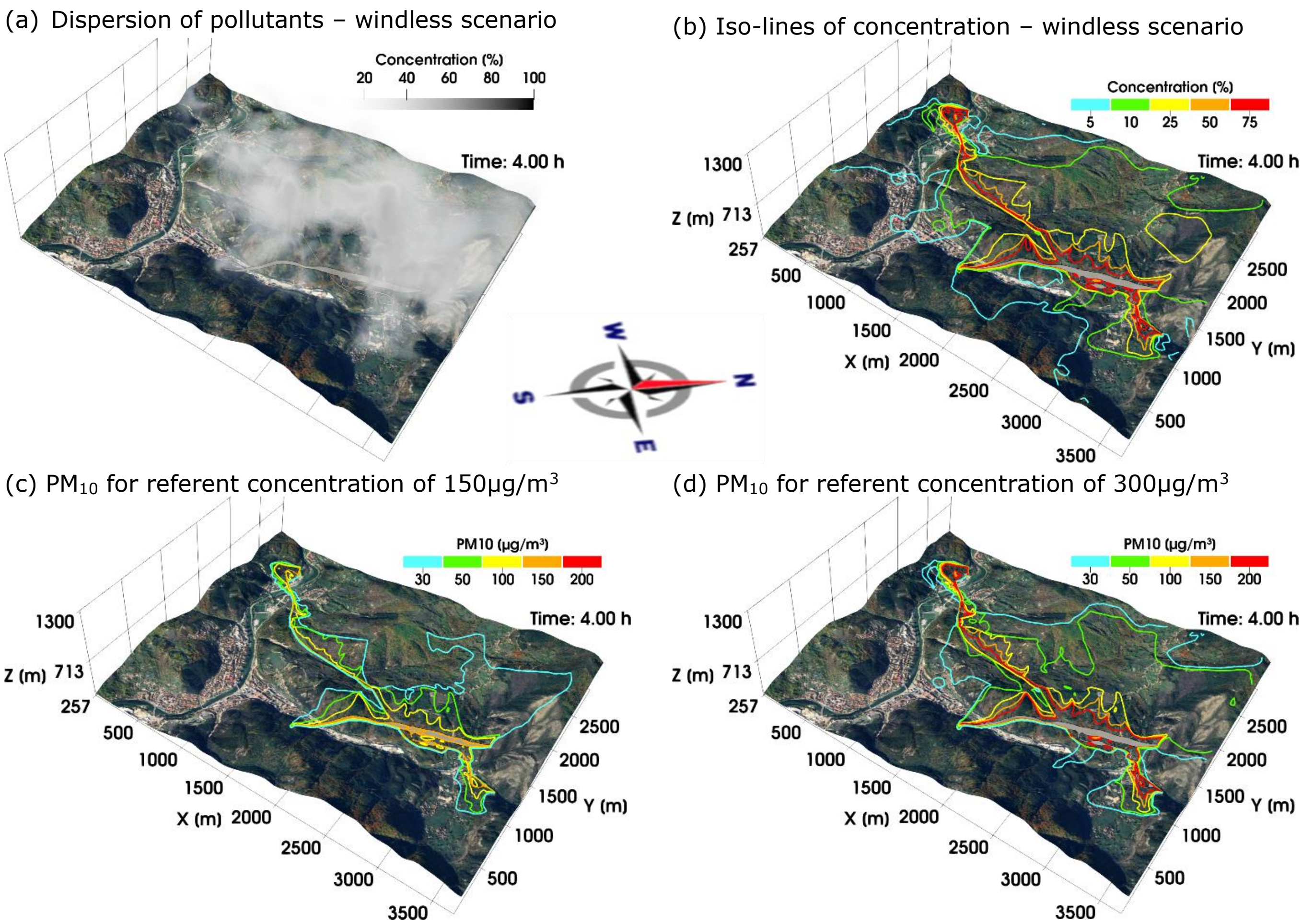


Figure 10-26: (a) Dispersion of pollutants expressed in relative values for windless scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150µg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300µg/m^3

10.3.3.2.2 Sub-domain B

The terrain of sub-domain B with main landmarks is shown in Figure 10-13. Figure 10-27 shows instantaneous values of the pollutant three hours after construction works started (four hours of total time). Figure 10-27(a) shows dispersion of the pollutants in the three-dimensional space while Figure 10-27(b) shows the pollutant spreading at the surface. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150µg/m^3) and high-intensity construction activities (300µg/m^3). Figure 10-27 (c), (d) shows distribution of the instantaneous pollutant concentration on the surface for two reference pollutant. In the first 2 hours of the construction work, the pollutants are not dispersed into the residential area in significant amount (< 5%). However, after approximately 4.5 hours, the area of concentration large than 5% expands in the direction of agriculture and settlement areas, see Figure 10-27 (b). This results in extra 30μg/m^3 of PM_{10} in part of the residential area for the high reference pollution value (300μg/m^3). The lower reference value (150μg/m^3) is adding up extra 30μg/m^3 of PM_{10} in the much smaller region, close to the corridor.

Based on the simulation results the application of mitigation strategy is recommended in the first 3 hours of the construction work in the corridor part defined from km 3+700 (end of right tunnel tube T-2) to km 4+800 (Polje Bijela settlement), with a total length of 1100 m. This is especially important when the unfavourable weather conditions are present (dry, low humidity) and emission-intensive activities are taking place on the corridor. As the construction work is time-limited, it is not expected to have a long-term negative impact on air quality in the sub-section B of the corridor.

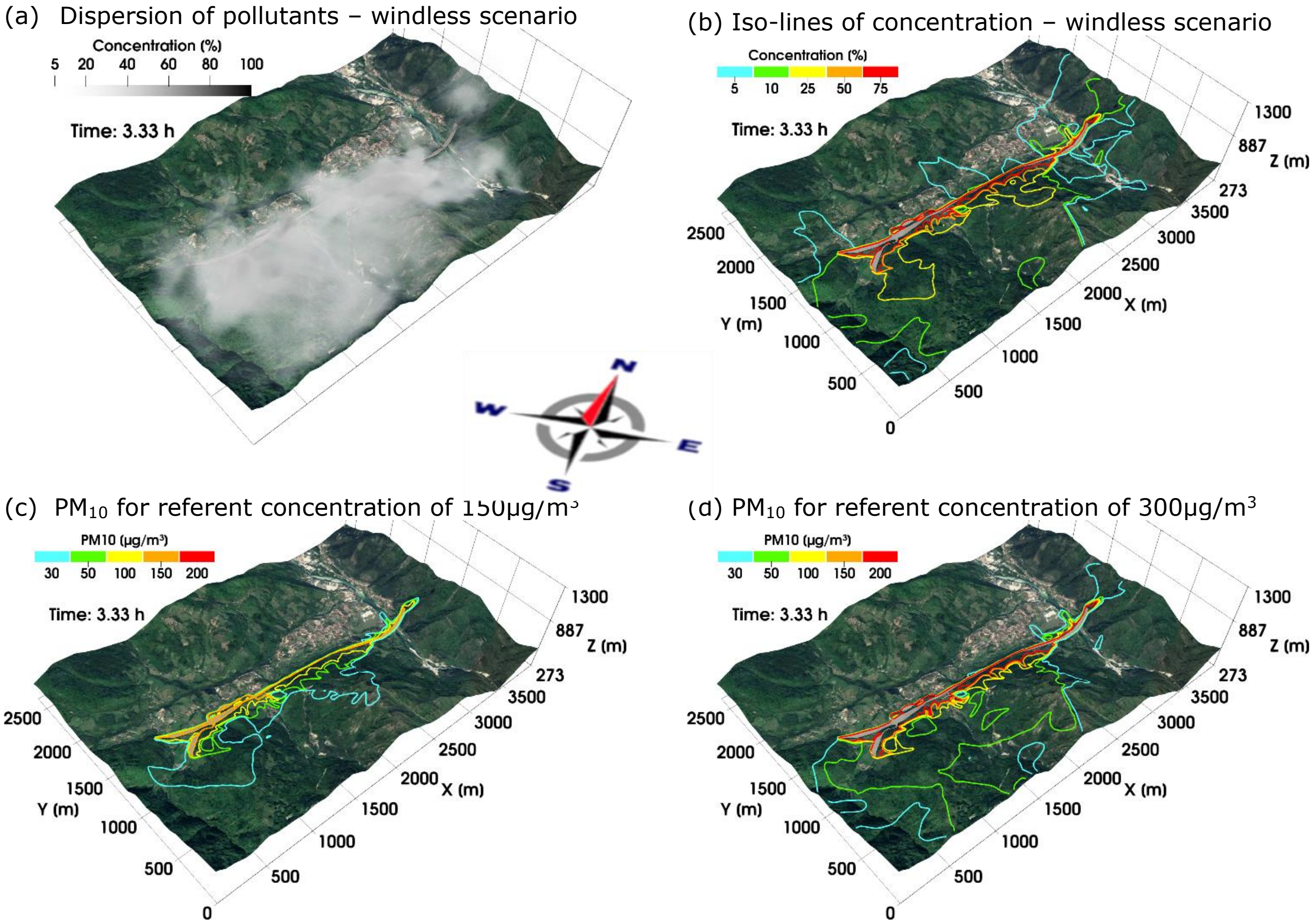


Figure 10-27: (a) Dispersion of pollutants expressed in relative values for windless scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150μg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300μg/m^3

10.3.3.2.3 Sub-domain C

The terrain of sub-domain C with main landmarks is shown in Figure 10-14. Figure 10-28 shows instantaneous values of the pollutant three hours after construction works started (four hours of total time). Figure 10-28(a) shows dispersion of the pollutants in the three-dimensional space while Figure 10-28(b) shows the pollutant spreading at the surface. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150μg/m^3) and high-intensity construction activities (300μg/m^3). Figure 10-28(c), (d) present distribution of the instantaneous pollutant concentration on the surface for two reference pollutant. As the sub-domain C does not have residential areas nor significant agricultural land, it is not expected that the pollutant dispersion will have a long-term negative impact on air quality in the sub-section C of the corridor. Mitigation strategy is not necessary for the sub-domain C.

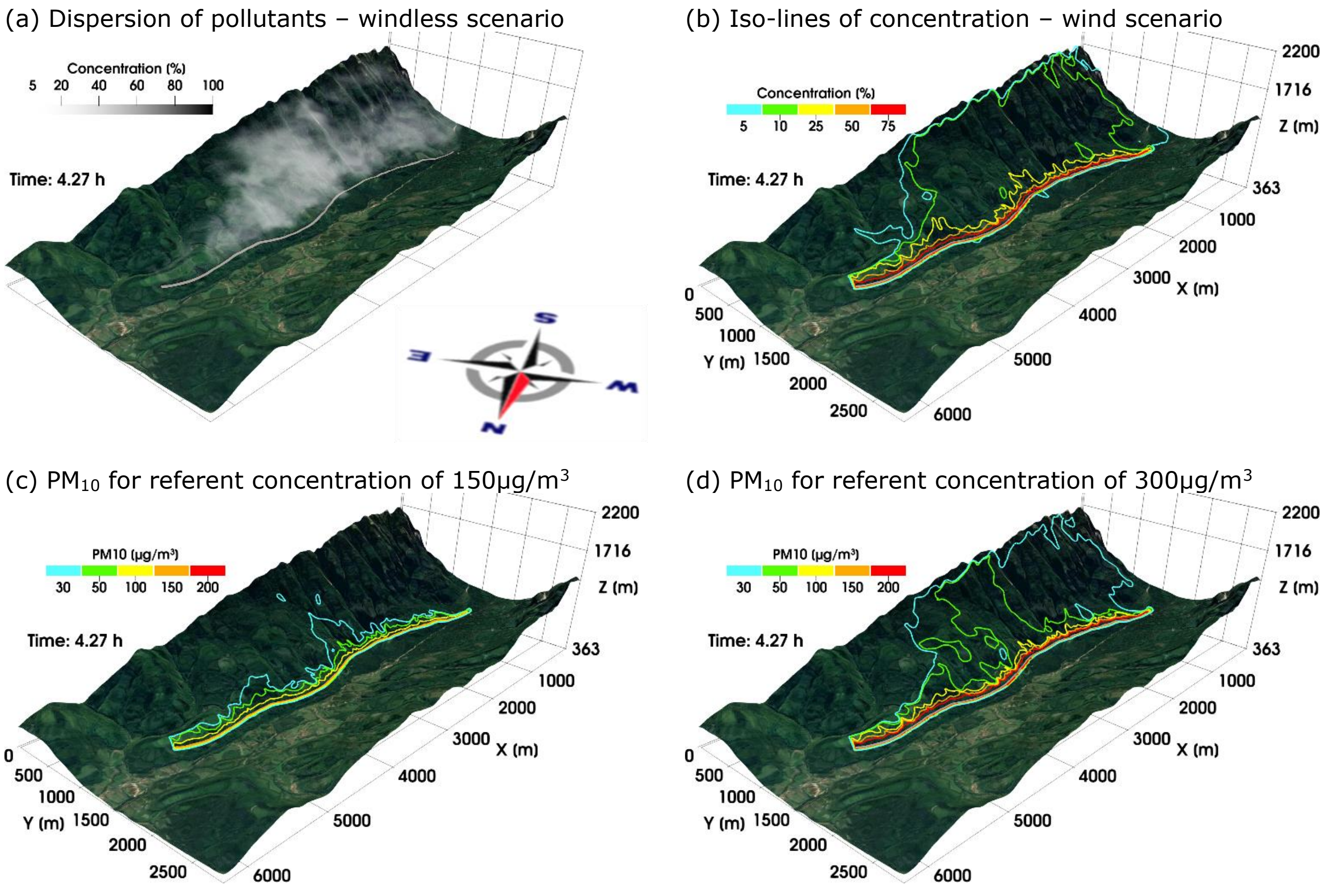


Figure 10-28: (a) Dispersion of pollutants expressed in relative values for windless scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150μg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300μg/m^3

10.3.3.2.4 Sub-domain D

The terrain of sub-domain D with main landmarks is shown in Figure 10-15. Figure 10-29 shows instantaneous values of the pollutant three hours after construction works started (four hours of total time). Figure 10-29(a) shows dispersion of the pollutants in the three-dimensional space while Figure 10-29(b) shows the pollutant spreading at the surface. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150μg/m^3) and high-intensity construction activities (300µg/m³). Figure 10-29(c), (d) shows distribution of the instantaneous pollutant concentration on the surface for two reference pollutant. Under the windless weather condition, the pollutants from the corridor are transported away from the agriculture land as it can be seen in Figure 10-29. The results suggest that the pollutant will not be dispersed in the direction of the residential and agriculture area. Mitigation strategy is not necessary for the sub-domain D.

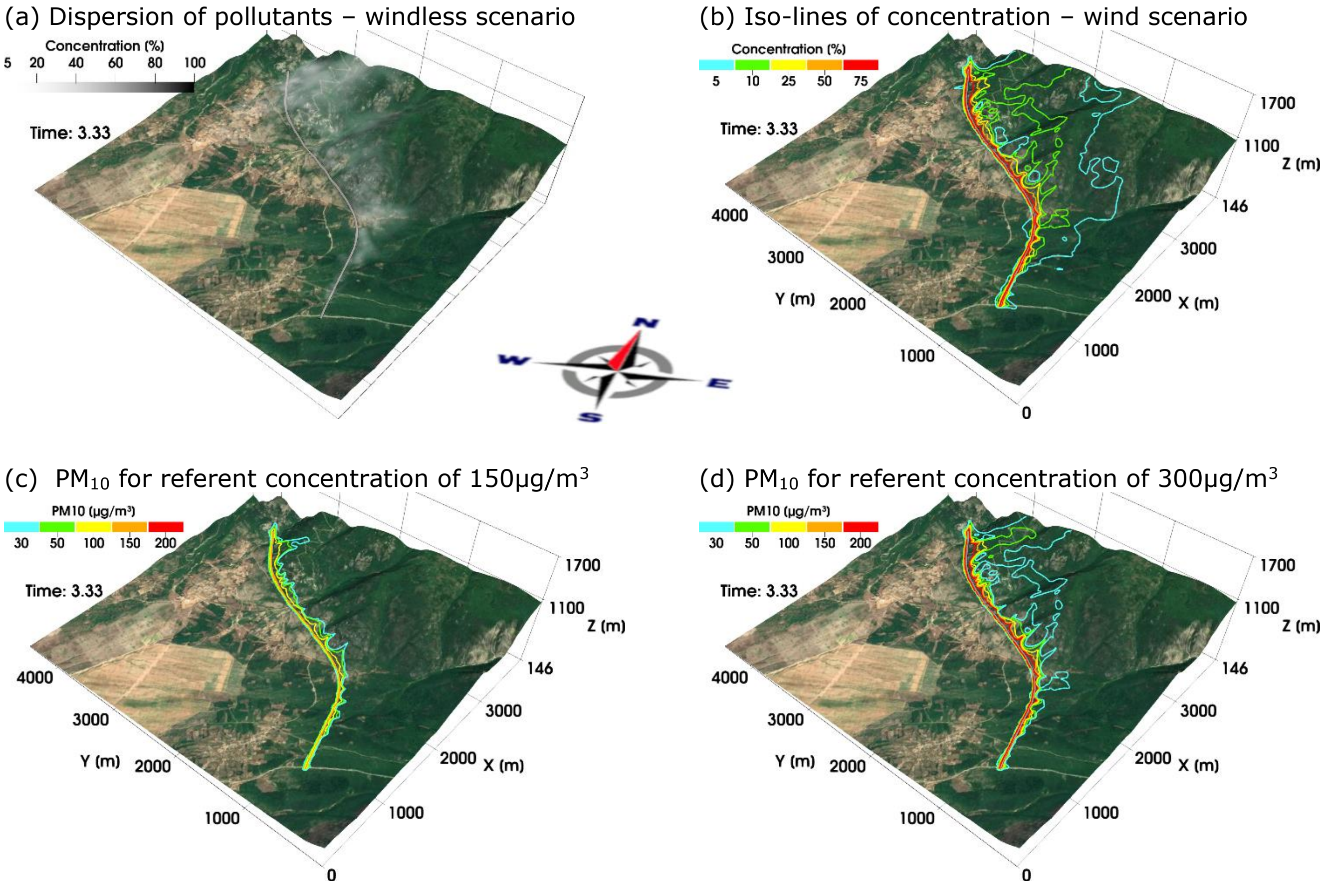


Figure 10-29: (a) Dispersion of pollutants expressed in relative values for windless scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150µg/m³, (d) Iso-surface of PM_{10} values for reference value of 300µg/m³

10.3.3.2.5 Sub-domain E

The terrain of sub-domain E with main landmarks is shown in Figure 10-16. Figure 10-30 shows instantaneous values of the pollutant three hours after construction works started (four hours of total time). Figure 10-30(a) shows dispersion of the pollutants in the three-dimensional space while Figure 10-30(b) shows the pollutant spreading at the surface. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150µg/m³) and high-intensity construction activities (300µg/m³). Figure 10-30(c), (d) show distribution of the instantaneous pollutant concentration on the surface for two reference pollutant. Under the windless weather condition, the pollutants from the corridor are transported away from the agriculture land during the hours when the most intensive constructions activities are expected, see Figure 10-30. The results suggest that the pollutant will not be dispersed in the direction of the residential and agriculture area. Mitigation strategy is not necessary for the sub-domain E.

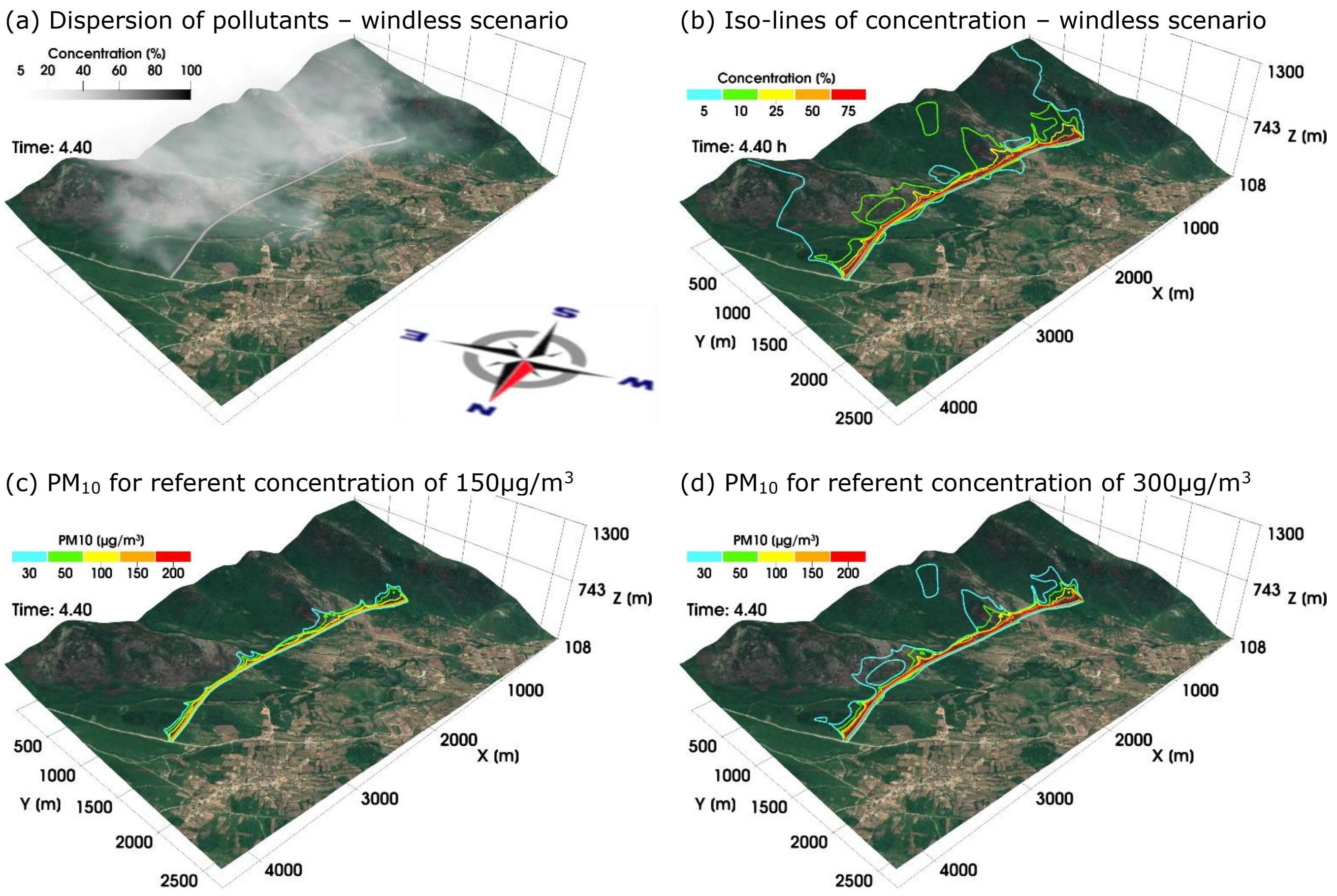


Figure 10-30: (a) Dispersion of pollutants expressed in relative values for windless scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150µg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300µg/m^3

10.3.3.2.6 Sub-domain F

The terrain of sub-domain F with main landmarks is shown in Figure 10-17. Figure 10-31 shows instantaneous values of the pollutant three hours after construction works started (four hours of total time). Figure 10-31(a) shows dispersion of the pollutants in the three-dimensional space while Figure 10-31(b) shows the pollutant spreading at the surface. Two reference values of the pollutant at the corridor are considered due to the emissions during the construction works, medium-intensity (150µg/m^3) and high-intensity construction activities (300µg/m^3). Figure 10-31(c), (d) present distribution of the instantaneous pollutant concentration on the surface for two reference pollutant. Under the windless weather condition, the pollutants from the corridor are dispersed some 200m from the corridor, see Figure 10-31. Based on the simulation results it is concluded that the mitigation strategy is not needed.

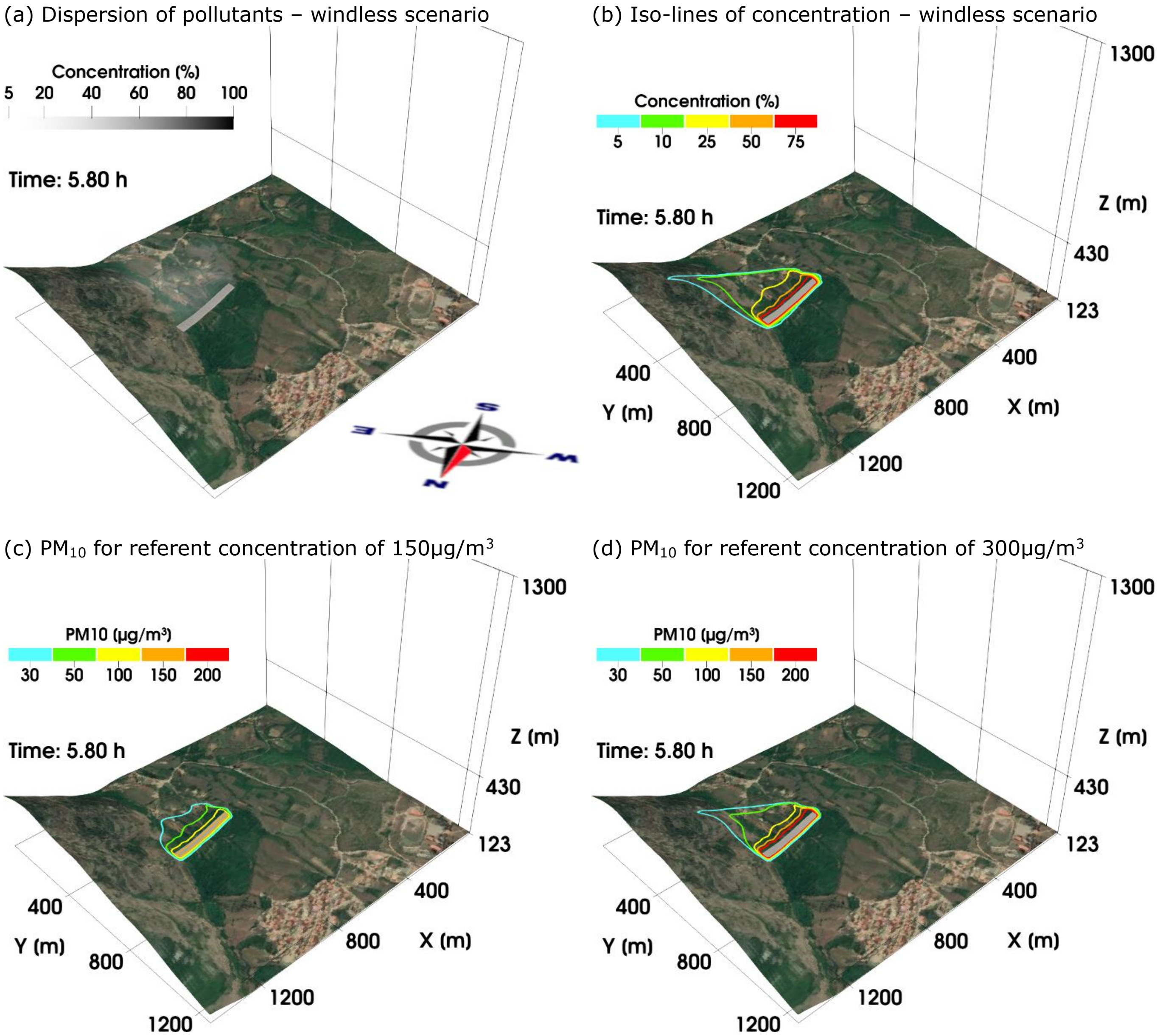


Figure 10-31: (a) Dispersion of pollutants expressed in relative values for windless scenario, (b) Iso-contours of general pollutant on the surface, (c) Iso-surface of PM_{10} values for reference value of 150μg/m^3, (d) Iso-surface of PM_{10} values for reference value of 300μg/m^3

10.3.3.2.7 Conclusions

The dispersion of pollutant is simulatedbduring the first six hours of construction phase under the windless condition. Two reference values for the intensity of the PM_{10} emissions are adopted: during medium-intensity construction activities (150 μg/m^3) and high-intensity construction activities (300 μg/m^3). During the first 2 hours of construction activities, the pollutant is mainly distributed away from the residential areas and agriculture land and only a small amount of pollutant (< 5%) reaches these areas. After approximately 2-3 hours of activities, larger values of pollutant (> 10%) expand towards the residential areas and agriculture land in some sub-sections, resulting in an increase of PM_{10} concentration for least 30 μg/m^3 when high-intensity construction activities take place. The area of influence expands approximately 200 meters from both sides of the corridor. The area which is affected the most is the City of Konjic.

Based on the simulation results the application of mitigation strategy is recommended especially when the unfavourable weather conditions are present (dry, low humidity) and emission-intensive activities are taking place on the corridor on the following sections:

- in the first 4 hours of the construction work in the sub-domain A from km 0+900 (100 m before viaduct V-2) to km 1+800 (start of tunnel tube T-1), with a total length of 900 m, along the whole connection road to Ovcari Interchange, and along the first 1000 m of Konjic bypass road.
- in the first 3 hours of the construction work in the sub-domain B from km 3+700 (end of right tunnel tube T-2) to km 4+800 (Polje Bijela settlement), with a total length of 1100 m.

As the construction work is time-limited, it is not expected to have a long-term negative impact on air quality on the corridor.

10.3.3.3 Operational phase: Wind and windless scenario

10.3.3.3.1 Sub-domain A

The terrain of sub-domain A with main landmarks is shown in Figure 10-12. Figure 10-32(a), (b) show dispersion of PM_{10} for the operational phase for the wind and windless scenarios, respectively. The reference value of PM_{10} is set to 40μg/m^3 which assumes busy traffic on the corridor. PM_{10} values shown in the figures represent 6-hour mean for both the wind and windless scenarios.

The region of the highest contribution of PM_{10} in the case of wind scenario is located at the end of the corridor in the sub-section A where viaduct will be located. The elevation of the corridor on the viaduct will help to disperse the pollutants coming from the traffic. The breaching of the limiting values of PM_{10} in the corridor vicinity for the wind scenario is not expected.

The same conclusion holds for the windless scenario as well. The pollutants produce on the corridor are transported uphill and dispersed in the atmosphere so no higher increase of pollution in the residential area is expected.

(a) Iso-lines of concentration – wind scenario

(b) Iso-lines of concentration – windless scenario

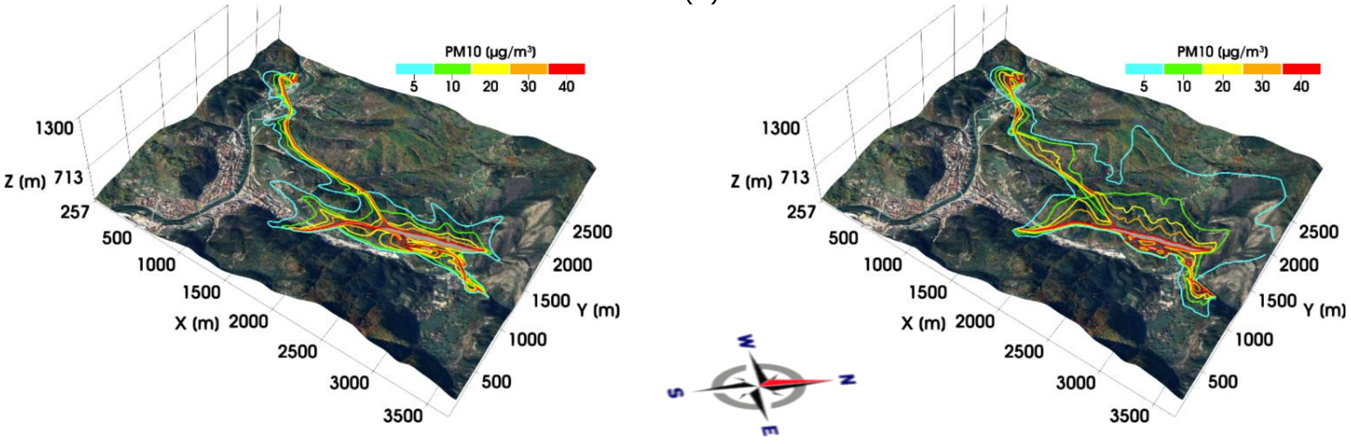


Figure 10-32: (a) Iso-surface of PM_{10} values for reference value of 40μg/m^3 for wind scenario, (b) Iso-surface of 6-hour mean PM_{10} values for reference value of 40μg/m^3 for windless scenario

10.3.3.3.2 Sub-domain B

The terrain of sub-domain B with main landmarks is shown in

Figure 10-13. Figure 10-33(a),(b) show dispersion of PM_{10} for the operational phase for the wind and windless scenarios, respectively. The reference value of PM_{10} is set to 40μg/m^3 which assumes busy traffic on the corridor. PM_{10} values shown in the figures represent 6-hour mean for both the wind and windless scenarios.

Figure 10-33 (a) shows 5 to 10μg/m^3 increase of PM_{10} in the part of the residential area while an increase larger than 10% is limited to the region approximately 80m wide towards NW. The windless scenario shows that the pollutants are transported uphill located on SE away from the residential areas. The breaching of the limiting values of PM_{10} in the sub-section B of the corridor is not expected.

(a) Iso-lines of concentration – wind scenario

(b) Iso-lines of concentration – windless scenario

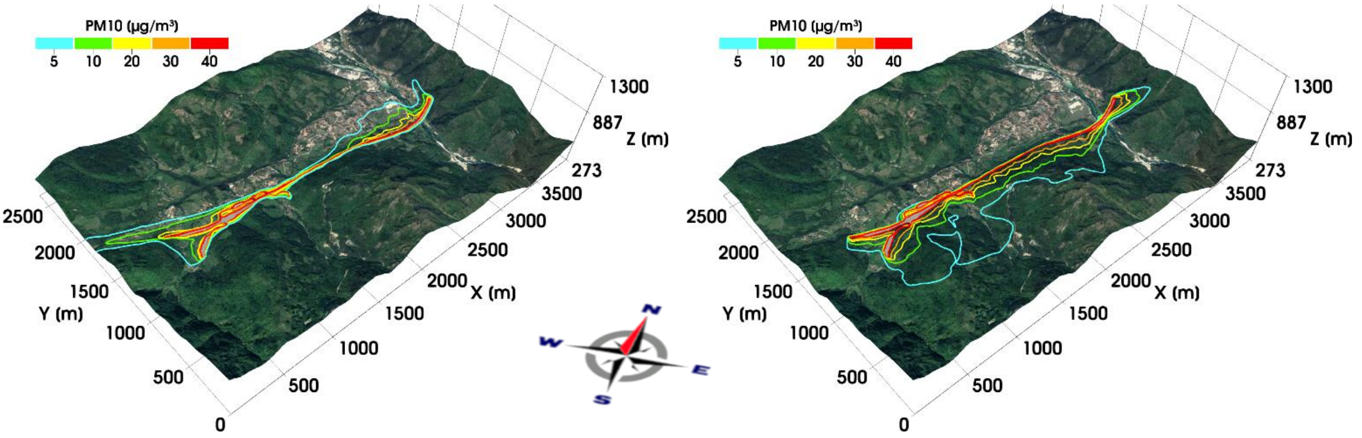


Figure 10-33: (a) Iso-surface of PM_{10} values for reference value of 40μg/m^3 for wind scenario, (b) Iso-surface of 6-hour mean PM_{10} values for reference value of 40μg/m^3 for windless scenario

10.3.3.3.3 Sub-domain C

The terrain of sub-domain C with main landmarks is shown in Figure 10-14. Figure 10-34(a), (b) show dispersion of PM_{10} for the operational phase for the wind and windless scenarios, respectively. The reference value of PM_{10} is set to 40μg/m^3 which assumes busy traffic on the corridor. PM_{10} values shown in the figures represent 6-hour mean for both the wind and windless scenarios.

As the sub-domain C does not have residential areas nor significant agricultural land, it is not expected that the pollutant dispersion will have a long-term negative impact on air quality in the sub-section C of the corridor.

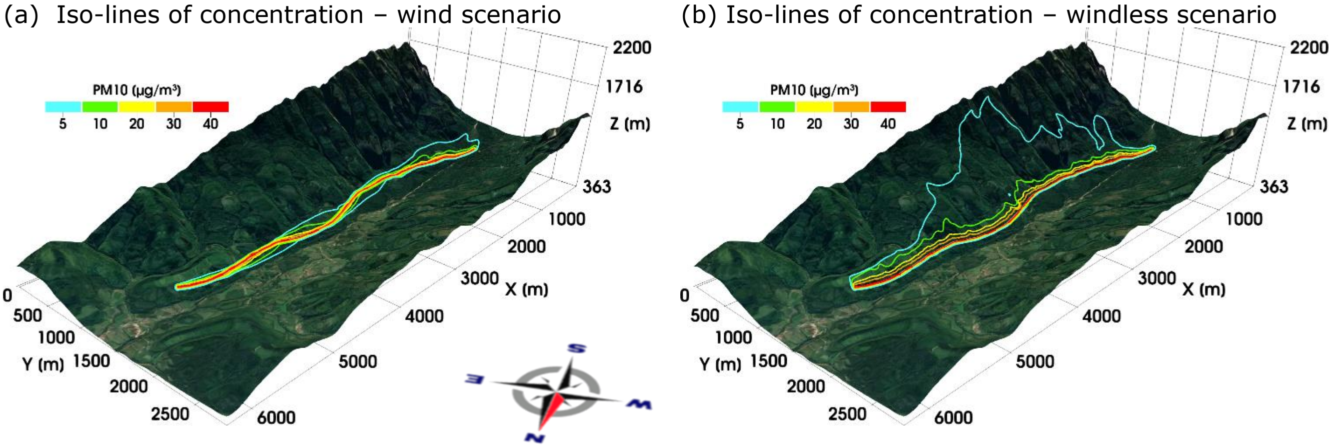


Figure 10-34: (a) Iso-surface of 6-hour mean PM_{10} values for reference value of 40μg/m^3 for wind scenario, (b) Iso-surface of PM_{10} values for reference value of 40μg/m^3 for windless scenario

10.3.3.3.4 Sub-domain D

The terrain of sub-domain D with main landmarks is shown in Figure 10-15. Figure 10-35(a), (b) show dispersion of PM_{10} for the operational phase for the wind and windless scenarios, respectively. The reference value of PM_{10} is set to 40μg/m^3 which assumes busy traffic on the corridor. PM_{10} values shown in the figures represent 6-hour mean for both the wind and windless scenarios.

Figure 10-35 (a) shows 5 to 10μg/m^3 increase of PM_{10} under the wind condition in the area that includes agriculture land. As the agriculture land is in the proximity of the corridor, the pollution by NO_x from the corridor is realistic scenario in the exceptional cases of heavy traffic (such as traffic congestions). That is why protection measures are recommended on the segment of the corridor defined from km 24+750 (end of the left tunnel tube T-4) to km 25+450 (end of the viaduct), with a total length of 700 m.

The windless scenario shows that the pollutants are transported uphill for most of the day, away from the agriculture area. The breaching of the limiting values of PM_{10} in the sub-section D of the corridor is not expected.

(a) Iso-lines of concentration – wind scenario (b) Iso-lines of concentration – windless scenario

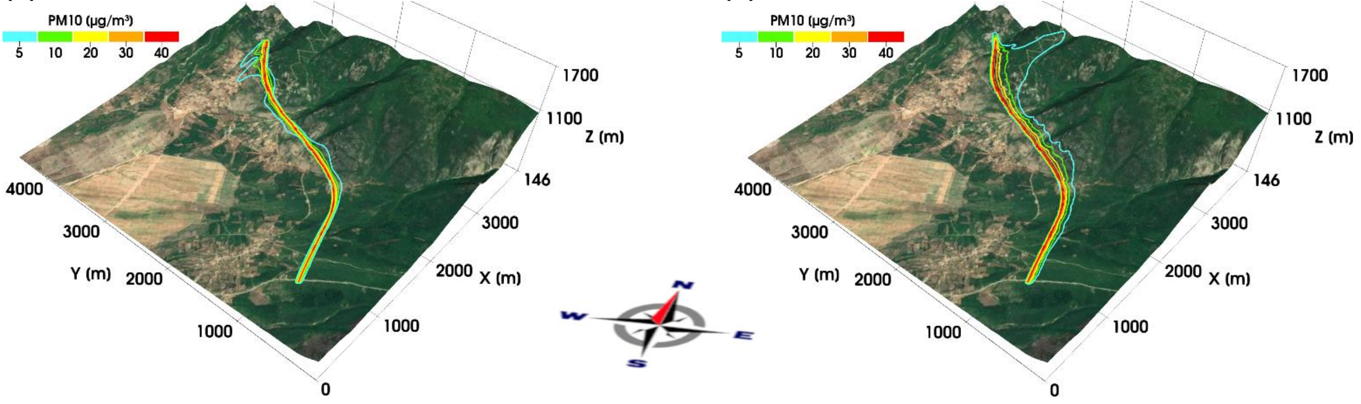


Figure 10-35: (a) Iso-surface of PM_{10} values for reference value of 40μg/m^3 for wind scenario, (b) Iso-surface of PM_{10} values for reference value of 40μg/m^3 for windless scenario

10.3.3.3.5 Sub-domain E

The terrain of sub-domain E with main landmarks is shown in Figure 10-16. Figure 10-36 shows dispersion of PM_{10} for the operational phase for the wind and windless scenarios. The reference value of PM_{10} is set to 40μg/m^3 which assumes busy traffic on the corridor. PM_{10} values shown in the figures represent 6-hour mean for both the wind and windless scenarios.

Figure 10-36 (a) shows 5 to 10μg/m^3 increase of PM_{10} under the wind condition in the area that includes agriculture land. As the agriculture land is in the proximity of the corridor, the pollution by NO_x from the corridor is realistic scenario in the exceptional cases of heavy traffic (such as traffic congestions). That is why the protection measures are recommended on the segment of the corridor defined from km 29+150 (road overpass Humilišani) to km 30+000, with a total length of 850 m, and from km 30+900 to km 32+400 (Entrance to tunnel T-5), with a length of 1500 m.

The windless scenario shows that the pollutants are transported uphill for most of the day, away from the agriculture area. The breaching of the limiting values of PM_{10} in the sub-section E of the corridor is not expected.

(a) Iso-lines of concentration – wind scenario (b) Iso-lines of concentration – windless scenario

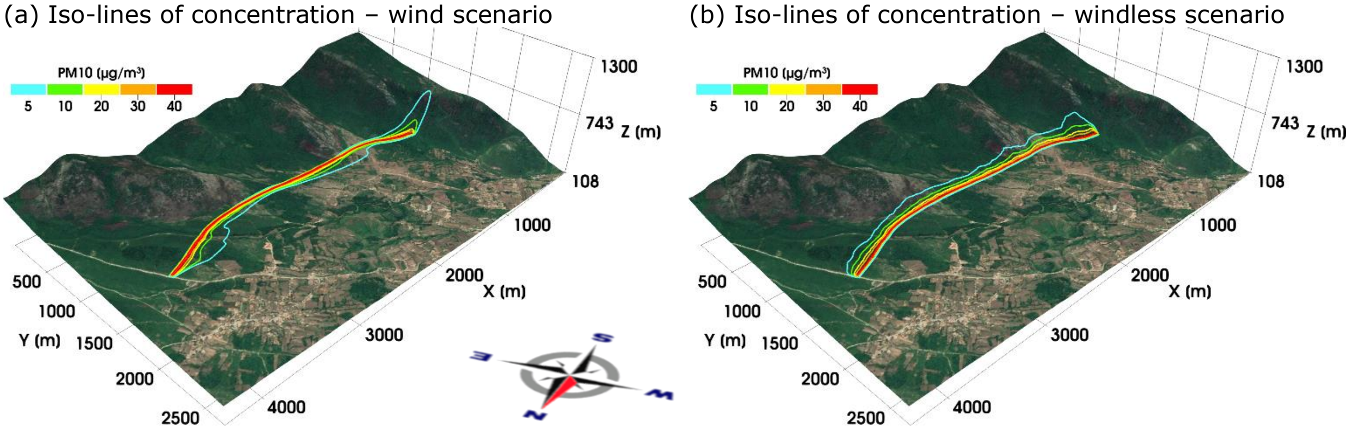


Figure 10-36: (a) Iso-surface of PM_{10} values for reference value of 40µg/m^3 for wind scenario, (b) Iso-surface of PM_{10} values for reference value of 40µg/m^3 for windless scenario

10.3.3.3.6 Sub-domain F

The terrain of sub-domain F with main landmarks is shown in Figure 10-17. Figure 10-37 shows dispersion of PM_{10} for the operational phase for the wind and windless scenarios. The reference value of PM_{10} is set to 40µg/m^3 which assumes busy traffic on the corridor. PM_{10} values shown in the figures represent 6-hour mean for both the wind and windless scenarios.

Figure 10-37 (a) shows 5 to 10µg/m^3 increase of PM_{10} under the wind condition in the area that includes agriculture land. As the agriculture land is in the proximity of the corridor, the pollution by NO_x from the corridor is realistic scenario in the exceptional cases of heavy traffic (such as traffic congestions). That is why the protection measures are recommended along the whole subdomain F.

The windless scenario shows that the pollutants are dispersed far from the corridor. The breaching of the limiting values of PM_{10} in the sub-section F of the corridor is not expected.

(a) Iso-lines of concentration – wind scenario (b) Iso-lines of concentration – windless scenario

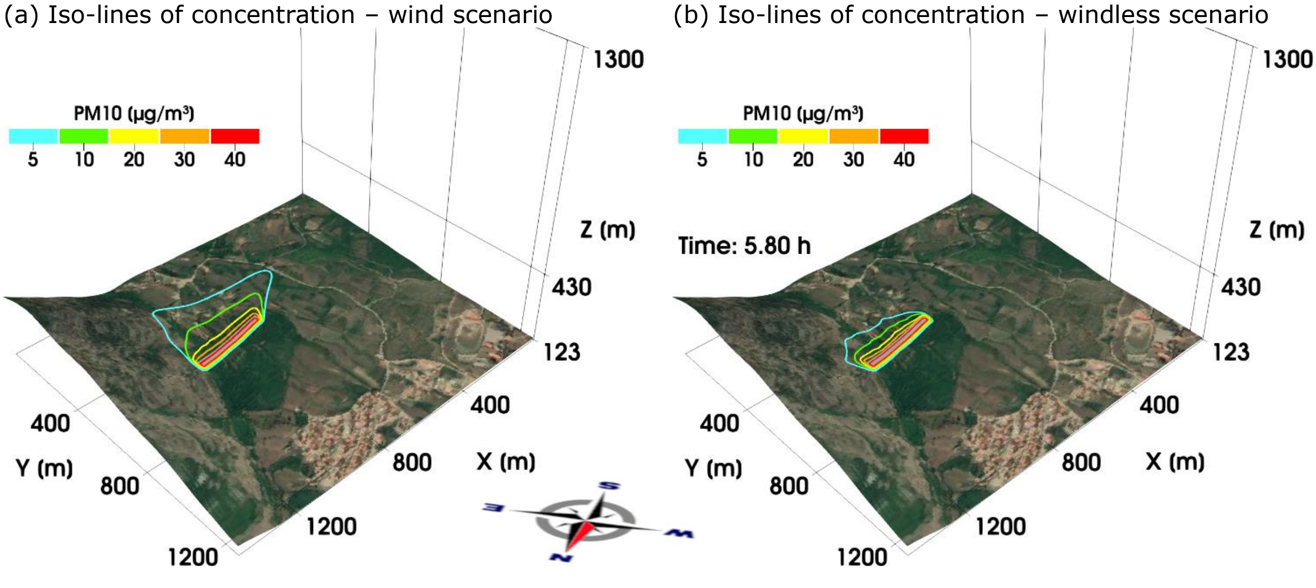


Figure 10-37: (a) Iso-surface of PM_{10} values for reference value of 40µg/m^3 for wind scenario, (b) Iso-surface of PM_{10} values for reference value of 40µg/m^3 for windless scenario

10.3.3.3.7 Total pollutant emissions from traffic-related sources

Total annual emissions from traffic during the operational phase are estimated based on the number of vehicles per hour expected on the Corridor, and mean fuel-based emission factors. According to the Traffic Study for Section of Corridor Vc: Konjic (Ovcari Interchange) – Mostar North Interchange (2016), the estimated size of normal traffic on this section in 2020 is 9252 vehicles per day. The number of vehicles per category is given in Table 10-25.

Table 10-25: The estimated size of traffic on the planned highway section on Corridor Vc in 2020. Source: Traffic Study (2016).

Section	Length [km]	Average annual daily traffic [veh/day]						
		PC	Bus	LCV	MCV	HCV	CW	TOTAL
Konjic - Mostar	35.6	8328	138	133	160	152	341	9252

Many studies[15] [16] [17]have tried to estimate the amount of pollutants emitted from vehicle exhausts. Generally, the most reliable sources of emission factors are European and national inventories, such as EMEP/EEA Air Pollutant Emission Inventory Guidebook[18]. This Guidebook provides emission factors for different vehicle categories by fuel type, engine displacement and technology.

To calculate total emissions from vehicles exhaust, it is necessary to have the information about number of vehicles per fuel type (petrol, diesel, LPG), and per technology (European emission standard e.g. Conventional, EURO 1 – 6) for each vehicle category. BIHAMK (Bosnia-Herzegovinian Auto – Moto Club) reports on annual statistics of number of vehicles per fuel type and EURO standard.[19] The statistics for year 2019 are given in Table 10-26. Almost 75% of vehicles use diesel fuel, while around 25% use petrol and/or combination of petrol and LPG. Regarding emission standard, 83% of vehicles use engines with EURO 4 standard or lower.

In calculating the total emission, car-wagon category is added to passenger cars category. Also, medium and heavy commercial vehicles are grouped in a single category. This is done based on the similarity of emission factors for these vehicle categories. Additionally, because of the lack of information, it is assumed that percentages given in Table 10-26 are valid for each vehicle category.

Three types of pollutants resulting from fuel combustion are considered: particulate matter (PM), CO and NO_x. The values for emission factors are taken from the EEA Guidebook (2019). The total emission of pollutants is obtained by multiplying the number of vehicles belonging to a certain category, fuel type, and technology by corresponding emission factor, length of the Corridor and number of days in a year. The final results are reported in tons per year (ta^{-1}) and are given in Table 10-27.

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[15] Maricq, M. M., Szente, J., Loos, M., & Vogt, R. (2011). Motor vehicle PM emissions measurement at LEV III levels. SAE International Journal of Engines, 4(1), 597-609.
[16] Aikawa, K., Sakurai, T., & Jetter, J. J. (2010). Development of a predictive model for gasoline vehicle particulate matter emissions. SAE International Journal of Fuels and Lubricants, 3(2), 610-622.
[17] Liang, B., Ge, Y., Tan, J., Han, X., Gao, L., Hao, L., ... & Dai, P. (2013). Comparison of PM emissions from a gasoline direct injected (GDI) vehicle and a port fuel injected (PFI) vehicle measured by electrical low pressure impactor (ELPI) with two fuels: Gasoline and M15 methanol gasoline. Journal of Aerosol Science, 57, 22-31.
[18] Ntziachristos, L., Samaras, Z. (2019). EMEP/EEA Emission Inventory Guidebook: Exhaust emissions from road transport [Internet]. Copenhagen: EEA; updated 2019.
[19] BIHAMK (2020). Informacija o registrovanim/registriranim drumskim/cestovnim vozilima u BiH u periodu januar/siječanj – decembar/prosinac 2019.

Table 10-26: Number of registered vehicles in Bosnia and Herzegovina per fuel type and technology for year 2019. Source: BIHAMK Report (2020).

Fuel type	Percentage [%]	Technology	Percentage [%]
Petrol	21.41	**Conventional**	15.15
Diesel	74.66	**EURO 1**	2.8
Petrol/LPG hybrid	3.82	**EURO 2**	6.82
Others	0.11	**EURO 3**	29.8
		EURO 4	28.23
		EURO 5	12.1
		EURO 6	4.9

Table 10-27: Annual emissions (in tonnes) of CO, NO_x, and PM from exhaust vehicle-related sources on Corridor Vc.

Vehicle category	Annual emission (ta-1)		
	CO	NOx	PM
PC	70.1	60.3	4.7
LCV	3.4	1.6	0.12
MCV + HCV	63.3	20.3	0.32
Buses	3.3	14.0	0.41
TOTAL	140.1	96.2	5.55

In addition to emissions from fossil fuels combustion, the particulate matter (PM) originate from non-exhaust processes. These processes include degradation of vehicle parts (tyre wear, brake wear) and road surface wear. On top of that, material deposited on the road surface (dust, particulate matter) can be resuspended by vehicle-generated turbulence or wind. The emission factors for tyre wear, break wear and road surface wear are provided by EEA Guidebook, while emission factors for resuspension are reported in the literature[20]. The total emissions of PM from non-exhaust vehicle-related sources are shown in Table 10-28.

Table 10-28: Annual emissions of PM_{10} and $PM_{2.5}$ from non-exhaust vehicle-related sources on Corridor Vc

Emission source	Annual emission (ta-1)	
	PM10	PM2.5
Tyre and brake wear	1.9	1.0
Road surface wear	1.1	0.6
Resuspension	13.5	4.1
TOTAL	16.5	5.7

[20] Timmers, V. R., & Achten, P. A. (2016). Non-exhaust PM emissions from electric vehicles. Atmospheric Environment, 134, 10-17.

The annual emission of 140 tonnes of CO from the corridor during the operational phase accounts for an additional 0.044 kg of CO per capita in BiH. For the sake of comparison, the total emissions of CO in the United States in 2012 was 173 kg per capita. Similarly, the annual emission of NO_x from the corridor accounts for extra 0.03 kg per capita, while the total emissions of NO_x in the US in 2012 was 39 kg per capita.

10.3.3.3.8 Conclusions

During the operational phase, the reference value of PM_{10} is set to 40μg/m^3 which assumes busy traffic on the corridor for both wind and windless scenarios. The NE-SW wind of intensity 3 m/s is assumed for the wind scenario, and air motion due to buoyancy force only is assumed for the windless scenario. The results represent 6-hour mean for both scenarios.

Since the operational phase is much less intensive in terms of emissions of pollutants than the construction phase, especially when it comes to PM emissions, the breaching of the EU limits set for PM_{10} during the windless scenario is not expected.

During the wind scenario an increase of 10-30μg/m^3 in PM_{10} concentration is expected in the settlement of Podgorani (sub-domain D) and Potoci (sub-domain E) in the vicinity of the corridor. However, from the simulation results the breaching of the EU limits set for PM_{10} during the windless scenario is not expected. As the agriculture land is in the proximity of the corridor on these locations, the pollution by NO_x from the corridor is realistic scenario in the exceptional cases of heavy traffic (such as traffic congestions). Therefore, the implementation of mitigation measures is recommended:

- in the sub-domain D from km 24+50 (end of the right tunnel tube T-4) to km 26+300 (Podgorani settlement), with a total length of 2250 m.
- in the sub-domain E from km 28+400 (overpass 3) to km 29+750 (Humilišani settlement), with a total length of 1350 m.

The total emissions of CO and NO_x from the vehicles on the corridor during the operational phase in a single year account for an increase of 0.044 kg per capita and 0.03 kg per capita, respectively, in BiH. For the comparison, these values are less than 0.08 % of total emissions of CO and NO_x per capita in the United States.

10.4 Assessment of Potential Impacts

The corridor impact on the air quality is taking place during the construction phase and operational phase. The construction phase is more intensive in terms of pollutant emissions compared to the operational phase where the main source of air pollution are emissions from vehicle traffic on the corridor.

During the construction phase, the main causes of potential negative impact on air quality are nature of construction works and presence of construction machines at the site. The construction phase impact on air quality is due to:

- Emissions of construction dust associated with the soil management, loading activities, storage of material onsite, transport of materials within site, drilling and digging (including soil excavation), movement on unpaved roads and transport of material offsite, asphalt and concrete laying.
- Emission of exhaust gases from combustion processes in generators and other construction equipment/vehicles that contain nitrogen oxides (NO_X), sulphur dioxide (SO_2), carbon monoxide (CO) and fine particulate matter

The risk of dust emissions from construction site causing loss of amenity and/or health or ecological impacts is related to[21]:

- the activities being undertaken (earth works, number of vehicles etc.),
- the interval of these activities,
- the scope of the site,
- the meteorological conditions (wind speed, direction and rainfall),
- the proximity of receptors to the activities,
- the adequacy of the mitigation measures applied to reduce or eliminate dust, and
- the sensitivity of the receptors to dust.

Based on criteria presented in the *Guidance on the assessment of dust from demolition and construction*, the potential for dust emission magnitude from earthworks, construction and movement of vehicles is defined to be large (Table 10-29)[22]. Translated into impact magnitude, the assessment results in overall moderate impact magnitude, that produces detectable change but not a fundamental temporary or permanent change.

Table 10-29: Dust emission and impact magnitude

Activity	Criteria	Dust emission magnitude	Impact magnitude
Earth works	› site area > 10,000 m^2 › the soil type is potentially dusty › > 10 heavy moving vehicles active at any time › total material moved > 100,000 tones	Large	Moderate
Construction	› site area > 10,000 m^2 › the soil type is potentially dusty › potentially dusty surface material	Large	

[21] Institute of Air Quality Management (2014) Guidance on the assessment of dust from demolition and construction, version 1.1. available at http://www.iaqm.co.uk/text/guidance/construction-dust-2014.pdf
[22] Ibid.

Activity	Criteria	Dust emission magnitude	Impact magnitude
Vehicle movement	> vehicles >3.5 t outward movements in any one day > potentially dusty surface material > unpaved road length is > 100 m	Large	

The two main receptors of concern are:

- "human receptors" – referring to any location where a person or property may experience the adverse effects of airborne dust or dust soiling or exposure to PM_{10} over a time period relevant to the air quality objectives and
- "ecological receptors" – referring to any sensitive habitat affected by dust soiling. These consist of the direct impact on vegetation or aquatic ecosystems of dust deposition and the indirect impacts on fauna (e.g. on scavenging habitats).

In the Project area of influence, both types of receptors are present.

Construction works will be carried out in a close vicinity of the City of Konjic, and private houses in the settlements of Ovcari, Polje Bijela, Mladeskovici, Humilisani, Podgorani, as well as in a proximity of thermophilic forests in a major part of the Project area, and agriculture land and vineyards.

The receptor sensitivity analysis takes account of a number of factors, such as:

- the specific sensitivities of receptors in the area,
- the proximity and number of those receptors,
- in the case of PM_{10}, the local background concentration,
- site-specific factors, such as low presence of natural shelters, such as tall trees, to reduce the risk of wind-blown dust and strong winds.

Based on criteria presented in the *Guidance on the assessment of dust from demolition and construction*, the sensitivity of receptor is defined to be medium (Table 10-30)[23].

Table 10-30: Dust emission and impact magnitude

Activity	Criteria	Sensitivity of receptors
Sensitivity of people to dust soiling effect	> The enjoyment of amenity would not reasonably be expected	Medium

[23] Institute of Air Quality Management (2014) Guidance on the assessment of dust from demolition and construction, version 1.1. available at http://www.iaqm.co.uk/text/guidance/construction-dust-2014.pdf

Activity	Criteria	Sensitivity of receptors
	> Property would not reasonably be expected to be diminished in appearance, aesthetics or value by soiling > The people or property would reasonably be expected to be present continuously or at least regularly for extended periods, as part of the normal pattern of use of the land.	
Sensitivity of people to the health effects of PM_{10}	> Location where members of the public and workers are exposed over a time period	Medium
Sensitivity of receptors to ecological effects	> Location with a local designation where the features may be affected by dust deposition > Potential ecological receptors are located near the construction site	Medium

In the operation phase, the main causes of potential negative impact on air quality is the movement of vehicles on the motorway. Therefore, the operational impacts are anticipated to include reduction of air quality due to emission of exhaust gases from combustion processes in vehicles that contain nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO) and fine particulate matter.

The modelling results has shown that:

- The intensity of pollutants emissions during the construction phase is greater than during the operational phase where the main source of pollutants are the emissions from traffic on the corridor. Consequently, the concentration of pollutants is higher during the construction phase.
- The scenario with wind during the construction phase is the most unfavourable of all in terms of concentration of pollutants in residential areas and agriculture land. During this scenario, high values of PM_{10} concentration occur in the area up to 500 m from the corridor, and even medium-intensity construction activities can lead to a significant increase in the PM_{10} concentration in this area (from 30 μg/m^3 up to even 150 μg/m^3). The populated areas of Konjic, Polje Bijela, Humilišani, Podgorani, Potoci, and the agriculture land in these settlements are the exposed to the highest values of PM_{10} concentration.
- During the construction phase in the windless scenario, the pollutant does not reach residential areas or agriculture land during the first 2 hours of activities. However, after 2-3 hours significant values of pollutant expand towards the residential areas and agriculture land, which results in the increase of PM_{10} concentration of at least 30 μg/m^3 when high-intensity construction activities take place. The City of Konjic is the most affected area in this scenario.
- During the wind scenario in operational phase an increase of 10-30μg/m^3 in PM_{10} concentration is expected in the settlement of Podgorani and Potoci in the vicinity of the corridor. However, from the simulation results the

breaching of the EU limits set for PM_{10} during the windless scenario is not expected. As the agriculture land is in the proximity of the corridor on these locations, the pollution by NO_x from the corridor is realistic scenario in the exceptional cases of heavy traffic (such as traffic congestions).

Based on the simulation results, the application of mitigation strategy is recommended such as active wetting of soil on the corridor when the unfavourable weather conditions are present (presence of wind, low humidity) and emission-intensive activities are taking place on the corridor. The locations where these measures should be implemented are listed in the following table.

Table 10-31 below provides a summary of impacts and assessment of their significance based on the modelling results.

Table 10-31: Summary of potential impacts on air quality and assessment of their significance before mitigation

Phase	Type of impact	Adverse/ Beneficial	Magnitude	Sensitivity	Impact evaluation	Significance (before mitigation)
Air quality						
Pre-construction	Due to the timespan between preparation of this Study and start of construction works, up-to-date information on air quality in the project areas will be needed to determine baseline conditions	Adverse	Moderate	Medium	Moderate	Significant
Construction	Reduction in air quality due to: › Emissions of construction dust › Emission of exhaust gases from combustion processes in generators and other construction equipment /vehicles.	Adverse	Moderate	Medium	Moderate	Significant
Operation	Reduction in air quality due to emission from exhaust gases from vehicles using the motorway	Adverse	Minor	Medium	Minor	Not significant

10.5 Mitigation and Enhancement Measures

10.5.1 Preconstruction phase

During the pre-construction phase, due to the timespan between preparation of this Study and start of construction works, up-to-date information on air quality in the project areas will be needed to determine baseline conditions. Therefore, the following mitigation and enhancement measures to address potential impact on air quality are:

- Repeat the analysis of air quality in the project area, possibly in two seasons (summer and winter).

10.5.2 Construction phase

Increased air emissions from construction works

The CESMP is to include an air quality management chapter with:

- identification of all air emission sources including motorway construction activities, concrete and asphalt production facilities, sourcing and transport of construction materials, and other emissions generating facilities,
- identification of all types of emission from each source,
- details of mitigation measures for each source,
- specific location and schedule where such measures shall be implemented to minimise impacts to sensitive receptors due to the presence construction work (see Table 10-32 for details),
- monitoring and reporting.

Specific mitigation measures for air quality management shall include, but will not be limited to:

- for dust from construction activities, implement the schedule of active wetting of soil on the corridor when the unfavourable weather conditions are present (presence of wind, low humidity) and emission-intensive activities are taking place on the corridor according. Active wetting shall be performed according to the schedule given in Table 10-32.
- avoid overwatering as this may make the surrounding muddy,
- earthwork operation to be suspended when the wind speed exceeds 20 km/h in areas within 500 m of any community,
- ensure proper state of maintenance machinery and vehicles to minimise air emissions,
- smoke emitting vehicles and equipment shall not be allowed and shall be repaired or removed,
- undertake immediate repairs of any malfunctioning construction vehicles and equipment,
- use construction equipment and vehicles that meet national emission standards,

- wherever possible, use electrically powered equipment rather than gas or diesel-powered equipment,
- give priority to fuel efficient machinery,
- ensure that all diesel and petrol running machinery use equipped with catalytic convertors,
- position any stationary emission sources (e.g., portable diesel generators, compressors, etc.) as far as is practical from sensitive receptors,
- provide truck-washing facilities at tunnel portal and viaduct construction sites to prevent truck-out of mud and dust; above ground option is deemed to be the priority,
- rock crushing plant equipment shall be fitted with water sprinklers that will run while the plant is operational,
- if the sprinklers stop working, the plant shall also cease operation until the sprinklers are functioning,
- water run-off from the sprinkler system shall not discharge directly to environment without first passing through a silt trap or any other suitable device to prevent siltation of surface waters,
- emissions from on-road and off-road vehicles should comply with national or regional programs,
- regardless of the size or type of vehicle, owners and operators should implement the manufacturer recommended engine maintenance programs,
- drivers should be instructed on a routine basis by the Contractors Health and Safety Specialists on the benefits of driving practices that reduced both the risk of accidents and fuel consumption, including measured acceleration and driving within safe speed limits,
- implement a regular vehicle maintenance and repair program,
- conveyor belts (e.g. at batching plants and rock crushing plants) shall be fitted with windboards, and conveyor transfer points and hopper discharge areas shall be enclosed to minimize dust emissions,
- all trucks used for transporting materials to and from the site will be covered with canvas tarpaulins.

10.5.3 Operational phase

Mitigation and enhancement measures to address potential impacts on air quality leading to minor effects during the operational phase identified in Table 10-31 above are:

If measurement of standard air quality parameters show that values exceed maximum allowed values prescribed by national regulation, following protection measures must be undertaken:

- construction of barriers to prevent spreading the pollutants; best are wide leafed green plants,
- if this is not sufficient protection or these species cannot grow on the Project area, artificial barriers are also acceptable, e.g., noise barriers also prevent spread of air pollution, and their efficiency depends on their height (see Table 10-32 for details).

Table 10-32: Location on the route where mitigation strategies should be applied.

#	Section of the corridor					Mitigation strategy	Scenario for which the measures should be taken	Situations when mitigation strategy should be applied	Phase during which the measures should be taken
	Starting point		Ending point		Length [m]				
	Road mark [km]	Geographical indication	Road mark [km]	Geographical indication					
1	1+100	End of viaduct No. 2	1+800	Entrance to tunnel T-1	700	Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction
2	0+900	100m before viaduct No. 2	1+800	Entrance to tunnel T-1	900	Wetting of the soil	Windless	During the first 4 hours of activities, in case of dry, low humidity meteo conditions	Construction
3	3+800	End of tunnel T-2	5+400	Polje Bijela	1600	Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction
4	3+800	End of tunnel T-2	4+800	Polje Bijela	1100	Wetting of the soil	Windless	During the first 3 hours of activities, in case of dry, low humidity meteo conditions	Construction
5	24+750	End of tunnel T-4	25+450	Start of viaduct	700	Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction
6	29+150	Road Overpass Humilišani	30+000	Humilišani	850	Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction
7	30+900	Humilišani	31+900	Entrance to tunnel T-5	1000	Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction
8	34+750	End of tunnel T-5	35+100	Mostar North loop (end of the corridor)	350	Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction
9	Konjic Bypass Connecting Road – from km 0+000 to km 1+000					Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction

#	Section of the corridor					Mitigation strategy	Scenario for which the measures should be taken	Situations when mitigation strategy should be applied	Phase during which the measures should be taken
	Starting point		Ending point		Length [m]				
	Road mark [km]	Geographical indication	Road mark [km]	Geographical indication					
10	Konjic Bypass Connecting Road – from km 0+000 to km 1+000					Wetting of the soil	Windless	During the first 4 hours of activities, in case of dry, low humidity meteo conditions	Construction
11	Ovcari Interchange Connecting Road – from km 0+000 to km 0+400					Wetting of the soil	Wind	During the presence of northeast wind, low humidity meteo conditions	Construction
12	Ovcari Interchange Connecting Road – from km 0+000 to km 1+000					Wetting of the soil	Windless	During the first 4 hours of activities, in case of dry, low humidity meteo conditions	Construction
13	24+750	End of tunnel T-4	25+450	End of viaduct	700	Construction of barriers to prevent the spreading of air pollution	Wind and windless	Permanent presence of vertical solid road-side barriers of at least 3m height, on the right side of the motorway as close to the road surface as allowed	Operational
14	29+150	Road Overpass Humilisani	30+000	Humilisani	850	Construction of barriers to prevent the spreading of air pollution	Wind and windless	Permanent presence of vertical solid road-side barriers of at least 3m height, on the right side of the motorway as close to the road surface as allowed	Operational
15	30+900	Humilisani	32+400	Entrance to tunnel T-5	1500	Construction of barriers to prevent the spreading of air pollution	Wind and windless	Permanent presence of vertical solid road-side barriers of at least 3m height, on the right side of the motorway as close to the road surface as allowed	Operational