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Study of the impact of the waste pretreatment filter system and activated carbon filter within the waste-to-energy plant on the air quality of the wider location of the chemical industry complex in Prahovo

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1. INTRODUCTION

The purpose of this Study is to provide a representative assessment of the impact of the waste pretreatment filter system and activated carbon filter within the waste-to-energy plant, exclusively in the case when the boiler is not in operation, on the air quality of the wider location of the chemical industry complex in Prahovo. The assessment is based on the use of a computer-based dispersion model for the calculation of ground concentrations of pollutants in the area under consideration. In order to give a qualitative assessment of the contribution to the existing state of air quality, the results obtained by the mentioned model should be compared with the relevant national and international objectives for air quality.

For the purposes of this Study, the modeling was performed with the AERMOD software package using appropriate input parameters for the existing and future state of the plant.

This Study considered identified point and surface sources of emission and within them, depending on the scenario, the following pollutants: TVOC and PM10. The emission inventory, which was used for modeling purposes, was provided by the Client of the Study.

Given that the aim of air quality modeling, within this Study, is to provide a representative assessment of the impact of the facility in question on air quality in the considered model domain, other sources that do not belong to the chemical industry complex were not taken into account, nor was background pollution included in the presented modeling results. In addition, it should be noted that within the chemical industry complex in Prahovo there are emitters of the companies Elixir Prahovo and Phosphea, and that for the purposes of this Study, the point and surface emitters of both mentioned companies were considered in order to give the most representative assessment, considering that they represent the dominant sources of air pollution emissions in the domain under consideration. This approach gives the possibility of a clear perception of the future impact of the specific Project on air quality.

The results of the modeling, for the considered pollutant model, are graphically presented through spatial distributions of ground-level concentrations (isopleths) as maximum values obtained in accordance with the appropriate time periods of averaging.

2. MODEL DESCRIPTION

2.1 Models of pollutants spreading through the air

The concentration of a pollutant in a specific point or area depends on numerous variables, which include, among other things, emission values, distance from the source of pollution, as well as meteorological conditions.

In order to create the possibility of taking adequate preventive, spatial planning and environmental measures to protect air from excessive pollution, a system for monitoring air quality should be provided, with the aim of obtaining a precise image of air pollution on the territory of the observed area. In situations where there is no air quality measurement data from the field (at the design phase of new industrial facilities), mathematical modeling is used, that is, the simulation of processes in the atmosphere with the help of mathematical models. Atmospheric dispersion models of pollutants are used to determine the decrease in the concentration of pollutants in flue gas during the removal of the smoke plume from the source of emissions, and also to estimate their ground concentrations.

The dispersion model represents the mathematical expression of the influence of atmospheric processes on pollutants in the atmosphere. Atmospheric conditions (which include wind speed and direction, air temperature and mixing height) are simulated using dispersion models, and pollutant concentrations are estimated as they move away from the emitter. With the inclusion of atmospheric chemistry, these models can also generate estimated values of the concentration of pollutants produced in secondary reactions. Dispersion models can be used in assessment cases when determining the negative impact of a new source of pollution in an area, as well as in cases where the air quality can be positively influenced by the application of some measures. Therefore, dispersion models are used when it is necessary to give an estimate of the concentration of pollutants in the ambient air for the purposes of assessing the impact of a new emitter or in cases of verification of the implementation of mitigation measures on existing facilities. Existing dispersion models vary in complexity. For most models, as minimum input data, it is necessary to provide meteorological data, data on emissions, as well as certain data on the emitter (stack height, flue gas velocity in the emitter, etc.). For some more complex dispersion models, it is necessary to provide data on the topography of the terrain, more detailed data on pollutants as well as data on the characteristics of the soil in the model domain. As a result of the use of these models, the concentrations of the considered pollutants in a certain area are obtained, which is of interest for the assessment of ambient air quality and depends on the type of model used.

The models are more reliable for estimating average concentrations over longer periods of time than over shorter ones, for a specific location. They are reasonably reliable for estimating the value of the highest pollutant concentration that occurs somewhere at some time within the observed area. In general, modeling requires three types of information:

- on the source of emissions,
- on the meteorology of the area under observation, and
- about receptors (terrain characteristics).

2.2 Gaussian dispersion models

In methodological research and practice, Gaussian diffusion models are most often encountered. First of all, it should be stressed that this Gaussian model is quite empirical. These are the models that are most often applied in practice. The main reasons in favor of the application of these models are, first of all, the simplicity of their application as well as a relatively good match with physical experiments. Gaussian models are based on the assumption that the distribution of the concentration of a passive substance in the smoke plume has a certain mathematical form, so they contain the Gaussian diffusion equation, which, in fact, represents the solution of the Fick's diffusion equation with constant coefficients. The basis of the Gaussian model of the smoke plume is the following equation:

$$C(x,y,z)=\frac{Q}{2\pi u\sigma_y\sigma_z}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left\{\exp\left(-\frac{\left(z-H^2\right)}{2\sigma_z^2}\right)+\exp\left(-\frac{\left(z+H^2\right)}{2\sigma_z^2}\right)\right\}$$

Where:

$C(x,y,z)$	- Pollutant concentration at point (x,y,z) $\left[g/m^3\right]$
Q	- Mass flow of the pollutant at the emitter $\left[g/s\right]$
u	- Wind speed $\left[m/s\right]$
σ_y,σ_z	- Standard deviations of the smoke plume cross section $\left[m\right]$
H	- Effective stack height $\left[m\right]$
x	- Distance from the source, in the direction of the wind $\left[m\right]$
y	- Horizontal distance from the centerline of the smoke plume $\left[m\right]$
z	- Distance from the ground $\left[m\right]$

Figure 2.1 shows a schematic representation for easier understanding of the principles on which Gaussian models function, i.e. the coordinate system used in them. In these models, the discharge itself, i.e. the emitter is assumed to be the coordinate origin, while the calculation of the concentration and the spread of the smoke plume is observed in the *x*, *y* and *z* directions.

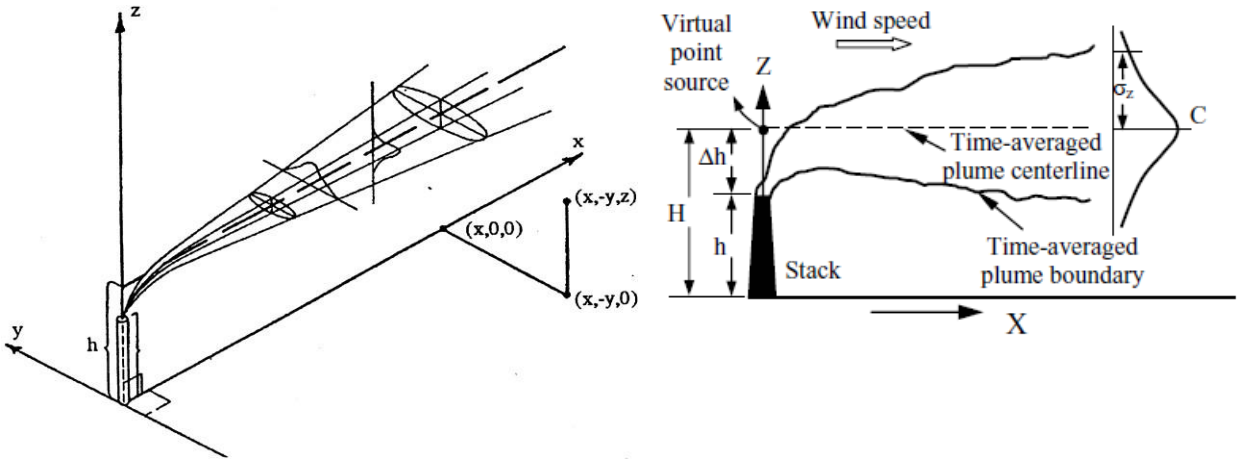


Figure 2.1 Layout of the coordinate system with Gaussian distribution in horizontal and vertical directions

H is the effective height of the stack (taking into account the additional height Δh, to which the plume of smoke rises above the physical height of the stack h, ie. $H = h + \Delta h$), while σ_y and σ_z are parameters of the normal distribution in the y and z directions, i.e. dispersion coefficients in y and z directions.

The Gaussian equation implies that the smoke plume spreads according to the Gaussian distribution principle in the horizontal and vertical planes. The standard deviation of the distribution of pollutant concentrations in the smoke plume in the horizontal (transverse) plane is denoted by *sigma y* (σ_y) and the corresponding distribution of concentration in the vertical plane is denoted by *sigma z* (σ_z). As already noted, these are called dispersion or diffusion coefficients.The values of the diffusion coefficients vary depending on the height above the ground, roughness of the ground, wind speed and distance from the emitter. The values of the diffusion coefficients are usually determined on the basis of the stability classes of the atmosphere.

The model introduces the following assumptions:
1. Emission value is constant;
2. Dispersion (diffusion) in the direction (x) of the wind is negligible;
3. Meteorological conditions in the horizontal plane are constant throughout the model domain. For each modeled hour:
   a. The average value of wind speed is used.
   b. The wind direction is constant.
   c. The temperature is constant.
   d. The atmospheric stability class of the atmosphere is constant.
   e. The mixing height is constant.
4. There is no change in the vertical gradient of the wind speed.
5. The characteristics of the smoke plume are finite (the smoke plume is independent for each hour, and values originating from the previous hour have no effect on its characteristics).

6. Pollutants are considered as inert gases or aerosols that remain suspended in the air and follow turbulent atmospheric movements.
7. Dispersion in the transverse (*y* direction) and vertical (*z* direction) takes place in the form of a Gaussian distribution around the center line of the smoke plume.

2.3 Description of the model used in the Study

In order to analyze the impact of the waste pretreatment filter system and activated carbon filter within the waste-to-energy plant on the air quality of the wider location of the chemical industry complex in Prahovo, the software package AERMOD was used, i.e. a model based on the Gaussian distribution and recommended by by the EPA (U.S. Environmental Protection Agency). AERMOD includes a wide range of capabilities for modeling the impact of pollutants on air pollution. The mentioned model provides the possibility of modeling a number of pollution sources, including point, line, surface and volume sources. The model contains algorithms for the analysis of aerodynamic flow in the vicinity of and around buildings (*building downwash*). The values of emissions of polluting substances from the source can be treated as constant during the analysis period, or they can vary during the month, the observed period, the hour or some optional time of occurrence of changes.

The results shown in this Study were achieved using a model that included emissions of particulate matter (shown as PM10) and TVOC. Namely, this Study considers the case when the boiler plant ceases to operate, and the waste pretreatment system, with the associated emitter and filter system, continues to operate for a shorter period of time, which is no longer than a few hours. Since only the mentioned pollutants can be expected from the mentioned emitter, they were taken into consideration. Particulate matters are shown as PM10, considering that for PM 2.5 neither national nor EU legislation prescribes limit values for air quality for an averaging time period of less than one calendar year. According to the Decree on the conditions for monitoring and air quality requirements ("Official Gazette of the Republic of Serbia", No. 11/10, 75/10 and 63/13), the shortest averaging period for PM10 is one day, which is also unjustified from the time aspect of possible operation of the waste pretreatment system after the shutdown of the boiler plant, but this was taken as a conservative scenario. During modeling, other emission sources outside the chemical industry complex were not considered, nor was background pollution included.

AERMOD is a stationary plume model, which starts from the assumption that in a stable boundary layer, the concentration of pollutant in both vertical and horizontal directions can be described by a Gaussian distribution. In the convective boundary layer, in the horizontal direction it is assumed that the concentration of the pollutant takes a Gaussian distribution, while the vertical distribution is described with a bi-Gaussian probability density function. Additionally, AERMOD considers "plum-lofting" in the convective boundary layer, where part of the smoke plume mass, released from the lift source, rises and remains near the top of the boundary layer before mixing in the convective boundary layer. AERMOD also tracks any smoke plume mass that penetrates the elevated stable

layer and then allows it to repenetrate the boundary layer when and if possible.

Figure 2.2 shows the information flow and processing in the AERMOD software package. The model consists of a main program (AERMOD) and two pre-processors (AERMET and AERMAP).

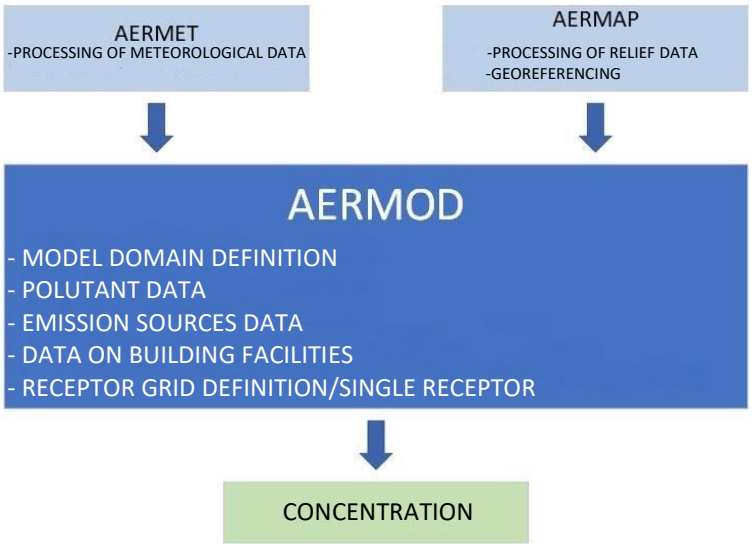


Figure 2.2 Information flow and processing in the AERMOD software package

The main purpose of the AERMET pre-processor is to, based on representative meteorological measurements on the model domain, determine the boundary layer parameters that are used to estimate the wind, turbulence and temperature profiles for the model's needs. The parameters of the surface layer provided by AERMET are Monin-Obukhov length, surface friction velocity, surface roughness, surface heat flux and convection velocity. AERMET also provides estimates of convective and mechanical mixed layer heights.

Although AERMOD has the ability to estimate meteorological profiles with measurement data from only one height, it will use as much data as the user can provide to define the vertical boundary layer structure.

As it is very difficult to represent the real terrain as a set of idealized terrain features and associate it with each receptor, AERMAP (terrain pre-processor for AERMOD), operates from the receptor's point of view and takes into account the terrain features around each receptor to objectively determine the representative terrain height associated with a specific receptor. The AERMAP terrain pre-processor uses terrain data to calculate terrain height effects. The terrain height is uniquely defined for each receptor at a site and is used to calculate the streamline height. The data grid required for AERMAP is obtained from the DEM model (Digital Elevation Model). AERMAP is also used to create the receptor grid. Through AERMAP, an altitude is automatically assigned to each receptor.

AERMAP defines the input data for each receptor to AERMOD: the location of the receptor, its elevation, and the specific elevation scale of the receptor's terrain.

The emission modeling procedure included the following stages:
1. Creation of plant plan, including sources and facilities;
2. Defining the domain of the model and the location of the receptor;
3. Creation of emission inventory of all monitored emitters;
4. Characterization of the type of sources;
5. Entry and analysis of data on buildings;
6. Processing necessary meteorological data;
7. Processing of terrain data;
8. Modeling and analysis of results.

2.4 Terrain data

AERMOD includes significant flexibility in specifying receptor location. The user has the possibility of specifying a complex grid of receptors in the analysis, where a combination of *Cartesian* and polar receptor grids is also possible. During modeling, AERMOD takes into account the topography of the terrain as well as the height of the receptors in relation to the existing terrain. Terrain elevation data is key to characterizing the variability of terrain, sources, buildings, and receptor elevations in the model domain. Terrain elevations affect emissions concentrations by moving the bisector of the plume closer to or farther from the receptor. Computer models accept a digital data file from which elevation data can be interpolated. During model development, Digital Elevation Model (DEM) data was entered into AERMOD, which assigned elevations to receptors, sources and buildings.
During modeling for the needs of this Study, NASA digital maps SRTM1 - Shuttle Radar Topography Mission (resolution ~30m, 1 arc-sec) processed by AERMAP were used (Figure 2.3).

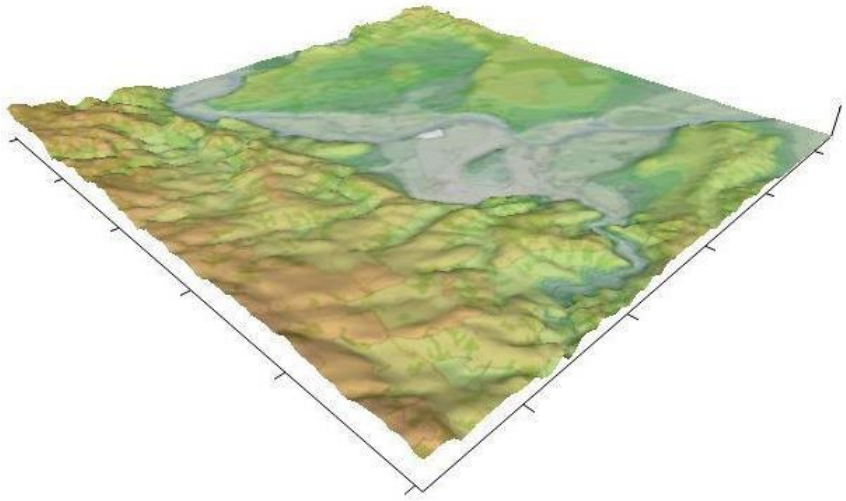


Figure 2.3 Overview of Processed 3D Model Domain Terrain

It was necessary to define terrain elevations, as well as locations and intervals between receptors and facilities based on the Universal Transverse Mercator – UTM coordinate system. Receptors are usually positioned on a coordinate grid (grid), as well as on some specific locations (*discrete*). A grid of receptors covers a large area, while individual receptors can be defined as objects of special interest (eg a school, hospital or nearest neighboring property).

The modeling for the purposes of this Study covered an impact zone of 50 km x 50 km, that is, an area of 2500 km^2 (Figure 2.4). When creating the model, a **Cartesian coordinate system was used with a variable distance (Multi-Tier Grid)** between adjacent points (receptors), as follows:

20 m…at a distance of up to 3000 m from the emitter,
100 m…at a distance of up to 5000 m from the emitter,
250 m…at a distance of up to 10000 m from the emitter,
1000 m…at a distance of up to 25000 m from the emitter,

which makes a total of 104121 receptors, which are defined by x and y coordinates expressed in meters and in the Cartesian coordinate system.

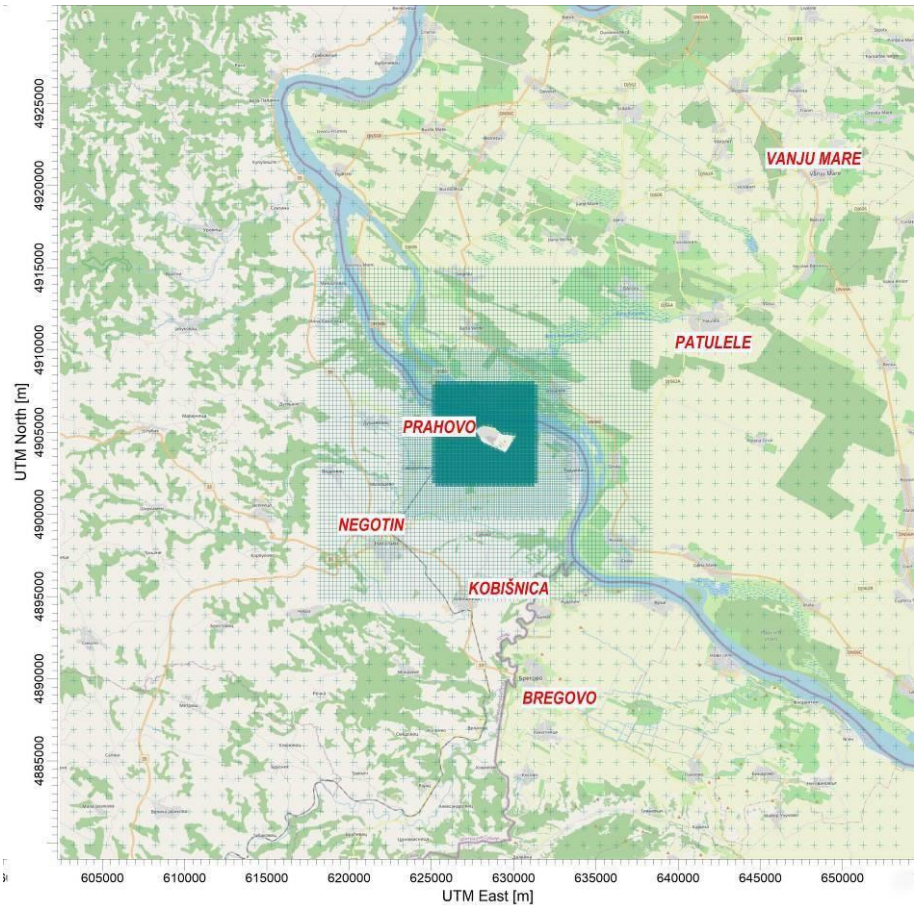


Figure 2.4 Display of 2D model domain terrain and UTM coordinate system

2.5 Meteorological data

AERMET, a meteorological pre-processor, prepares hourly values of surface and upper atmosphere data for use in AERMOD. The input data in AERMET are data on surface observations of hourly values of surface level parameters, which include, among others, wind speed, temperature and cloudiness, while a file containing data on the upper layers of the atmosphere provides information on the vertical structure of the atmosphere. This includes layer height, pressure, temperature, and relative humidity.
Meteorological data used for the preparation of this Study include hourly values of the following parameters:

- Wind speed,
- Wind direction,
- Air temperature,
- Relative air humidity,
- Atmospheric pressure,
- Cloudiness.

With the aim of defining local prevailing meteorological parameters, WRF-MMIF hourly meteorological data for a specific location (Prahovo Chemical Complex) and for a time period of five consecutive calendar years (from 2017 to 2021) were acquired from the company *Lakes Environmental Consultants* from Canada. This data set consists of information about the surface and upper layers of the atmosphere, which are needed to run the dispersion model. Figures 2.5-2.10 show the wind rose analysis (wind blowing direction) and the wind blowing frequency analysis, based on meteorological data for the period 2017-2021.

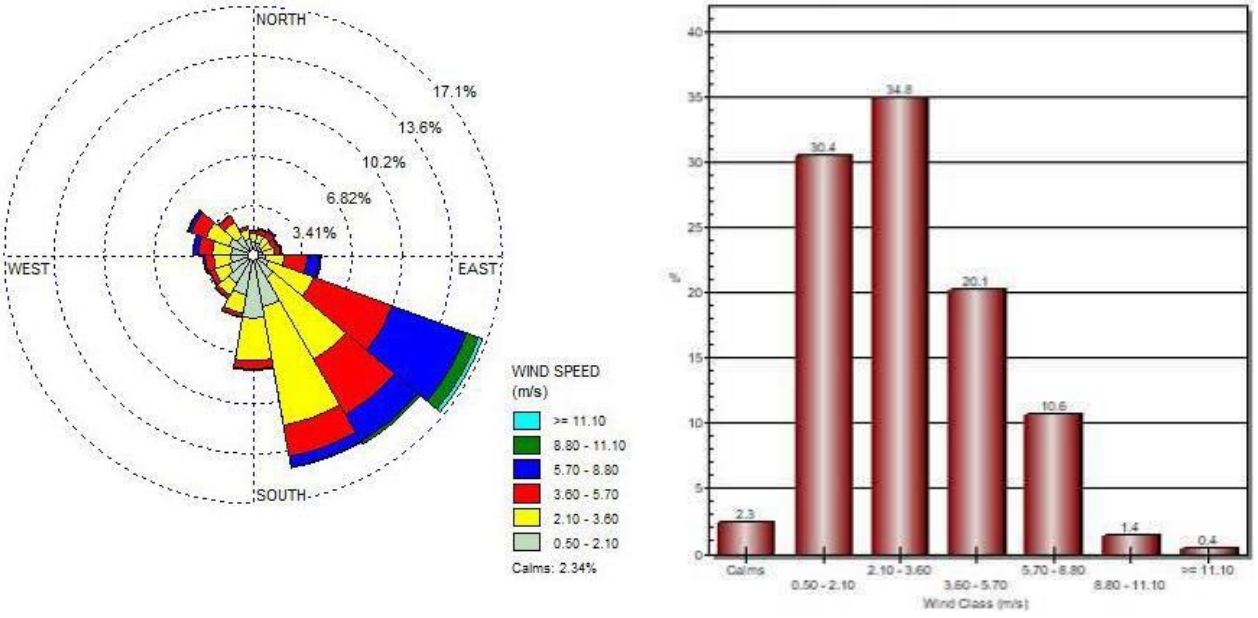


Figure 2.5 Wind rose and frequency chart for 2017-2021

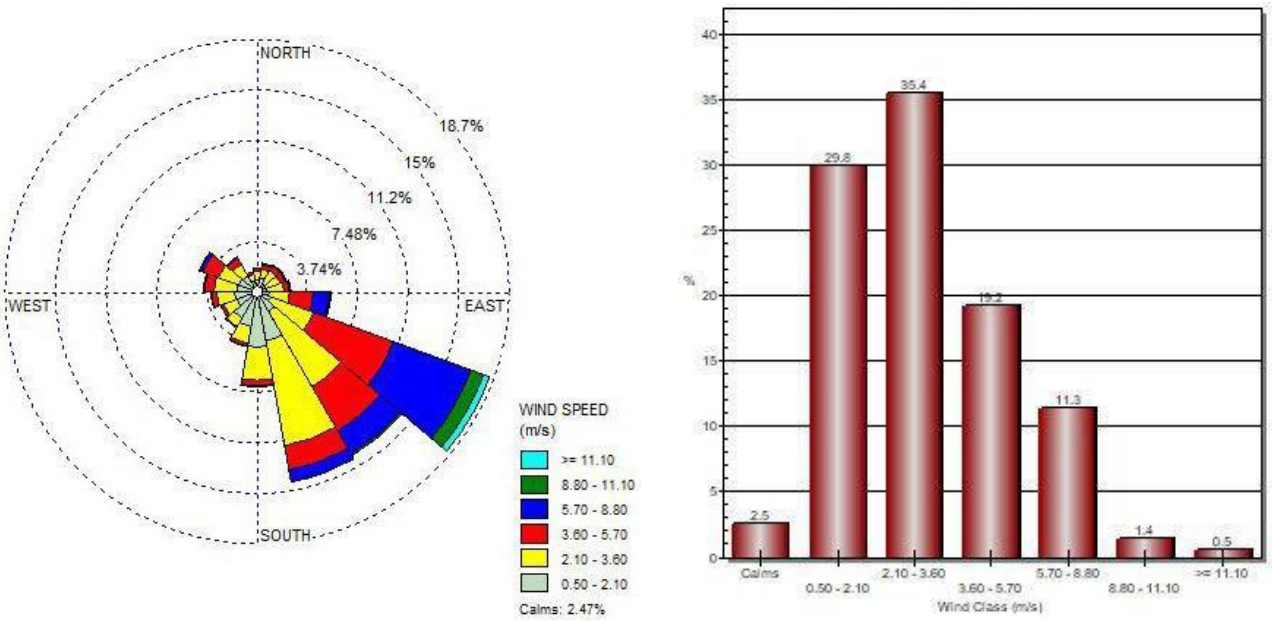


Figure 2.6 Wind rose and frequency chart for 2017

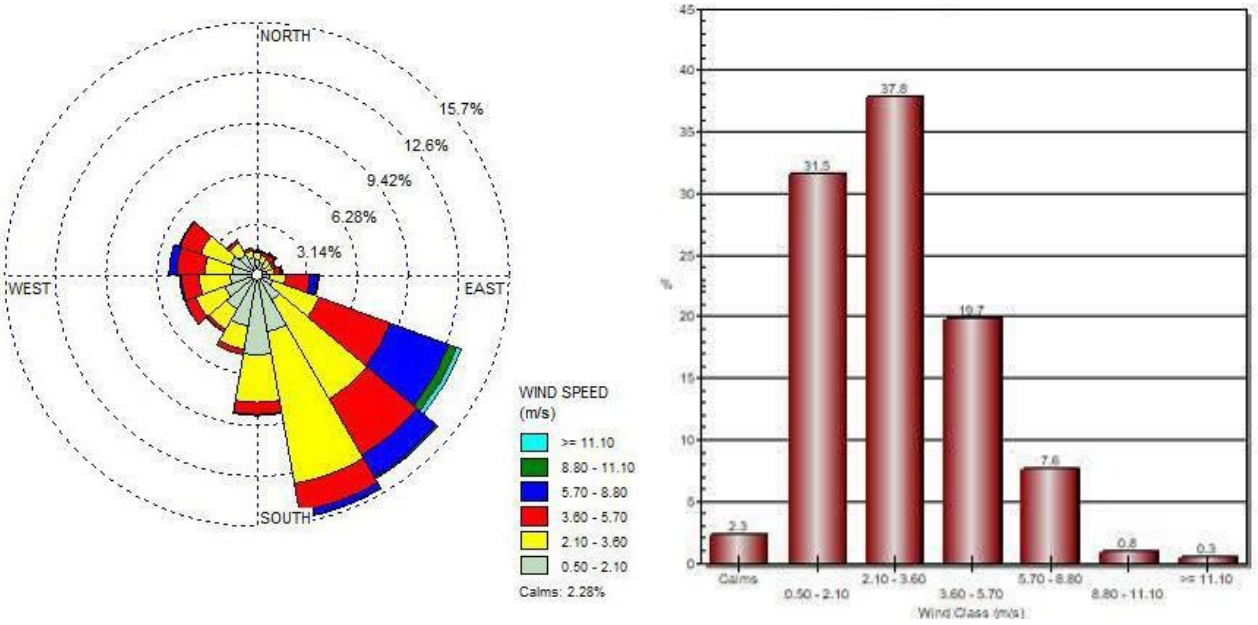


Figure 2.7 Wind rose and frequency chart for 2018.

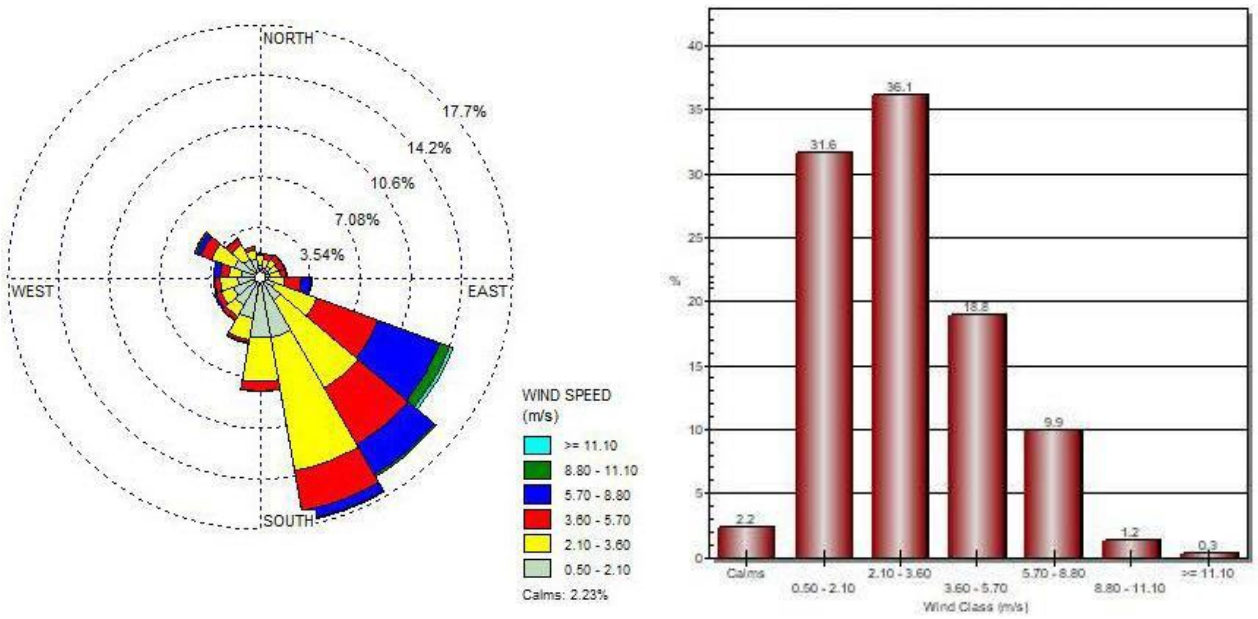


Figure 2.8 Wind rose and frequency chart for 2019.

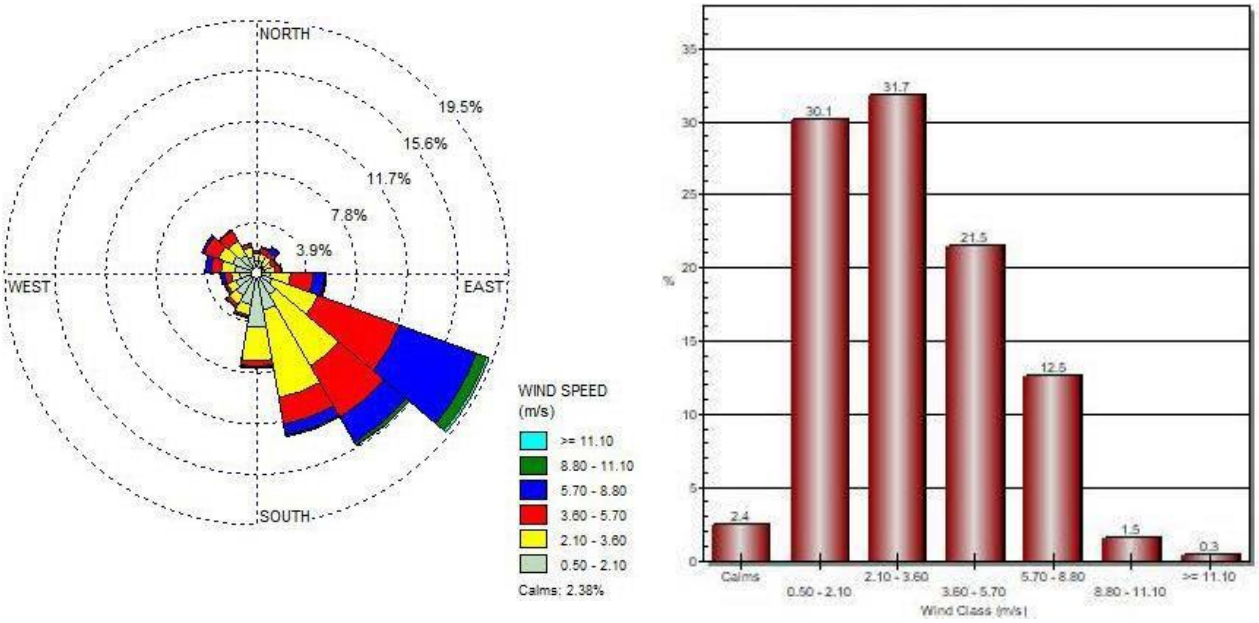


Figure 2.9 Wind rose and frequency chart for 2020.

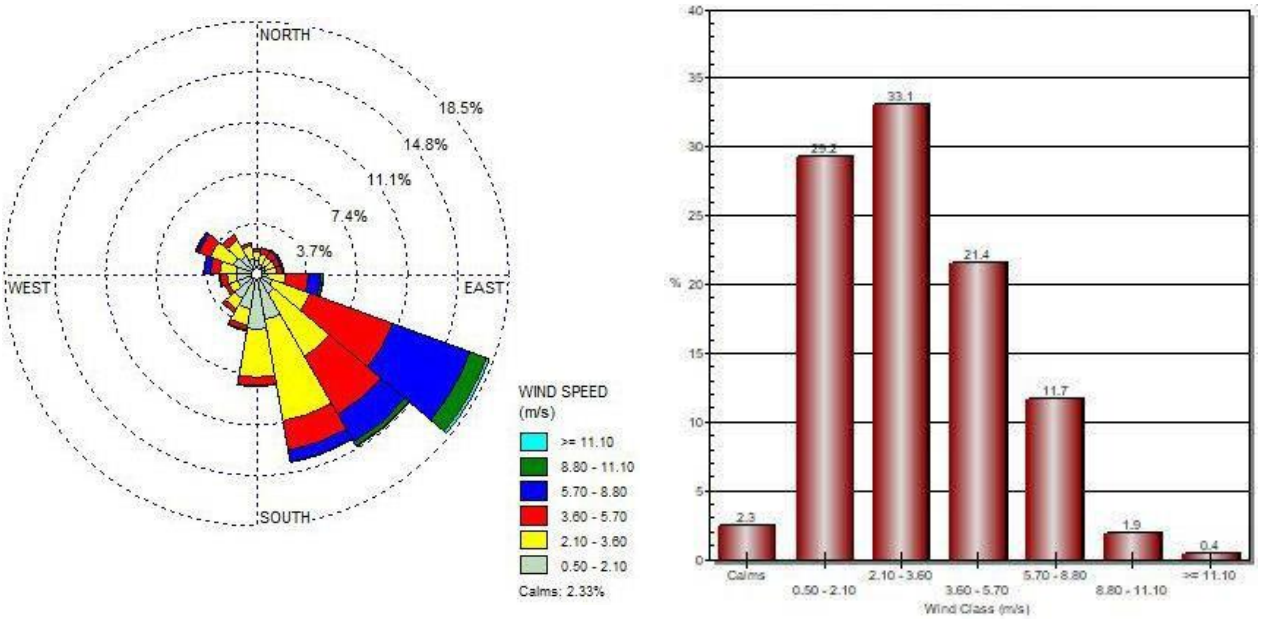


Figure 2.10 Wind rose and frequency chart for 2021.

2.6 Characteristics of sources

Appendix I of this Study provides data on emission sources for the case when the waste-to-energy plant operates according to the design parameters of normal operation and for the case when the boiler plant ceases to operate, because both cases were used as input parameters for the model.

The operating time of each project activity is also of great importance for an adequate assessment of the impact of the subject plant on air quality. During the creation of the model, in order to model the most unfavorable conditions, the assumption was introduced that during normal operation of the plant, all point sources emit 24 hours, 365 days a year at full capacity, which is certainly not the case. As a result, the expected ground concentrations of pollutants in the observed area, i.e. the results obtained by the model, are higher than the real values. When it comes to surface sources of emissions, i.e. phosphogypsum storage and non-hazardous waste landfill, they are dependent on the wind speed, as shown in Appendix I of this Study. Considering the characteristics of the solidificate that is being deposited, the expected emissions of particle matter from the non-hazardous waste landfill will be practically negligible, and they may eventually come from limited areas in combination with cracking of the solidificate surface layer, due to the movement of trucks over the landfill and strong winds. A very conservative case was considered for modeling purposes, which implies a 95% reduction in spreading and that aeolian erosion occurs from the entire surface of the landfill over which machinery can move at the moment of opening Phase 2 of landfilling. Considering these introduced assumptions, the results of particle matter dispersion modeling from the non-hazardous waste landfill are expected to be certainly higher than the real ones.

Considering the projected evacuation of waste gases during the regular operation of the plant, only particle matter emissions can be expected from the emitters of the waste pre-treatment filter system and activated carbon filters, while TVOC emissions can also be expected from this emitter when the boiler plant is not in operation.

When modeling, it is also necessary to take into account the construction facilities on the location, given that their dimensions can greatly affect the dispersion of polluting substances. *Building Downwash* is a phenomenon that occurs when buildings or structures are located in such a way that they represent obstacles in the path of the smoke plume. In this case, the streamlines will rise from the building on the windward side, and descend down the leeward side. Immediately behind the building, frictional resistance and a decrease in movement speed appear, which results in the inverse movement of streamlines at ground level, creating recirculation - a region of hollow. As the distance from the building increases, turbulence decreases.

It is necessary to have the following data on objects in the vicinity of the emitter in order to successfully take into account the possible occurrence of the *downwash effect*:

- geographic coordinates of the observed objects,
- orientation of objects in relation to emitters,
- characteristic dimensions of objects.

For the needs of this Study, also using AERMOD, a 3D model of the chemical industry complex was developed. This model includes only objects significant for dispersion modeling, i.e. objects where a *downwash effect* may occur. Figure 2.11 shows a 3D model of the most significant construction buildings for the future state of the chemical industry complex, with all sources of emissions considered in this Study.

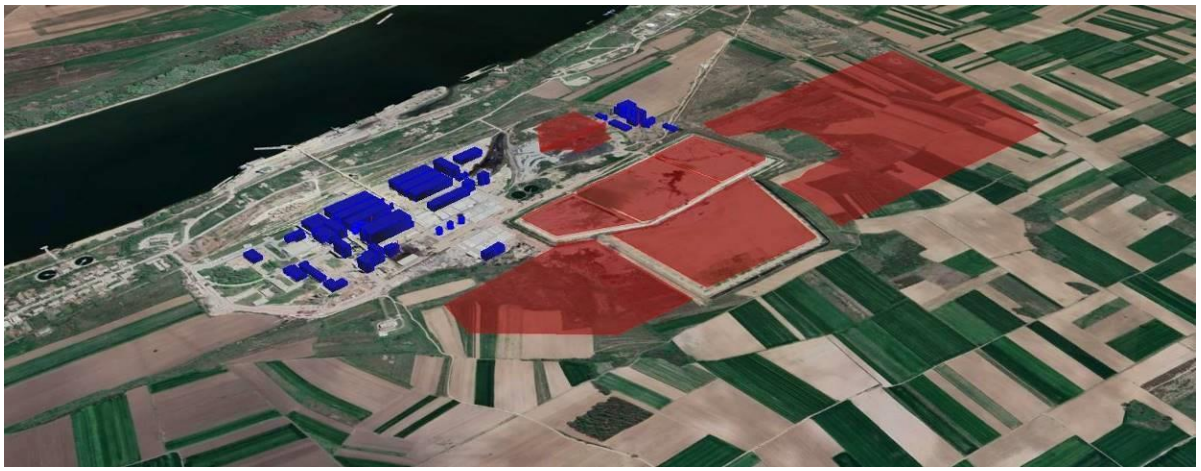


Figure 2.11 3D model of the chemical industry complex in Prahovo, future state

2.7 Requirements for air quality

In order to give an assessment of the impact of the operation of a facility on air quality, it is necessary to compare the results obtained by modeling with the corresponding requirements for air quality that are prescribed by national legislation. The Decree on the conditions for monitoring and air quality requirements ("Official Gazette of the Republic of Serbia", No. 11/10, 75/10 and 63/13) represents the basic national regulation for defining air quality, according to which the limit value for PM10 for the smallest averaging period of one day is 50 μg/m^3. Limit values for TVOC are not defined in the aforementioned Decree, as well as in international legislation. In order to give at least an estimate of the order of magnitude of the obtained results, we state the limit value of 400 μg/m^3, which refers to indoor air quality and which is prescribed by the Ministry of Health of Japan[1].

3. RESULTS

Considering that in this Study, the models do not include background pollution, the results obtained by this modeling do not represent the air quality in the area of the model domain, but only the contribution of the represented emitters of the subject plant to the overall air quality. The results of this Study, which are given in the form of graphical presentations of ground concentrations of pollutants (isopleths), are shown in accordance with the defined method of presentation and averaging periods, as well as the aforementioned legislation.

It should be borne in mind that the results presented in this Study represent the highest possible ground concentrations of the considered pollutants, which are the result of the most unfavorable operating parameters and the most unfavorable meteorological conditions during the given averaging period (1/3/24 hours) during five consecutive years (from 2017 until 2021). Namely, the potential highest concentration for each of the receptors is shown for the corresponding averaging period over a period of five years. Annual concentrations are shown on the basis of the average for the total number of hours.

PM 10 concentration values obtained

Figure 3.12 shows isopleths of PM10 ground level concentrations, in the case when the boiler plant is not operating, which refer to the first maximum of possible PM10 concentration values for the averaging period of one day, where the maximum observed concentration is 97.76 μg/m³, which is far above the limit value of 50 μg/m³. This concentration, as well as the zone with the greatest impact for this averaging period, is located along the eastern part of the future phosphogypsum landfill, i.e. the south-eastern border of the factory property. Zones with high PM10 concentrations of over 50 μg/m³ are a direct consequence of a combination of certain meteorological conditions and, above all, a consequence of the presence of a phosphogypsum landfill. Other parts of the model domain are far below the limit value.

[1] https://www.nihs.go.jp/mhlw/chemical/situnai/kentoukai/rep-eng2.pdf

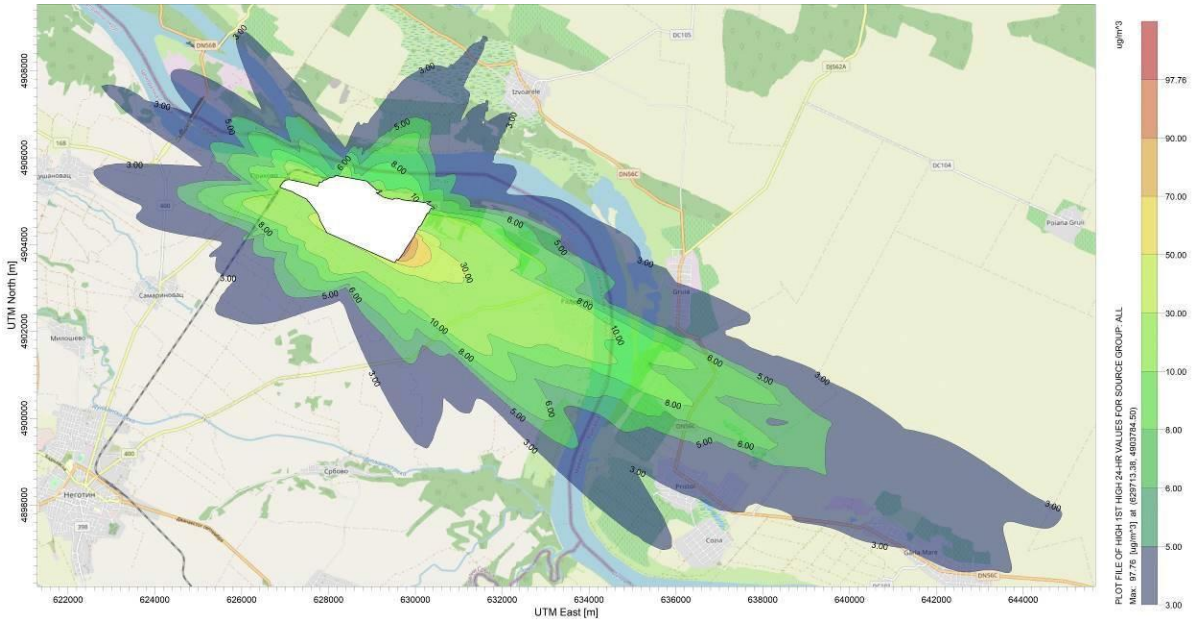


Figure 3.12 Maximum ground-level PM10 concentrations for a one-day averaging period [μg/m^3]

In order to additionally present the impact of the future plant for the thermal treatment of waste materials on the ground-level PM10 concentration, modeling was carried out where only sources related to this plant were taken into consideration, i.e. the case when the boiler plant is not in operation was considered, which implies waste pretreatment and solidification emitters as well as solidificate landfill. The modeling results, shown in Figure 3.13, indicate that in that case the total impact of the waste thermal treatment plant will be almost negligible (the maximum value obtained is 4,12 μg/m^3).

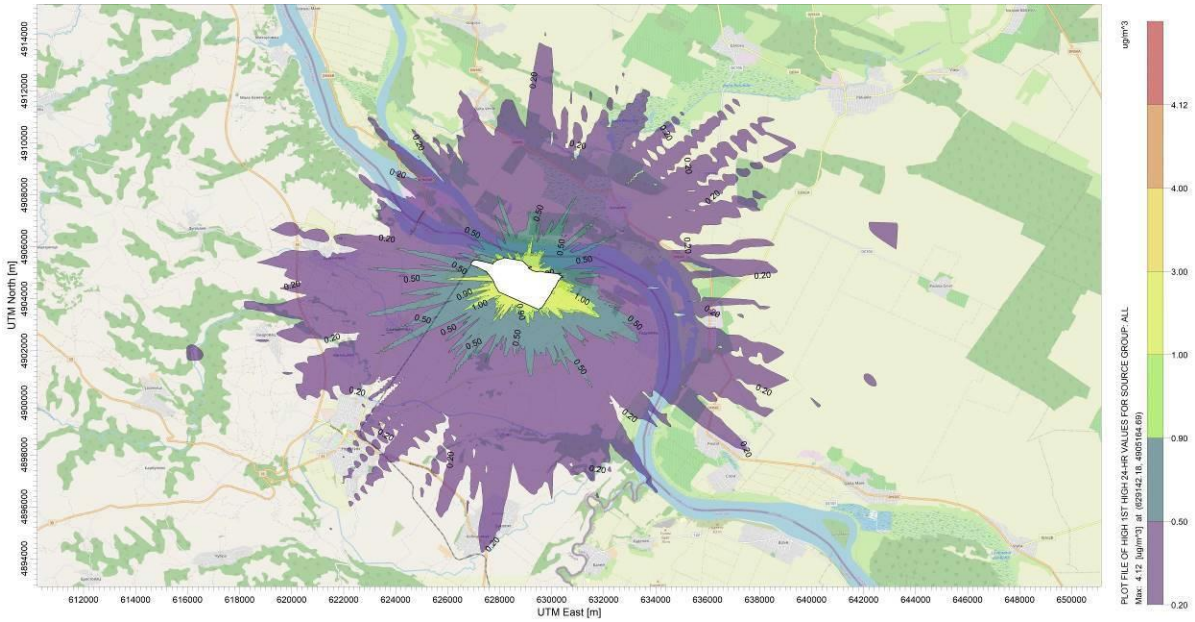


Figure 3.13 Maximum ground-level PM10 concentrations for a one-day averaging period [μg/m^3]

Considering the modeling results presented in the *Study of Plant for energy utilization of waste and landfill of non-hazardous waste impact on air quality of the wider location of the chemical industry complex in Prahovo*, where the waste-to-energy plant was considered during normal operation with the boiler plant (Figure 3.14). , it can be clearly seen that there is practically no difference in the obtained results when the first maxima of the daily averages are in question, which further indicates the dominance of the phosphogypsum landfill as well as the existing point emitters of the chemical complex (Figure 3.12), i.e. the emitters of waste pretreatment and solidification (Figure 3.13) as potential air pollutants.

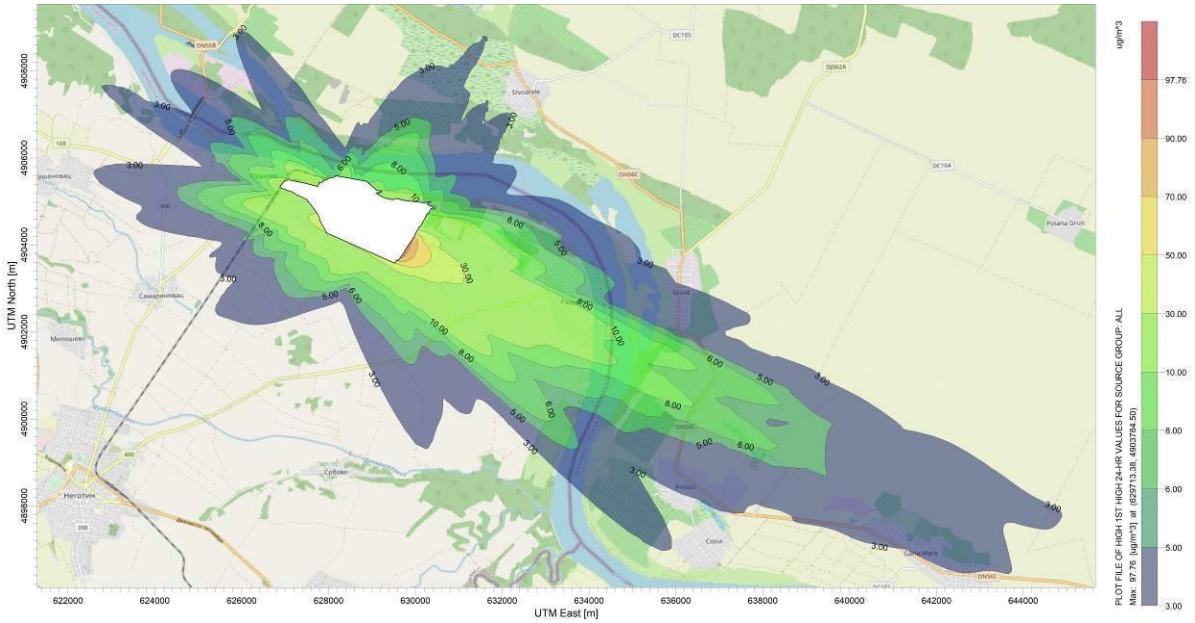


Figure 3.14 Maximum ground-level PM10 concentrations for a one-day averaging period – case when boiler plant is operating [μg/m^3]

Everything presented so far leads to the conclusion that the emitter of the boiler plant itself has a negligible impact in terms of PM10 concentration, due to its physical characteristics, primarily its height, which is almost three times higher than the mentioned two emitters, as well as due to the process characteristics of the flue gas.

TVOC concentration values obtained

Figures 3.15 – 3.19 present the modeling results for TVOC in the case when the boiler plant is not in operation, that is, when this pollutant is emitted from the emitter of the waste pretreatment plant. The highest TVOC concentrations obtained by modeling, for averaging periods of 1h, 3h and 24h, can be observed immediately next to the northern border of the property and were 109 μg/m³, 36.9 μg/m³ and 5.59 μg/m³, respectively. Considering the indicated limit value (400 μg/m³) for TVOC concentration in indoor air, it can be concluded that the values obtained by the model are far below the specified limit.

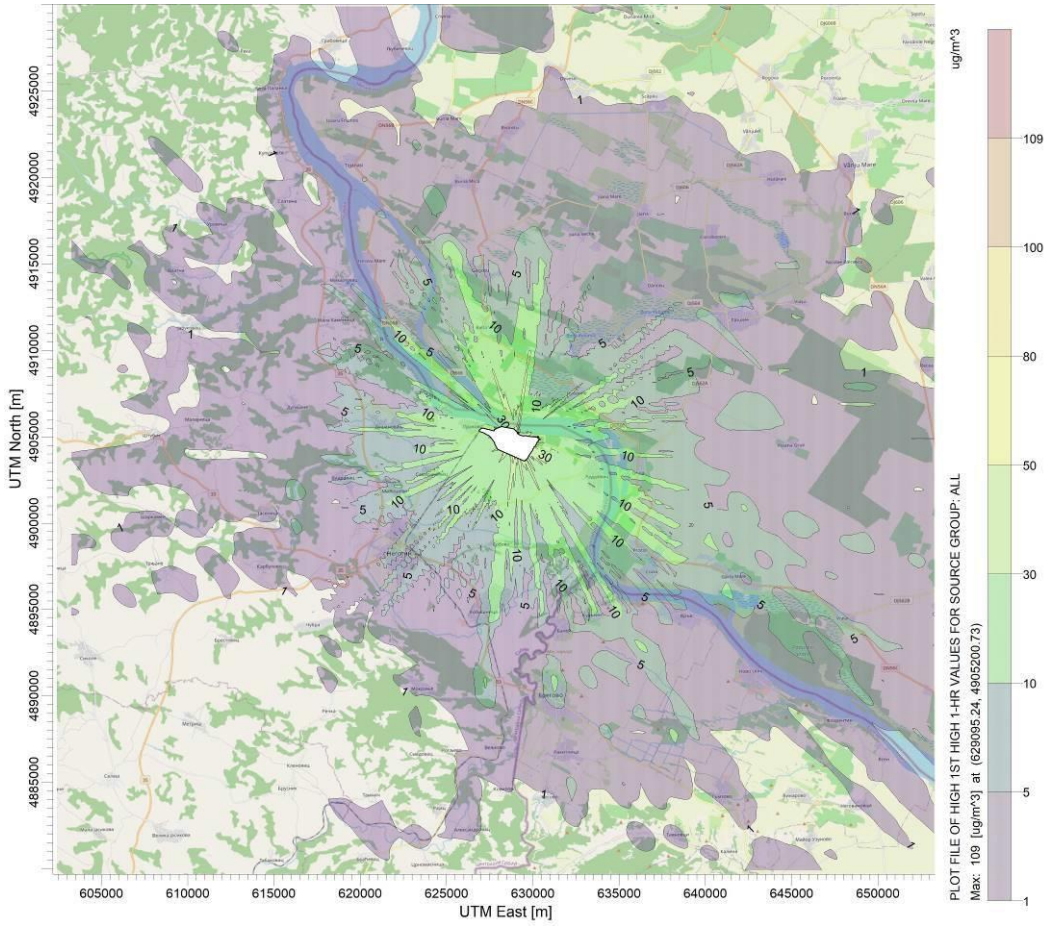


Figure 3.15 Maximum ground-level TVOC concentrations (first maximum) for a one-hour averaging period [μg/m^3]

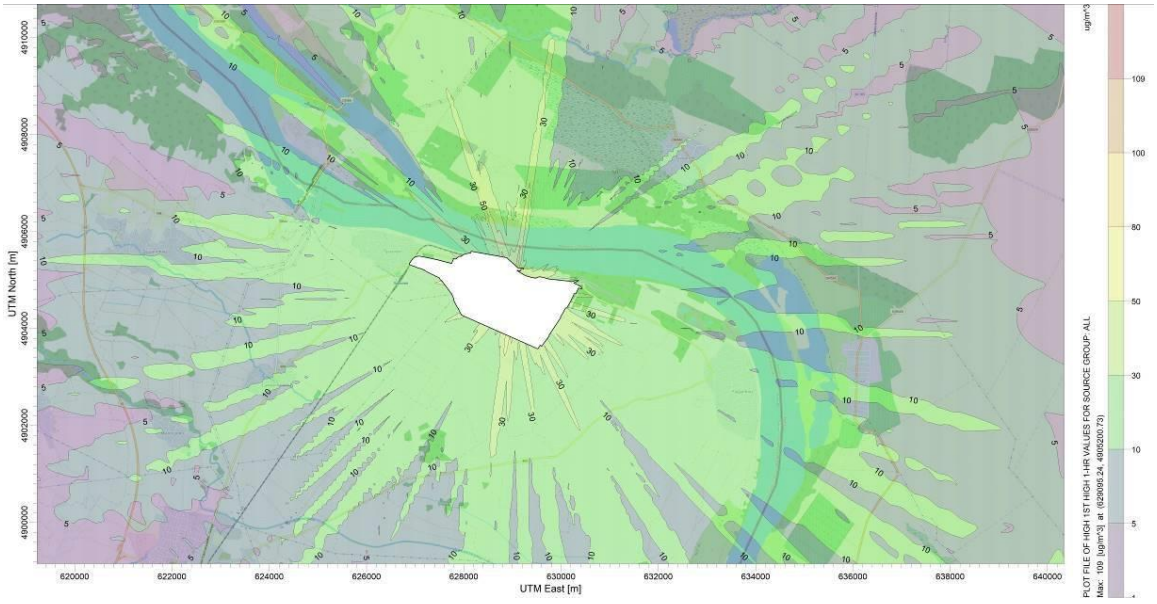


Figure 3.16 Maximum ground-level TVOC concentrations (first maximum) for a one-hour averaging period [μg/m^3] (presentation of the narrow location of the plant)

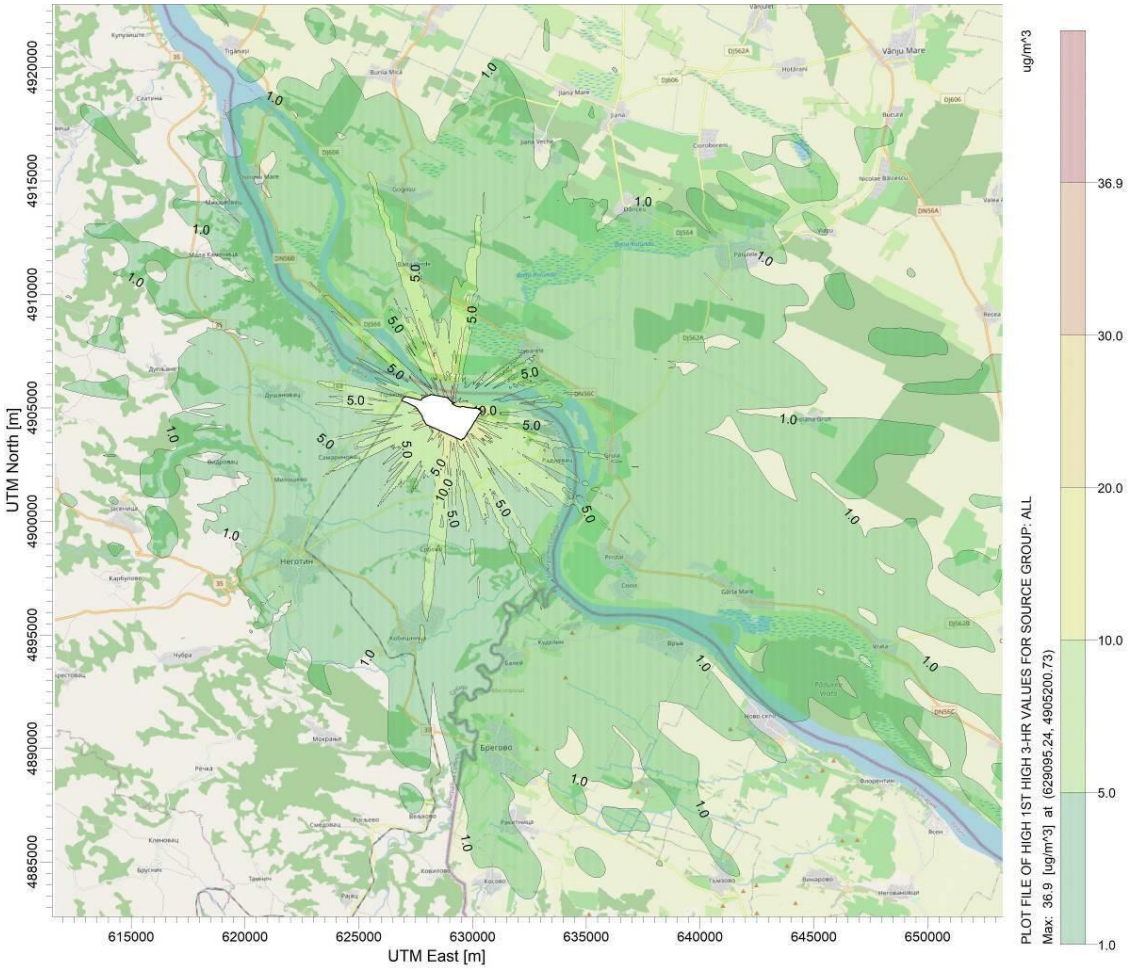


Figure 3.17 Maximum ground-level 3-hour daily TVOC concentrations [μg/m^3]

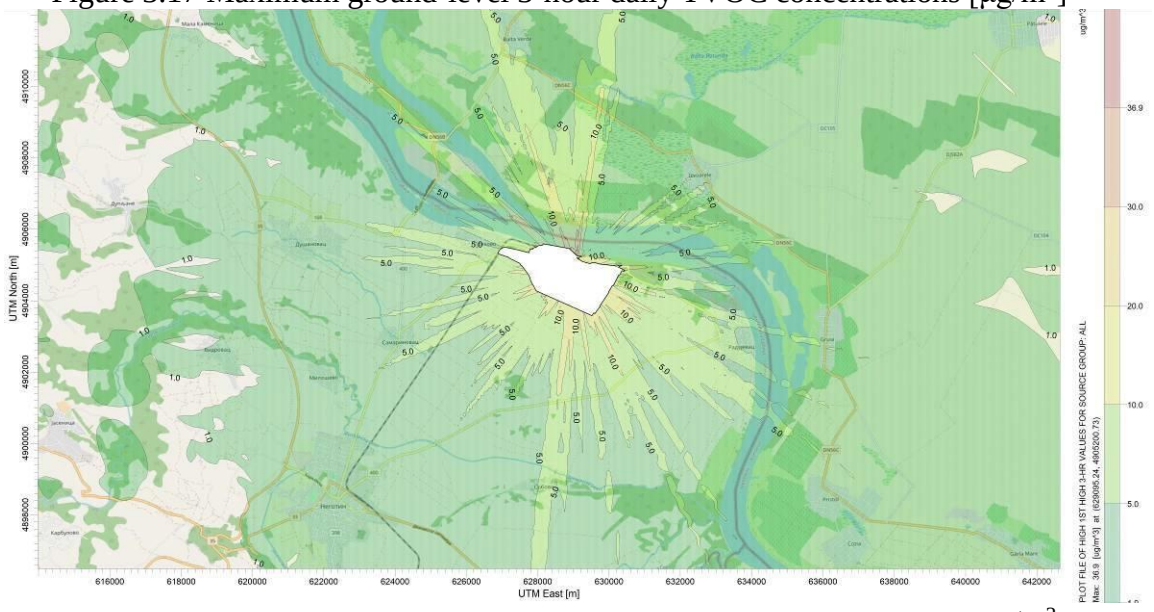


Figure 3.18 Maximum ground-level 3-hour daily TVOC concentrations [μg/m^3]
(presentation of the narrow location of the plant)

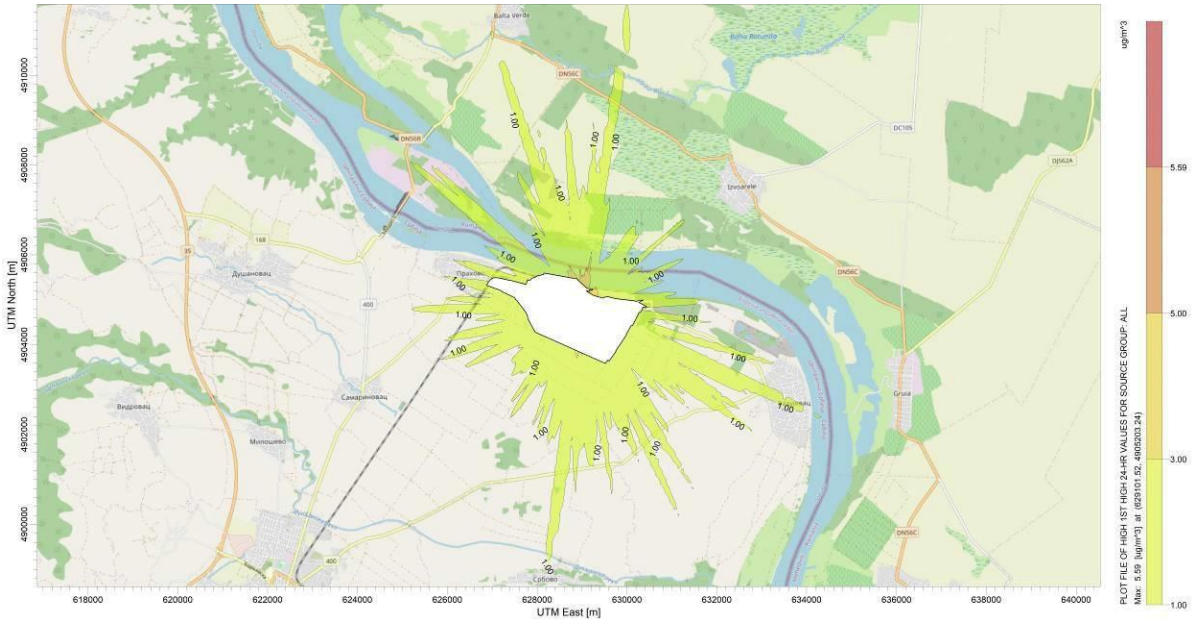


Figure 3.19 Maximum ground-level TVOC concentrations for a one-day averaging period [μg/m^3]

Given that during the regular operation of the waste-to-energy plant, it can be expected that TVOC will be emitted from the emitter of the boiler plant, modeling was also carried out for the scenario of regular operation of the plant.. Figures 3.20 - 3.22 show the results of the first maxima for the averaging periods of 1h, 3h and 24h. The highest TVOC concentrations obtained by modeling are 2.32 μg/m³, 1.38 μg/m³ and 0.68 μg/m³, respectively. Considering the indicated limit value (400 μg/m³) for TVOC concentration in indoor air, it can be concluded that the values obtained by the model are practically negligible.

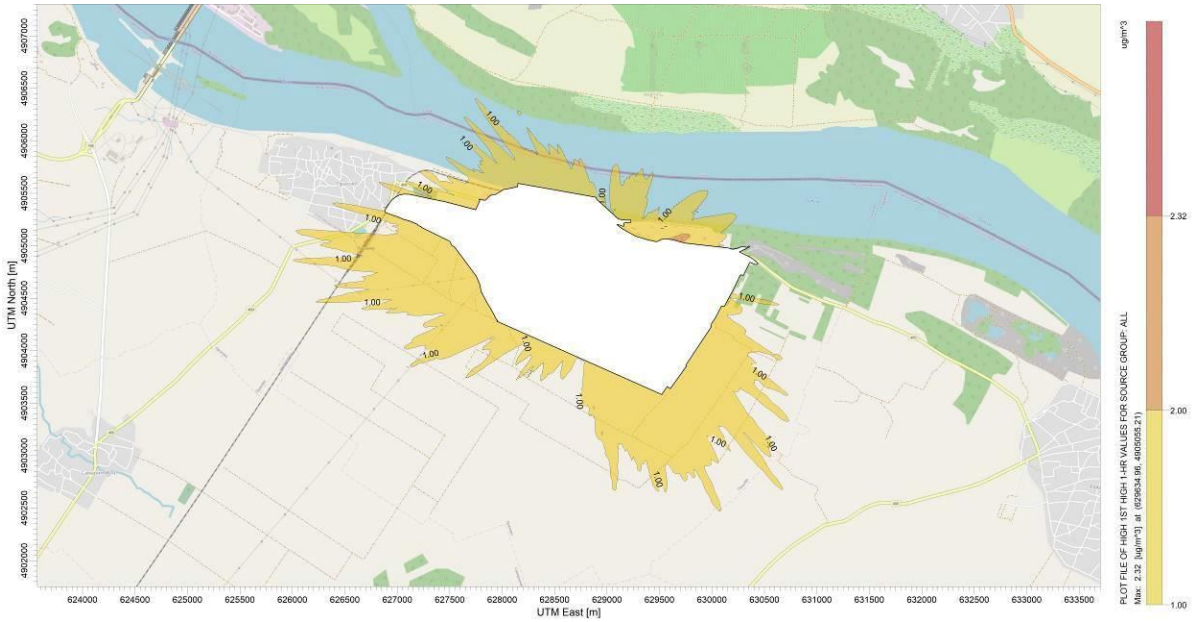


Figure 3.20 Maximum ground-level TVOC concentrations (first maximum) for a one-hour averaging period [μg/m^3]

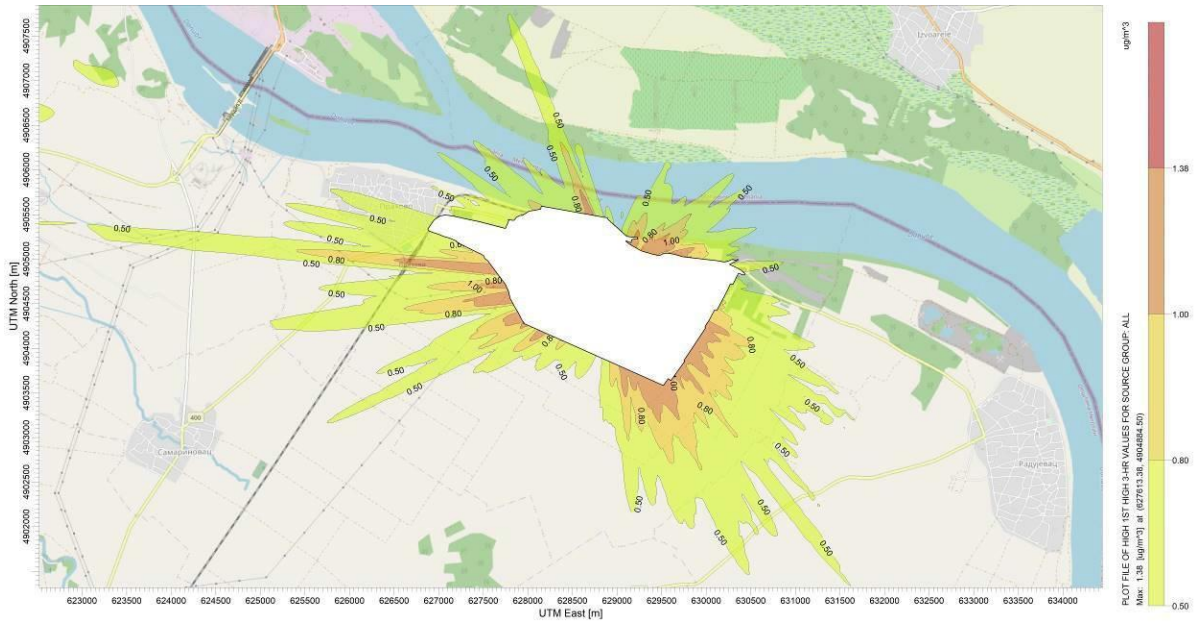


Figure 3.21 Maximum ground-level 3-hour daily TVOC concentrations [μg/m^3]

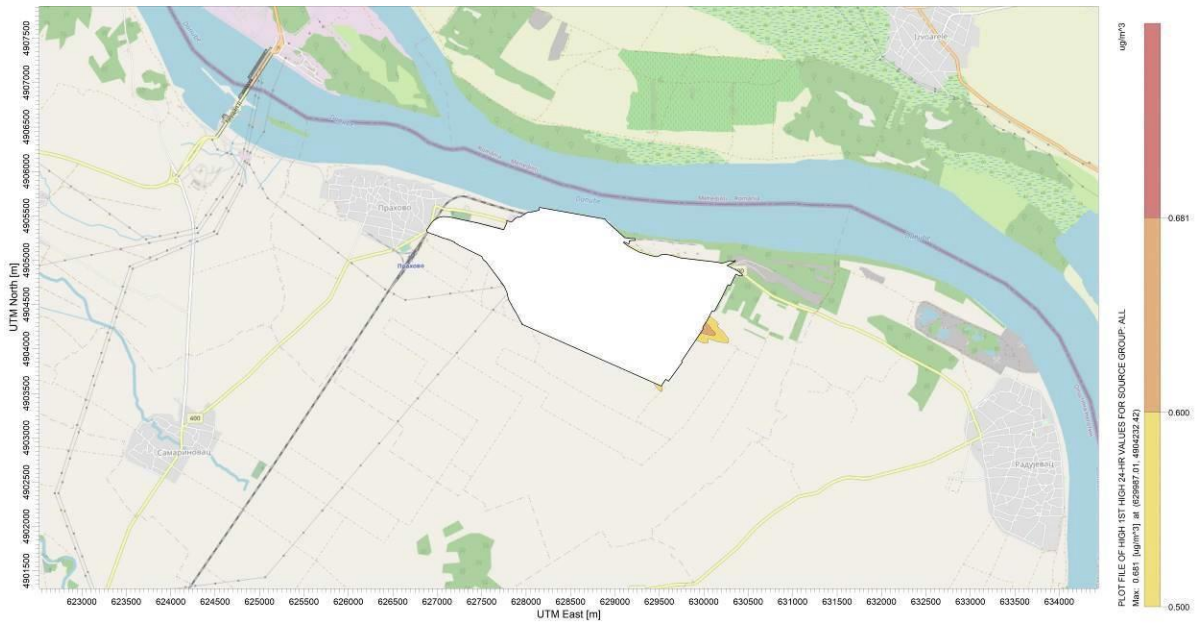


Figure 3.22 Maximum ground-level TVOC concentrations for a one-day averaging period [μg/m^3]

The presented results additionally indicate that, as with PM10, emitters of auxiliary waste-to-energy plant systems have a dominant impact, that is, in the case of TVOC, emitters of waste pretreatment. Considering the differences in the height of the emitters, process parameters of the flue/waste gas, as well as the TVOC emission values themselves, such results are quite expected.

4. CONCLUSION

This Study considered the impact of the waste pretreatment filter system and activated carbon filter within the waste-to-energy plant on the air quality of the wider location of the chemical industry complex in Prahovo. Modeling for the purposes of this Study was carried out with the AERMOD software package using the appropriate relevant source parameters (Appendix I).

By analyzing the obtained results, it can be concluded that the impact of the waste pretreatment filter system and activated carbon filter within the waste-to-energy plant on the air quality of the wider location of the chemical industry complex in Prahovo is practically negligible from the aspect of PM10 and TVOC. From the presented results, it can also be clearly seen that within the aforementioned plant, the emitters of auxiliary systems (waste preparation and solidification) have a dominant impact on air quality in both cases, when the boiler plant is operating and when it is not. It should also be noted that there is no prescribed maximum allowed concentration in ambient air for TVOC, so only an indicative value for indoor air quality was used in this Study.

Considering that due to the location of the chemical industry complex in Prahovo, there is a potential effect of cross-border pollution, and bearing in mind the trend of decreasing ground-level pollutant concentrations for all averaging periods, where already after a few hundred meters from the boundaries of the complex the concentration becomes extremely low, it can be concluded that the potential cross-border effect is practically negligible.

APPENDIX I

DATA ON EMITTERS

Point emitters[2]

Emitter name: E3 – Steam boiler emitter (coal fired)		
Parameter	**Value**	**Unit**
Emitter height	40 m in relation to level 0	[m]
The inner diameter of the emitter at its top	1,5	[m]
Flue gas temperature at the top of the emitter	154,27 ± 1,88	[°C]
Flue gas volume flow through the emitter	29 367,33	[Nm^3/h]
Mass flow of particle matter, PM	≈ 1,201	kg/h
Geographical coordinates of the emitter	44,286642 22,605533	[Lat/Long]

Name of the emitter: E4 – HTL device emitter		
Parameter	**Value**	**Unit**
Emitter height	35 m in relation to level 0	[m]
The inner diameter of the emitter at its top	0,4	[m]
Flue gas temperature at the top of the emitter	245,23 ± 1,88	[°C]
Flue gas volume flow through the emitter	2999,67	[Nm^3/h]
Mass flow of particulate matter, PM	5,695	g/h
Geographical coordinates of the emitter	44,286478 22,610283	[Lat/Long]

Emitter name: E6 – Emitter after scrubber, Emitter ALPHA		
Parametri	**Value**	**Unit**
Emitter height	40,6 m in relation to level 0	[m]
The inner diameter of the emitter at its top	0,6	[m]
Flue gas temperature at the top of the emitter	41,67 ± 1,88	[°C]
Flue gas volume flow through the emitter	≈ 8423	[Nm^3/h]
Mass flow of particulate matter, PM	≈ 77,97	g/h
Geographical coordinates of the emitter	44,286478 22,610283	[Lat/Long]

Emitter name: E7 – Emitter of the final rinser (tower) NPK		
Parameter	**Value**	**Unit**
Emitter height	44,5 m in relation to level 0	[m]
The inner diameter of the emitter at its top	2,8	[m]
Flue gas temperature at the top of the emitter	63,63 ± 1,30	[°C]
Flue gas volume flow through the emitter	≈ 169 351,33	[Nm^3/h]

[2] Emitter labels are kept as in *Study of Plant for energy utilization of waste and landfill of non-hazardous waste impact on air quality of the wider location of the chemical industry complex in Prahovo*

Mass flow of particulate matter, PM	≈ 2,020	kg/h
Geographical coordinates of the emitter	44,287122 22,606778	[Lat/Long]

Emitter name: E8 – Emitter of old fluidization cooler		
Parameter	**Value**	**Unit**
Emitter height	26,5 m in relation to level 0	[m]
The inner diameter of the emitter at its top	2	[m]
Flue gas temperature at the top of the emitter	51,47 ± 1,88	[°C]
Flue gas volume flow through the emitter	≈ 82 936	[Nm^3/h]
Mass flow of particulate matter, PM	≈ 1,232	kg/h
Geographical coordinates of the emitter	44,287122 22,606778	[Lat/Long]

Emitter name: E9 – Emitter of the new fluidization cooler		
Parameter	**Value**	**Unit**
Emitter height	21 m in relation to level 0	[m]
The inner diameter of the emitter at its top	0,7	[m]
Flue gas temperature at the top of the emitter	58,67	[°C]
Flue gas volume flow through the emitter	≈ 10 755	[Nm^3/h]
Mass flow of particulate matter, PM	≈ 0,180	kg/h
Geographical coordinates of the emitter	44,287122 22,606778	[Lat/Long]

Emitter name: E10 – Phosphoric acid production plant emitter - end tower		
Parameter	**Value**	**Unit**
Emitter height	34,5 in relation to level 0	[m]
The inner diameter of the emitter at its top	2,1	[m]
Flue gas temperature at the top of the emitter	48,90 ± 1,88	[°C]
Flue gas volume flow through the emitter	187 413,67	[Nm^3/h]
Mass flow of particulate matter, PM	≈ 1,254	kg/h
Geographical coordinates of the emitter	44,286719 22,603942	[Lat/Long]

Emitter name: E11 – Emitter of phosphate grinding mills plant		
Parameter	**Value**	**Unit**
Emitter height	31 m in relation to level 0	[m]
The inner diameter of the emitter at its top	0,6	[m]
Flue gas temperature at the top of the emitter	42,63 ± 1,88	[°C]
Flue gas volume flow through the emitter	14 919,33	[Nm^3/h]

Mass flow of particulate matter, PM	0,271	kg/h
Geographical coordinates of the emitter	44,286642 22,605533	[Lat/Long]

Emitter name: E12 – Vibro sieve and hopper plant emitter		
Parameter	**Value**	**Unit**
Emitter height	28 in relation to level 0	[m]
The inner diameter of the emitter at its top	0,9	[m]
Flue gas temperature at the top of the emitter	25,67 ± 1,88	[°C]
Flue gas volume flow through the emitter	≈ 35 475	[Nm^3/h]
Mass flow of particulate matter, PM	≈ 0,093	kg/h
Geographical coordinates of the emitter	44,286642 22,605533	[Lat/Long]

Emitter name: E13 – Emitter of dryer's dust separator and granulator, rotary cooler and process sieve, chain mill, recycling silo, bands and elevators **		
Parameter	**Value**	**Unit**
Emitter height	28 m in relation to level 0	[m]
The inner diameter of the emitter at its top	2,8	[m]
Flue gas temperature at the top of the emitter	52,50 ± 0,2	[°C]
Waste gas flow	119 556 ± 6576	[Nm^3/h]
Dry waste gas flow under standard conditions	93 111	[Nm^3/h]
Mass flow of particulate matter, PM	4,678	kg/h
Geographical coordinates of the emitter	44,288139 22,605764	[Lat/Long]

**Emitter belongs to Phosphea company

Emitter name: E14 – Fluidized cooler emitter **		
Parameter	**Value**	**Unit**
Emitter height	18,5 m in relation to level 0	[m]
The inner diameter of the emitter at its top	0,8	[m]
Flue gas temperature at the top of the emitter	30,2 ± 0,1	[°C]
Waste gas flow	18 433 ± 1014	[Nm^3/h]
Dry waste gas flow under standard conditions	15 411	[Nm^3/h]
Mass flow of particulate matter, PM	0,014	kg/h
Geographical coordinates of the emitter	44,288189 22,605375	[Lat/Long]

**Emitter belongs to Phosphea company

Emitter Name: E15 – Ball Mill Emitter **		
Parameter	**Value**	**Unit**
Emitter height	25m in relation to level 0	[m]
The inner diameter of the emitter at its top	0,5	[m]
Flue gas temperature at the top of the emitter	52,1 ± 0,2	[°C]
Waste gas flow	8 608 ± 473	[Nm^3/h]
Dry waste gas flow under standard conditions	6712	[Nm^3/h]
Mass flow of particulate matter, PM	0,058	kg/h
Geographical coordinates of the emitter	44,288044 22,6053	[Lat/Long]

**Emitter belongs to Phosphea company

Emitter name: E17 – Emitter of dust remover of finished products **		
Parameter	**Value**	**Unit**
Emitter height	19 m in relation to level 0	[m]
The inner diameter of the emitter at its top	0,6	[m]
Flue gas temperature at the top of the emitter	28,8 ± 0,1	[°C]
Waste gas flow	12 022 ± 661	[Nm^3/h]
Dry waste gas flow under standard conditions	10 098	[Nm^3/h]
Mass flow of particulate matter, PM	0,092	kg/h
Geographical coordinates of the emitter	44,287936 22,605522	[Lat/Long]

**Emitter belongs to Phosphea company

Emitter name: E18 – Boiler plant emitter (W-C14)		
Parameter	**Value**	**Unit**
Emitter height	56 m in relation to level 0	[m]
The inner diameter of the emitter at its top	1,7	[m]
Flue gas temperature at the top of the emitter	147 ± 3	[°C]
Flue gas volume flow through the emitter	70.000	[Nm^3/h]
Mass flow of particulate matter , PM	0,35	kg/h
Mass flow of TVOC	0,72	kg/h
Geographical coordinates of the emitter	44.284570 22.616845	[Lat/Long]

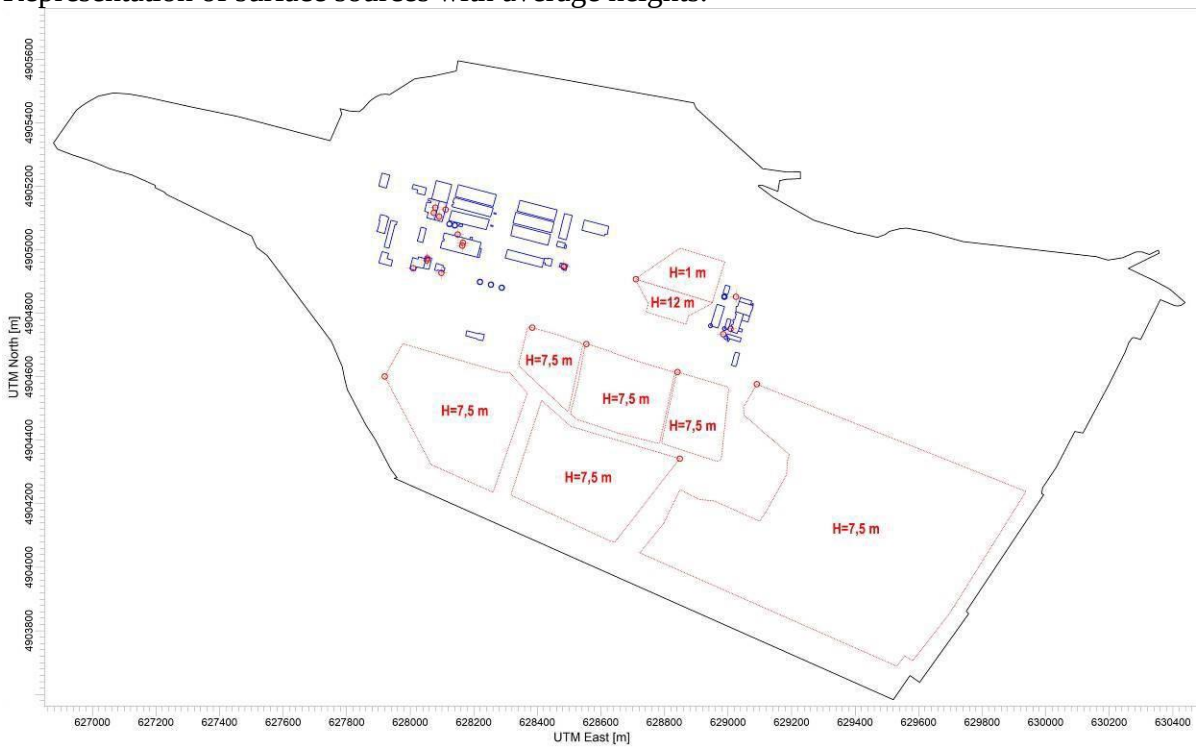
Emitter name: E19 – Emitter of solidification plant (W-C16)		
Parameter	**Value**	**Unit**
Emitter height	21,5 m in relation to level 0	[m]
The inner diameter of the emitter at its top	1,2	[m]
Flue gas temperature at the top of the emitter	ambiental	[°C]
Flue gas volume flow through the emitter	25.000	[Nm^3/h]
Mass flow of particulate matter , PM	0,125	kg/h

Geographical coordinates of the emitter	44.284418 22.616549	[Lat/Long]

Emitter name: E20 – Emitter of the Waste Pre-treatment Filter System and Activated Carbon Filter (W-C09)		
Parameter	**Value**	**Unit**
Emitter height	21,5 m in relation to level 0	[m]
The inner diameter of the emitter at its top	1,2	[m]
Flue gas temperature at the top of the emitter	ambiental	[°C]
Flue gas volume flow through the emitter	24.000	[Nm^3/h]
Mass flow of particulate matter, PM	0,45	kg/h
Mass flow of TVOC	0,72	kg/h
Geographical coordinates of the emitter	44.285472 22.617081	[Lat/Long]

Surface emitters

Representation of surface sources with average heights:



Emissions of particulate matter from surface sources are defined in accordance with the recommendations of US EPA AP42, Air Emissions Database:

$$E_{PM10} = 1{,}8 \cdot u \cdot 0{,}5\ (1-\eta)\ [g/(m^2 \cdot s)]$$
$$E_{PM2.5} = 1{,}8 \cdot u \cdot 0{,}075\ (1-\eta)\ [g/(m^2 \cdot s)]$$

where:

u – wind speed [m/s],
η – the degree of spreading out decay.

Emissions of particulate matter from existing surface sources (phosphogypsum storage) depending on the wind speed and the degree of spreading out decay of 75%:

u	**PM10**	**PM2.5**
[m/s]	[g/(m^2·s)]	[g/(m^2·s)]
< 5,14	-	-
5,14 – 8,23	0.00004181	0.000006272
8,23 – 10,8	0.00005950	0.000008925
> 10,8	0.00008925	0.000013387

Emissions of particulate matter from the future phosphogypsum storage depending on the wind speed and the degree of spreading out decay of 90%:

u	**PM10**	**PM2.5**
[m/s]	[g/(m^2·s)]	[g/(m^2·s)]
< 5,14	-	-
5,14 – 8,23	0.000016725	0.000002509
8,23 – 10,8	0.0000238	0.00000357
> 10,8	0.0000357	0.000005355

Emissions of particulate matter from the future solidificate landfill (at the moment as defined in point 2.6 of this Study) depending on the wind speed and the degree of spreading out decay of 95%:

u	**PM10**	**PM2.5**
[m/s]	[g/(m^2·s)]	[g/(m^2·s)]
< 5,14	-	-
5,14 – 8,23	8.3625E-06	1.25438E-06
8,23 – 10,8	0.0000119	1.785 E-06
> 10,8	0.00001785	2.6775E-06