

Memo Silicon Plant Helguvik

Title Dispersion calculations for Silicon production plant in Helguvik, Iceland

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As part of an Environmental Impact Assessment for the silicon plant in Helguvik, Iceland, there has performed calculations of air dispersion for different pollutants, from the future silicon production plant in Helguvik, Iceland.

The dispersion calculations have been performed with use of the AIRMOD dispersion model, created by US Environmental Protection Agency (EPA), with user interface by Lakes Environmental. AIRMOD is a Gaussian air dispersion model, which calculates multi source dispersion, and includes upper air data, terrain contours, buildings, temperature differences, cloud hours and calculates the air concentration for multiple receptors.

The model has been built with a circular grid of 440 receptors around the emission points (filter houses) with a radius of 1.6 km around the future production plant, and included results for 8 receptors located at the plant boundary.

The source of the pollutants has been provided by production plant manufacturer Tenova\Pyromet, and verified by silicon metal production specialist Kjell Nordstrøm. The source type is calculated as a series of 60 stacks located on the roof of the two air filter houses.

The source data used as input to the model is the following:

Source	SO ₂	NO _x	PAH ₁₆	POP	PM ₁₀
Unit	ton/year	ton/year	ton/year	g/year	ton/year
Yearly average emission	1500	520	0.18	0,32	130
Yearly average gram/sec.	47.5	16.4	0.006	0.01	4.2

Table 1: Yearly emissions from the production with full production

Tenova Pyromet has provided the data for the total airflow from the production plant will be 132 m³/sec. from each filter house, and the emissions temperature will be in the range of 80 degrees Celsius, which is included in the calculations, to accurately model the actual situation.

The weather data has been received from the Icelandic Meteorological Office, which provided a 5-years series for both surface air data and upper air data from 2006-2011, from Keflavik Airport, located approx 5 km from the site in Helguvik. This data series has been read into the AIRMOD model, by using the AIRMET program created by US EPA.

The model calculates the 6 year period and renders the results from the yearly average concentrations and the highest occurring concentrations occurring for 1 day and 1 hours during this 6-year interval.

The detailed calculations for the whole surrounding area has been made for the components sulfate SO₂, nitrogen oxides NO_x and dust PM₁₀, for year average and the 24 hours and 1 hours percentiles corresponding to the Icelandic legislation. The results are presented in the following pages and in the table below.

Resulting emissions	Time frame	Resulting maximum concentration µg/Nm ³	Icelandic air quality criteria µg/Nm ³	Percentile
SO ₂	Year	9.9	20	
	24 hr.	21.5	50	98% (7 times pr. yr)
	24 hr.	27.6	125	99,2% (3 times pr. yr)
	1 hr.	161	350	99,75% (24 times pr. yr)
NO&NO ₂	Year	3.4	30	
	24 hr.	7.5	75	98% (7 times pr. yr)
	1 hr.	13.9	110	98,1% (175 times pr. yr)
	1 hr.	56	200	99,75% (18 times pr. yr)
Dust (PM ₁₀)	Year	0.96	20	
	24 hr.	2.0	50	98% (7 times pr. yr)
PAH ₁₆	Year	0.0014	0.1*	
POP	Year	<0,0000001	0,001 (EU law)	

Table 2: Resulting maximum concentrations anywhere around the plant using average raw materials

* Criteria derived from benzo(a)pyrene

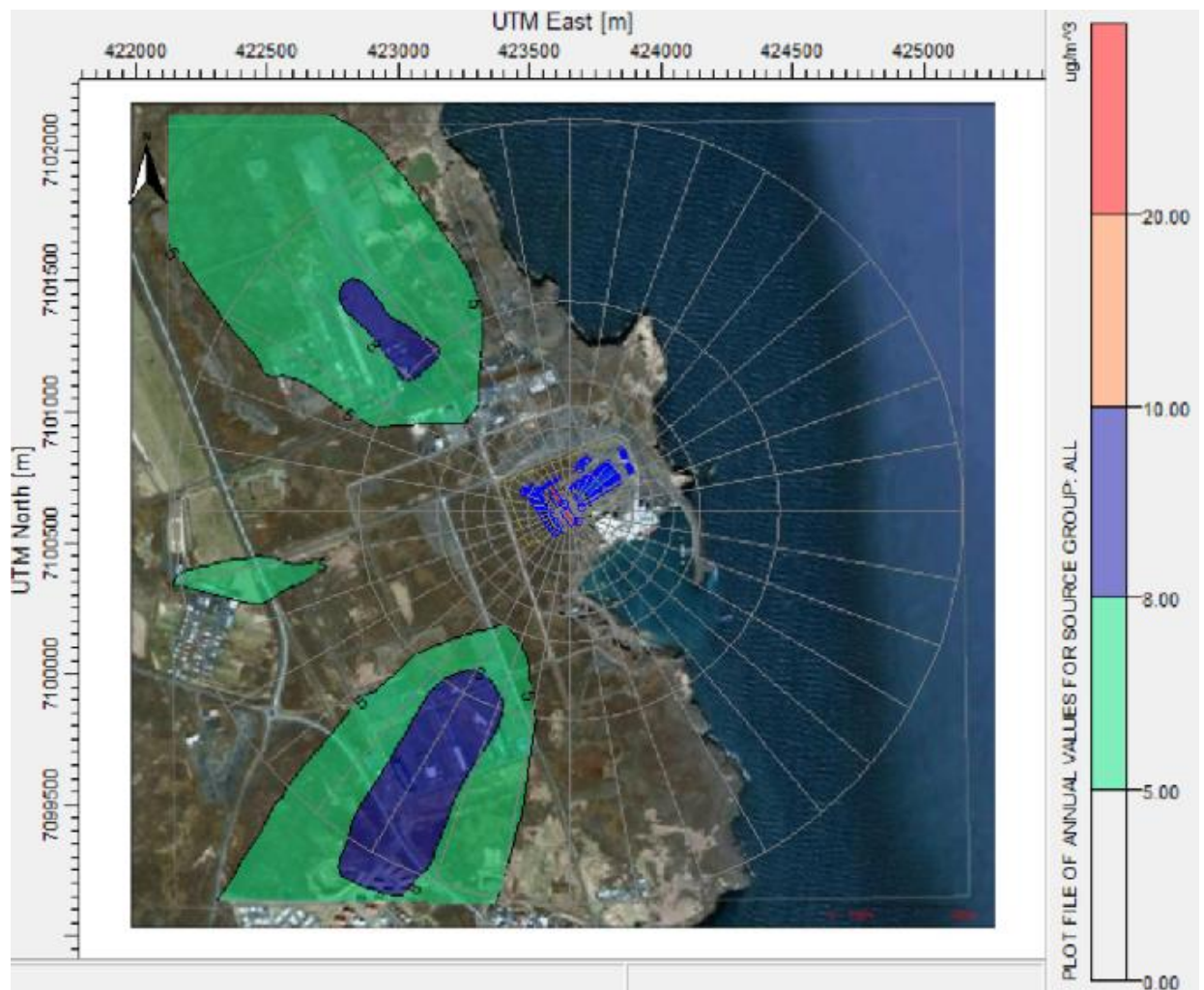
There has been made a screening for persistent organic compounds POP and polyaromatic hydrocarbons PAH₁₆, which show that concentrations are well below all air quality standards in all places around the production plant.

The conclusion of the dispersion calculations is that the concentration of all compounds are lower than the Icelandic air quality criteria, in all places, at all times, during the five year modeled period from 2006-2011.

All the following presented results are presented for filter bag-house emissions from the roof, modeled as 60 stacks placed beside each other with openings sized 2 m, to allow for correct modeling of the temperature difference compared to the surrounding air.

The results of the air dispersion model is presented, for each time scenario, in the following pages:

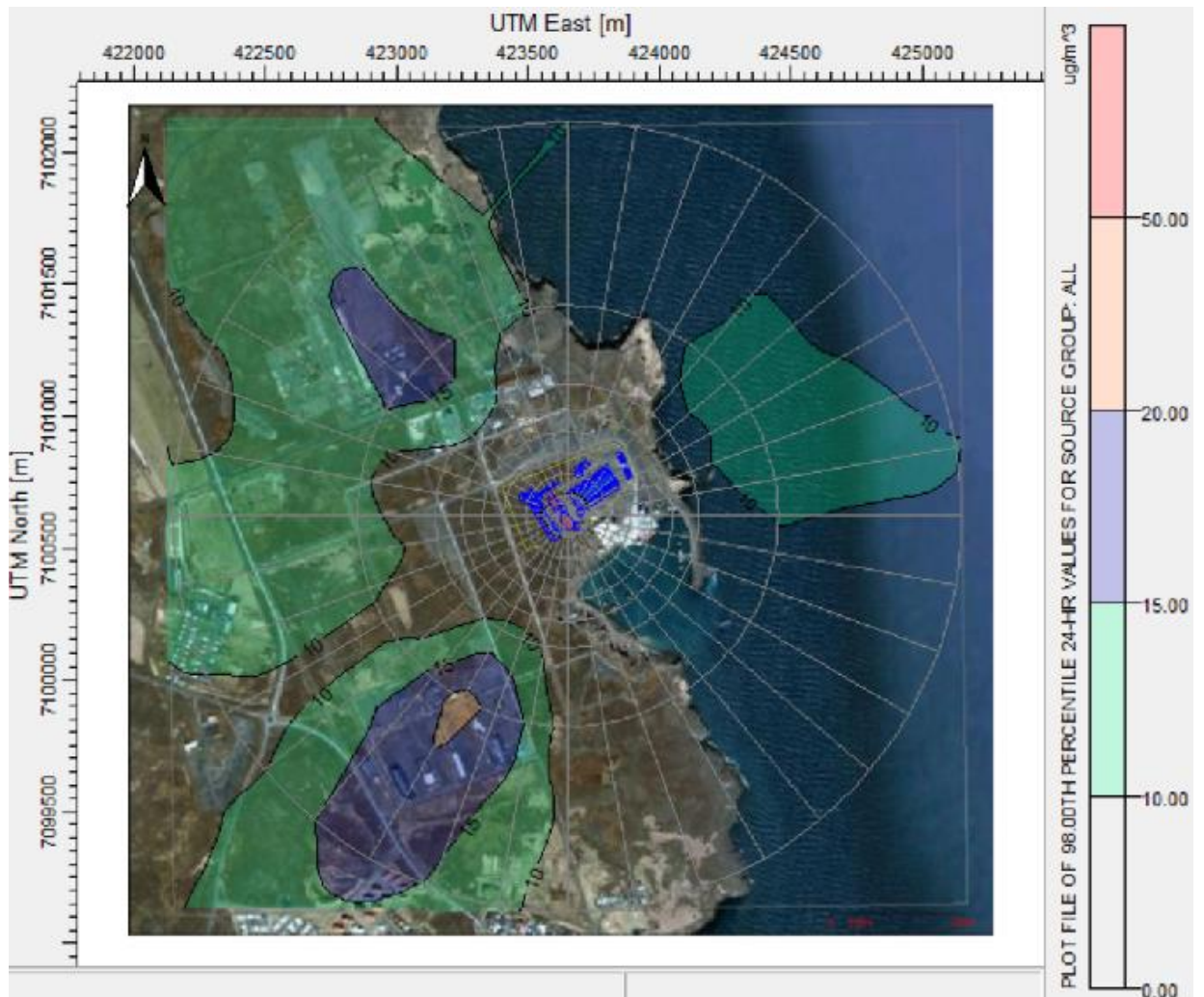
Average SO₂ concentration 1 year



Maximum SO₂ concentration in any place for this period is 9.9 µg/m³.

Compares to Icelandic air quality criteria of 20 µg/m³.

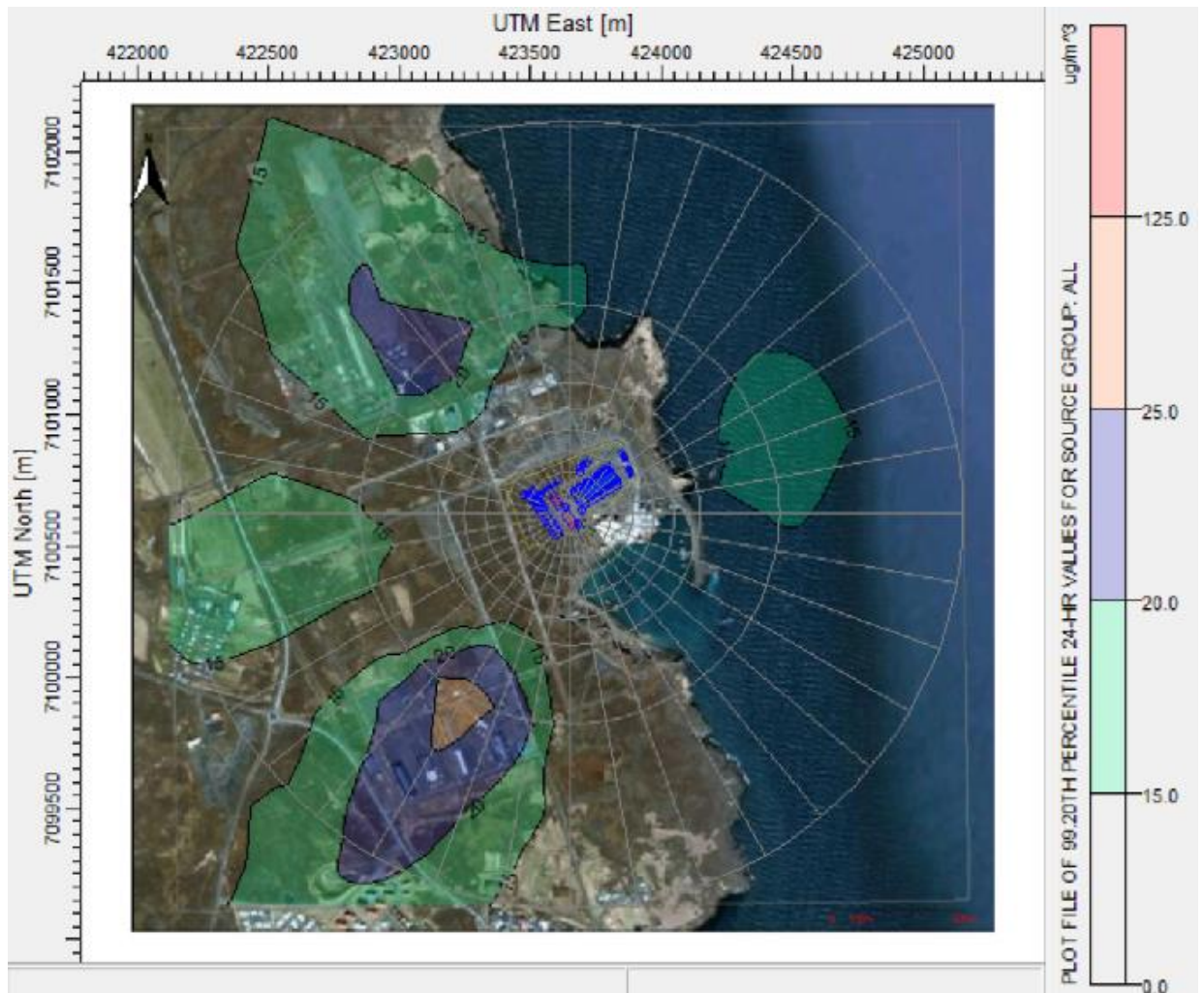
**SO₂ Concentration 24 hours 98 % percentile
(7 times pr. year)**



Maximum SO₂ concentration in any place calculated for this period is 21,5 µg/m³.

Compares to Icelandic air quality criteria of 50 µg/m³.

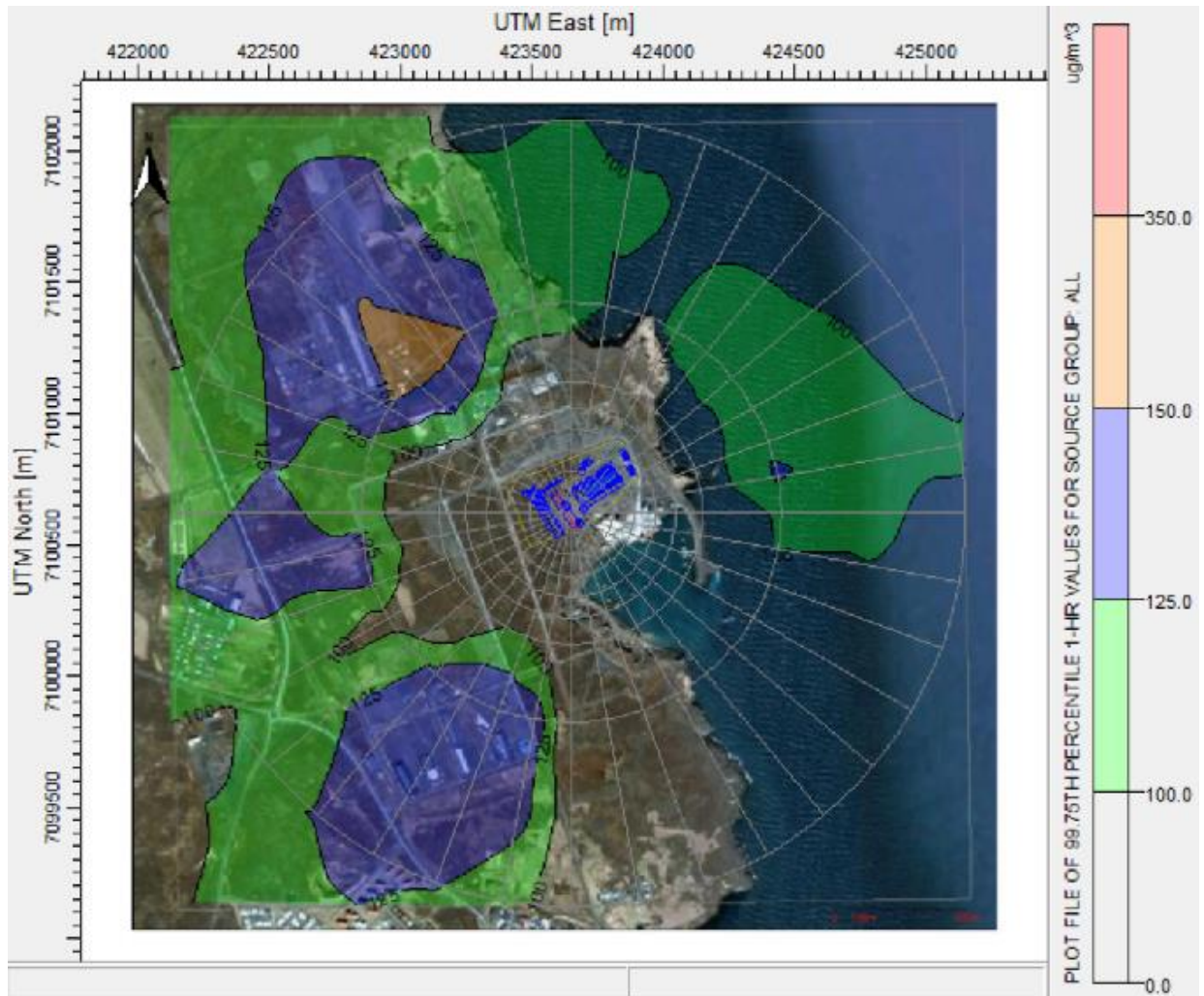
**SO₂ Concentration 24 hours 99,2 % percentile
(3times pr. year)**



Maximum SO₂ concentration in any place calculated for this period is 27,6 $\mu\text{g}/\text{m}^3$.

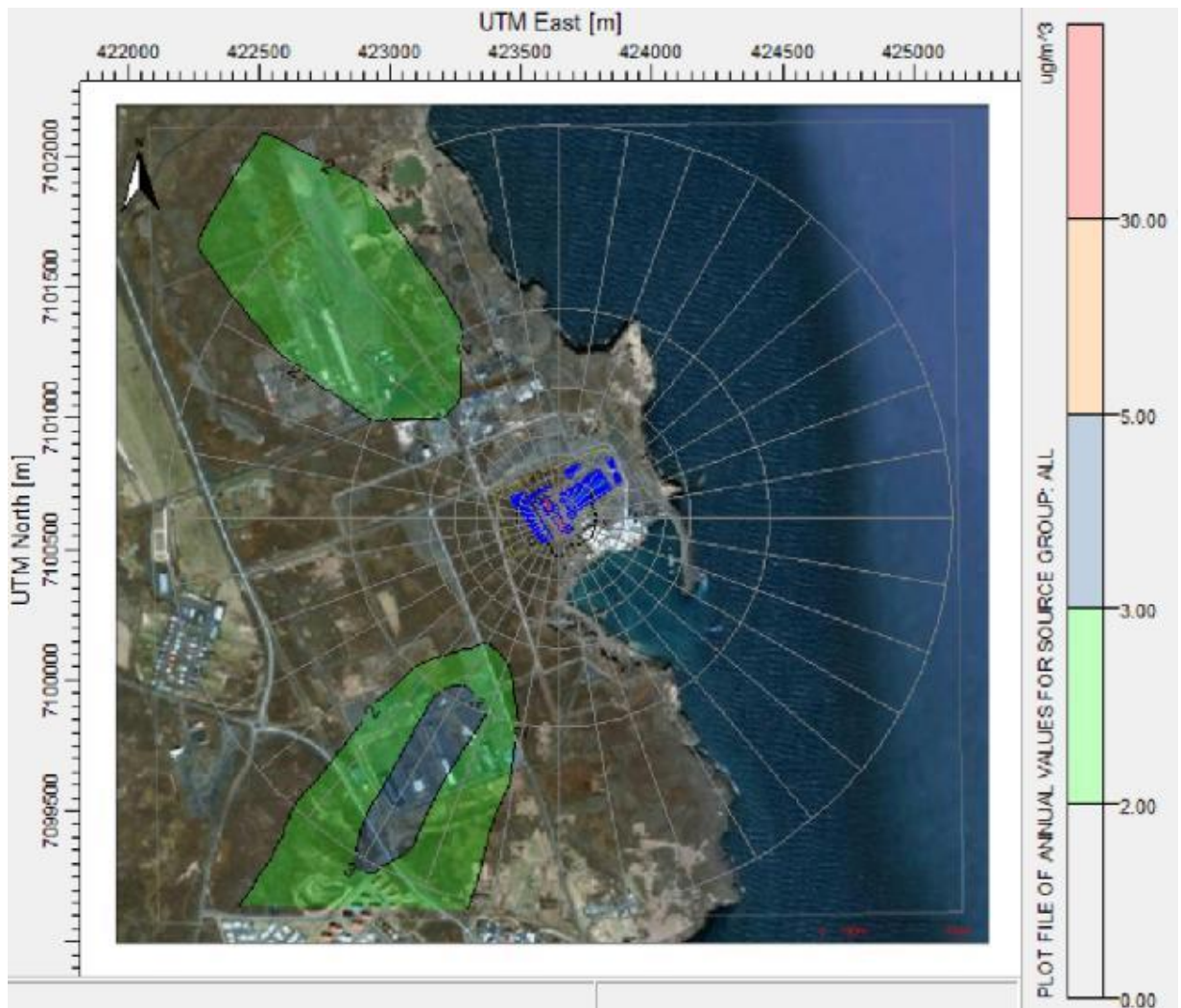
Compares to Icelandic air quality criteria of 125 $\mu\text{g}/\text{m}^3$

**SO₂ Concentration 1-hour 99,75% percentile
(24 times pr. year)**



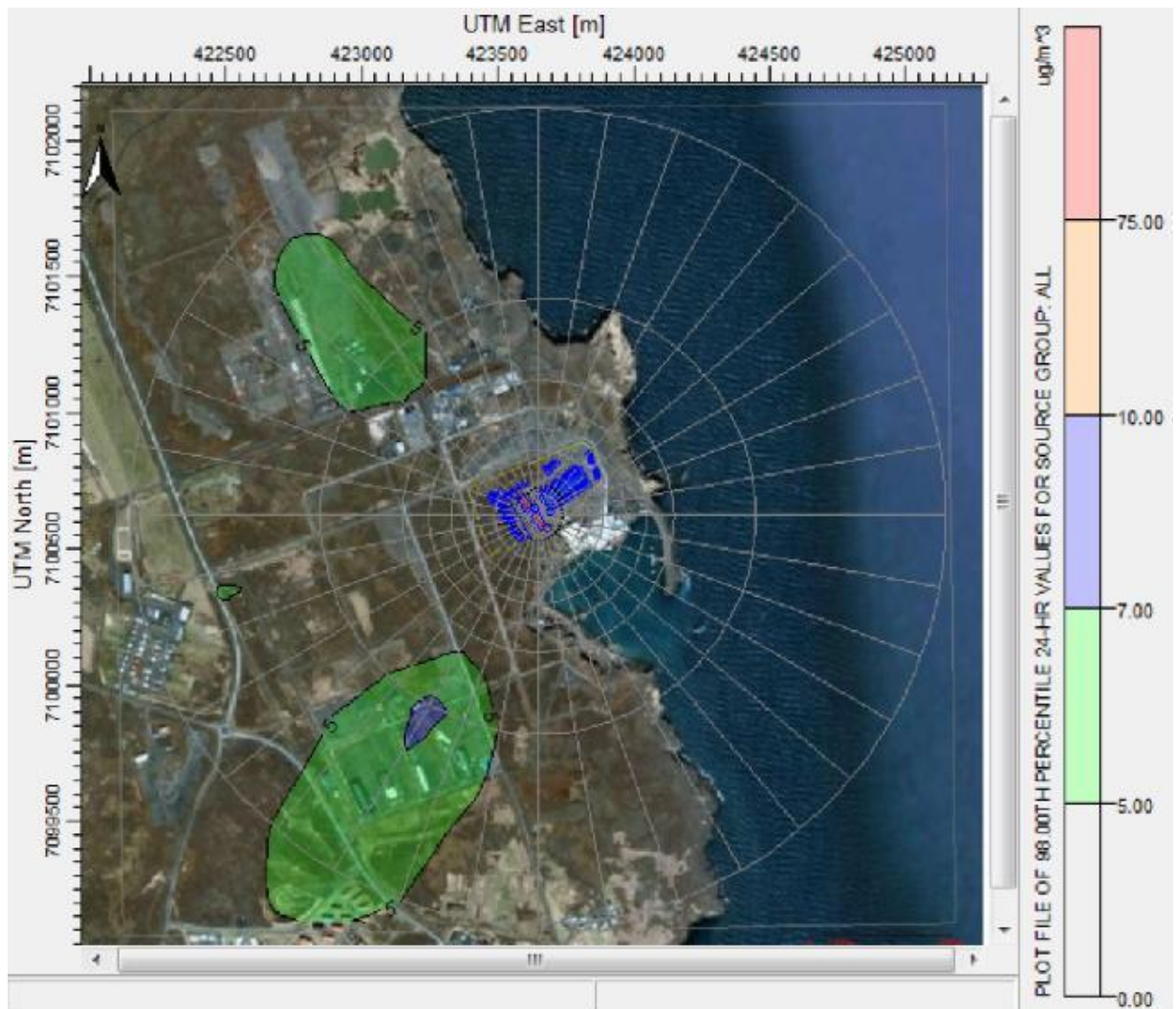
Maximum SO₂ concentration in any place calculated for this period is 161 $\mu\text{g}/\text{m}^3$.

Compares to Icelandic air quality criteria of 350 $\mu\text{g}/\text{m}^3$.

NO_x concentration 1 year

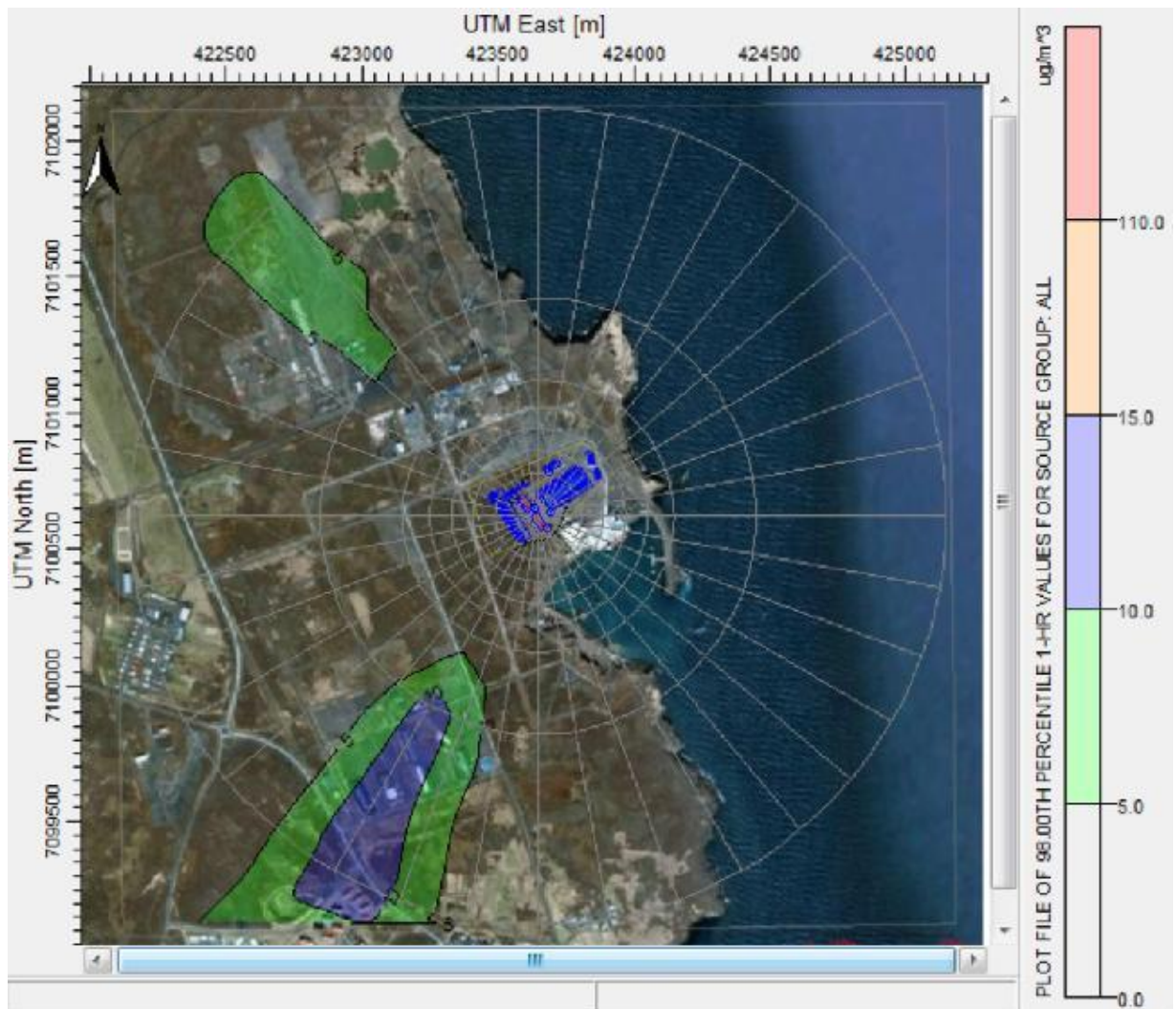
Maximum yearly average concentration of NO_x at any place around the plant is 3.4 µg/m³.

Compares to Icelandic air quality criteria of 30 µg/m³.

NO_x concentration 24 hour 98,1% percentile

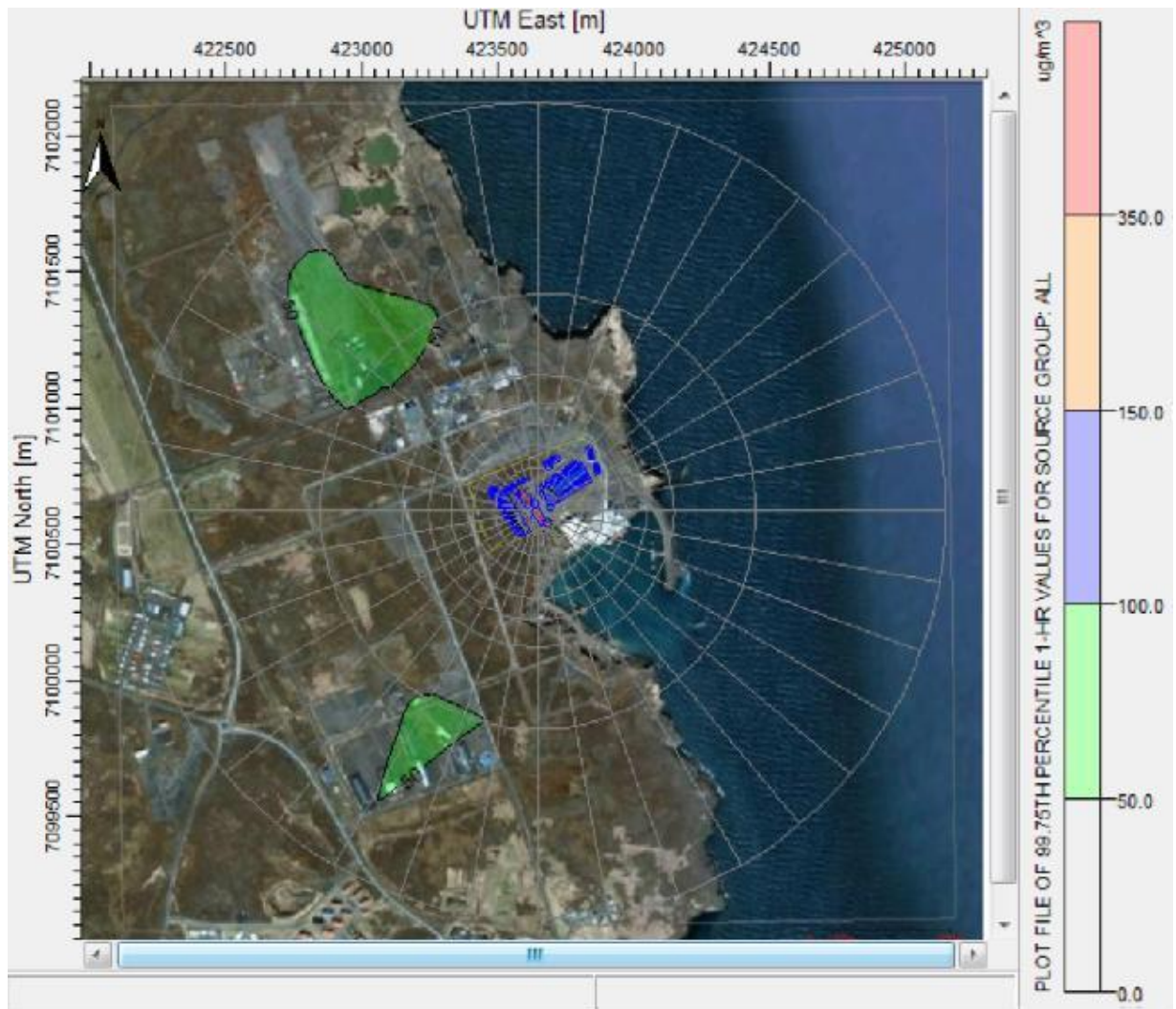
Maximum concentration of NO_x at any place around the plant for this period is 7.5 µg/m³.

Compares to Icelandic air quality criteria of 75 µg/m³.

NO_x concentration 1 hour 98,1% percentile

Maximum concentration of NO_x at any place around the plant for this period is 13.9 µg/m³.

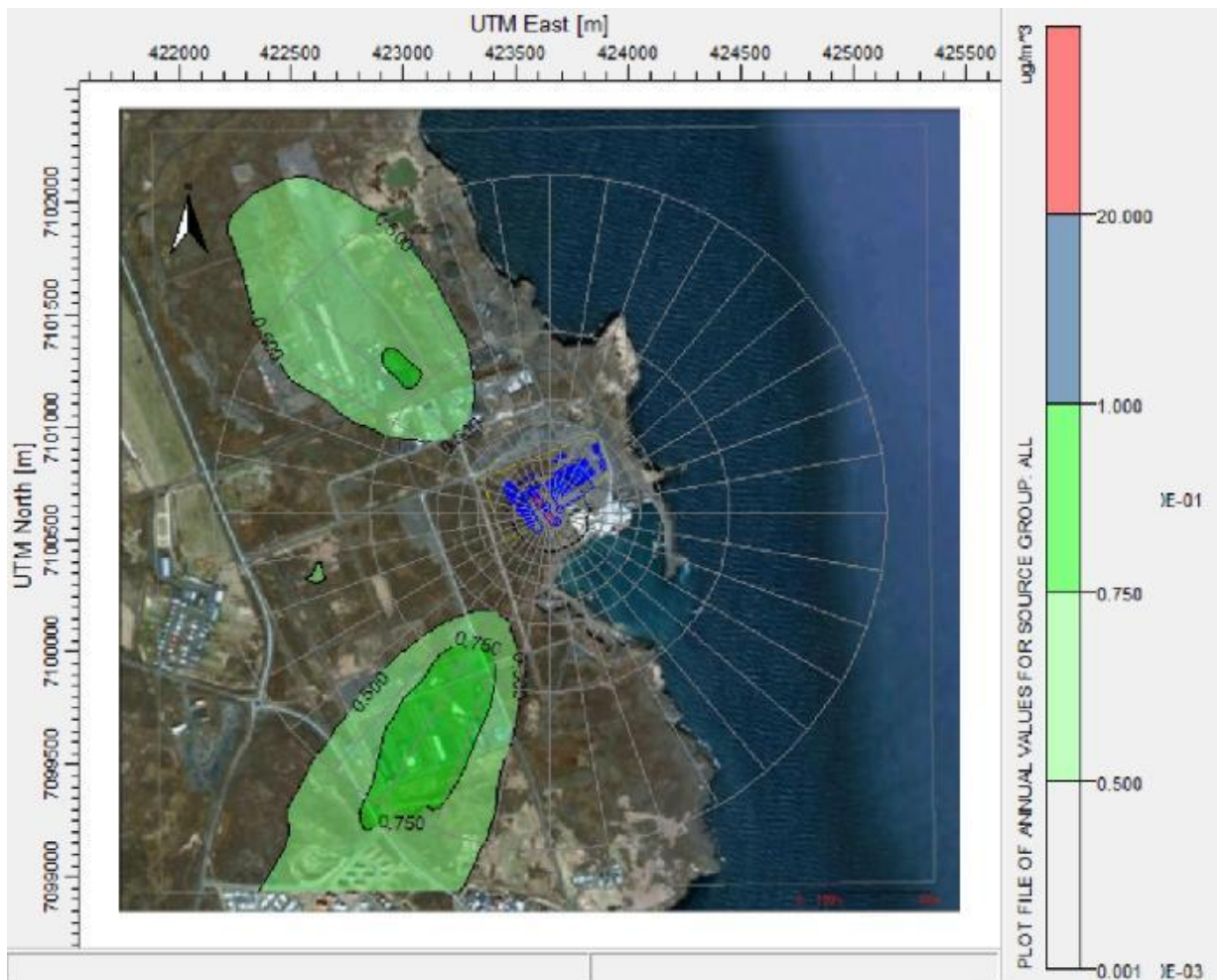
Compares to Icelandic air quality criteria of 110 µg/m³.

NO_x concentration 1 hour 99,8% percentile

Maximum concentration of NO_x calculated for this period is 56 µg/m³.

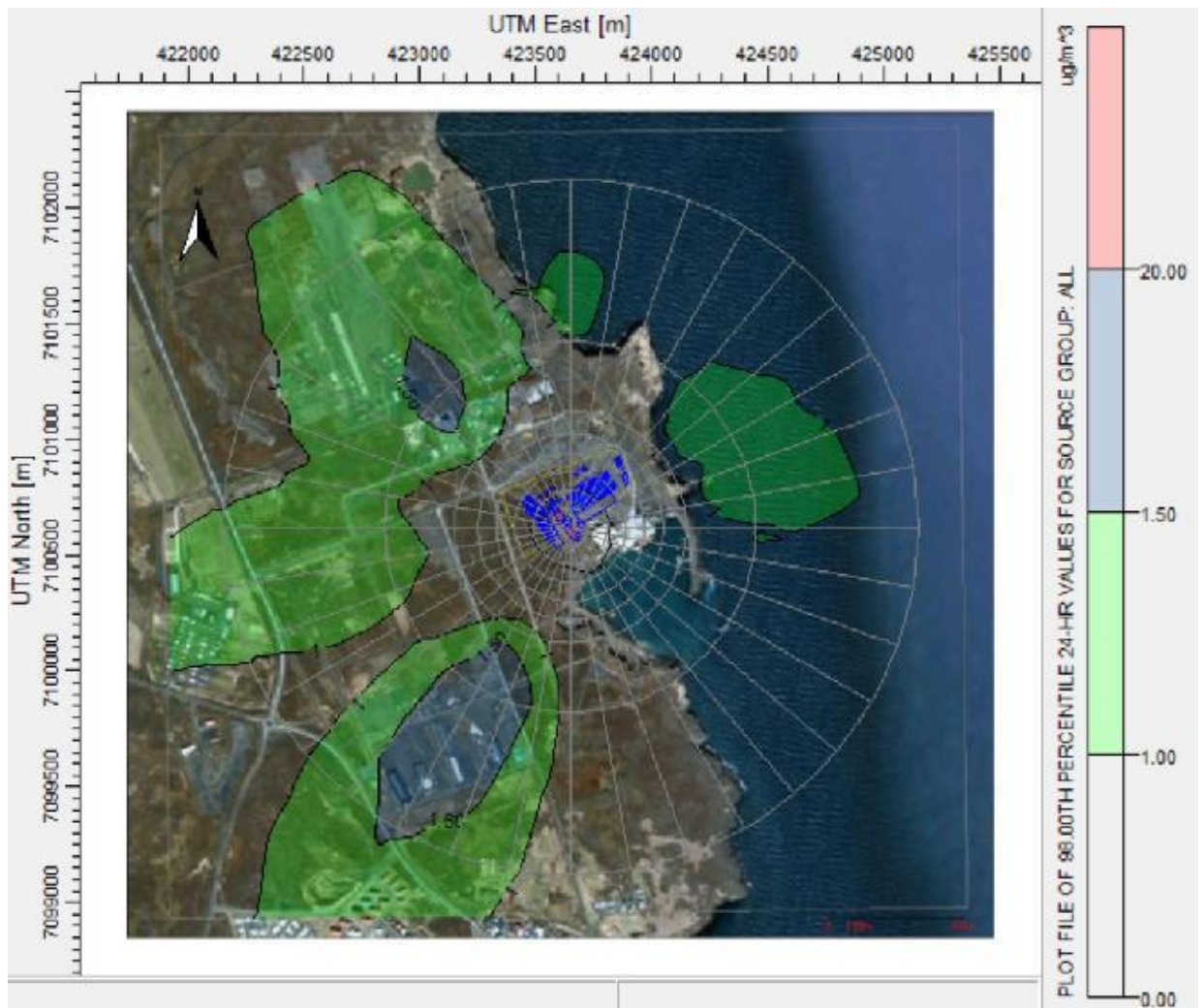
Compares to Icelandic air quality criteria of 200 µg/m³.

Dust (PM₁₀) concentration 1 year



Maximum yearly average concentration of dust at any place around the plant is $0,96 \mu\text{g}/\text{m}^3$.

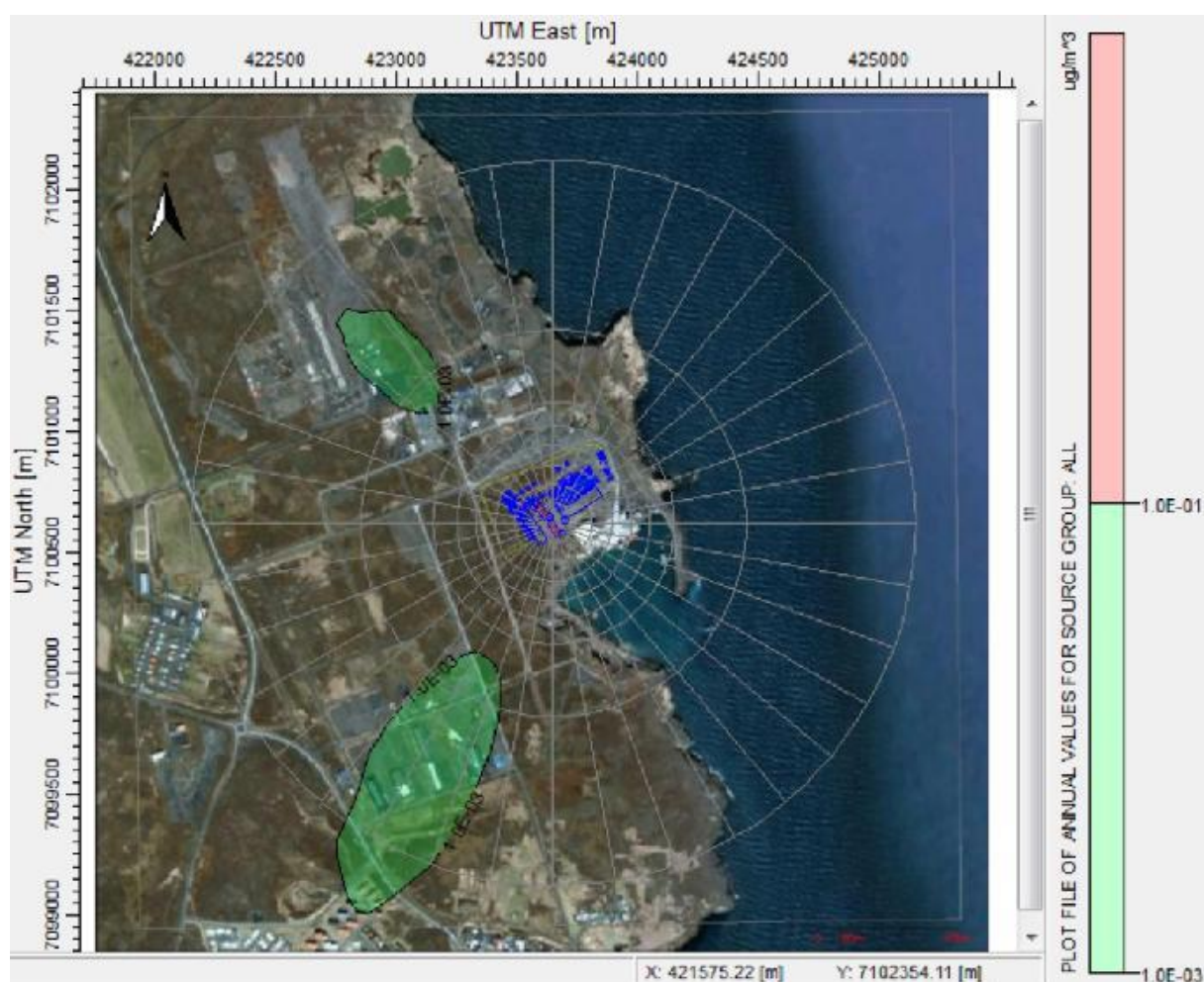
Compares to Icelandic air quality criteria of $20 \mu\text{g}/\text{m}^3$.

Dust (PM₁₀) concentration 24 hours 98% fractile

Maximum daily average concentration of dust calculated at any place around the plant is located over the sea at 2.0 $\mu\text{g}/\text{m}^3$.

Compares to Icelandic air quality criteria of 50 $\mu\text{g}/\text{m}^3$.

PAH concentration 1 year



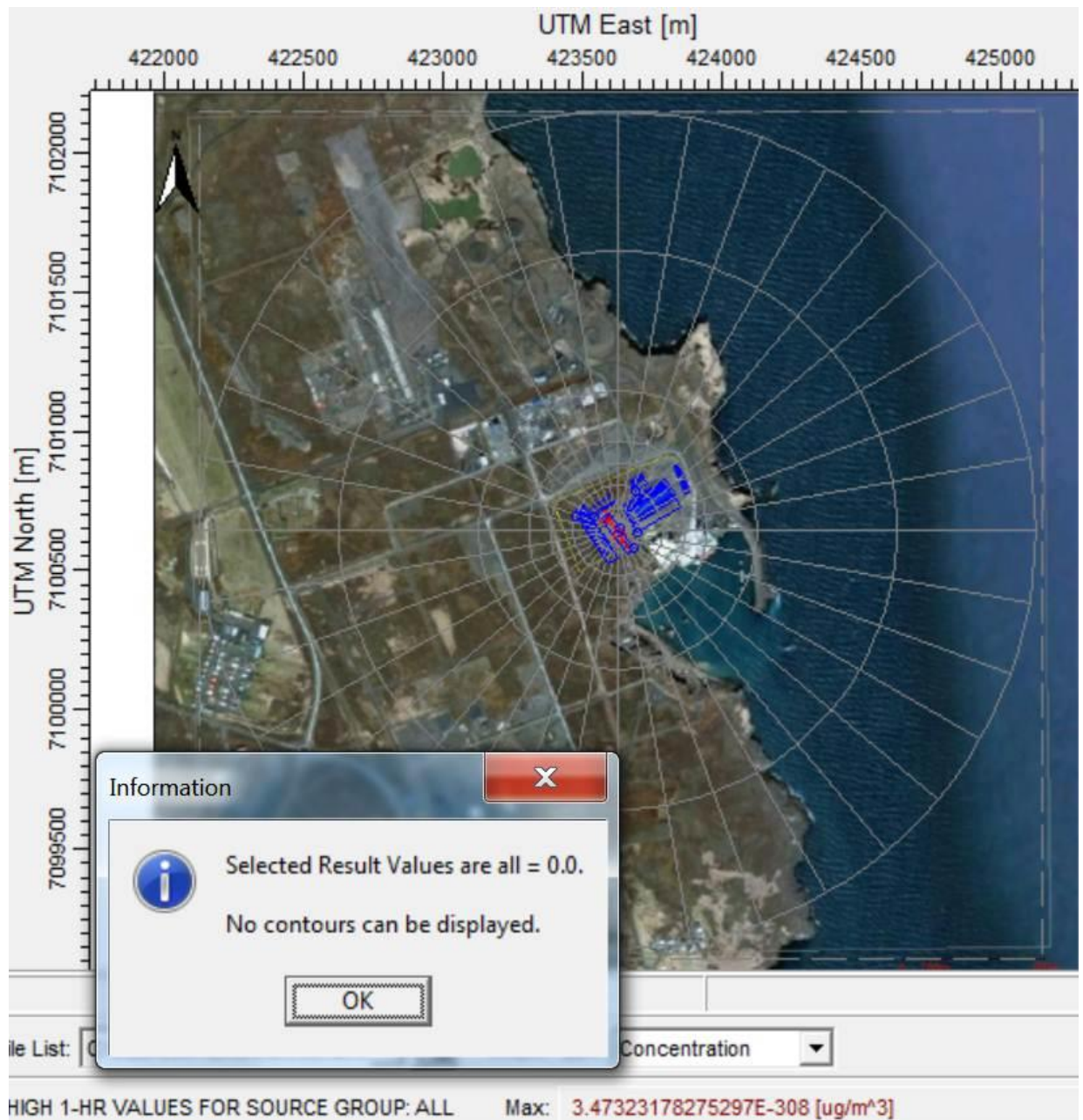
Maximum concentration of total-PAH calculated for this period is $0.0014 \mu\text{g}/\text{m}^3$.

No Icelandic air quality criteria in force* ($0.1 \mu\text{g}/\text{m}^3$ is comparable)*

*EU law has a criteria for benzo(a)pyrene of $0.001 \mu\text{g}/\text{m}^3$, and studies has shown that approx. 1% of PAH is benzo(a)pyrene. A corresponsive criteria for PAH in that case would be $0.1 \mu\text{g}/\text{m}^3$.

POP concentration 1 year

Compares to European Union air quality criteria of $0,001 \mu\text{g}/\text{m}^3$



Maximum concentration of POP is below detectible levels $<0,0000001 \mu\text{g}/\text{m}^3$.

As a comment to the Environmental Impact Assessment from the Icelandic Weather Center, asked the question how would the air quality around the plant be affected if the raw materials used in the production contained maximum level of pollutants instead of the average level, which is normally calculated.

Source	SO ₂	NO _x	PAH ₁₆	POP	PM ₁₀
Unit	ton/year	ton/year	ton/year	g/year	ton/year
Yearly max. emission	2400	780	0.27	0.48	195
Max. emission gram/sec.	76	24.6	0.009	0.015	6.3

Table 1B: Yearly emissions from the production with full production

The input to the air dispersion mode was changed to include the maximum concentrations of pollutants according to table 1B above, and the resulting maximum concentrations from re-calculating the air dispersion simulation model for each of legislative defined time interims are the following:

Resulting emissions	Time frame	Resulting maximum concentration µg/Nm ³	Icelandic air quality criteria µg/Nm ³	Percentile
SO ₂	Year	16.9	20	98% (7 times pr. yr) 99,2% (3 times pr. yr) 99,75% (24 times pr. yr)
	24 hr.	36.1	50	
	24 hr.	46.4	125	
	1 hr.	271	350	
NO&NO ₂	Year	5.1	30	98% (7 times pr. yr) 98,1% (175 times pr. yr) 99,75% (18 times pr. yr)
	24 hr.	11.25	75	
	1 hr.	20.9	110	
	1 hr.	84	200	
Dust (PM ₁₀)	Year	1.44	20	98% (7 times pr. yr)
	24 hr.	3.0	50	
PAH ₁₆	Year	0.002	0.1*	
POP	Year	<0,0000001	0,001 (EU law)	

Table 3: Resulting maximum concentrations anywhere around the plant using maximum level of pollutants in raw materials.

The conclusion from the calculation is, that the concentration of each pollutants at any time during the 5 year period calculated, is still below the Icelandic air quality criteria, as shown in table 3 above.

Chapter 2:**Accumulated effects from surrounding emission points**

We have been asked to evaluate the resulting air quality concentrations when including emissions from surrounding industries in the area.

The following industries/future possible industries and their corresponding emission points have been added to the air dispersion model:

Industry / Source	Unit	SO ₂	NO _x	PAH ₁₆	POP	PM ₁₀
		ton/year	ton/year	ton/year	g/year	ton/year
<u>1. Silicon Plant Helguvik:</u>						
Yearly average emission		1500	520	0.18	0,32	130
Yearly average gram/sec.		47.5	16.4	0.006	0.01	4.2
<u>2. Fish processing plant Helguvik</u>						
Yearly average emission		39	-	-	-	-
Yearly average gram/sec.		0.87	-	-	-	-
<u>3. Kalka</u>						
Yearly average emission		1.091	19.961	-	-	0.022
Yearly average gram/sec.		0.035	0.633	-	-	0.0001
<u>4. Alur (aluminum)</u>						
Yearly average emission		0.525	6.45	-	-	0.417
Yearly average gram/sec.		0.017	0.204	-	-	0.013
<u>5. Nordural (aluminum)</u>						
Yearly average emission		3750	750	-	-	250
Yearly average gram/sec.		119	24	-	-	7.9

Table 4: Sources of pollution from surrounding industries in the Helguvik area

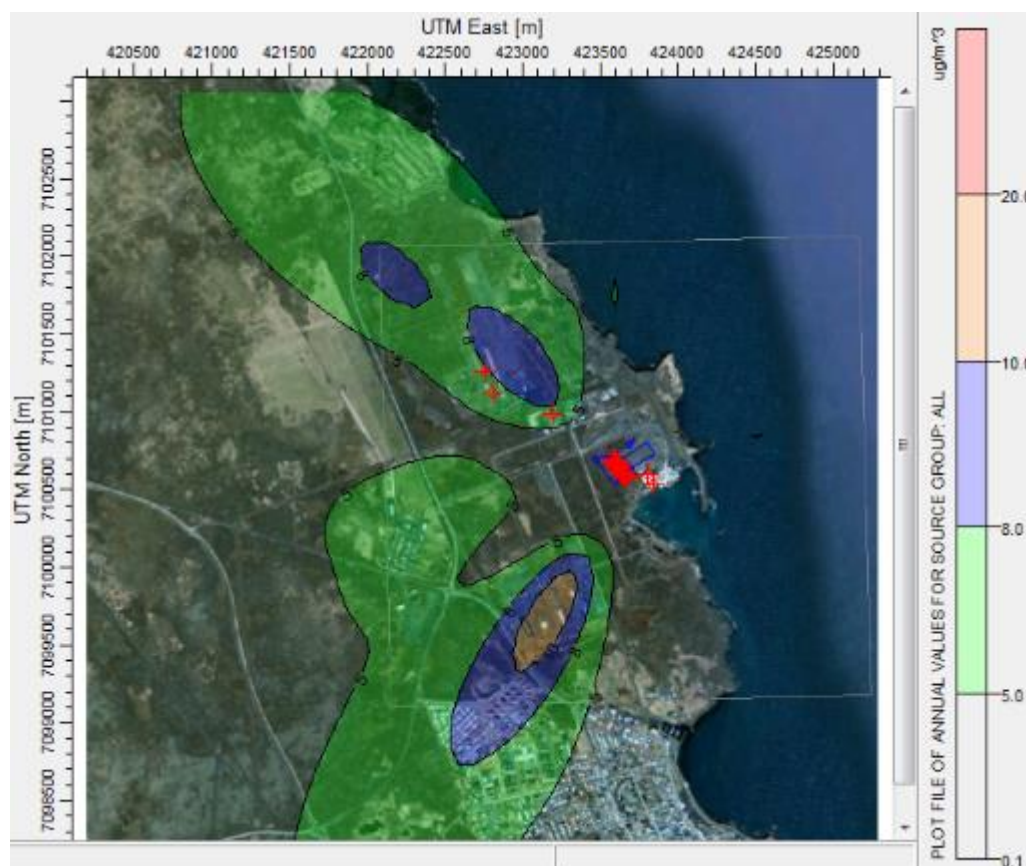
Results of accumulated sources

The summary of all of the modeled pollutants reflecting the highest concentration of any substance in the area during the modeled time interval from 2006-2011 is summarized in the table below:

Resulting emissions	Time frame	Resulting maximum concentration $\mu\text{g}/\text{Nm}^3$	Icelandic air quality criteria $\mu\text{g}/\text{Nm}^3$	Percentile
SO ₂	Year	11.2	20	
	24 hr.	22.6	50	98% (7 times pr. yr)
	24 hr.	29.1	125	99,2% (3 times pr. yr)
	1 hr.	167	350	99,75% (24 times pr. yr)
NO&NO ₂	Year	3.82	30	
	24 hr.	7.72	75	98% (7 times pr. yr)
	1 hr.	16.8	110	98,1% (175 times pr. yr)
	1 hr.	57.3	200	99,75% (18 times pr. yr)
Dust (PM ₁₀)	Year	0.94	20	
	24 hr.	1.92	50	98% (7 times pr. yr)

Table 5: Resulting accumulated maximum concentrations of pollutants anywhere around the plant using all sources from table 4.

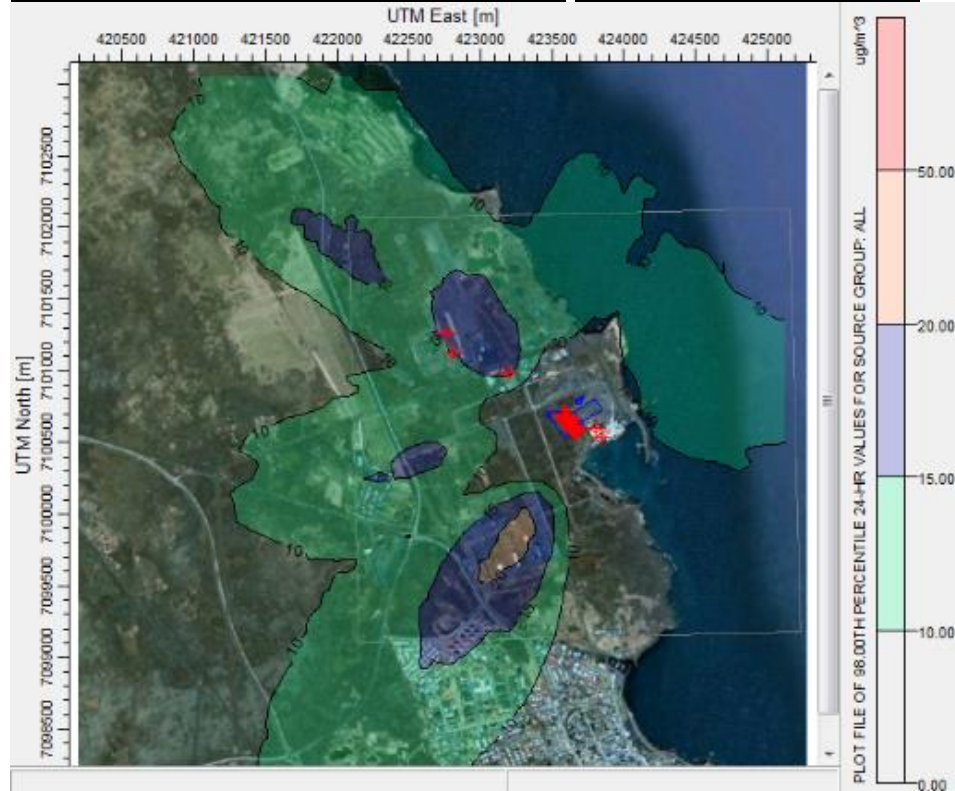
All sources concentration distribution: 1 year average SO₂ concentration:



Maximum SO₂ concentration in any place for this period is 11.2 $\mu\text{g}/\text{m}^3$.

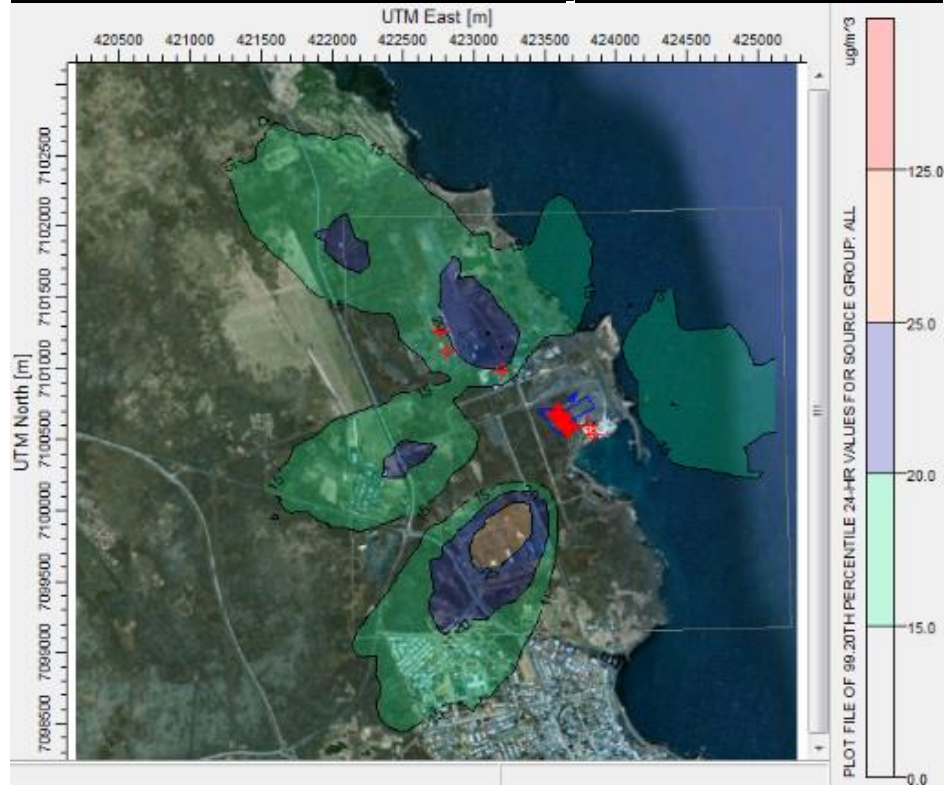
Compares to Icelandic air quality criteria of 20 $\mu\text{g}/\text{m}^3$.

All sources concentration distribution: SO₂ 24 hours 98 % percentile:



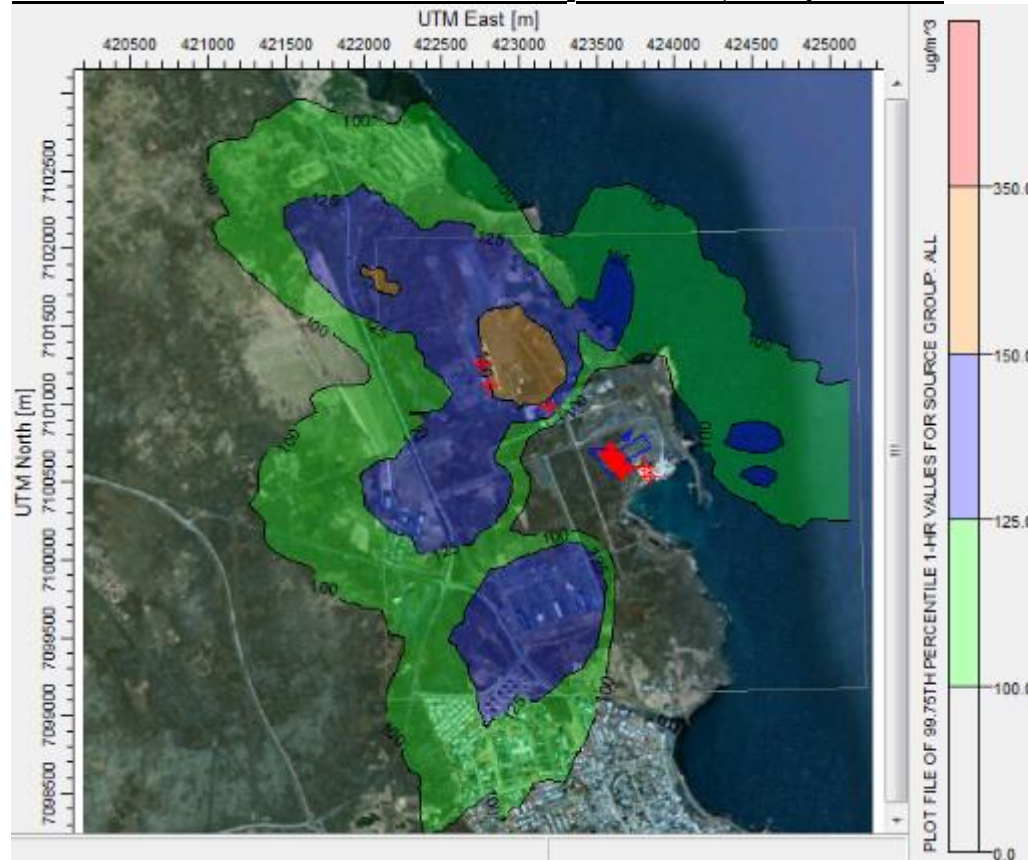
Maximum SO₂ concentration in any place calculated for this period is 22.6 µg/m³. - Compares to Icelandic air quality criteria of 50 µg/m³.

All sources concentration distribution: SO₂ 24 hours 99,2 % percentile:



Maximum SO₂ concentration in any place calculated for this period is 29.1 µg/m³. - Compares to Icelandic air quality criteria of 125 µg/m³

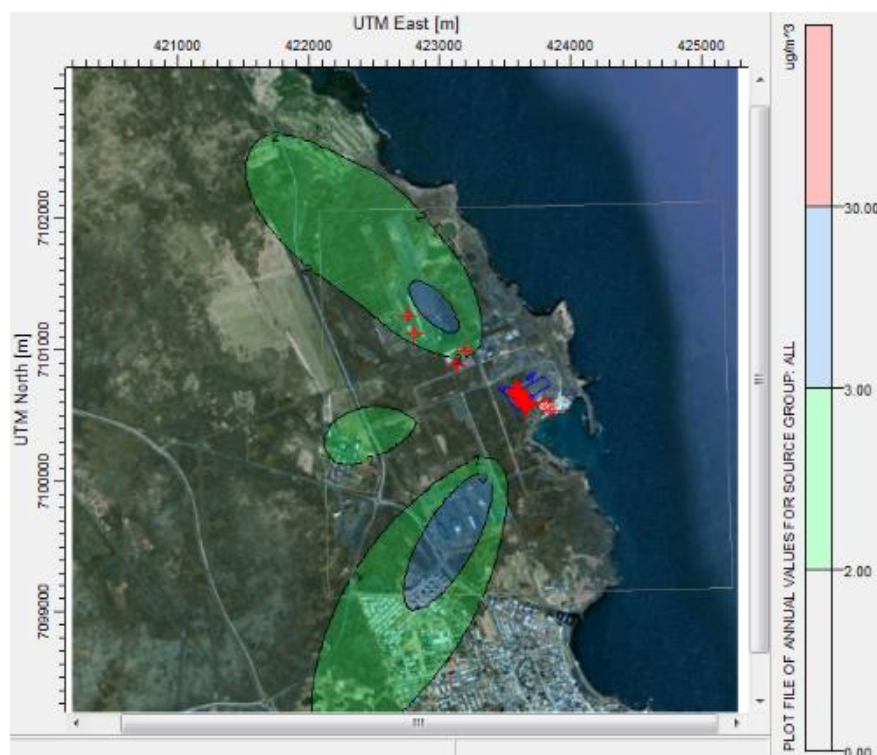
All sources concentration distribution: SO₂ 1 hours 99,75 % percentile:



Maximum SO₂ concentration in any place calculated for this period is 167 µg/m³.

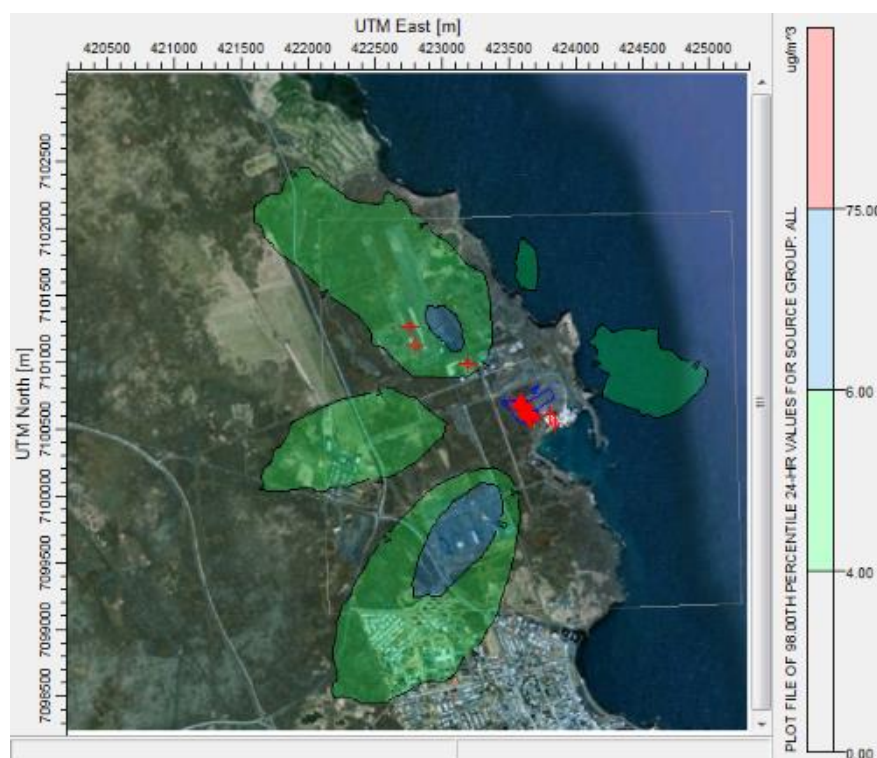
Compares to Icelandic air quality criteria of 350 µg/m³.

All sources concentration distribution: 1 year average NOx concentration:



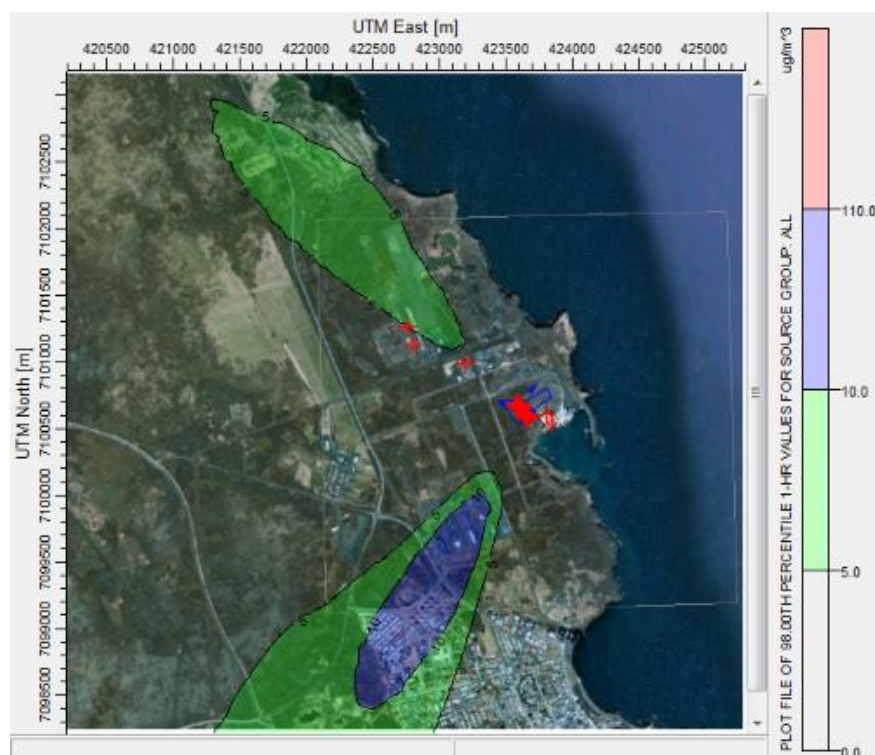
Maximum NOx concentration in any place for this period is $3.82 \mu\text{g}/\text{m}^3$. Compares to Icelandic air quality criteria of $30 \mu\text{g}/\text{m}^3$.

All sources concentration distribution: 24h 98% fractile NOx concentration:



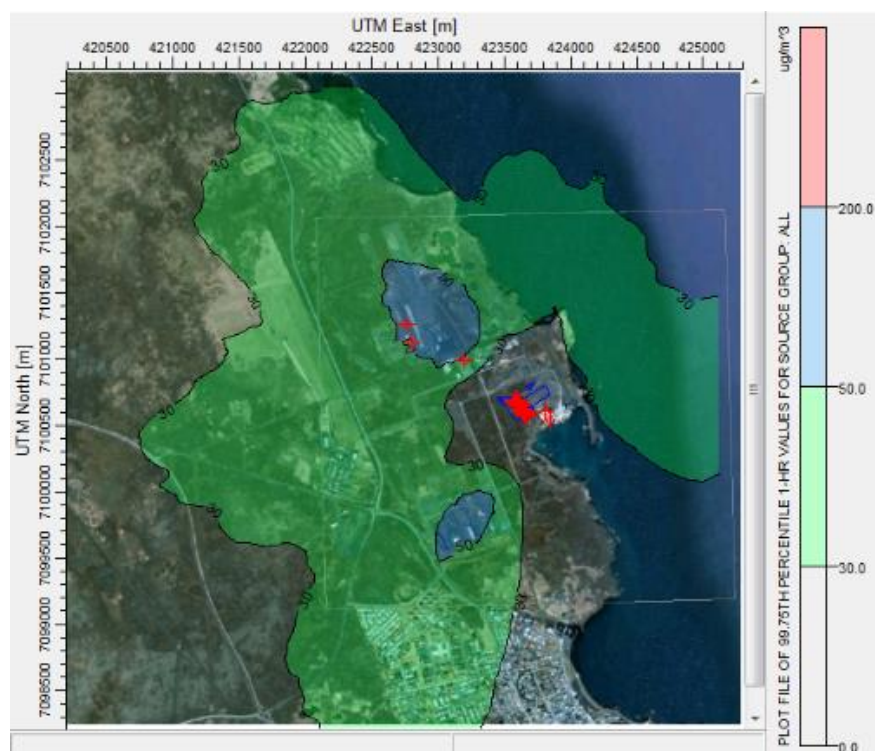
Maximum NOx concentration in any place for this period is $7.72 \mu\text{g}/\text{m}^3$. Compares to Icelandic air quality criteria of $75 \mu\text{g}/\text{m}^3$

All sources concentration distribution: 1h 98% fractile NO_x concentration:



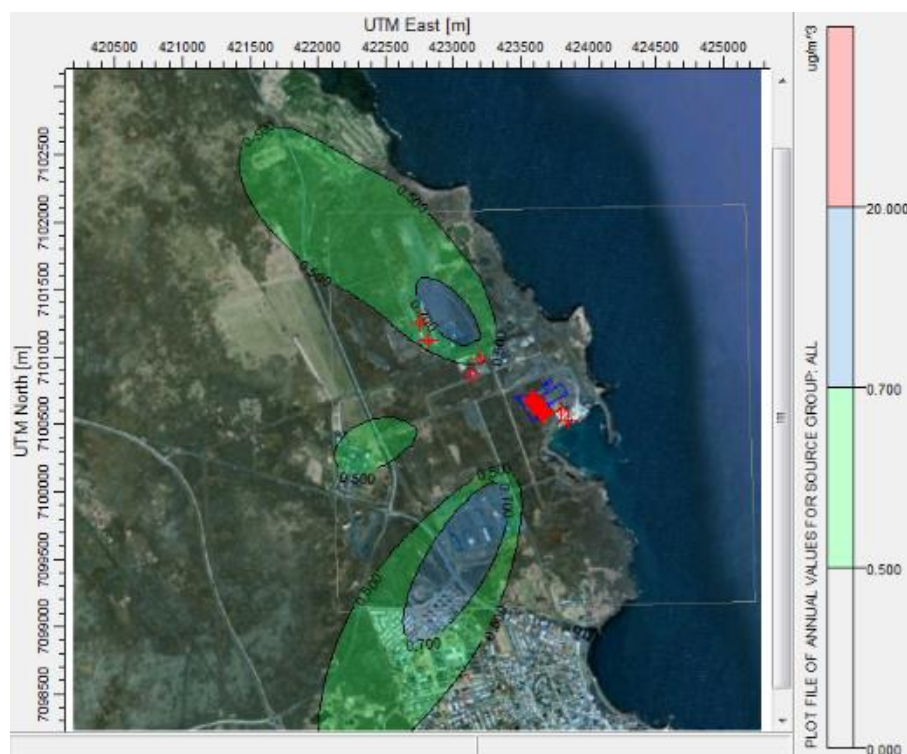
Maximum NO_x concentration in any place for this period is 16.8 µg/m³. Compares to Icelandic air quality criteria of 110 µg/m³.

All sources concentration distribution: 1h 99.75% fractile NO_x concentration:



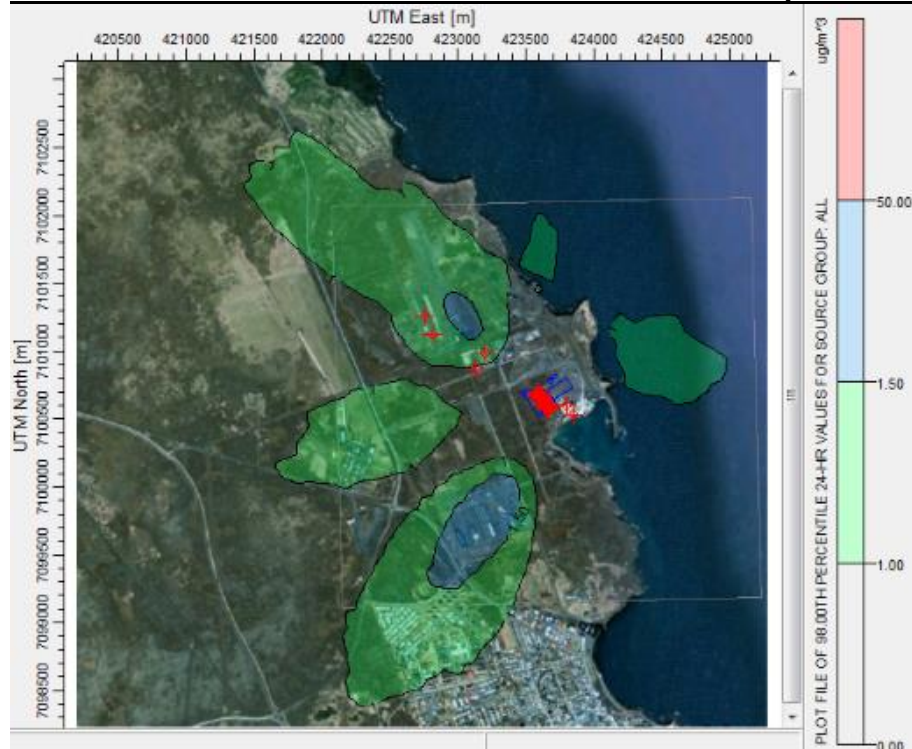
Maximum NO_x concentration in any place for this period is 53.7 µg/m³. Compares to Icelandic air quality criteria of 200 µg/m³.

All sources concentration distribution: 1 year average dust (PM₁₀) concentration:



Maximum dust (PM₁₀) concentration in any place for this period is 0.94 µg/m³. Compares to Icelandic air quality criteria of 20 µg/m³.

All sources concentration distribution: Dust 24 hours 98% percentile:



Maximum Dust concentration in any place calculated for this period is 1.92 µg/m³. - Compares to Icelandic air quality criteria of 50 µg/m³.