NILU: OR 62/2001

NILU: OR 62/2001
REFERENCE: O-2161
DATE: NOVEMBER 2001
ISBN: 82-425-1314-7

Dispersion and stack height estimates for a planned aluminium smelter in Reyðarfjördur, Iceland

Fume treatment plant of the anode-baking furnace

Cristina Guerreiro

Contents

Summary

The Norwegian Institute for Air Research (NILU) was requested by Reydaral to carry out dispersion calculations for three different stack heights (28, 40 and 50 m) of the Fume treatment plant of the anode-baking furnace (FTC) of a planned aluminium smelter in Reyðarfjördur on the east coast of Iceland.

Two emission alternatives have been looked into. Phase 1 is emissions to air from a production of 280 000 tons of aluminium per year. Phase 2 is emissions to air from a production of 420 000 tons of aluminium per year. The dispersion calculations were made for maximum SO_2 hourly concentrations for different wind speeds and atmospheric stability conditions.

There is a large difference between the estimated SO_2 concentrations near the source with an increase of the stack height from 28 to 40 m, for high wind speeds. This is due to the fact that the plume is influenced by turbulence induced by the adjacent building, with a height of 21 m, and the plume will therefore be mixed rapidly to the ground for the 28 m stack. The 40 m stack is tall enough for the plume to travel outside this zone and hence produce a much smaller concentration close to the source. This is illustrated in figures A, B and C. Figure 10 shows the extreme meteorological case when the concentrations drop drastically with the increase of the stack height from 28 to 40 m. Such conditions occur very seldom, but may occur more than 24 hours a year being responsible for maximum SO_2 concentrations higher than 350 $\mu g/m^3$, up to 3000 m from the source for both Phase 1 and Phase 2. NILU recommends that the FTC stack is at least 40 m high, in order to avoid trapping of the plume in the cavity zone of adjacent buildings and to improve the ground level concentrations near the source.

For a stack height of 40 m, the maximum SO_2 hourly concentration will not exceed 200 $\mu g/m^3$ for all meteorological conditions and distances longer than 500 m from the source. Since the Fume treatment plant is responsible for more than 75% of the total SO_2 emissions from the plant and the SO_2 background concentrations in the area are quite low (estimated to be around 5 $\mu g/m^3$), one can conclude that the Air Quality Guideline of 350 $\mu g/m^3$ (percentile 99.7) is unlikely to be exceeded with direct impact from FTC with a 40 m stack or higher, outside the industrial area. Nevertheless, these simple calculations do not take into account the possibility of accumulation of concentrations due to situations where the pollutants are transported back and forth in the fjord (Re-entries), which are connected to poor dispersion conditions. It also does not consider the contribution from the low sources in the plant (potrooms), which under stable conditions will have impact on the ground level concentrations outside the plant, even if their emission rates are about 10 times lower than the emissions from FTC.

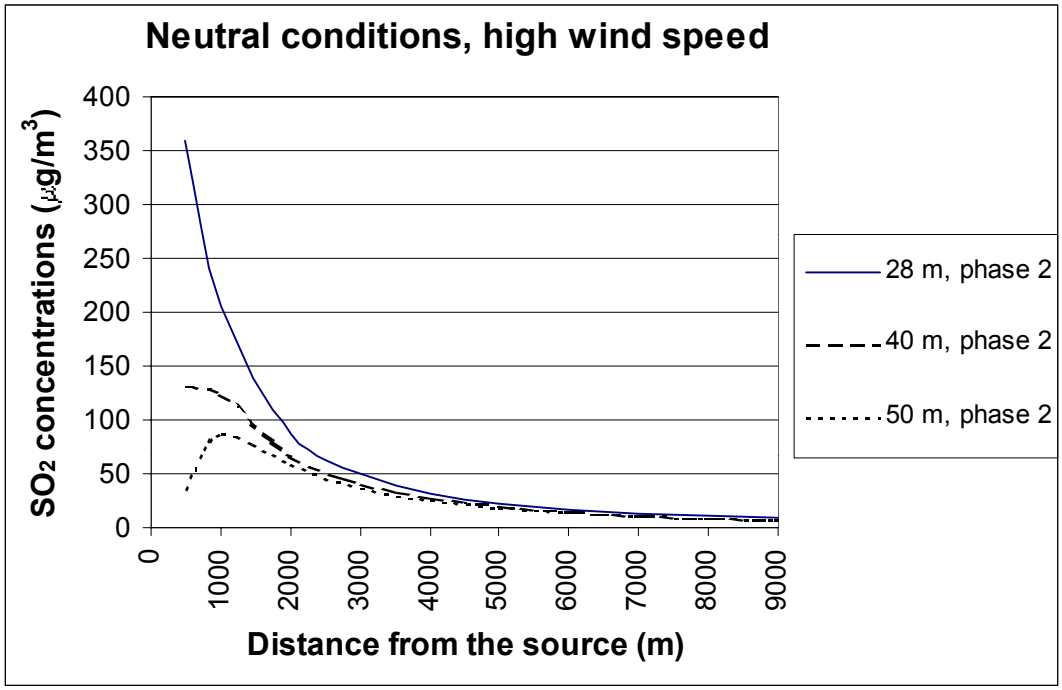

Figure A: Maximum one-hour concentration of SO_2 in µg/m^3 at ground level, as a function of distance to the source, for different stack heights for Phase 2 and under neutral stability conditions and high wind speeds.

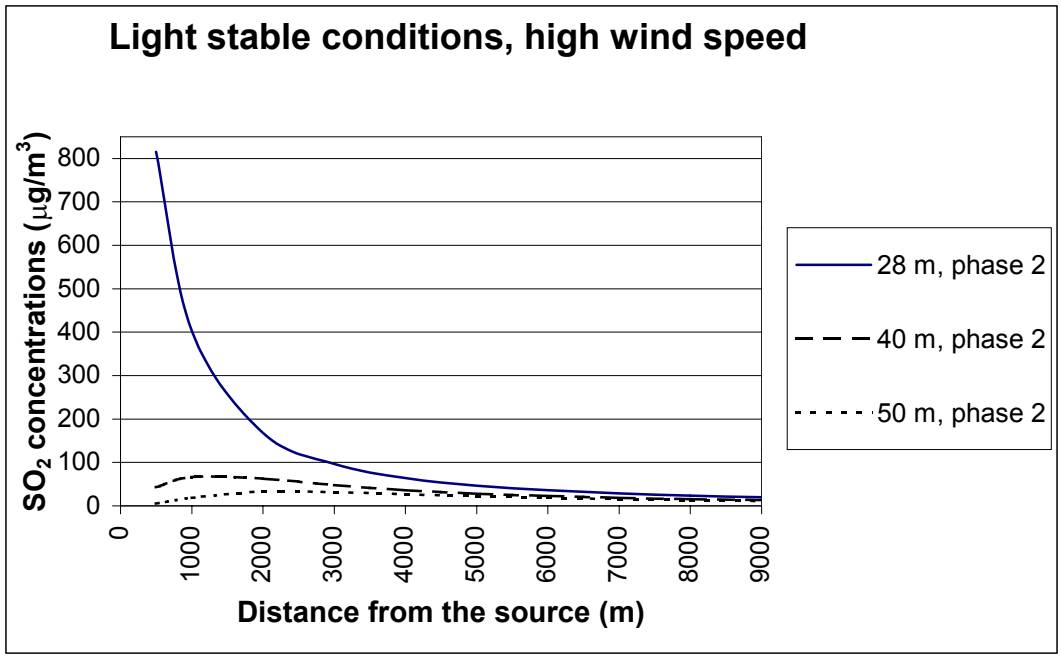

Figure B: Maximum one-hour concentration of SO_2 in µg/m^3 at ground level, as a function of distance to the source, for different stack heights for Phase 2 and under light stable conditions and high wind speeds.

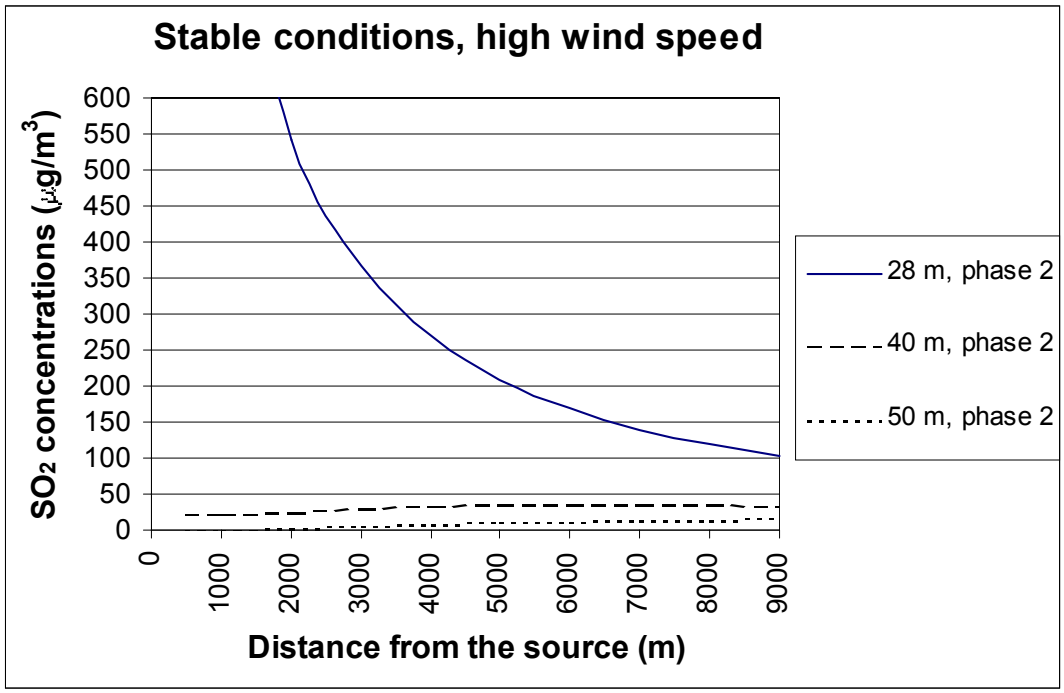

Figure C: Maximum one-hour concentration of SO_2 in µg/m^3 at ground level, as a function of distance to the source, for different stack heights for Phase 2 and under stable conditions and high wind speeds. For a 28 m stack the calculated maximum one-hour concentration of SO_2 is 950 and 1450 µg/m^3, at 1000 m and 500 m from the source, respectively.

Dispersion and stack height estimates for a planned aluminium smelter in Reyðarfjördur, Iceland

Fume treatment plant of the anode-baking furnace

1 Introduction

The Norwegian Institute for Air Research (NILU) was requested by Reydaral to carry out dispersion calculations for different stack heights of the Fume treatment plant of the anode-baking furnace (FTC) of a planned aluminium smelter in Reyðarfjördur on the east coast of Iceland.

Two emission alternatives have been looked into. Phase 1 is emissions to air from a production of 280 000 tons of aluminium per year. Phase 2 is emissions to air from a production of 420 000 tons of aluminium per year.

Three different stack heights were considered: 28, 40 and 50 m. The dispersion calculations were made for maximum SO_2 hourly concentrations for different wind speeds and atmospheric stability conditions.

2 Proposed air quality guidelines

Only EU has proposed air quality guideline for hourly sulphur dioxide. The proposed guideline is presented in Table 1 below.

Table 1: Air quality guideline for hourly SO_2 in EU. Unit: $\mu g/m^3$.

Component	Country	1 Hour
Sulphur dioxide	EU	350[1)]

1) May be exceeded 24 times a year, valid from 01.01.2005.

3 Emission data

The aluminium smelter at Reyðarfjördur is planned in two stages. The first stage will have a production of aluminium of 280 000 tpy, in the second phase there will be a production of 420 000 tpy.

The layout of the aluminium smelter is shown in Figure 1. This study only takes into account the SO_2 emissions to air from the Fume treatment plant of the anode-baking furnace (cooling, electrostatic precipitator, dry scrubbing). The position of the stack is shown in Figure 1 and is marked FTC (code 6). The emission parameters from the FTC plant are shown in Table 2.

The emissions and emission parameters have been given by Reydaral based on Norsk Hydro technology.

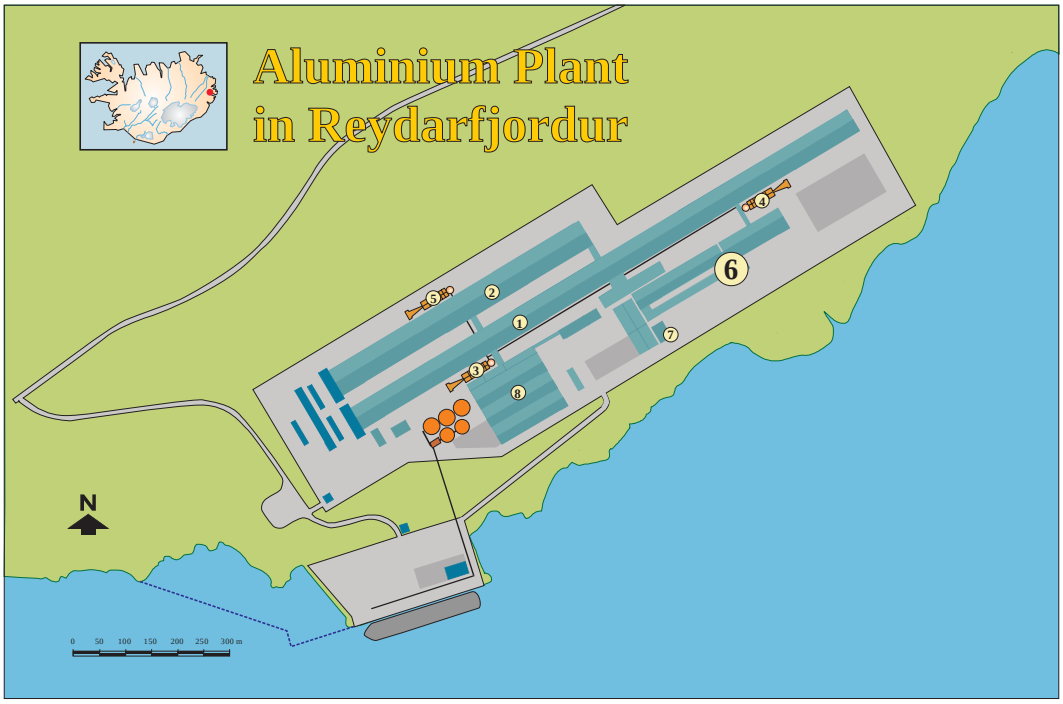

Figure 1: Layout of the aluminium smelter. 1) Potroom 1, 2) Potroom 2, 3), 4) and 5) Fume Treatment Plant (FTP 1, FTP 2, FTP 3), 6) Fume Treatment Carbon (FTC), 7) Green anode plant (GAP), 8) CastHo

Table 2: Emission parameters for the Fume treatment plant of the anode-baking furnace.

	Unit	Phase 1	Phase 2
Aluminium production	tpy	280 000	420 000
Gas Volume	Nm^3/s	28,1	37,6
Gas Temp	°C	60	60
Stack Diameter	m	1,69	1,69
Gas Velocity	m/s	15	20
Stack Height	m	28, 40, 50	28, 40, 50
Closest building height	m	21	21
Closest building length	m	50	50
SO_2 emissions	g/s	18,4	24,5

4 Dispersion calculations

NILU's dispersion model, CONCX (Bøhler, 1987), was used to calculate short-term hourly concentrations of SO_2. The program takes into account effects of stack downwash, building turbulence, wind profiles, topography and penetration through an elevated stable layer. The CONCX model, as most Gaussian plume models, is a conservative model, i.e. it has a higher probability of overestimating concentrations than of underestimating them. The emission data, given in Table 2 has been used as input to the short-term average dispersion calculations.

Maximum one-hour average SO_2 concentrations were calculated for different possible combinations of wind speed and atmospheric stability conditions. These values are the estimated highest one-hour average concentrations at ground level that can occur at a certain distance from the source, along the centre-line of the plume, due to the meteorological conditions considered.

4.1 Short-term maximum SO_2- concentrations

Figure 2 to Figure 7 show SO_2 ground-level concentrations as a function of downwind distance from the source. Concentration values are given as one-hour averages. The meteorological conditions have been chosen to give maximum ground level concentrations of SO_2.

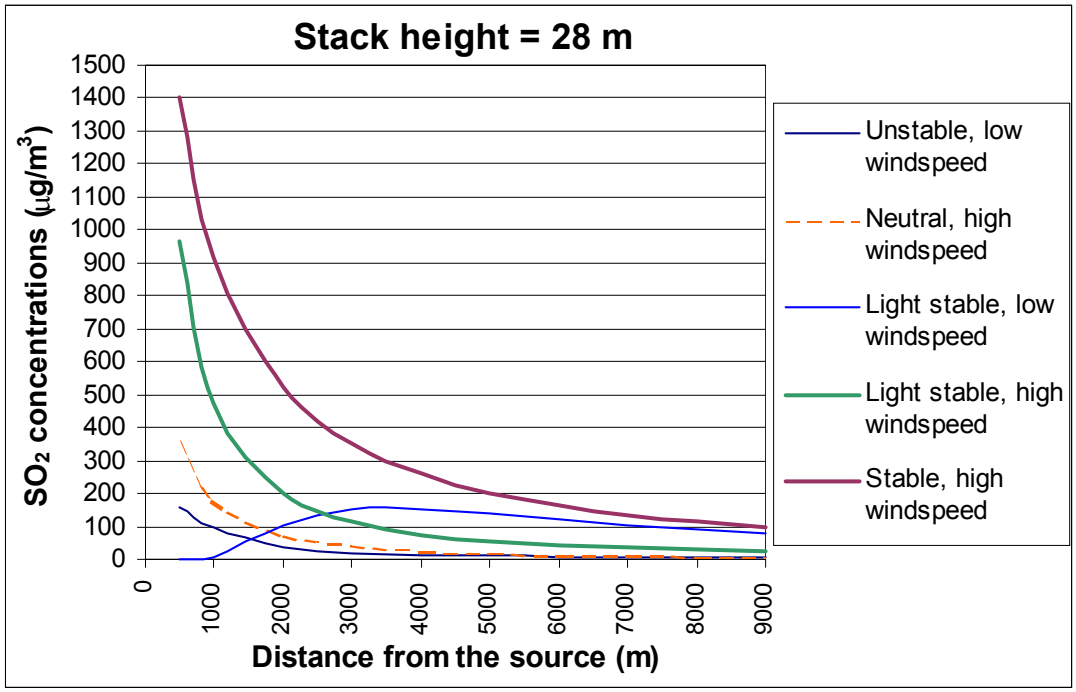

Figure 2: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different meteorological conditions, for a stack height of 28 m, Phase 1.

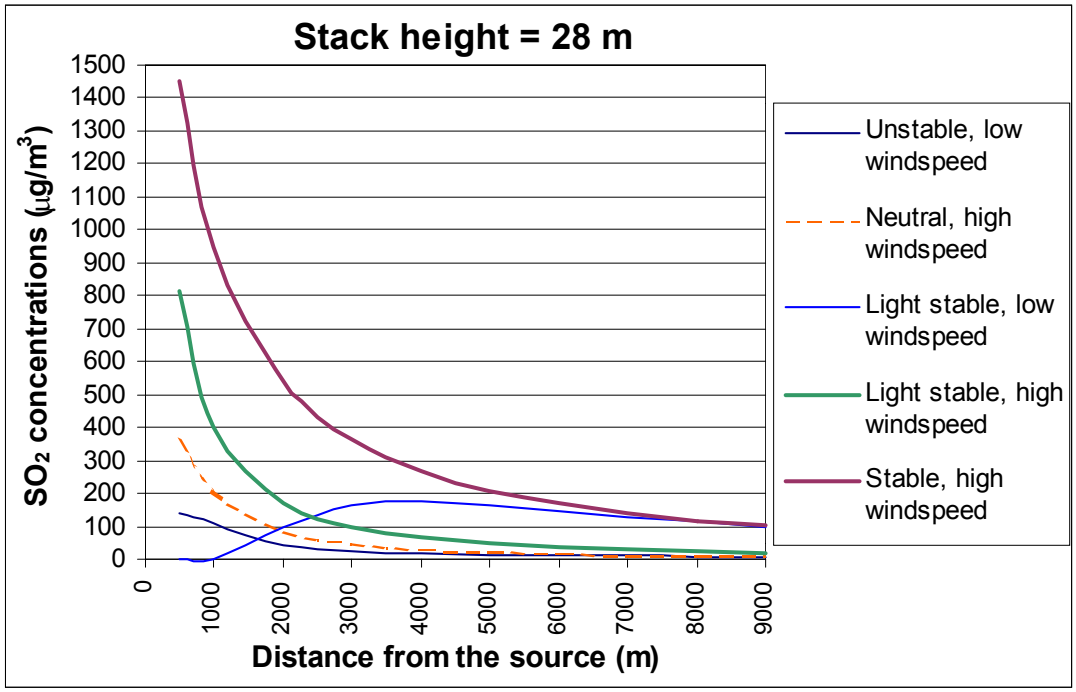

Figure 3: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different meteorological conditions, for a stack height of 28 m, Phase 2.

The one-hour average concentration of SO_2 as a function of down-wind distance from the source, with stack height of 28 m is presented in Figure 2 and Figure 3, for production phase 1 and 2, respectively. Concentrations are highest for high wind speeds, and especially near the source they can reach very high values. This is due to the fact that the plume is influenced by turbulence induced by the adjacent building, with a height of 21 m, and the plume will therefore be mixed rapidly to the ground for the 28 m stack. The highest concentrations occur under stable conditions and high wind speeds, which occur very seldom, but may occur more than 24 hours a year (Guerreiro et al., 2001). The maximum SO_2 concentrations under such meteorological conditions will be higher than 350 $\mu g/m^3$, up to 3000 m from the source for both Phase 1 and Phase 2. The maximum SO_2 concentrations under light stable conditions and low wind speed, which occur around 10% of time (Guerreiro et al., 2001) are about 150 $\mu g/m^3$, 2000 to 3000 m from the source for Phase 1; and between 160 and 180 $\mu g/m^3$, 3000 to 5000 m from the source for Phase 2.

For a stack height of 40 m, the one-hour average concentration of SO_2 is presented in Figure 4 (Phase 1) and Figure 5 (Phase 2). For production Phase 1 the SO_2 concentrations are highest for neutral atmospheric conditions and high wind speeds near the source (500 m), reaching 200 $\mu g/m^3$. Outside the industrial area the highest concentrations occur under light stable conditions and low wind speed, which occur around 10% of time (Guerreiro et al., 2001). The maximum SO_2 concentrations under such meteorological conditions are about 125 $\mu g/m^3$ for Phase 1 and 145 $\mu g/m^3$ for Phase 2, 4000 m from the source in both cases.

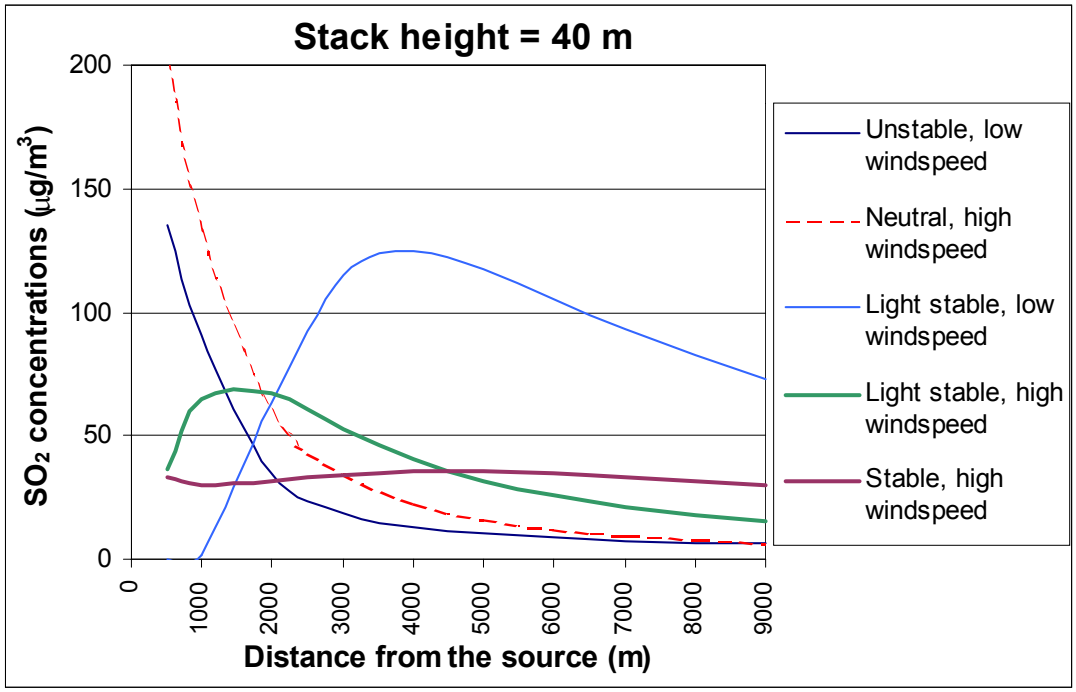

Figure 4: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different meteorological conditions, for a stack height of 40 m, Phase 1.

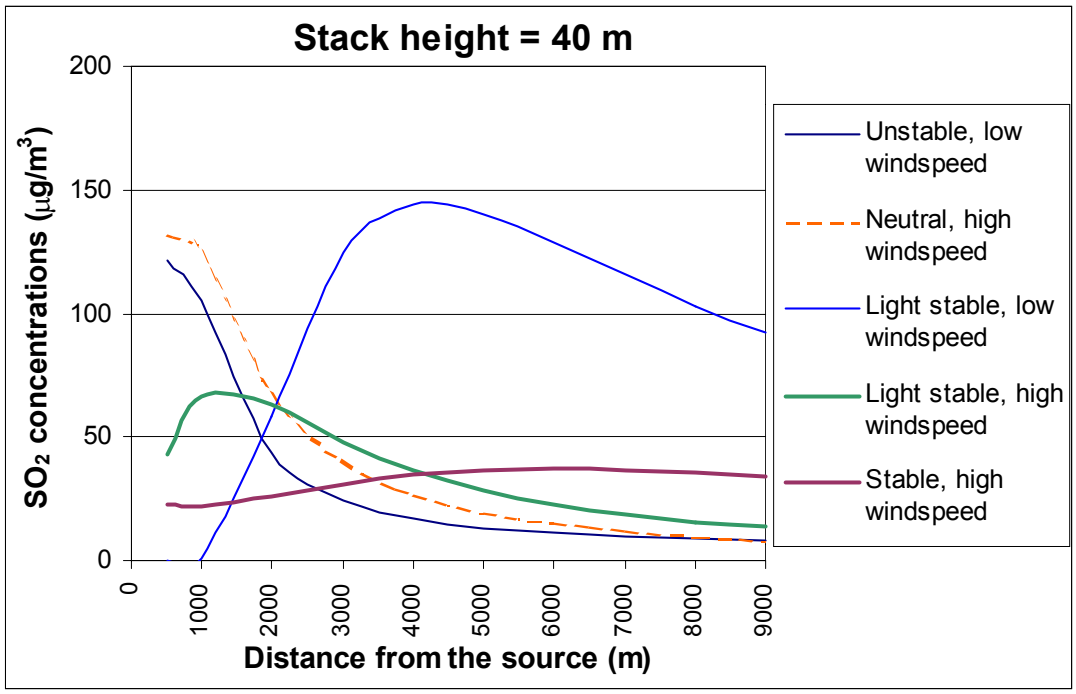

Figure 5: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different meteorological conditions, for a stack height of 40 m, Phase 2.

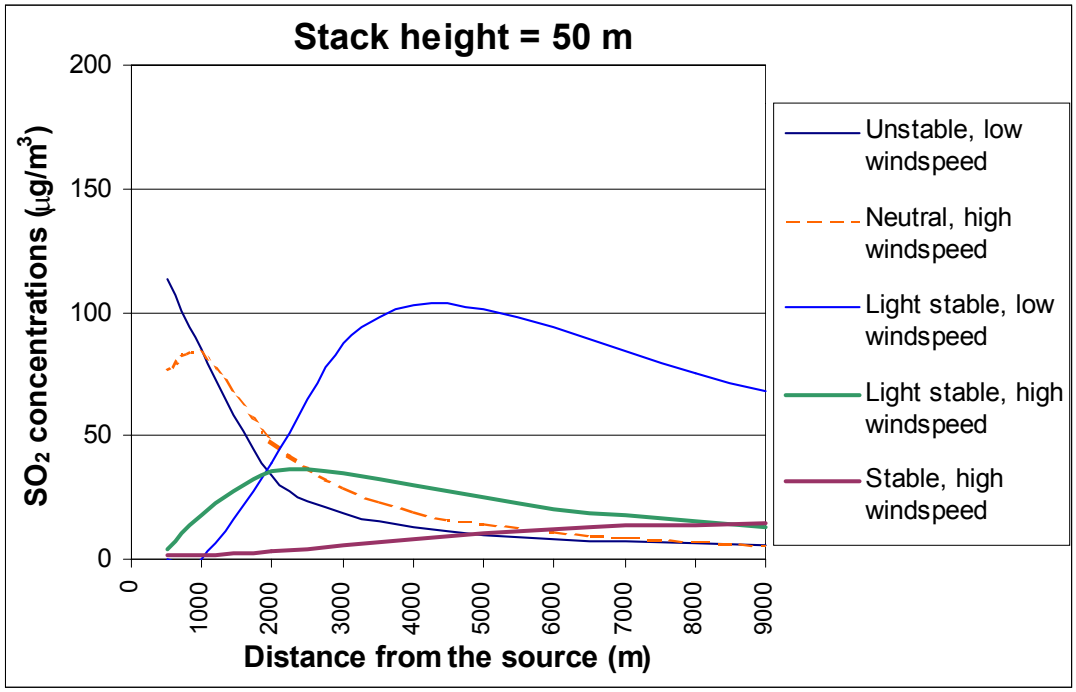

Figure 6: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different meteorological conditions, for a stack height of 50 m, Phase 1.

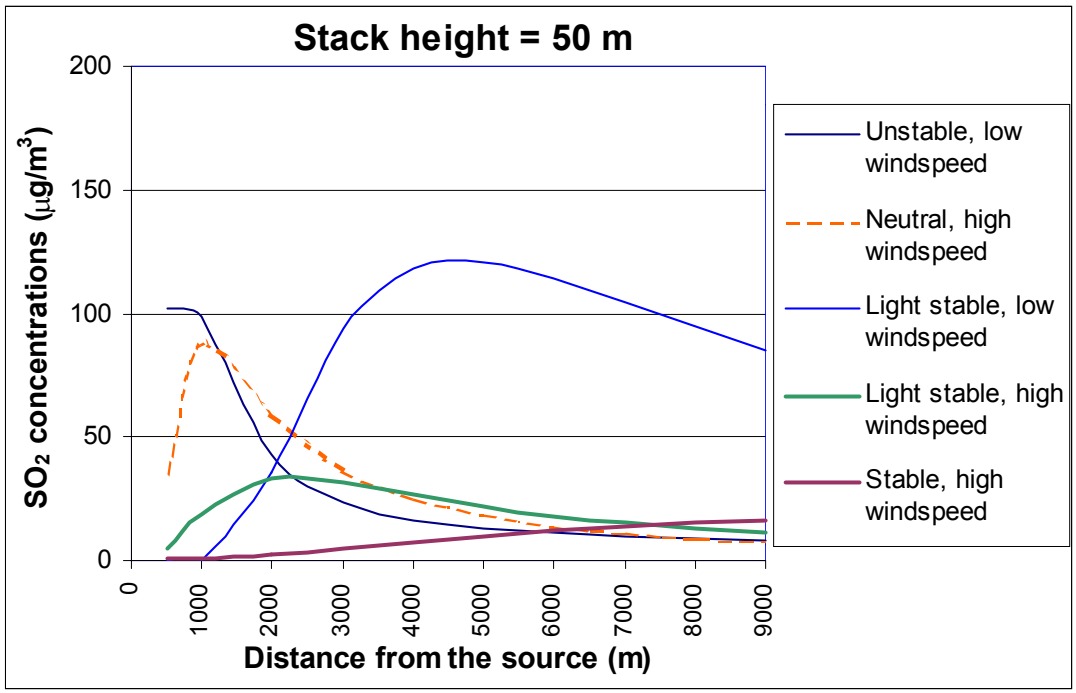

Figure 7: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different meteorological conditions, for a stack height of 50 m, Phase 2.

The one-hour average concentration of SO_2 as a function of down-wind distance from the source, with stack height of 50 m is presented in Figure 6 (Phase 1) and Figure 7 (Phase 2). Concentrations are highest outside the industrial area under light stable conditions and low wind speed, which occur around 10% of time (Guerreiro et al., 2001). The maximum SO_2 concentrations are about 100 µg/m^3, 4000 to 5000 m from the source for Phase 1; and 115-120 µg/m^3, 4000 to 6000 m from the source for Phase 2.

4.2 Discussion

There is a large difference between the estimated concentrations near the source with an increase of the stack height from 28 to 40 m, for high wind speeds. This is due to the fact that the plume is influenced by turbulence induced by the adjacent building, with a height of 21 m, and the plume will therefore be mixed rapidly to the ground for the 28 m stack. The 40 m stack is tall enough for the plume to travel outside this zone and hence produce a much smaller concentration close to the source. This is illustrated in Figure 8 to Figure 10. Figure 10 shows the extreme meteorological case when the concentrations drop drastically with the increase of the stack height from 28 to 40 m. Such conditions occur very seldom, but may occur more than 24 hours a year (Guerreiro et al., 2001), being responsible for maximum SO_2 concentrations higher than 350 µg/m^3, up to 3000 m from the source for both Phase 1 and Phase 2. NILU recommends that the FTC stack is at least 40 m high, in order to avoid trapping of the plume in the cavity zone of adjacent buildings and to improve the ground level concentrations near the source.

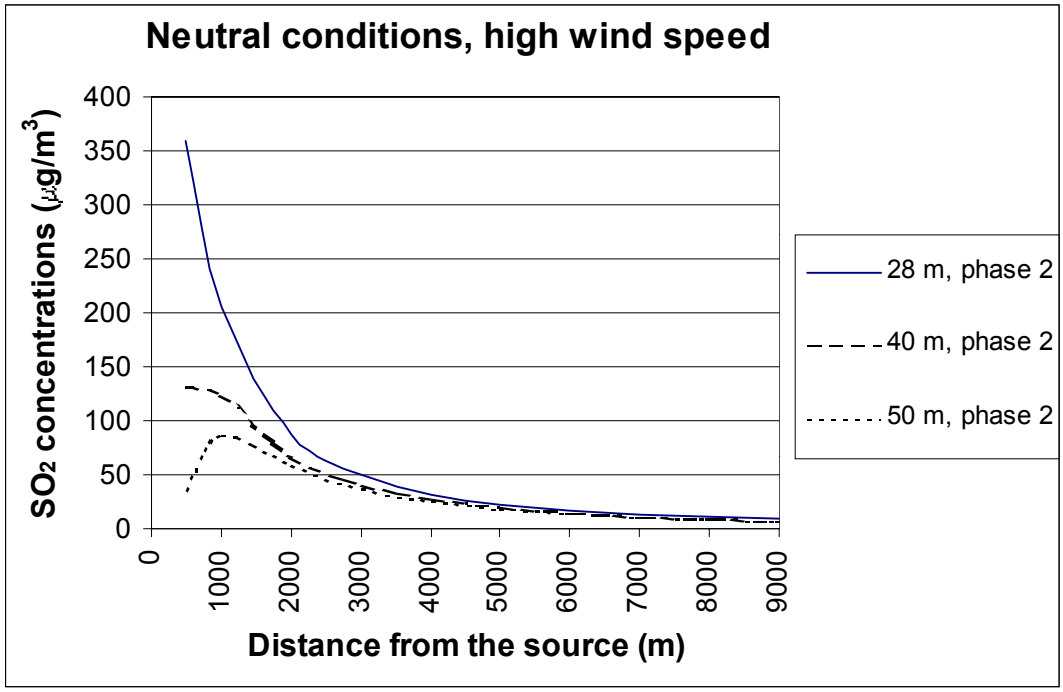

Figure 8: Maximum one-hour concentration of SO_2 in µg/m^3 at ground level, as a function of distance to the source, for different stack heights for Phase 2 and under neutral stability conditions and high wind speeds.

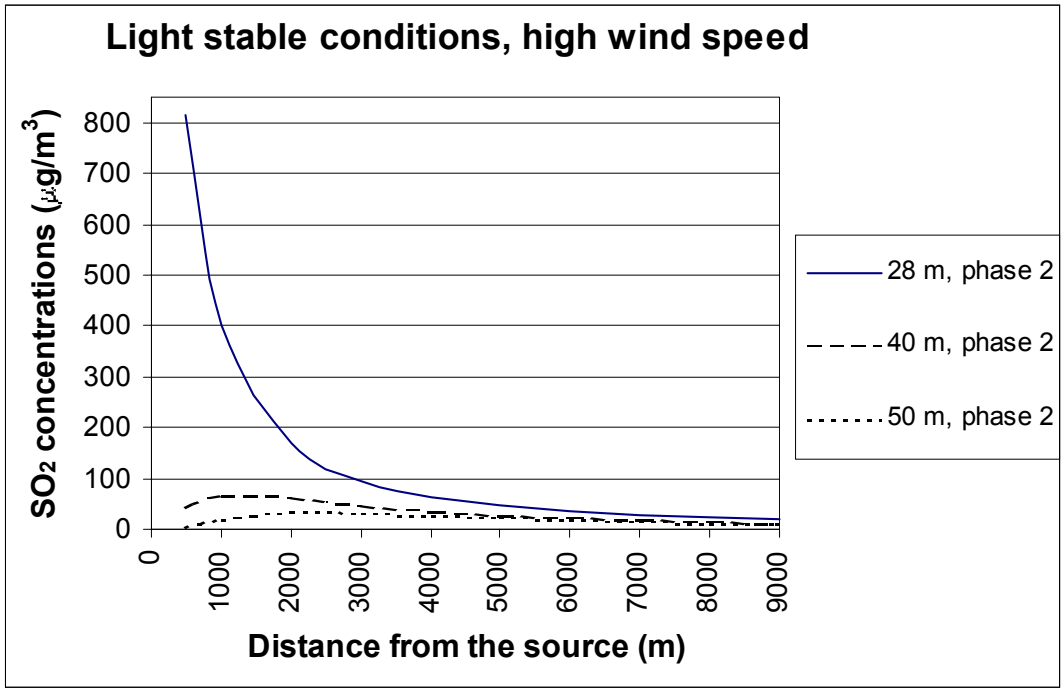

Figure 9: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different stack heights for Phase 2 and under light-stable conditions and high wind speeds.

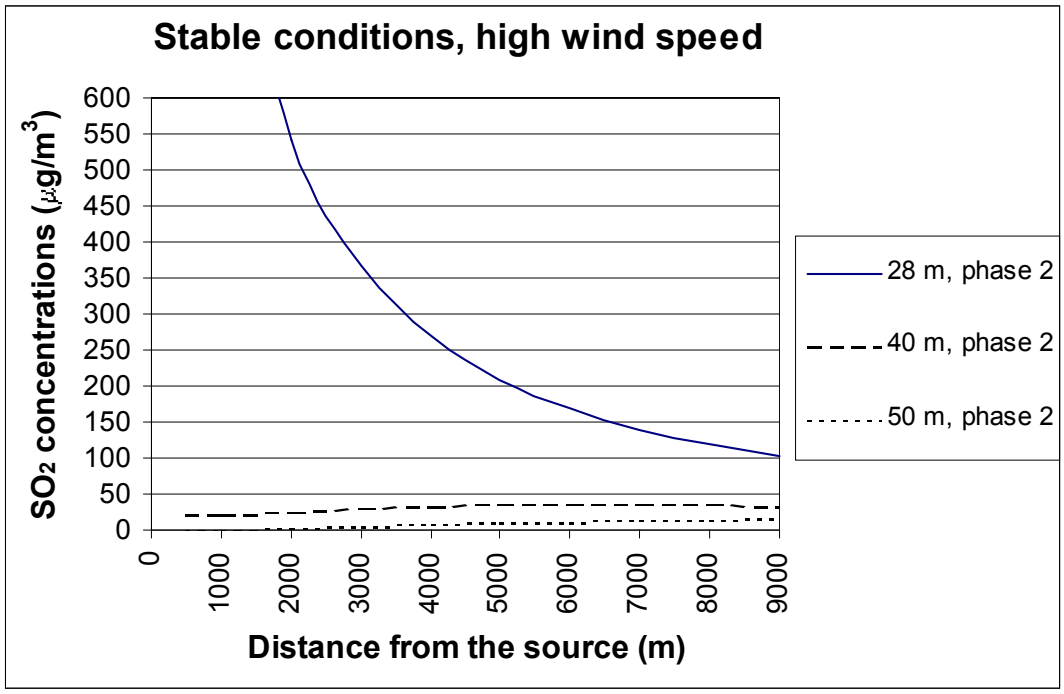

Figure 10: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different stack heights for Phase 2 and under stable conditions and high wind speeds. For a 28 m stack the calculated maximum one-hour concentration of SO_2 is 950 and 1450 $\mu g/m^3$, at 1000 m and 500 m from the source, respectively.

For a stack height of 40 m, the maximum SO_2 hourly concentration will be 200 µg/m^3 for all meteorological conditions and bigger distances than 500 m from the source. Since the Fume treatment plant is responsible for more than 75% of the total SO_2 emissions from the plant and the SO_2 background concentrations in the area are quite low (estimated to be around 5 µg/m^3), one can conclude that the Air Quality Guideline of 350 µg/m^3 (percentile 99.7) is unlikely to be exceeded for a stack height of 40 m or higher, outside the industrial area. Nevertheless, these simple calculations do not take into account the possibility of accumulation of concentrations due to situations where the pollutants are transported back and forth in the fjord (Re-entries), which are connected to poor dispersion conditions with low wind speeds. It also does not consider the contribution from the low sources in the plant (potrooms), which under stable conditions may have some accumulative impact in the concentrations outside the plant, even if their emission rates are about 10 times lower than the FTC ones.

The highest SO_2 concentrations outside the industrial area for a stack of 40 m or higher occur under light stable atmospheric conditions and low wind speeds, between 3000 and up to 6000 m down-wind from the source for all the stack heights and production phases. Such meteorological conditions occur around 10% of time in the area (Guerreiro et al., 2001). The difference between the lines plotted in Figure 11 and Figure 12 show the improvement in the maximum concentrations that can be achieved by increasing the stack height, for Phase 1 and 2.

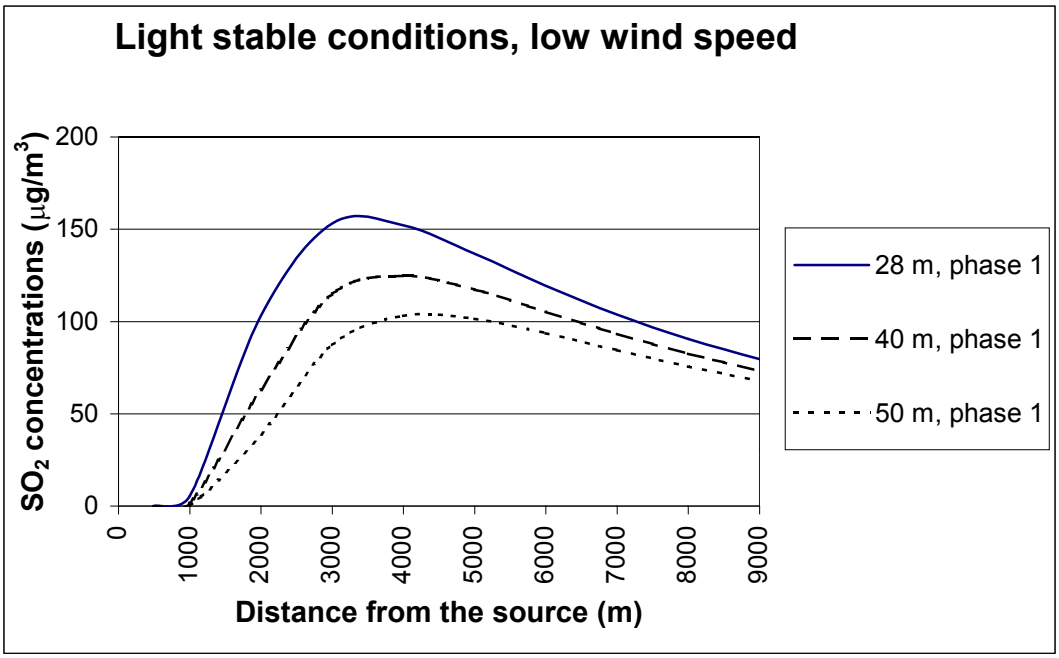

Figure 11: Maximum one-hour concentration of SO_2 in µg/m^3 at ground level, as a function of distance to the source, for different stack heights for Phase 1, under light stable conditions and low wind speeds.

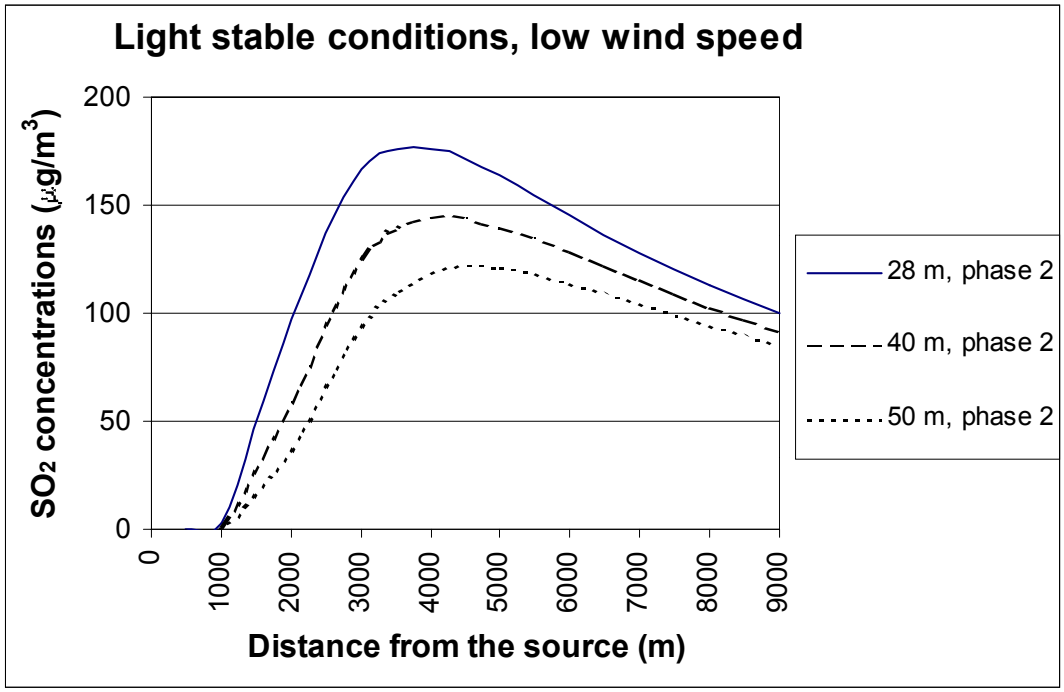

Figure 12: Maximum one-hour concentration of SO_2 in $\mu g/m^3$ at ground level, as a function of distance to the source, for different stack heights for Phase 2, under light stable conditions and low wind speeds.

The difference between maximum SO_2 concentrations in Phase 1 and Phase 2 is much smaller than the difference between the SO_2 emission rates for both phases. This is due to the fact that in Phase 2 the gas volume and velocity are higher than in Phase 1. The higher emission in Phase 2 is compensated with a similar concentration of the pollutant in the gas and a higher plume rise with better dispersion of the pollutant before reaching the ground.

5 References

Bøhler, T. (1987) Users guide for the Gaussian type dispersion models CONCX and CONDEP. Lillestrøm (NILU TR 8/87).

Guerreiro, C. Laupsa, H. and Knudsen, S. (2001) Impact assessment for emissions to air from a planned aluminium smelter in Reyðarfjördur, Iceland. Kjeller (NILU OR 25/01).

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REPORT SERIES	REPORT NO. OR 62/2001	ISBN 82-425-1314-7	
SCIENTIFIC REPORT		ISSN 0807-7207	
DATE	SIGN.	NO. OF PAGES	PRICE
		14	NOK 45,-

TITLE	PROJECT LEADER
Dispersion and stack height estimates for a planned aluminium smelter in Reyðarfjördur, Iceland Fume treatment plant of the anode-baking furnace	Cristina Guerreiro NILU PROJECT NO. O-2161
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ABSTRACT
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NORWEGIAN TITLE

Skorsteinshøyde- og spredningsberegninger for et planlagt aluminiumsverk i Reyðarfjördur, Island.

KEYWORDS		
Aluminium	Stack height	Model calculation

ABSTRACT (in Norwegian)

** Classification*
A Unclassified (can be ordered from NILU)
B Restricted distribution
C Classified (not to be distributed)