Pollution from Nickel Smelters in Norwegian-Russian Border Area, A Combined Monitoring And Modelling Study

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Background/rationale

The North Calotte, including the Russian-Norwegian border areas is rich in metals and minerals. There are numerous mines and processing facilities in the area to exploit these resources. In the Russian cities of Zapolyarny and Nikel close to Norway there is a briquetting facility and nickel smelter respectively producing nickel. These two plants emit large quantities of sulphur dioxide (SO_2) and heavy metals (Ni, Cu, Co and As). These emissions affect the environment on a local to regional scale. During episodes of easterly and southerly winds the emissions enter into Norway given that Zapolyarny and Nikel are located a few km from the Norwegian border. Total emissions of SO_2 add up to over 100 000 tonnes per year, approximately 40 000 tonnes from Zapolyarny and 60 000 tonnes from Nikel. The official emission numbers of heavy metals sum up to several hundred tonnes annually. These emission numbers will likely change as there will be a new production line in Zapolyarny giving less emissions there, but increased emissions from Nikel. In Nikel, a large part of the emissions come from the buildings, diffusive emissions.

Nikel smelter seen from Height 96 in the Pasvik valley. Photo taken 8 Dec 2014 during polar night. Photo: Januus Remm, Univ. Tartu, Estonia

Monitoring

There are two monitoring stations at the Norwegian side of the border, Svanvik (west of Nikel) and Karpdalen (north of Nikel and Zapolyarny), monitoring:

- SO_2 (continuously using monitor)
- Heavy metals in air (weekly sampling and analysis)
- Heavy metals in precipitation (weekly sampling and analysis)
- Meteorology (wind direction and speed, T, RH, p)

SO_2 concentrations put online in near-real time (www.luftkvalitet.info)
Results (SO_2 and heavy metals) are published in annual reports.
Murmansk HydroMet are responsible for Russian monitoring.

Map of Nikel and Zapolyarny facilities and Norwegian monitoring stations in the border areas.

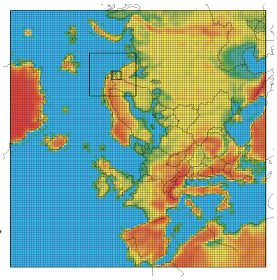
Modelling

The WRF-EMEP model system has been set up in a nested mode to study emissions, dispersion, chemical loss and deposition of pollution from the Nikel and Zapolyarny facilities.

The WRF model (Weather Research and Forecast) has been applied to elaborate meteorological input data, updated every 6 hrs. The model has been run with data representing the years 2011 and 2012.

The EMEP chemical module (www.emep.int) is used to calculate emissions, chemical loss and deposition. The main output is concentrations of SO_2, i.e. hourly mean for selected stations (Svanvik, Karpdalen, Nikel, Zapolyarny), as well as fields of monthly mean and annual mean for the model domain.

Concentrations of SO_2 are compared with observations for model validation. Also heavy metals, i.e. Ni and Cu, is included using the MSC-East parameterization.



The three nested model domains applied in the WRF-EMEP set-up

For metals, tests have been performed using the Engdahl and Velken parameterization assuming on hydrophobic/hydrophilic aerosols and conversion rate/ lifetime between the two modes.

Monitoring results

Both Svanvik and Karpdalen often show short term elevated concentrations (episodes).
Karpdalen is most affected in winter time due to prevailing wind direction from the south.

Key values for SO_2 measurements taken from 1 April 2014 – 31 March 2015, as well as calendar year 2014

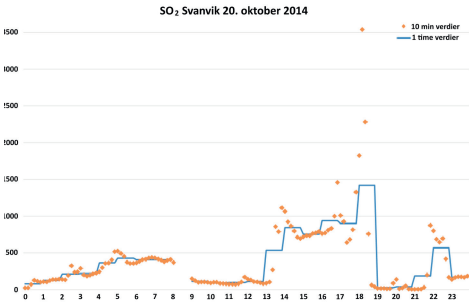
1 April 2014 – 31 March 2015	Svanvik	Karpdalen
Highest 10 minute value µg/m³	3541	871
Highest hourly average value µg/m³	1418	616
# Hourly average values > 350 µg/m³ summer	9	0
# Hourly average values > 350 µg/m³ winter	11	27
Highest daily average µg/m³ summer	160	59
Highest daily average µg/m³ winter	396	366
# Daily averages > 125 µg/m³	2	4
Average value µg/m³ summer	8.6	6.4
[1] Average value µg/m³ winter	8.9	18.2
Calendar year 2014		
[2] # Hourly average values > 350 µg/m³	24	15
[3] # Daily averages > 125 µg/m³	2	3
[1] Average value µg/m³	8.8	13.2

1) *Norwegian limit value for impacts to ecosystems is 20 µg/m³ SO_2 per winter season and per calendar year.*
2) *Norwegian limit value for hourly mean SO_2 concentrations is 350 µg/m³, and can be exceeded no more than 24 times a year.*
3) *Norwegian limit value for daily mean SO_2 concentration is 125 µg/m³, and can be exceeded no more than 3 times a year.*

Average values of elements found in air at Svanvik and in Karpdalen during calendar year 2014.

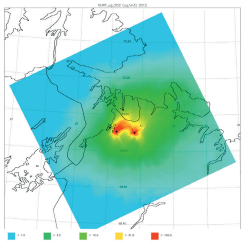
Station	Ni ng/m³	As ng/m³	Cu ng/m³	Co ng/m³
Svanvik	7,77	2,02	6,67	0,31
Karpdalen	7,38	2,12	6,81	0,29

SO_2 concentrations at Svanvik during the episode 20. October 2014 given as 10-minutes mean (orange dots) and hourly mean (blue line). Unit: µg/m³.

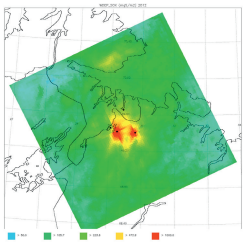


SO_2 concentrations at Svanvik during the episode 20. October 2014 given as 10-minutes mean (orange dots) and hourly mean (blue line). Unit: µg/m³. Maximum 10-minutes: 3541 µg/m³, maximum hourly mean 1418 µg/m³.

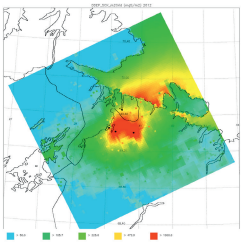
Modelling results



Annual mean surface concentrations of SO_2 in the inner model domain. Unit: µg/m³



Annual mean wet deposition of SO_2 in the inner model domain. Unit: µg/m² year

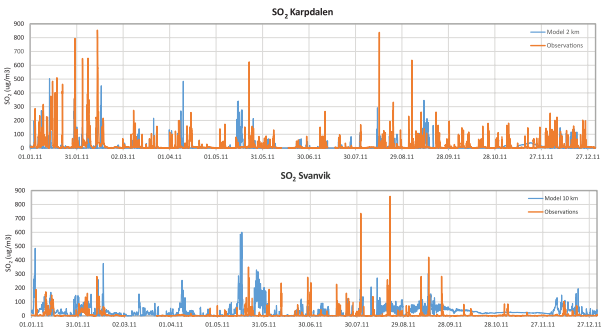


Annual mean dry deposition of SO_2 in the inner model domain. Unit: µg/m² year

The annual mean surface concentrations show elevated values to the north due to prevailing wind direction from south during winter time.

Wet deposition is a dependent upon concentrations of SO_2 in the column, solubility, clouds and rain fall.

Dry deposition is dependent upon surface concentrations and deposition velocity. Please note the difference between land and sea surface in the right plot.



Both observations and model show elevated concentrations (episodes). These are linked to wind direction coming from the smelters in Zapolyarny and Nikel.

Model-observation validation for the stations Karpdalen (upper panel) and Svanvik (lower panel) for the year 2011 (inner model domain resolution 2 km). Unit: µg/m³.

Conclusions

Monitoring show enhanced concentrations of SO_2 and Ni, Cu, Co, and As in the Russian-Norwegian border area due to emissions from smelter activity in Zapolyarny and Nikel.

The concentrations are highest in the vicinity of the smelters, especially in Nikel due to diffusive emissions from the buildings.

Modelling is a valuable tool to understand emissions, dispersion, chemical cycle and deposition of pollution emitted from Zapolyarny and Nikel.

The **combined environmental stress** from pollution, climate change and new environmental toxics is important and should be investigated further. The sum of the stressors is larger than the impact from the stressors seen separately.

Acknowledgements – further reading

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The monitoring report for the period April 2014 – March 2015 can be downloaded at http://www.miljodirektoratet.no/no/Publikasjoner/2015/September-2015/Grenseomradene-Norge-Russland/
Russian monitoring data is available at: http://www.kolgimet.ru/index.php?option=com_content&view=article&id=54&Itemid=239
Common Russian – Norwegian monitoring report:
http://www.miljodirektoratet.no/no/Publikasjoner/2015/Januar1/Russian-Norwegian-ambient-air-monitoring-in-the-border-areas/

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