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Mercury in terrestrial mosses in the vicinity of the Norgips plant at Tørkop

The plant of Norgips Norge AS at Tørkop
Photo: Jarl Eivind Løvik

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REPORT

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Abstract

The Norgips plasterboard plant at Tørkop in Vestfold County, Norway, are now using industrial gypsum as a raw material in their production. This is a by-product from the cleaning of flue-gases from coal power plants. Industrial gypsum contains, in general, less heavy metals than the before used natural occurring gypsum, with the exception of a higher content of mercury (Hg). The production at the plant has increased the recent years. The atmospheric emission of mercury from the plant is now 15 kg per year, which is 2% of the annual man-made atmospheric emissions in Norway. To reveal the extent of Hg pollutions from the plant, Hg concentrations in terrestrial mosses were examined at 15 locations in the vicinity of Tørkop. Elevated Hg concentrations were found in mosses from the immediate area of the plant. This may be attributed to depositions of dust from raw materials and depositions of reactive gas-phase mercury from the production. However, this needs be verified with more specialized surveys. There could not be established any systematic concentration gradient outside the immediate area. Mercury released through the heating process exists most likely as gaseous mercury. This phase is more mobile and has a different transport and deposition pattern than particle bound mercury in the dust originating from the raw materials.

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1. Gipsprodukter	1. Gypsum products
2. Kvikksølv	2. Mercury
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Foreword

The County Governor of Vestfold has in a letter of 2005-09-27, requested Norgips Norge AS to work out a report concerning environmental effects, local and global, of mercury emissions from their plant at Tørkop. Actions for reducing the emissions should also be evaluated, and an economic assessment would also be appreciated. The work should be done by external expertise. Norgips Norge AS, by Production and Laboratory Manager Cecile Holm, contacted Norwegian Institute for Water Research (NIVA) and a meeting was arranged at the plant at Tørkop, 2005-11-01, with representatives from Norgips, the Environmental Protection Branch of the County Governor and NIVA. The representatives from the County Governor pointed out that the report should be completed as soon as possible. NIVA suggested a survey of mercury concentrations in terrestrial mosses in the immediate area of the plant, as well as in the surrounding district. According to NIVA, this could give a good indication on the significance of the mercury depositions originating from the activities at the plant. It was concluded that this survey should be carried out immediately.

Moss samples were collected 11th and 12th November by Jarl Eivind Løvik from NIVA, Regional Office Østlandet. The mild autumn made it possible to collect good samples of the mosses. The chemical analyses were done at NIVA's laboratory in Oslo, and Sigurd Rognerud and Eirik Fjeld authored the report.[1]

Ottestad, 2006-03-02

Sigurd Rognerud

Sigurd Rognerud

[1] This is an English translated version of the original Norwegian report. Eirik Fjeld, Oslo, 2006-04-25

Content

Summary

Norgips Norge was founded in 1964 and the first plasterboards were produced the following year. Since then, the plant at Tørkop outside the city of Drammen has expanded and has been modernized. The plant used natural occurring gypsum as a raw material in earlier years, but now this has been replaced entirely by industrial gypsum. This is a by-product from the cleaning of flue gases from coal power plants. In general, industrial gypsum contains insignificant amounts of heavy metals, as these mostly are retained in the ash from the power plants. However, volatile sulphur oxides together with volatile metals, such as mercury (Hg), are lead to a reaction with calcium carbonate in the flue gas desulphurisation (FGD) systems. This industrial gypsum formed during this process may therefore contain traces of mercury. This mercury may be carried to the environment at Tørkop through waste gases from the plant and from dust whirled up during unloading and transport of gypsum in dry periods. To reveal the extent of mercury pollution from the plant, it was chosen to carry out a simple survey of mercury concentrations in terrestrial mosses at 15 locations in the vicinity of the plant at Tørkop. This survey was accomplished by the same methods as the national moss surveys of the Norwegian Pollution Control Authority (SFT). These have been carried out every fifth year since 1985 (Steinnes et al. 1995, 2001).

The moss analyses indicated an increase in the atmospheric deposition of mercury in the immediate area of the plant. The depositions in this area may be explained as an effect caused by depositions of dust originating from the raw material used in the production and of depositions of reactive gaseous mercury. However, this remains to be verified by dedicated methods. Apart from the increase in the concentration in the mosses in the immediate area of the plant, there was no sign of a systematic gradient in the concentrations that could be related to emissions from the plant. However, we emphasize that the number of samples is limited, and the results also should be compared to a recent larger national or regional data set.

According to information from the company, the mercury emissions from the production, released through the chimney stack, are about 15 kg per year. This amounts to approximately 2% of the annual national man-made emissions and is an insignificant fraction of the global man-made emissions (1900 metric tons per year, according to Pacyna and Pacyna 2002). It is likely that this mercury exists as gaseous mercury, which has a different deposition pattern than the particle bound mercury originating from the dust of the raw materials used in the production.

1. Introduction

Norgips Norway was founded in 1964, and the first plasterboards were produced the following year. Since then, the plant at Tørkop, outside the city of Drammen, has expanded and has been modernized. The plant used natural occurring gypsum as a raw material in the former years, but this has now been replaced entirely by industrial gypsum. This is a by-product from the cleaning of flue gases from coal power plants. In general, industrial gypsum contains insignificant amounts of heavy metals, as these mostly are retained in the ash from the power plants. However, in the power plants are volatile sulphur oxides, together with volatile mercury species, lead to the flue gas desulphurisation (FGD) systems. Here, the sulphur reacts with calcium carbonate to gypsum. The industrial gypsum formed during this process may therefore contain traces of mercury.

The product specification sheet for FGD plaster (dated 17th Jan. 1997), handed over to NIVA from the company, states the mercury concentration to be equal to or less than 1.3 µg/g dry weight (d.w.) (i.e. the concentration is not exactly specified). This is in general twice as high as of the highest concentration found in Norwegian lake sediments (Rognerud and Fjeld 2000). Analyses of dried gypsum, calcinated gypsum and rehydrated gypsum, done for the company in 2005 and 2006, showed mercury concentrations in the range 0.2-0.4 µg/g d.w. This is considerably lower than the upper limit given in the FGD specification. It is reasonable to assume that the concentration in the raw materials will vary somewhat depending on the types of coal and the producers. Together with the increase in the mercury content of raw materials, the production volume has increased the latest years. This gives the possibility for an increase in the mercury emissions to the environment. The annual emission is now about 15 kg of mercury.

Mercury is supplied to the environment through waste gases from the plant, and also from dust whirled up during unloading and transport of gypsum in dry periods (Veritas 2000). Determination of mercury in the waste gases from the plant over time is an expensive and complicated task. It is also necessary to discriminate between different mercury species, such as elementary (Hg-0) and divalent mercury (Hg-II) because their deposition pattern will differ considerably. Divalent mercury exists as particle bound mercury or as reactive gaseous mercury (RGM). The latter is rapidly adsorbed to particles and aerosols. Atmospheric Hg-0 exists as the less reactive elemental gaseous mercury and must be oxidized to Hg-II to be deposited effectively. Hence, emissions of Hg-II from the plant are likely deposited in a greater extent in the nearby area than emissions of Hg-0.

Survey of lake sediments may also reveal the temporal trends in atmospheric depositions of mercury. Because of the tight time schedule, it was chosen to make a simpler survey of mercury concentrations in terrestrial mosses at 15 locations in the vicinity of plant at Tørkop. The survey was accomplished by the same methods as the national moss surveys of the Norwegian Pollution Control Authority (SFT). These have been carried out every fifth year since 1985 (Steinnes et al. 1995, 2001). The results for 2005 are not yet ready, but the analyses in our report should be compared with these when they are available.

The objective with the present study is to reveal relative differences in mercury concentrations in terrestrial mosses sampled at different ranges from the plant at Tørkop, and use these as an indication on the extent of mercury pollution originating from the plant.

2. Methods

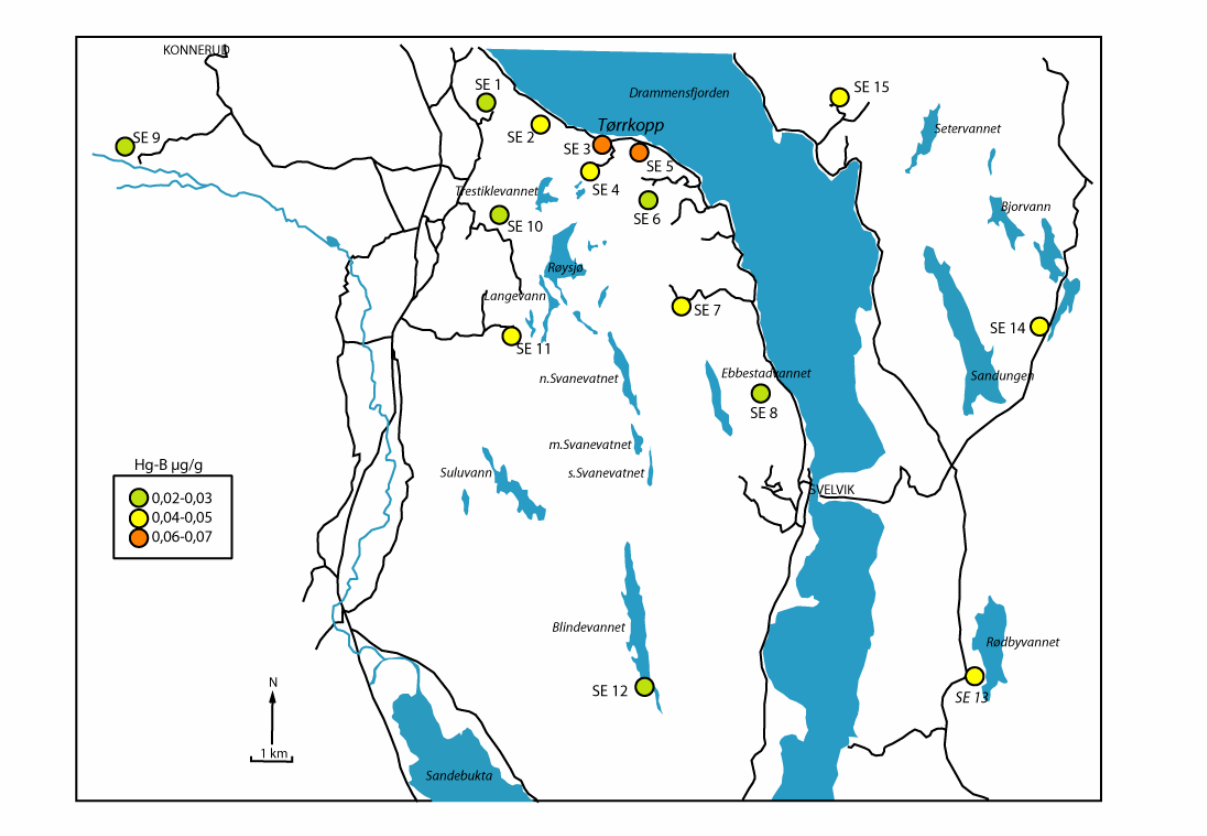
The sampling of Stair-step moss (*Hylocomium splendens*) followed the protocol given in SFT report 691/97 (Steinnes et al. 1997). This implies that the samples are not taken from mat layers growing under trees and shrubs, but from open spaces. The samples were dried at 35°C, digested in nitric acid, and analyzed at NIVA's laboratory according to an accredited method (E-3-3, cold vapor atom-absorption spectroscopy). The mosses were sampled 11th-12th Nov. 2005.

3. Results

Map coordinates and concentrations of mercury in the moss samples are given i Tab. 1. The concentrations varied between 0.024 and 0.071 µg/g d.w. The geographical distribution of the concentrations is illustrated by dividing the concentrations in three classes, color coded in green, yellow and orange (Fig. 1). The colors have been chosen only to illustrate increasing concentrations. They should not be associated with the national classification schemes for environmental conditions, given by SFT.

Tabell 1. *Map coordinates (as registered by GPS) and mercury concentrations in Stair-step mosses (*Hylocomium splendens*) at Tørkop and the surrounding area.*

Date	Station	UTM-zone	UTM-EV	UTM-NS	Hg concentration, µg/g dry weight
11.11.2005	SE 1	32v	571779	6618513	0,032
11.11.2005	SE 2	32v	572980	6618118	0,053
11.11.2005	SE 3	32v	574359	6617692	0,071
11.11.2005	SE 4	32v	574462	6617373	0,036
11.11.2005	SE 5	32v	575422	6617562	0,058
11.11.2005	SE 6	32v	575578	6616233	0,034
11.11.2005	SE 7	32v	576474	6613759	0,048
11.11.2005	SE 8	32v	578334	6611443	0,031
12.11.2005	SE 9	32v	563051	6617263	0,024
12.11.2005	SE 10	32v	571847	6615452	0,031
12.11.2005	SE 11	32v	572191	6613110	0,039
12.11.2005	SE 12	32v	575568	6604550	0,029
12.11.2005	SE 13	32v	583534	6605091	0,050
12.11.2005	SE 14	32v	584938	6613505	0,035
12.11.2005	SE 15	32v	580009	6618851	0,035



Figur 1. *Mercury concentrations in Stair-step mosses (*Hylocomium splendens*) sampled at different stations. The concentrations are divided in three classes, depicted by different color codes. (The codes should not be associated with the national classification schemes for environmental conditions, given by SFT).*

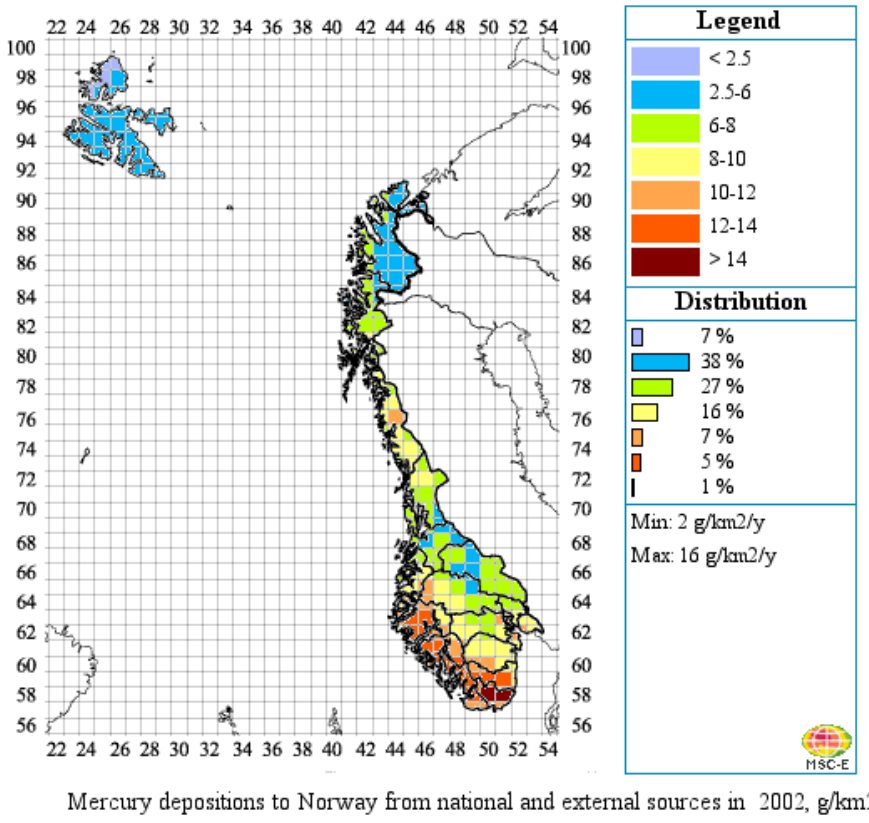
4. Evaluation of results

In the following we make an assessment of the results, with focus on a discussion on the elevated concentrations found in the moss samples collected in the immediate area of the plant, and compare the depositions and emission data with national data.

Based on the present data, a noticeable increase of mercury deposition appears to be rather local and confined to the immediate area around the plant. The highest concentrations of mercury in mosses were found close to the plant, at the sample stations SE3 and SE5. The concentrations here were 0.071 and 0.058 µg/g d.w., respectively. No other systematic gradients could be demonstrated. As a comparison, the median concentration for the whole set of samples was 0.035 µg/g d.w. We will regard this as the common background level for the region.

Transport and handling of raw materials have caused fallout of dust in the immediate area of the plant (Veritas 2000). Average monthly deposition rate of such dust has been measured to be 4 g/m^2. The mercury concentrations of the raw materials (SGD gypsum) are reported to be about 0.3 µg/g d.w. This implies that the increase in the annual mercury deposition close to the plant, originating from

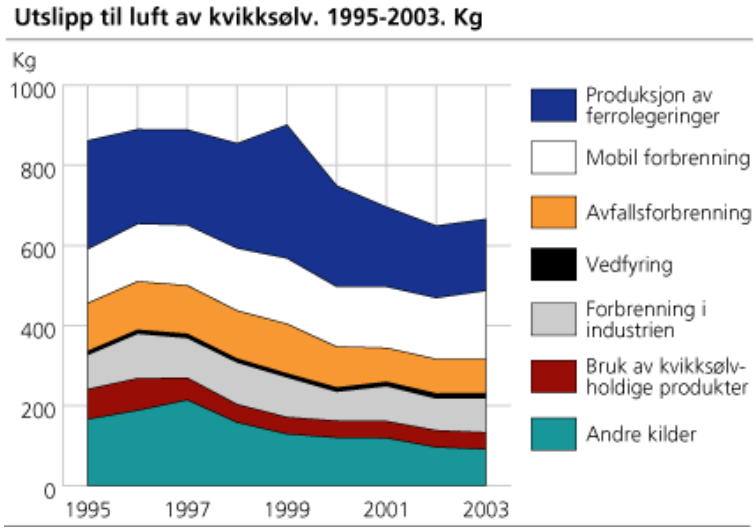
fallout of dust from the raw materials, is about 15 µg/m^2. As a comparison, the average mercury deposition in the region of inner Oslofjord is estimated to be about 10 µg/m^2. Based on these figures, it can be inferred that the fallout of dust from the raw materials results in a 2.5 times higher mercury deposition rate in the immediate area of the plant, as compared to the background levels



Figur 2. *Atmospheric depositions of mercury in Norway. The fluxes are based on model calculations done on behalf of EMEP.* (http://www.msceast.org/countries/Norway/index.html).

The increase in mercury concentrations of the mosses at sampling station SE3 and SE5, compared to the assumed background levels, was about 0.03 µg/g d.w. This is close to a doubling of the background level. If the increased concentrations were caused by dust fallout alone, it would mean that the moss samples contained 10% gypsum dust. Although mosses effectively can retain dust particles on the leaf surfaces, in leaf pits, and at the leaf stalks, we believe that a dust content of 10% is unrealistically high. If this were the case, we would expect to find a visible dust cover on the moss samples. As this was not observed, we assume that only a minor fraction of the dust fallout was retained on the mosses. This leads to the hypothesis that there also must be deposited some of the mercury released as gaseous mercury species during the heating/drying processes in the production.

The company informs that the annual mercury emissions to air, caused by the production at the plant, are about 15 kg per year. The man-made (anthropogenic) atmospheric emissions of mercury in Norway were in total about 600 kg in the year 2003. This means that the mercury emissions from the plant amounts to about 2% of the national atmospheric emissions. Compared to the global anthropogenic emissions to the atmosphere, which was estimated to be approximately 1900 metric tons for 1989 (Pacyna and Pacyna, 2002), are these emissions rather insignificant – not more than one-thousandths parts of a per mille.



Figur 3. *National emissions of anthropogenic mercury to the atmosphere. Colour codes: Blue, production of ferro-alloys; White, mobile combustion; Yellow, waste incineration; Black, wood combustion; Grey, industrial combustion; Brown, use of mercury containing products; Turquoise, other sources. Source: Norway Statistics.* http://www.ssb.no/milgiftn/main.html

There have not been performed any direct measurements of the fluxes and the species of mercury emitted through the pipe stack at the plant, but according to the available information is the fraction of dust insignificant. Hence, the emitted mercury is therefore most likely in the gaseous state. This can be fractionated as elementary gaseous mercury (Hg-0) and as reactive gaseous mercury (RGM). Elementary mercury has a long atmospheric residence time, as it has to be oxidized to divalent mercury (Hg-II) to readily deposit. However, RGM are divalent mercury species with strong particle affinity, hence they are deposited far more effective than elementary mercury.

The present mercury analyses of the mosses give no indication of significant mercury depositions outside the immediate area of the plant. However, one should have a somewhat larger data set, together with the data from the national moss survey of 2005, to examine this more closely.

To summarize, our conclusions are:

- Moss samples indicated an increased atmospheric deposition of mercury in the immediate area of the plant.
- The increased depositions in the immediate area may be explained by fallout of dust originating from the raw materials used at the plant, together with depositions of reactive gaseous mercury originating from the production. However, this has to be verified with dedicated methods.
- Beyond the increase in the mercury concentration in the moss samples taken in the immediate area, there was no sign of a systematic concentration gradient that could be related to emissions from the plant. However, the data are limited and a more thoroughly comparison with a larger national/regional data set would be advantageous
- The atmospheric emissions of mercury from the plant amount to 15 kg per year, according to information from the company. This is about 2% of the national anthropogenic mercury emissions. The emissions are most likely dominated by gaseous mercury species, with a deposition pattern different from the particle bound mercury in the dust of the raw material used in the production.

5. References

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