Nitrogen oxides in German potash and hard coal mining, exposure assessment within two epidemiological studies

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Introduction

In order to provide data for risk assessment of the participating mining companies and additionally to elucidate the exposure situation keeping in mind a possibly changing threshold limit situation for nitrogen oxides in Europe, IGF has taken part in two epidemiological studies in German potash and hard coal mining. The first study was a longitudinal study in two German potash mines. The second one provided exposure data on a much smaller scale, due to severe limitations with respect to available measurement capacities. IGF provided data on the exposure situation in both cases. In the case of the potash study the epidemiological and medical investigations were performed by the German Federal Institute for Occupational Safety and Health (BAuA) and in the case of the hard coal study by the Institute for Occupational Medicine of Cologne University. These results are published separately (1, 2, 3, 4).

This presentation gives the results of the extensive exposure assessment in both mine types, describes the availability and applicability of current measurement techniques and discusses shortly the possibility of further decreasing exposure levels in both mine types in Germany.

Description of Potash Mines

In Germany a potash production of about 40 million tons crude ore a year is done by five mines. Due to the complicated geological situation mining is done predominantly by drill and blast while worldwide cutting methods are more common. For the various mining processes and the subsequent support and logistic functions a fleet of, about 1,700 mainly diesel powered parts of equipment with an installed total power of the diesel engines of 135 MW is in operation. The loaders for face haulage are of decisive importance for the diesel fuel consumption and thus for the emissions due to their high power and utilization time. Dependent on the deposit loaders with payloads of 9–20 tons and rated power of 187–320 kW are in operation. In the mines with suitable conditions also electric powered loaders are in operation, in two mines the proportion of haulage with these loaders is in the range of more than 40%. The working process of the most other production machines, i.e. auger and blast-hole drilling, roof bolting and explosive loading is already electrified, thus the diesel engine is only in operation for translocation from one workplace to the other. By contrast the diesel engine is essential for cleanup-loaders and scaling machines due to the requirements of the working process. For the transport of men and material mainly modified standard off-road vehicles with four-wheel drive are in operation. Mounting and dismounting of the stationary equipment is done with various service machines, i.e. fork lifts, cranes, etc. For roadway maintenance different construction machines, i.e. road cutting machines, graders, dozers, etc. are employed. For all the latter machine groups the diesel engine is essential due to the increasing distances of more than 10 km between the shafts and the production areas. The two mines investigated in this project can be regarded as representative for the industry. In both mines state-of-the-art conditions are realized with respect to the exposure situation. Production is running in a three-shift system with 15–18 regular shifts per week. Working time at the face is about 5.5–5.8 h of an 8 h shift. Sources of nitrogen oxides in the mines are diesel exhaust and the blasting processes.
Blasting is only performed in “empty mines” during changing of the shifts. A total of about 2,600 miners are working in the two mines. All data refer to the time period of about 2005-2007

Description of hard coal mines

In German hard coal mining, about 21 million tons of hard coal were mined annually by RAG in 8 different mines with about 30,000 miners underground in 2007. Mining is performed exclusively in the long wall caving technique employing shearer loaders or coal planes (5, 6). The underground roadways are cut by selective head cutting machines (a total length of about 23,000 m in 2007) or prepared conventionally by drilling and blasting (about 32,000 m in 2007). The selection of the roadway preparation technique is depending on the rock composition, the methane exhalations, and the length of the intended roadways. In blasting, advance so-called “ventilation explosives” of comparably low explosive force are applied. Under certain conditions, explosives with high explosive force (rock explosives) are used. A regulation on the maximum amount of explosives allowed per blasting procedure is fixed by the mining authorities. While coal transportation underground is almost exclusively performed by rubber belt conveyor systems, diesel powered train engines or one-rail suspended trains (“Einschienenhängebahn” in German and usually abbreviated as “EHB”) are used for transportation of miners and material in large quantities. Currently, RAG operates about 95 conventional train engines with a total of installed power of 6,500 kW and about 130 one-rail suspended train engines with a total of installed power of about 12,000 kW. The use of electrically powered locomotives and EHBs is negligible for safety and technical reasons.

The diesel engines may only be applied if fresh air ventilation depending on the engine’s power is provided in the respective workplace. Only engines which have been specifically designed and developed for hard coal mining are used. Non-rail engines, as they are used in large quantities in salt and potash mining for example (rubber-wheeled loaders and transportation vehicles), have only a very small application in German hard-coal mining. Additional auxiliary equipment, like loaders in roadway advance or drillers is operated electrically.

Methods

The exposure assessments have been performed in 1994/5 and 2000 in one and 1999 and 2003 in the second potash mine, and in 2007 in two hard coal mines.

We report here only the results of exposure versus NO and NO₂. In all mines carbon monoxide has been determined additionally. In the potash mines respirable dust, inhalable dust and elementary carbon from diesel engines was determined as well. For all the components time weighted 8-h shift values were determined according to German regulations. As it was generally not possible to run the samplers on a whole shift base, i.e. from entry of the miners into the mine to exit, time weighting was done by measuring during time of exposure and numerical calculation including “exposure-free” time periods (e.g. travelling to the worksite). This is exactly the required procedure for the German compliance process, thus the results give a good description of the exposure situation in legal terms. As a rule of thumb personal sampling was generally preferred, but for several reasons in some cases stationary
samplers had to be applied as well. So, in low-exposure situations, for example in the repair shops, which were located near the intake shafts of both of the potash mines, the personal samplers for the four gaseous components were generally not suitable because of their insufficient lower detection limits. As a consequence and because the concentrations especially of the nitrogen oxides were required for comparison purposes in these settings, stationary instruments had to be applied as well.

As instruments person carried electrochemical cells (Draeger – Multiwarn) and stationary chemoluminescence devices (Tecan) have been used. It needs to be stressed that the latter cannot be employed in hard coal mines (electrical safety) specifically and generally in all kinds of mining environments as they are much too fragile and only suited for fairly “clean” conditions and can therefore currently not be considered as “state of the art”. Currently the Multiwarns and their successor instruments are only distributed as so-called “warning instruments” (i.e. they are meant to indicate the violation of a pre-selected threshold concentration) and not as complete measuring instruments. Therefore a very careful quality-control-process especially with respect to the correct calibration has to be implemented. The manufacturer does not give a detection limit of the devices. We estimate the respective lower detection limit to be at about 1 ppm for NO and NO2 though this may just be regarded as a rough estimation. A detailed discussion can be found in the papers. Successor instruments may have been improved in the meantime.

A total of several hundred shift measurements in the potash mines A and B have been performed. Because of severe limitations in hard coal mining only a much smaller number could be obtained. The Multiwarn instruments recorded one-minute average values in all campaigns. Therefore we also determined the 15-minute short term exposure data. For this procedure we applied a procedure, which we published several years ago (7). The sequence of 1-min-averages obtained by the instruments is exported into a suitable spreadsheet program. By using a moving average filter the highest 15-minute-average is calculated from this data set. The respective 15 minutes are then removed. The moving average is then applied a second time to identify the second highest 15-minute-average value and so on. Result is a succession of declining 15 minute short term exposure periods which describe the profile of short term exposure in those circumstances/workplaces where these periods are not known beforehand. We called this data set the workplace exposure profile (WEP).

Results

The following Tables 1 and 2 shows the eight hour shift exposure data for campaigns A2, B1, and B2 per job category for nitrogen dioxide and nitrogen monoxide (potash mines A and B, reference to the 1st and 2nd measurements campaign in the respective mines. In mine A during the first assessment period no NOx data were obtained).

Table 3 gives our results for the two components in hard coal mines and compare them to three other papers and their results (8, 9, 10).
<table>
<thead>
<tr>
<th>Type of workplace</th>
<th>NO&lt;sub&gt;2&lt;/sub&gt; ppm campaign A2</th>
<th>NO&lt;sub&gt;2&lt;/sub&gt; ppm campaign B1</th>
<th>NO&lt;sub&gt;2&lt;/sub&gt; ppm campaign B2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Geom. mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Diesel loader</td>
<td>4.70</td>
<td>4.22</td>
<td>2.58</td>
</tr>
<tr>
<td>Electric loader</td>
<td>5.00</td>
<td>2.69</td>
<td>2.36</td>
</tr>
<tr>
<td>Scaling machine</td>
<td>4.41</td>
<td>4.17</td>
<td>2.49</td>
</tr>
<tr>
<td>Drilling jumbo</td>
<td>3.64</td>
<td>3.22</td>
<td>2.07</td>
</tr>
<tr>
<td>Explosive vehicle</td>
<td>2.21</td>
<td>1.38</td>
<td>3.10</td>
</tr>
<tr>
<td>Small transportation</td>
<td>2.87</td>
<td>2.05</td>
<td>3.35</td>
</tr>
<tr>
<td>vehicle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administration area</td>
<td>1.17</td>
<td>0.10</td>
<td>0.97</td>
</tr>
<tr>
<td>Main work shop</td>
<td>0.56</td>
<td>0.42</td>
<td>0.41</td>
</tr>
<tr>
<td>Electrical work shop</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Small work shop</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UWD</td>
<td>0.52</td>
<td>0.30</td>
<td>0.39</td>
</tr>
<tr>
<td>Belt-repair site/mobile repair personnel</td>
<td>2.28</td>
<td>2.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Table 1: Eight hour shift exposure data for campaigns A2, B1, and B2 per job category, nitrogen dioxide
comparable to the shifts and workplaces as of tables 1 and 2 for NO\textsubscript{2} and NO. Because of the limited number of measurements no similar table is available for hard coal mining.

Table 3 Average shift exposures for NO\textsubscript{2} and NO (in ppm), Robertson does not differentiate between different types of workplaces

Tables 4 and 5 give the maximum short term (15-minutes) average concentrations directly comparable to the shifts and workplaces as of tables 1 and 2 for NO\textsubscript{2} and NO. Because of the limited number of measurements no similar table is available for hard coal mining.
Table 5: Maximum short time (15 min) exposure data nitrogen monoxide

Discussion

The resulting data have been directly implemented into the companies’ risk assessment procedures. In all cases the technical and organizational conditions in the respective workplaces can be regarded as “state of the art”. A detailed discussion of this aspect is given in the indicated papers. The corresponding epidemiological investigations have shown considerably small health effects in all cases. Whereas a small decrease of lung function parameters in highly exposed potash miners was detected (3) compared to less exposed workers, in hard coal mining these effects were negligible. This is all the more remarkable as miners can be considered as highly exposed not only towards nitrogen oxides but also to salt dust (respirable and inhalable in potash mines) and elementary carbon (in both mining types). Unfortunately in potash mines these high exposures are also highly correlated. Therefore miners in the winning region of the potash mines are highly exposed to ALL the components. Thus the German MAK commission as well as the European SCOEL would not accept the potash paper as giving evidence towards a threshold limit for ONLY NO or ONLY NO₂ though a combination of these two noxes did fail to produce a significant health effect. We have to accept this.

SCOEL has recently proposed threshold limits for the two components (2 ppm for NO and 0.5 ppm for NO₂ as shift values) (11, 12), which definitely will cause problems in some respects in mining, and in other branches of industry as well.
References


