Euromines Report

of compliance and measures implemented to reduce OELs for Nitrogen Oxides, Carbon Monoxide, and Diesel engine exhaust emissions

Brussels, 10 October 2022

Summary

On 31 January 2017, the European Commission released the fourth list of indicative occupational exposure limit values (OEL) for Nitrogen Monoxide, Nitrogen Dioxide, and Carbon Monoxide as part of the Chemical Agents Directive with a transitional period ending at the latest on 21 August 2023 for underground mining and tunnelling. Likewise, on 16 January 2019, the European Commission released the second list of binding occupational exposure limit values for Diesel engine exhaust emissions (measured as elemental carbon) as part of the Carcinogens and Mutagens Directive, this limit value shall apply from 21 February 2023, and for underground mining and tunnel construction, the limit value shall apply from 21 February 2026.

During the last years, the European mining industry has undertaken substantial efforts to comply with the new occupational exposure limits for Nitrogen Oxides, Carbon Monoxide, and Diesel particle emissions. Comprehensive measures for reducing emissions and the level of exposure have been identified, examined, and put into place. However, the transitional processes take longer than expected, largely due to technological limitations and availabilities. The European mining sector will not be able to meet the new OELs within the planned timeline despite the progress already made and the measures that have been introduced in underground mining practice. Therefore, Euromines asks the European Commission for a further extension of the 3-year transition period for Nitrogen Monoxide, Nitrogen Dioxide, and Carbon Monoxide.

Implemented measures to reduce emission levels

Depending on the individual situation of each mining company, measures in several technical and organizational fields have been implemented:

A. Monitoring
B. Mobile mining machines and vehicles
C. Optimization of mine ventilation
D. Use of low-emission explosives
E. Change of organizational and workflow processes

The possible implementation of these measures depends on, among other aspects, the following conditions:

- ⇒ Market availability of the technology and the technologies emerging from that
- ⇒ Production and delivery time frames of technology after the orders have been placed
- ⇒ Implementation of the organizational adaptations and optimizations of work processes
- ⇒ Planning and approval processes
- ⇒ Economic aspects

With respect to **monitoring**, multiple actions have been taken, including industrial hygiene exposure assessments of underground employees, as well as health and epidemiological assessments, among others. Following the control hierarchy, mining companies have prioritized the implementation of engineering controls, such as improved ventilation monitoring systems, and automation, among others. In the same way, robust individual gas monitors for personnel working underground, as well as stationary gas monitors have been implemented in different areas to monitor Nitrogen Oxides, Carbon Monoxide, and Diesel particle concentrations. The extractive industry recognizes the importance of such monitoring and invests heavily in new devices to ensure that reliable monitoring systems are in place.

In general, according to a Euromines members survey, it can be concluded that currently, 65 % of the mining companies that participated in the survey are expected to meet the new occupational exposure limits for Nitrogen Oxides as a time-weighted average value (TWA) and 33 % cannot meet them, 50 % of the companies are able to meet the new occupational exposure limit for Carbon Monoxide and 50 % cannot meet it, as a time-weighted average value (TWA).[1] Regarding Diesel engine exhaust emissions (measured as Elemental Carbon) most companies currently cannot meet the new occupational exposure limit, some have not measured this factor as Elemental Carbon yet.

It is worth noting that the company`s ability to meet the OEL is strongly dependent on supply chains and manufacturers' capacities to produce and deliver the ordered mobile mining machines and vehicles.

The German Social Accident Insurance legal body conducted a large-scale epidemiological study in 2017-2018 at two K+S potash mines to monitor the health effects of underground employees with exposure to Diesel particles and blast fumes (Nitrogen Oxides, Carbon Monoxide). This study aims to ensure that during the transitional period no workers are harmed, the study focuses on the short-term effects, and the results were no observable adverse health effects in the workplace. In addition, it is intended to update this study after 5 years to evaluate potential long-term effects.

[1] For the whole EU mining industry, it is expected that the percentage of mining companies not being able to meet the new OELs in time is higher.

K+S is implementing the latest technology in semi-stationary underground gas measurement and monitoring, but due to problems and delays in the supply chains, special technical devices, and rugged environment computers are not available in time (delivery times of 12 months or longer), so the monitoring concept implementation is not progressing as planned. It is to be mentioned, that currently there is no officially accredited measurement system in Germany, the systems used are accepted by the authorities since they have proven efficiency.

Likewise, for more than five years, Swedish mines have jointly conducted studies to increase knowledge of exposure to gases for different work groups in underground environments. For instance, in Sweden, LKAB has collaborated with Occupational Medicine at Lund University to increase knowledge about the medical impact of exposure to exhaust gases in underground mines "Renewable Diesel fuels and emission control strategies, Implications for occupational exposure, human health, and the environment".

Further actions are planned in the coming years with the installation of permanent monitoring equipment, the expansion of smart ventilation pilot plans, and the installation of additional stationary monitors.

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Regarding **mobile mining machines and vehicles**, the change to stricter emission standards will have a large effect on emissions reduction. According to a Euromines members survey, already today a significantly higher percentage of around 70 % of EU Stage III/US TIER 3 and EU Stage IV/US TIER 4 engines is used in mining, followed by EU Stage II/US TIER 2 and EU Stage I/US TIER 1 engines with 16 % and 6 % respectively, the rest of 8 % corresponds to the EU Stage V and Electric generation. The US nonroad emission standards are harmonized to a certain degree with European nonroad emission standards.

Actions aimed at limiting emissions or reducing exposure have been demonstrated since the adoption of OELs, as follows:

⇒ It is planned to continuously reduce the number of EU Stage I, EU Stage II, and Stage III exhaust emission standard machines and increase the number of Stage IV / EU Stage V machines and replace Diesel machines with electric vehicles.

⇒ In Poland, in KGHM mines the share of machines with stage V engines will account for three-quarters of all mining machines by 2026.

⇒ In Some Swedish companies, currently, all new machines are foreseen with EU Stage V or electric.

⇒ In the mining industry, electric drives for mobile equipment have been used for decades and are continuously improving and increasing in use. However, there are limitations to their use due to, the mining methods used, systems of work, conditions of roadways underground, and the size of loads, some of which currently cannot be handled by electric vehicles.

- ⇒ Replacement of Diesel engines by electrical drive systems is and will be increasingly done where possible and practicable. However, there are limited machinery options due to market availability and high investment costs. For instance, at K+S in Germany, the prototype of the new electric loader generation was delayed for 24 months, and production and delivery of regular LHD type were 12 to 18 months.
- ⇒ In most machine cabins, air conditioning systems, gas, and particle capture filters have been installed, some of them are active Carbon filters to assure healthy breathing conditions for drivers.
- ⇒ KGHM is testing innovative cabin filters, which are particularly effective in absorbing Nitrogen Oxides located in the zones around the working machines.
- ⇒ Utilization of AdBlue as a fuel additive and Diesel HVO (Hydrotreated Vegetable Oil) is introduced to reduce the emission of Nitrogen Oxide gases. In addition, further alternative mobility options, such as liquefied gas and Hydrogen fuel cells, have been explored.
- ⇒ Most of the companies have invested in electric machines and vehicles such as electrical loaders with cables, production, and support drills, shotcrete sprayers, and stationary machines powered by cable as drill rigs. In some companies, the utilization of electrical vehicles is being explored by studying the feasibility of converting light mobile equipment to electric and testing prototype electric machines. For instance, in Poland, KGHM is testing prototype machines with battery drives such as the Face Master 1.7LE blast hole drilling machine, Roof Master 1.8KE roof bolting machine, and the loader ST14 Battery. In one company, operating vehicles are already today all hybrid (Diesel with electric energy). In Kiruna Sweden, LKAB is evaluating battery-electric machines such as 42-Tonne Epiroc trucks and 14-Tonne Epiroc loaders, both with zero emission performance which means zero exposure for the operators to diesel particulates. LKAB has a strategic agreement with Epiroc in their SUM project for sustainable underground mining.
- ⇒ However, it is important to highlight, that there are no large-scale mining machines with adequate battery capacity on the market yet. For now, battery operation is limited because of the low operation time (only 3-4 hours) and the long battery charging times. In addition, an extensive infrastructure to recharge these machines is needed.
- ⇒ Incorporation of automation and remote-controlled machinery, such as loaders and drilling machines running remotely will continue in the future. This allows machine operators to operate a distance away from the emission source, thus resulting in lower exposures. For instance, LKAB in Sweden is applying Sandvik AutoMine-Lite for loading and hauling, the new single loader and truck automation system. Furthermore, LKAB is testing and developing trucks with the Sandvik AutoMine-Lite.
- ⇒ In Kiruna Sweden, LKAB is investing around 12 million Euros annually in electrification. Each electric load haul dump (LHD) costs approximately twice the price compared to a Diesel driven LHD. Maintenance costs are expected to be similar for Diesel/cable LHD. In Malmberget, LKAB is investing around 8 million Euros annually for the electrification of machinery.
- ⇒ In Aitik Sweden, Boliden is implementing the Automated Hauling System budgeted at 18 million Euros approximately.
- ⇒ K+S in Germany is replacing 500 vehicles underground, representing 50 % of the fleet and 80 % of the mileage. 133 machines are being replaced, representing 33 % of the fleet, resulting in a 70 % reduction of Nitrogen Oxides emissions. A large portion of utility vehicles is replaced or rebuilt to run on most modern Diesel engines or Diesel particulate filter systems are installed. In this context, K+S will not be

able to complete all technical measures until August 2023 due to significant problems and delays at suppliers. K+S is currently facing delivery times of 15 months and more, even for regular machines, trucks, transport trucks, and vehicles.

Through optimization of mine **ventilation**, a reduction of exposures is possible.

Actions aimed at limiting emissions or reducing exposure have been demonstrated since the adoption of OELs, as follows:

⇒ All companies are working to improve airflow efficiency and increase ventilation speeds such as increasing airflow by ventilation systems or increasing the diameter of air tubes for secondary ventilation, use of ventilation-on-demand systems, installation of new ventilation bypasses, and remedies for partially blocked airways to increase the flow of fresh air into production areas and to reduce the ventilation time after blasting.

⇒ Smart ventilation and continuous development of innovative technologies for effective and efficient ventilation after blasting are introduced and tested.

⇒ Companies conduct continuous and routine maintenance of the ventilation network by sealing ventilation doors and stoppings to reduce internal losses in the ventilation network.

⇒ New shafts have been planned to introduce additional ventilation airflow to additional work areas. In areas mined out, the mines have closed off or bratticed old areas to reduce losses of fresh air into those areas.

⇒ Other examples of improving ventilation are explored in a pre-study for dimensioning and planning primary fans to double the pressure in the fresh air system and increase the flow to production areas, a smart ventilation pilot plan, and ventilation improvements such as separating fresh and return air circuits and implementation of more effective surface fans to existing ventilation shafts.

⇒ K+S in Germany has used modern software to calculate the volumes and plan the scheme of the mine ventilation system. They have made large-scale tests to optimize ventilation with several setups over several months. The effect was a 30 % reduction of the worker's exposure underground only by improving ventilation practices underground. The findings from the tests are the basis for new standards in mine ventilation allowing further optimization. The knowledge acquired has been formulated into instructions and is integrated into employee training, supported by a new training concept with a physical model (3 m x 1 m) that represents the underground ventilation conditions and allows training good practice in ventilation.

⇒ At Rävliden (Boliden-Sweden), the new shaft includes a ventilation fan that is budgeted for 19 Million Euros, and the new shaft at Tara underground mine is budged for 17 Million Euros. In Finland, Agnico Eagle will build a new ventilation shaft and the extension of the existing ventilation shafts to deeper levels need an investment of 2 Million Euros.

⇒ In Poland, KGHM is planning to build at least one large-diameter hole and is completing the construction of another ventilation shaft (budget is around 400 Million Euros), also plans to build three more

ventilation shafts. The implementation of these projects will improve the air quality in the underground mine excavations due to the adaptation to the new OEL values, shorten the road transportation of employees, and will maintain the possibility of meeting production goals in the future.

In the area of civil **explosives**, extensive investigations have been carried out in recent years to reduce Nitrogen Oxide emissions. Among other things, the further development of one of the current standard explosives Ammonium Nitrate Fuel Oil (ANFO), low emission emulsion explosives (Ammonium Nitrate based emulsions) as well as the use of bulk emulsion explosives have been tested. Emulsion explosives delivered a considerable contribution to reducing Nitrogen Oxide exposures in underground mining and maintaining short ventilation times after blasting. For this reason, most mining companies decided on the laborious and cost-intensive transition to bulk emulsion explosives with on-site mixing.

In Germany, MSW-Chemie, a K+S subsidiary, has invented a new type of explosive, an innovative granular explosive, which is handleable just like ANFO, in loading and application, and the Nitrogen Oxides emission reduction accounts for more than 85 %, while the Carbon Monoxide reduction is 50 %, and no complicated on-site mixing devices for manufacturing explosives related to processes with pumped fluid components are needed underground. With this granular explosive, the standard mine logistics, storage, and pneumatic loading machines can be kept in use. The responsibility for the safety and the quality of the explosives strictly remains with the manufacturing company, and not with the end-user. Currently, a new plant to produce this granulate explosive is to be built, however, due to the Covid situation and the war in Ukraine, there are problems sourcing the electronic components, special pumps, stainless steel tanks, and piping with delivery times ranging from 12 to 15 months. In addition, the availability of technical crew for construction is difficult to acquire. Therefore, getting this factory operational until August 2023 will be impossible.

Further actions have been implemented, such as:

⇒ Permanent evaluation and communication with manufacturers and suppliers to provide and test products with low-emission explosives. For instance, in Sweden, Boliden is developing ongoing trials with Hydrogen Peroxide emulsions (HPE) explosives, which do not generate ammonia nor NOx gases in post-detonation fumes. This ongoing project is expected to cost around 1 Million Euros.

⇒ Optimization of blasting to reduce the consumption of explosives, hence reducing the emissions. As well as decreasing the quantity of explosives used per mined ton of ore.

⇒ In Greece, Kassandra mines have developed a remote centralized blasting system from the surface, which costs approximately 70 000 Euros.

⇒ However, it is important to point out that blasting is performed while employees are outside the mining area, the mining works are started after the blast fumes have been removed by ventilation and the atmosphere is gas-tested prior to employee entry.

Optimization of processes (workflows and drives, operating and utilization) offer notable opportunities for reducing emissions for example by bundling transports, separating phases of the extraction process, working rotation, avoiding empty running as well as digitalization automation and electrification. For this purpose, processes have been checked and best practice target processes have been worked out.

Following the facts referred to in this document, we can show that there is not, nor can be any single standard package of measures for the reduction of Nitrogen Oxides, Carbon Monoxide, and Diesel particles emissions for all mines as each mine in Europe is constructed and designed differently due to the differences in the mineral ore deposits, conditions of mining, slopes, falls, distances, and un-continuity of ore and mineral bodies.

Correspondingly, the applicability and effectiveness of all possible measures at individual mines are very different. This means that for each mine, the appropriate combination of tools and measures must be chosen from the possible measures to comply with the upcoming occupational exposure limits.

Additionally, it should be noted that as the last level of the control hierarchy, mining companies have considered PPE implementation in the workplace as a temporary measure to keep worker exposure within the proposed OEL for NOx and CO. However, there are no effective sorbents for CO/NOx so air-purifying respirators cannot be utilized for these gases. The respirator manufacturer's selection guide recommends the use of Supplied Air respiratory protection which is not feasible for continuous use in an underground mine. As such, we will continue to invest in Engineering and Administrative controls to reduce CO/NOx levels in working environments.

Euromines suggests the following:

European mining companies are committed and intend to comply with the proposed OELs in the future, they do not question them, and they all have clear pathways to fulfil them despite the Covid-19 crisis and the Ukraine war. However, it takes longer than expected, largely due to technological limitations and availabilities. The European mining sector will not be able to meet the new OEL values within the planned timeline and is putting forward this information to apply for an extension of the transitional period.

According to the current state of knowledge, the currently effective five-year transitional period for the underground mining industry is not sufficient despite the progress already made and the measures that have been introduced in practice. The measures identified are not in all cases timely or fully available, so an extension of the transitional period will be necessary. An **additional period of 3 years** will allow e.g. the construction of new production capacities for low-emission explosives; the availability on the market of state-of-the-art Diesel engine technology or new electric drives, among others.

The mining sector will continue to work on the implementation of relevant measures to comply with the modified occupational exposure limits. In addition, over the next two years, Euromines members will monitor the effects of their activities, share good practices in this area, and conduct a reassessment and report in 2024.

Euromines, the European Association of Mining, Metal Ores & Industrial Minerals, represents large and small companies and subsidiaries in Europe and in other parts of the world which provide jobs to more than 350,000 people. Through the activities and operations of these members, more than 42 different metals and minerals are produced. Their sustainable exploitation can increase Europe's supply of mineral resources, help ease imports from third countries usually applying lower environmental, corporate and social standards and foster the socio-economic growth of Europe's Regions. The European mining industry plays a crucial role in the EU ability to nurture sustainable growth including access to and supply of raw materials, providing over 30 million jobs and playing a key role in the development of modern environmentally friendly technologies. More information on www.euromines.org