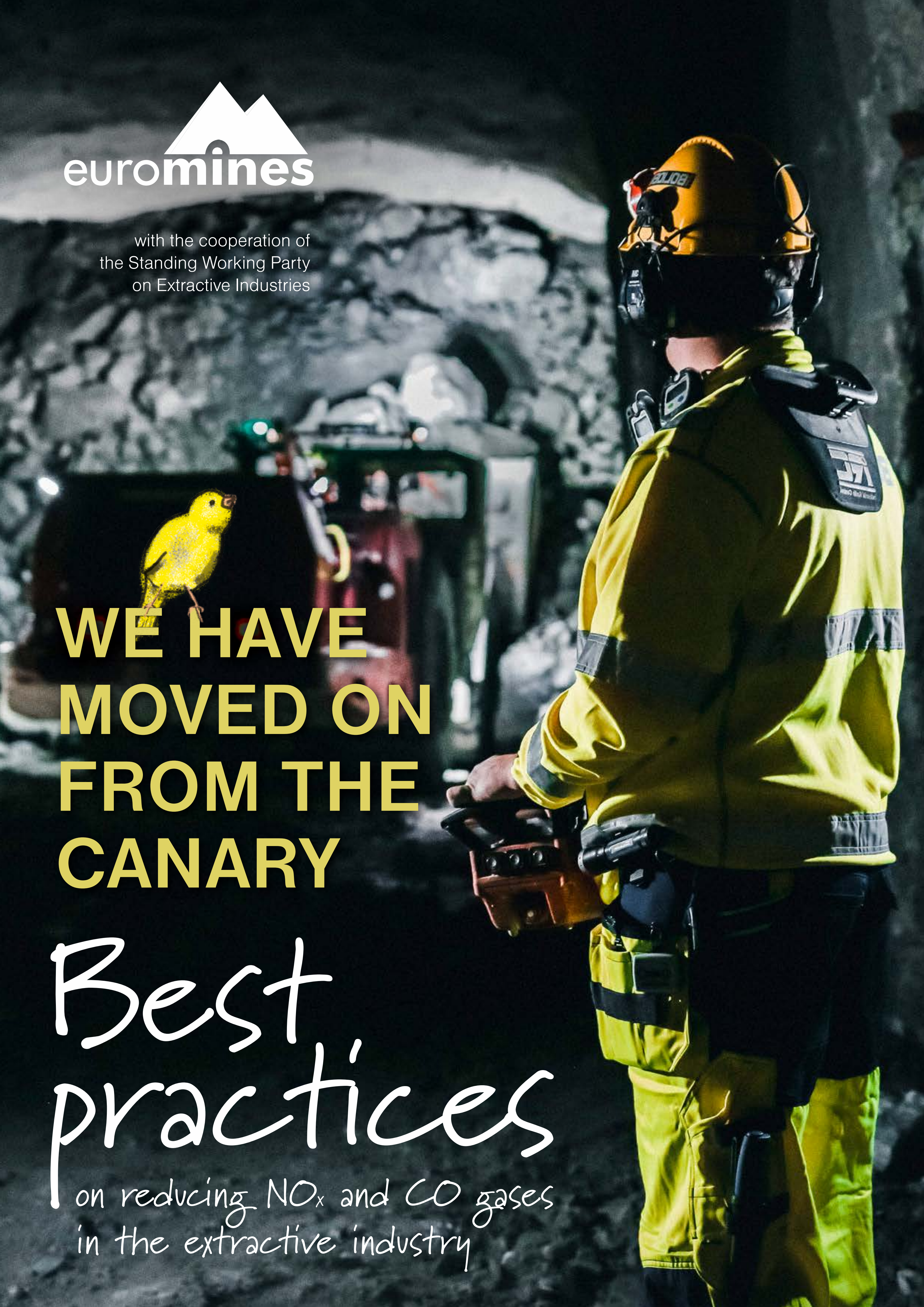


euromines

with the cooperation of
the Standing Working Party
on Extractive Industries

WE HAVE MOVED ON FROM THE CANARY

Best practices

on reducing NO_x and CO gases in the extractive industry

Introduction

Healthy workers are essential to the success of mining companies. Euromines member companies are driven in their protection of worker health and safety. Workforce protection should be built on; ensuring that a workplace culture of safety & health is embraced by all, recognising that occupational illnesses are preventable, ensuring that occurrences of any occupational disease do not reoccur, and promoting the setting and implementation of a consistent set of standards to prevent occupational illness or injury.

Hazards, such as toxic chemicals in the workplace, need to be identified, and the risks associated with them from any possible exposure need to be adequately controlled.

Hazards, such as toxic chemicals in the workplace, need to be identified, and the risks associated with them from any possible exposure needs to be adequately controlled. With the application of various management and occupational health & safety techniques, hazards to workers health & safety have been, and continue to be actively identified and controlled. Techniques range from epidemiological studies on health related effects, the elimination & substitution of hazardous chemicals where possible, the minimisation of exposure, to the application of modern methods of production, all of which reduce exposure to identified risks. The pro-active control of hazards is a well-recognised feature of modern mining practice, and is illustrated by the superior safety record of the mining sector compared to many other sectors of employment.

The concentration of NO, NO_2 and CO in workplaces in underground mines arises predominately from the use of explosives and from vehicles and mobile machines equipped with diesel engines. In the underground mining sector the use of diesel engines, in the short to medium term, will remain necessary. During the last few decades of diesel engine operation, a significant amount of research and improvements were made in the area of work environment and effective diesel engine operation, namely:

- Development and use of modern low emission engines;
- Improved fuel quality;
- Improved exhaust control technology;
- Improved ventilation design and control.

Engine exhaust emissions, consisting of NO and NO_2 are generally referred to as nitrogen oxides (NO_X) and Diesel Particulate Matter (DPM), represent the most difficult diesel engine emissions to control.

Complete elimination of these emissions arising from today's technology is not technically possible.

Complete elimination of these emissions arising from today's technology is not technically possible. Improvements in the control of exposure can be possible depending on local conditions. The document tries to highlight the various options and possibilities to reduce exposure.

Improvements might also be achieved through different planning of work flows (explosion, ventilation, extraction).

In some mines improvement of ventilation might be possible depending on availability and size of ventilation shafts and air flow volumes, respecting legal limitations which were introduced for workers protection.

Emphasis will be placed on technologies and measures that are currently available and provide possible improvements or solutions.

OELs at the European Level

OELs are established at EU and national level either as indicative OELS, typically supported by expert independent scientific committees which take into account all available scientific information, or binding OELs, based on scientific evaluation and taking into account technical and economic feasibility. OELs are complemented by information on exposure monitoring, such as sampling methodology, measurement methods and measurement systems.

At EU level, OELs are established in accordance with Directive 98/24/EC on the protection of the health and safety of workers from the risks related to chemical agents at work (Chemical Agents Directive) and Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (Carcinogens or Mutagens Directive). They are set on the advice of the Scientific Committee on Occupational Exposure Limit Values (SCOEL) and the Advisory Committee on Safety and Health at Work (ACSH) and in the case of relevance to the extactive sector also based on advice from the Standing Working Party on the Extractive Industry (SWPEI).

There are two different types of OELs set at EU level: Indicative Occupational Exposure Limit Values (IOELVs) established in accordance with the Chemical Agents Directive and, Binding Occupational Exposure Limit Values (BOELVs) established in accordance with the Chemical Agents Directive and also the Carcinogens or Mutagens Directive. A BOELV for asbestos is set in the Exposure to Asbestos at Work Directive (2009/148/EC).

IOELVs are health-based limit values below which adverse health effects are unlikely to occur for any given substance after short term or daily exposure over a working life time. They are established on the basis of an independent evidence-based scientific assessment of scientific information carried out by SCOEL and take into account the availability of measurement techniques. Where an EU IOELV has been set, Member States are required to establish a national OEL taking into account the EU limit value. Presently, there are about 123 EU IOELVs.

Unlike Derived No-Effect Levels (which are derived for all relevant routes of exposure i.e. inhalation, dermal and/or oral exposure -both long-term and acute exposure), OELs are predominantly established for the inhalation route of exposure. They can however indicate that another route of exposure is important; an example is the skin notation applied at EU level. OELs are established in order to be practically used and implemented including exposure monitoring measures.

Member States set national OELs according to their own legislation. Obligations for compliance with national OELs differ in the various Member States. National OELs have to be complied with even if the DNEL derived for REACH registration purposes for the same substance is higher.

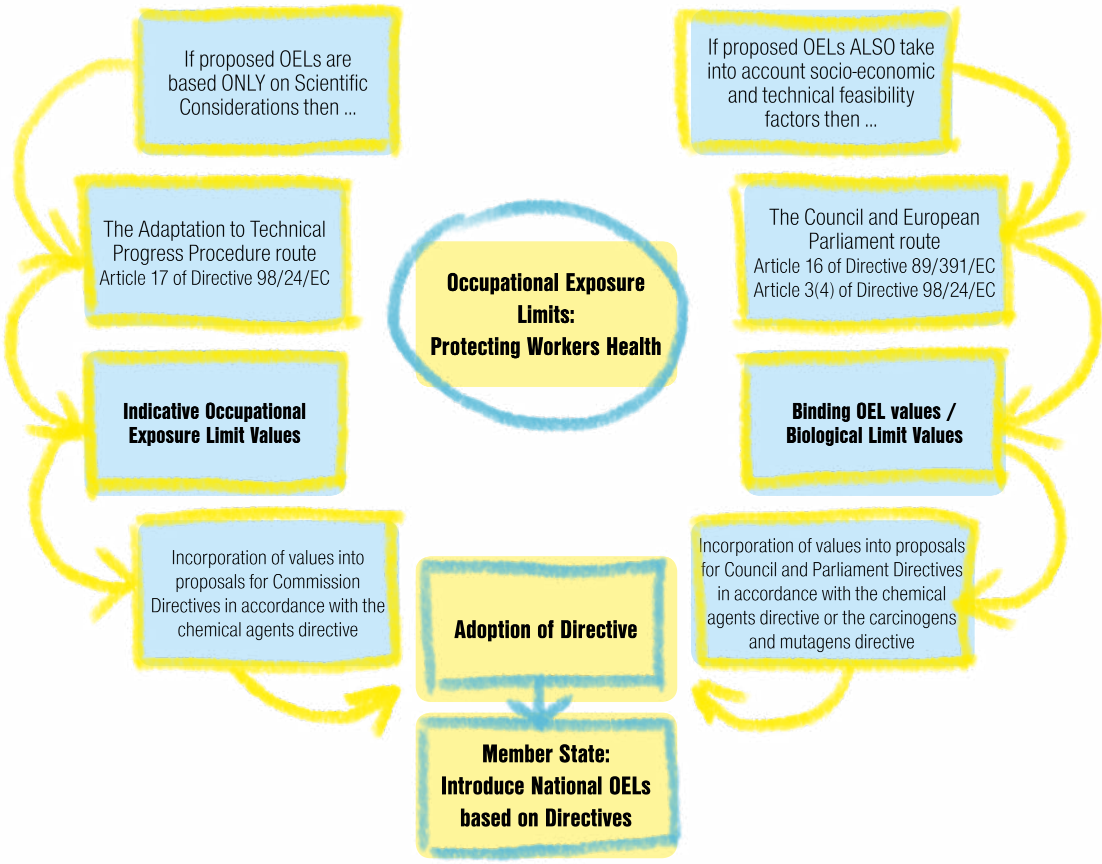
Where an OEL established in a Member State has been exceeded, the employer is required under the Chemical Agents Directive (Article 6 (5)) to take immediate steps to remedy the situation, taking into account the nature of the limit. Under the Carcinogens or Mutagens Directive, exposure must not exceed the limit value of a carcinogen as set out in that Directive (Article 5 (4)), and even in presence of such a limit value, the employer is required to ensure that the level of exposure of workers is reduced to as low a level as technically possible (Article 5 (4)).

Proposal for a Commission Directive establishing a fourth list of indicative occupational exposure limit values in implementation of Council Directive 98/24/EC and amending Commission Directive 2000/39/EC

The 4th list of indicative occupational exposure limit values (IOELVs) was submitted to Member State experts for discussion in September 2016. The Commission's Advisory Committee on Safety and Health at Work (ACSH) adopted a supplementary opinion on the recommendation on the 4th list of indicative occupational exposure limit values (IOELs) at the end of May 2015. The Working Party agreed that the following substances (among others) could be included:

- Nitrogen monoxide IOELV: 8h – TWA: 23 (2 ppm)
- Nitrogen dioxide IOELV: 8h – TWA: 0,995 mg/m³ (0,5 ppm) 15 min – STEL: 1,91 mg/m³ (1 ppm)

The formal legislative procedure for developing EU OELs



Which work places are concerned by these emissions in the underground operations?

The exposure of workers will mainly occur in active mining and extraction areas due to the machinery and explosives used. Therefore, there is potential for higher worker exposure particularly after blasting operations, in the vicinity of the mucking & haulage machines and in areas with return ventilation which contain exhaust & explosive fumes.

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, the size of loads, some of which cannot be handled by electric vehicles.

Electric vehicles already in use in the extractive industry:

- Roofbolters
- Scaling Equipment
- Drilling Euipment
- Explosives Loaders
- LHD's and other Loaders
- Haulage Vehicles
- Forklifts
- Personal transportation vehciles

Wherever possible the use of electric vehicles should be increased to minimise the presence of toxins.

OELs in Different Member States

Please see **Annex 1** for details.

TECHNICAL

- Electric driven machines/engines are not available for all types of vehicles used in the mining industry The use of electrical vehicles is often limited because of the limited performance of the available vehicles, the geological conditions of the mine and the flexibility required of mobile machines
- With improving performance of batteries for electric driven cars, the industry is currently testing more electric driven vehicles for underground use which may, in the medium term, prove useful for some mining operations and the transportation of personnel. Results will be available in the near future.
- Whilst there are some types of vehicles available for material transport, supplies transportation and bulk transport, however not all mines can use them due to their configurations and topographic conditions.
- For other types of vehicles new technology needs to be developed.
- In the hard coal mining industry, diesel-engine vehicles are mainly used for transport of materials and personnel. These vehicles cannot be replaced by electric vehicles due to ground conditions often involving uneven and steep roads and drifts
- The industry recognizes that a total machine replacement with TIER IV final /Euro 6 engines is needed where electric vehciles cannot be used. However, an appropriate transition period is necessary due to the fact that machines with TIER IV final engine are only relatively recently available. For smaller machinery up to 130 horsepower for use in underground mines there are no reliable TIER IV final engines available at the moment. Electric driven loaders could be an option in some applications – but not in all mines. They, in many cases, will have to be developed from scratch in the coming years.

SCIENTIFIC

- Electric mining machinery powered via cables with stationary batteries is not an alternative due to the current state of battery technology. For example, batteries, with limited capacity and operating time, cannot power machines which have to be designed for gross weights of up to 80 tonnes used for an eight-hour operation on roadways with gradients of up to 28 % for example in potash mining. The potential to replace diesel-engine vehicles with electrically driven ones is therefore currently limited. In practice, such diesel powered vehicles are needed generally for the extraction of minerals and materials.

NO, NO_2, CO – Controlling Technologies

SOUND ENGINE MAINTENANCE

Engine maintenance is an important part of a mine's overall strategy in optimising engine combustion therby minimising engine emissions, ensuring the safety & health of workers and the longevity of the machinery and generally reducing workers' exposure to diesel emissions.

- An important factor in maintaining a cleanburning engine is regular maintenance of the intake air cleaners. A blocked air filter results in an increase in fuel/air ratio, hence an increase in tailpipe diesel gases and particulate concentration.

ADVANCED DIESEL ENGINES

Today´s diesel engines are becoming more and more environmentally clean & efficient compared to their predecessors. However, there is a need for technological development to further reduce diesel exhausts. It is in the best interests of mining companies to use advanced diesel engine technologies and more efficient systems for exhaust after-treatment. Nevertheless, the potential for reducing emissions from machinery with diesel engines is limited.

The industry faces several challenges connected to the replacement of diesel engines:

ECONOMIC

- In July 2016 the European Parliament adopted, with a very strong majority, a Stage V for exhaust emissions from non-road mobile machinery (NRMM) engines. The replacement of mobile equipment technology requires substantial investment in machinery over a longer period of time as many machines with the required technical performance are not available yet and many companies have considerable fleets in their larger mines.

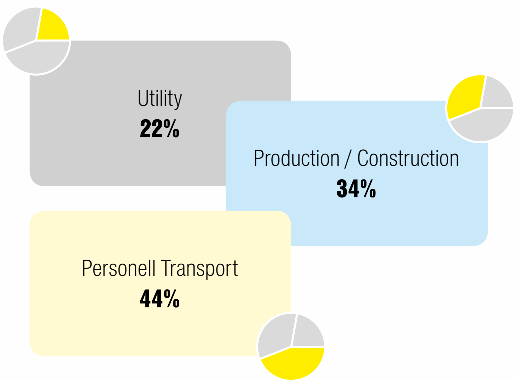
TECHNICAL

- Concerning the lead time for introduction of modern diesel engines (only STAGE IV currently available), those with power ranges of 75–560 kW are available, but engines <75 kW are still under development;
- Concerning the lead time for engineering of new machines: Simple engine replacement is usually not possible due to space requirements.

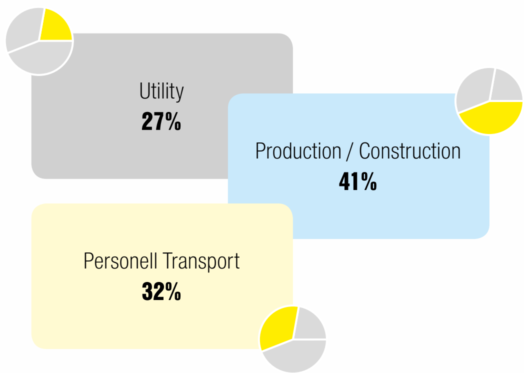
Mobile machines underground in German Mines

160315 OEL in Mining, TU-Sö

Number of mobile machines
Total: about 2.250



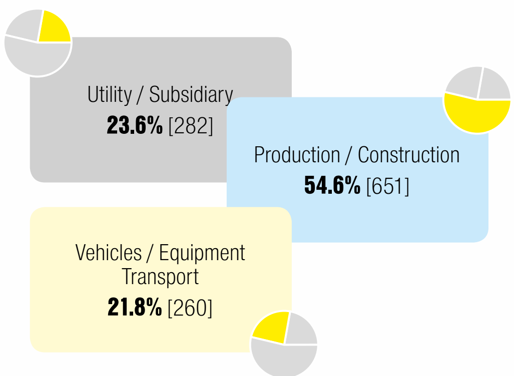
Installed diesel-Power
Total: about 200 MW



Mobile machines underground in KGHM Mines in Poland

as at 31. 12. 2015

Number of mobile machines
Total: 1193



In over 50 years of copper mining there has been a general increase in the use of modern technology with new machines using modern low-emission combustion engines introduced.

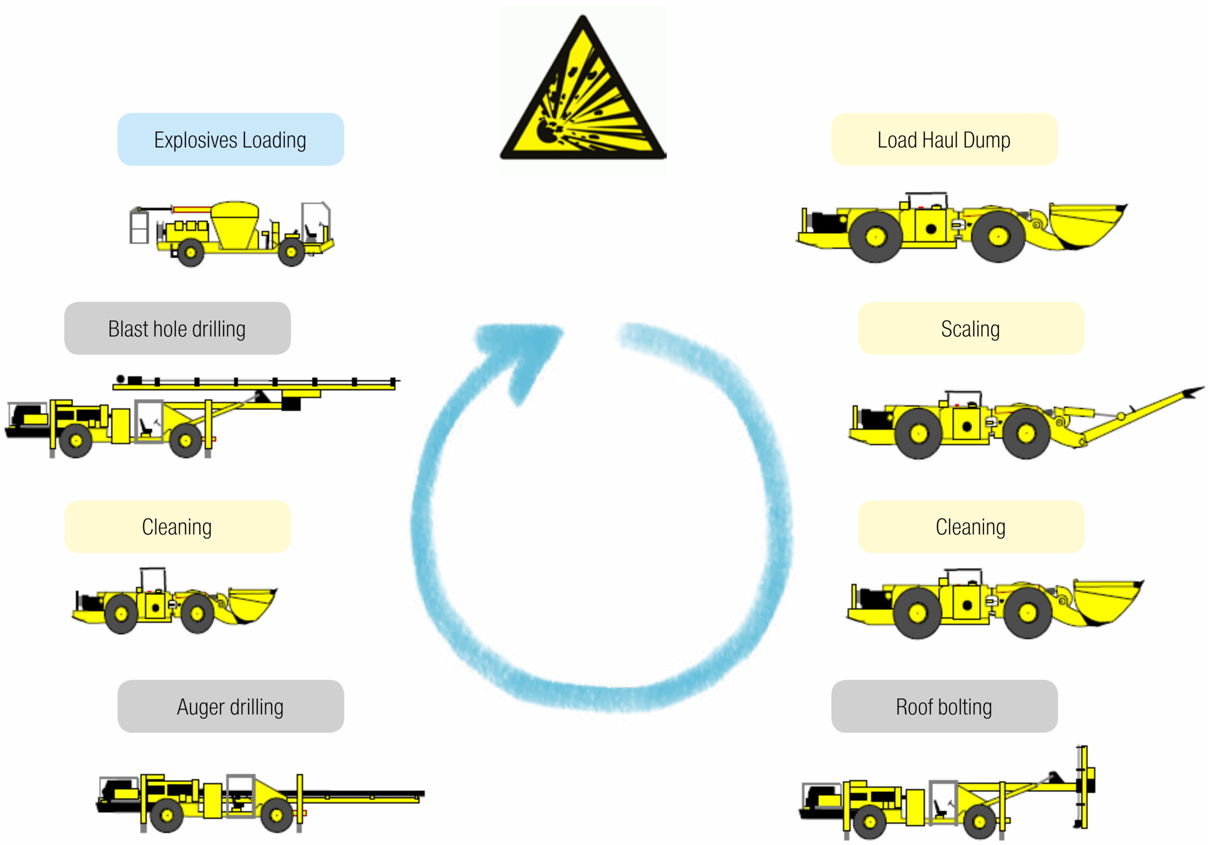
CURRENT EUROPEAN LANDSCAPE

In July 2016 the European Parliament adopted with a very strong majority a Stage V for exhaust emissions from non-road mobile machinery (NRMM) engines. New emission limits for engines used in land-based machinery, such as agricultural and construction equipment, in inland waterway vessels, in rail vehicles and in outdoor powered equipment will be introduced successively in the EU member states from 2019 onwards. In the 15 year journey since the NRMM Directive 97/68/EC became effective for selling new engines, through to the introduction of stage IV emission limits in 2014, the mass of NO_x and particulates emitted from certain new non-road diesel engines has already been reduced by more than 95%. The Amendment of the text adopted by the European Parliament challenges manufacturers to go further, is more comprehensive in the breadth of scope, and results in Europe having the most stringent package of NRMM engine exhaust emission limits in the world. The EU is taking the worldwide lead in regulating emissions from NRMM engines with the introduction of particle number (PN) limits for a number of key engine categories. It is estimated that more than 96% of all future new diesel-powered construction, agricultural and industrial NRMM for the EU market will be in-scope of the PN limit. Whilst manufacturers can now move forward with certainty on the limit values and introduction dates that must be achieved, the timely publication of the complementary Commission supplementing legislation is essential in order for manufacturers to know the full details of the engine type approval requirements with which they will need to comply to be able to supply Stage V engines.

Sources of Technical Emissions in Mining

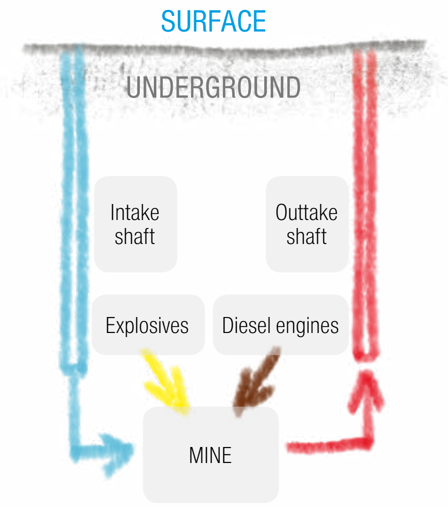
160315 OEL in Mining, TU-Sö

Mobile diesel machines: NO, NO_2, CO, CO_2, Particulate Matter
Blasting: NO, NO_2, CO, CO_2



ADEQUATE VENTILATION

Ventilation is a basic component of all underground mine operations. Ventilation is undertaken in order to introduce fresh, cool air to the workings and to remove stale, contaminated air. Within the mining industry, a safe, efficient and economical mine ventilation system is an essential component of all underground mines. Mining ventilation is based on keeping a stream of air circulating through the mine. This is done by maintaining a pressure difference between the inside of the mine and the surface using large fans, ventilators and regulators. Stale, dirty air and gases are expelled from the mine using massive extraction fans. The resulting vacuum sucks in fresh air from the surface, supported by more fans, to clean and dilute the air inside the mine.



There are two types of mining ventilation systems that are commonly used in modern mines:

- The main type is known as flow-through forced ventilation. This is the main circuit of air that travels through the mine. It enters a large ventilation shaft and travels throughout the mine before leaving by another ventilation shaft. The air is moved and controlled by a series of fans and regulators that ensure the air keeps moving.
- To get the fresh air to where the miners are, the second type of mining ventilation is used: auxiliary ventilation. This ventilation system takes air from the main circuit and directs it to where the miners are. Fans, ducting and special ventilation shafts are used to transport the air to where it is most needed and out again. These two mining ventilation streams work together and keeping the balance between the two is a full-time job for the ventilation engineers of the mine.

Calculation of ventilation requirements in German underground mines:

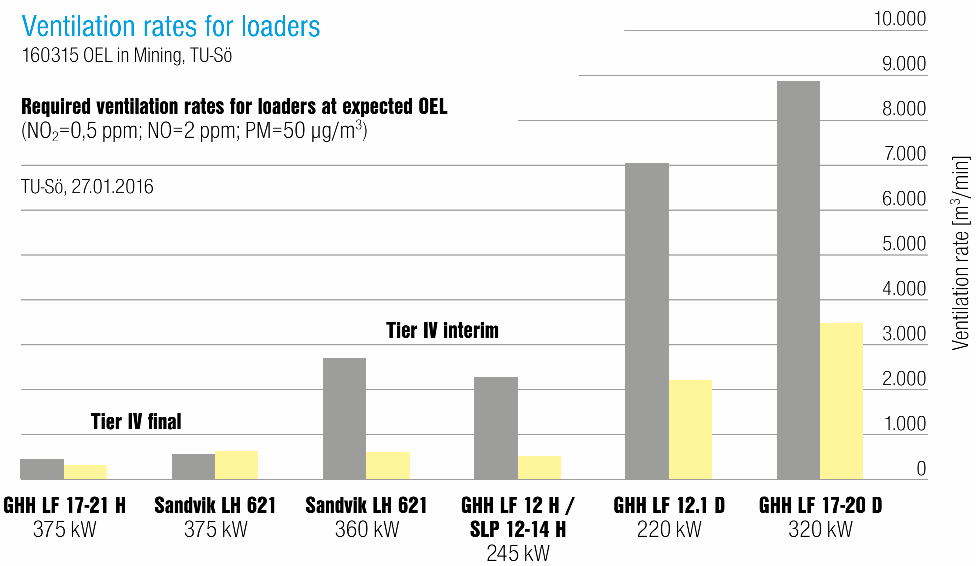
Heavy Duty Equipment / Light Duty Off-Road Equipment

- Exhaust emission values of engine certification for placing on the market according to EC-regulations
  CO, NO_x and Pt in g/kWh
- Fuel consumption and CO_2 - emission in g/kWh
  Assumption: raw exhaust with 10 % NO_2 and 90 % NO
  Oxidation within the district to 20 % NO_2 and 80 % NO

On-Road Vehicles

- Exhaust emission values based on certification of engines for placing these on the market according to EC-regulations
  CO, NO_x and Pt in g/km

The amount of air supplied to the mine ventilation network in KGHM to dilute gas emissions is 433, 000 m^3/min (about 520 Mg of air/min.)



Challenges that the industry faces are as follows:

TECHNICAL

- For undeground mines the size of the shafts define the technical limits for the ventilation air flow. There are limits in air speed in shafts. Sinking new shafts requires space and permitting which in some locations is physically impossible, in some cases developing shafts and increasing air flow is economically impossible due to the complexity of the mine or indeed the lifespan of the operation.
- The ventilation air from the intake shafts gets distributed properly into the working areas – complying with all actual regulations. A whole system of air handling constuctions and equipment (fan stations, auxilary fans, doors, regulators, ...) are installed in the mines to ensure good working conditions at the working areas for workers.
- The ventilation systems have to be optimized for an adequate distribution and guidance of the fresh air streams for immediate dilution and exhausting of the gaseous and particulate components. There are technical limitations to reducing these components with ventilation air flow.
- There are opportunities to improve ventilation in working areas by efficient removal of blasting fumes using a combination of regulated airflow, crosscuts optimizing, fan performance and bratice walls. The options need to be investigated and implemented by the ventilation engineers.
- Ventilation on demand can be an option to improve ventilation, but is not acheivable in every case.

SCIENTIFIC

- A 10 fold increase of ventilation to achieve the required dramatic decrease of OELs is not a viable option;
- Even if technically possible the increase in airspeed to the level required would have serious health effects for the workers and would eventually also be in breach of established legal requirements based on health protection.
- We must distinguish between free blasting fumes and blasting fumes contained in the blasted material. Free blasting fumes can to a large extent be exhausted/ventilated before workers get to the area. The fumes inside the heap of blasted raw material is released during loading – while personnel are in the working area.

These blasting fumes must then be removed;

- Efficient Auxillary Ventilation becomes crutical.
- Ventilation and exposure must be continiously controlled.
- When procuring new machines the best available standards must be applied.

ECONOMIC

- One of the main energy costs in underground mining is in ventilation. Therefore, mining companies strive to optimize ventilation systems. In this context, the clearance of workplaces at the face after blasting has to be utilised. If the lower limit values for NO and NO_2 are enforced, then an additional ventilation clearing time period would be required before the next shift could start working. This would result in significantly higher operating costs at all mines.
- Even a small increase in ventilation air flow at shafts (if technically possible) results in an enormous increase in ventilation costs and could lead to some mines becoming economically unviable.
- It will take a considerable period of time to change all the machinery underground to TIER 4 final stage or EURO 6 stage. The non-coal-mining in Germany would have roughly 2,500 vehicles to be purchased new. This is an enormous economical challenge which could lead to mine closures due to cost increases.

AFTER-TREATMENT TECHNOLOGIES

DIESEL OXIDATION CATALYST

Diesel Oxidation Catalysts (DOCs), are primarily designed to control carbon monoxide (CO), hydrocarbon (HC) and polycyclic aromatic hydrocarbons (PAH) emissions. Depending on catalyst formulation , DOCs might have substantial effects on gas phase organics, but typically have limited effects on the organic fraction of particulate matter. DOCs, initially introduced in underground mines to control the CO and HC emissions, became a widely used technology in mining applications. In recent years, DOCs have often been deployed to control emissions of hydrocarbons and the organic fraction of particulate matter emitted by mining vehicles fuelled with biodiesel.

DIESEL PARTICULATE FILTER SYSTEM

Diesel Particulate Filter (DPF) systems are designed to physically remove DPM from the exhaust of diesel engines. The majority of DPF systems currently present in the mining industry utilize, as a filtration strategy, the wall-flow system: the particles are trapped in the walls of the filter while the gases pass through them. The wall-flow system can provide up to 99% DPM mass filtration. The DPF must be periodically or continuously cleaned (regenerated) to avoid the occurrence of excessive engine back pressure. The regeneration is typically accomplished via oxidation of filtered DPM. Balancing NO_2 production with NO_2 consumption by the DPM plays a critical role in supporting regeneration while preventing a potential increase in NO_2 emissions from such a system, known as NO_2 slip. A proper choice of catalyst and settings of a DOC+DPF system theoretically can minimize the NO_2 slip. NO_2 slip can also be reduced by deploying the NO_2 abatement strategies.

SCRT-TECHNOLOGY

Four-way emission control system that delivers high NO_x reduction across a broad range of applications. For diesel applications where maximum NO_x reduction is critical, SCR technology provides the highest NO_x reduction available today. SCRT system reduces all four regulated exhaust emissions: CO, HC, and PM by over 90%, and NO_x by 70%.

MANAGEMENT OF EXPLOSIVES

Detonating explosives release toxic gases, primarily oxides of nitrogen and carbon monoxide. Nitric oxide (NO) and nitrogen dioxide (NO_2) are produced during blasting. NO released by the detonation oxidizes to NO_2 as the fumes mix and react with the atmosphere. There is a chemical balance between NO and NO_2 in the athmosphere. Excessive NO_2 production from incomplete detonation of explosives is visually apparent as an orange cloud that forms in the area of the blasting site.

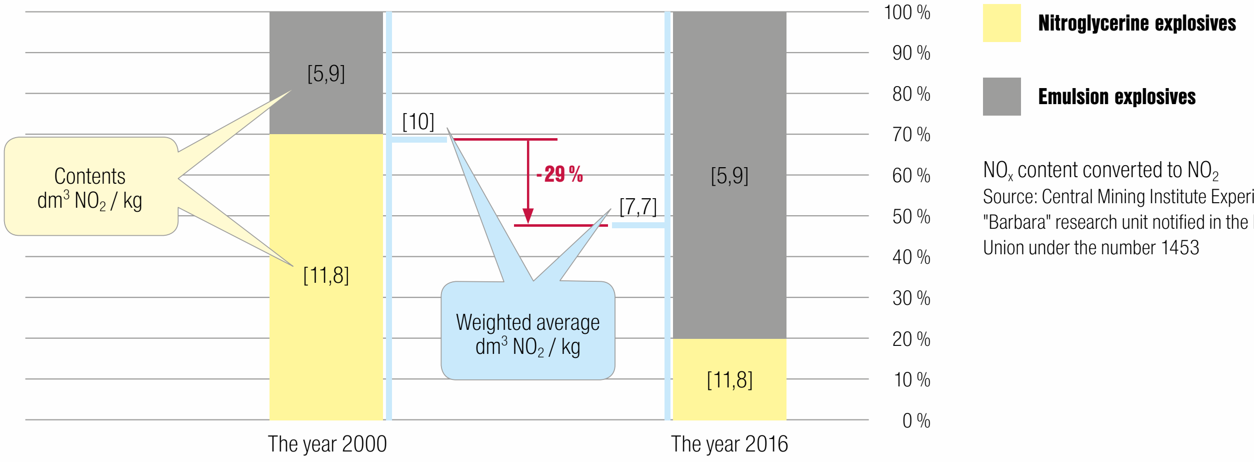
Carbon monoxide (CO) is also released by the detonation of explosives. CO is not a problem after large surface blasts because it quickly dissipates in the atmosphere to safe levels. CO dangers are more of a problem for construction, trench, tunnelling and underground blasting. If a mine worker enters a blast site too soon after a blast, the CO emanating from the muckpile poses a serious risk to the worker.

Industrial explosives are used for advancing tunnels and for the extraction of raw materials. The type and quantity of explosives used depends on the working methods and geological conditions as well as on the raw materials to be extracted.

In the mining operations emulsion explosive materials have been introduced, that emit lower amounts of noxious gases compared with the traditional ones (based on nitroglycerin) used previously.

Measures and actions to reduce NO_x emissions

Explosives – nitrogen oxides in post-blasting gases



NO_x content converted to NO_2
Source: Central Mining Institute Experimental Mine "Barbara" research unit notified in the European Union under the number 1453

Various factors should be considered when discussing the use of explosives by the mining industry:

TECHNICAL

- The significant reduction of exposure to nitrogen oxides resulting from blasting is naturally associated with higher emissions of carbon monoxide, due to the chemistry of the explosives. This comes into conflict with the current discussion on carbon monoxide limit values in the mining industry. The mining industry is keen to further encourage the manufacturers of industrial explosives to further reduce the formation of NO and NO_2.

SCIENTIFIC

- Explosives used in today's mining industry have been steadily developed over the years and now emit much less NO and NO_2 compared to previous generations of explosives.
- Mining Companies are interested in the further development of economically reasonable explosives to lower the amount of blasting fumes and optimise their components concerning new exposure limits.

ECONOMIC

The mining industry strives to optimise the use of explosives and minimise costs by:

- optimising blast design and explosives efficiency
- reducing the quantity and therefore the costs of explosives,
- minimizing the powder factor (use of explosives per unit of rock volume/mass),
- reducing the costs of drilling and blasting,

In addition to extraction by drilling and blasting, in some underground mines selective and full-cut heading machines are used where economic. For example, this procedure is preferred in the construction of headings, if it is technically possible, economically reasonable and where there is no increased risk to safety.

Therefore, in some areas prone to CO_2 outbursts in the Hessian potash districts, extraction with partly unmanned (in the moment of initiation) drilling and blasting technology is applicable exclusively. Other technical alternatives to drilling and blasting do not exist.

Also in hard-rock mining the use of selective and full-cut heading machines is often technically and economically limited. In other cases the high amount of fines (as a result of selective and fill-cut heading machines for extraction) is not useable and required for further production. Other technical alternatives to drilling and blasting do not exist.

Therefore, there will be an on-going need for the continued use of explosives in mining in the future.

USE OF LOW SULPHUR FUEL, FUEL ADDITIVES AND ALTERNATE FUELS (E.G. BIODIESEL FUELS)

In general, emissions can vary from engine to engine and across different engine load conditions, even though all engines are operated using the same basic type of fuel and fuel additives. Variations occur because the details of the combustion process differ with engine design and methods used to control fuel to the engine as well as with the duty cycle of the engine.

PERSONAL PROTECTION MEASURES

There are few industries where safety plays such an important role as in mining. Every step must be carefully planned and every decision is critical to ensure efficient and safe mining operation. The following measures protect workers from exposure to dust and toxic gases:

- **Respiratory and eye protection**
  Whether for drilling, extracting or loading, respiratory protection masks and protective eyewear offer the wearer not only effective protection against fine dust and particulates, but also simple handling and high wearing comfort.
- **Portable gas detection**
  For the underground mining sector, a comprehensive line of gas detection products exist to meet the needs of various applications, from personal air monitoring, fire and explosion prevention to confined space entry and post blast inspection.
- **Stationary gas detection system**
  For monitoring of toxic gases and ventilation efficiency underground there are accurate and reliable stationary gas detection systems to protect the workforce and speed up post blast clearance.
- **Diesel emission testing**
  For preventive maintenance, optimising engine efficiency and compliance with safety regulations, robust diesel exhaust gas testing equipment allows emission testing under harsh mining conditions.
- **Personal medical service**
  All employees working underground get an occupational health check at least every two years and in very many cases a health check is provided on an annual basis. It is still planned to carry out an additional epidemiological study in underground potash mines in Germany to check the health of underground staff in relation to current exposure of CO, NO_x and EC-DME.

Monitoring

Final conclusions from the SCOEL report, show that the new proposed limit values are based on the uncertainty of the measurement given the fact that usually, these are made periodically. In order to ensure that the risk to workers is reduced to the lowest possible level, instead of taking the experimental safe proved values (i.e. 2 ppm for NO_2) they increase the, let say „ safety coefficient“, to 2, then the OEL results in 1 ppm.

We could compare that situation with the current one for firedamp. Given the fact that methane could explode at 5%, the OEL for evacuation is 2.5 % if continuous monitoring is in place, giving a reasonable safety coefficient because METHANE may explode and also, because these emissions cannot easily be controlled as it’s a naturally occuring hazard.

This is not the case with CO, NO, or NO_2, so it should be permissible to have limits go up to 2 ppm as long as continuous monitoring is set in place, giving an automated warning when the measured (NO_2 for example) is approaching that value.

Conclusions

The ambient concentration of NO_x and CO gases in workplaces in underground mines come predominately from the utilisation of explosives and from vehicles and mobile machines equipped with diesel engines. During the last few decades of diesel engine operation & development, a significant amount of research and improvements were made in the area of work environment protection and diesel engine efficiency. The improvements are ongoing and there is a need for further technological development leading to the development of even more efficient and less polluting machinery. New NO_x limits are not easy to achieve in the underground environment, hence long transition periods are required (extreme cost factor for TIER IV final; lack of availability of new engines). It is in the best interests of mining companies to use advanced diesel engine technologies and more efficient systems for exhaust after treatment. The mining industry is fully committed – mainly driven by economic factors and workers protection – to optimise the use of explosives. That can be done thanks to the research put into explosives. Today’s explosives used in mining have been steadily developed over the years and now emit much less NO and NO_2 compared with previous generations of explosives. One of the main energy cost factors in underground mining is ventilation. Therefore, mining companies strive to optimize ventilation systems. Mining Companies are interested in the further development of economically reasonable explosives to lower the amount of blasting fumes and optimise their components concerning new exposure limits. Given the limitations on increasing ventilation flows and the enclosed nature of the working environment, the local build-up of NO_x and CO, may result in potential short and long term health issues; hence the importance of workplace environment monitoring to ensure the gas levels do not exceed the permissible exposure limit values. The extractive industry recognizes the importance of such monitoring and invests heavily in new devices to ensure reliable monitoring systems are in place.

During the last few decades of diesel engine operation & development, a significant amount of research and improvements were made in the area of work environment protection and diesel engine efficiency.

The improvements are ongoing and there is a need for further technological development leading to the development of even more efficient and less polluting machinery.

Annex 1

EXAMPLES FROM INDUSTRY/MINING OPERATIONS

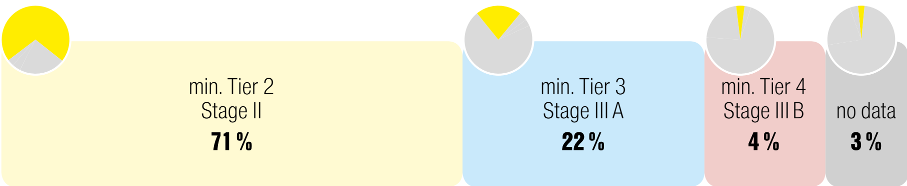
1. KGHM POLSKA MIEDZ

Reduction of NO_x emissions

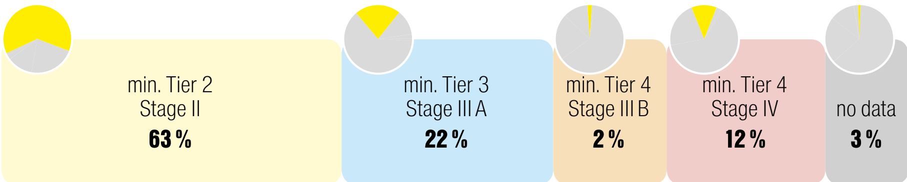
Mining machinery [1] powered by diesel engines

The structure of diesel engines according to the emission standards of combustion

2014 > 1.213 items



2014 > 1.213 items



(1) According to the quantitative status at the end of the periods, typical mining machinery, used in Energy and Mechanical units for Underground Equipment in Mines

Reduction of NO_x emissions

Blasting works

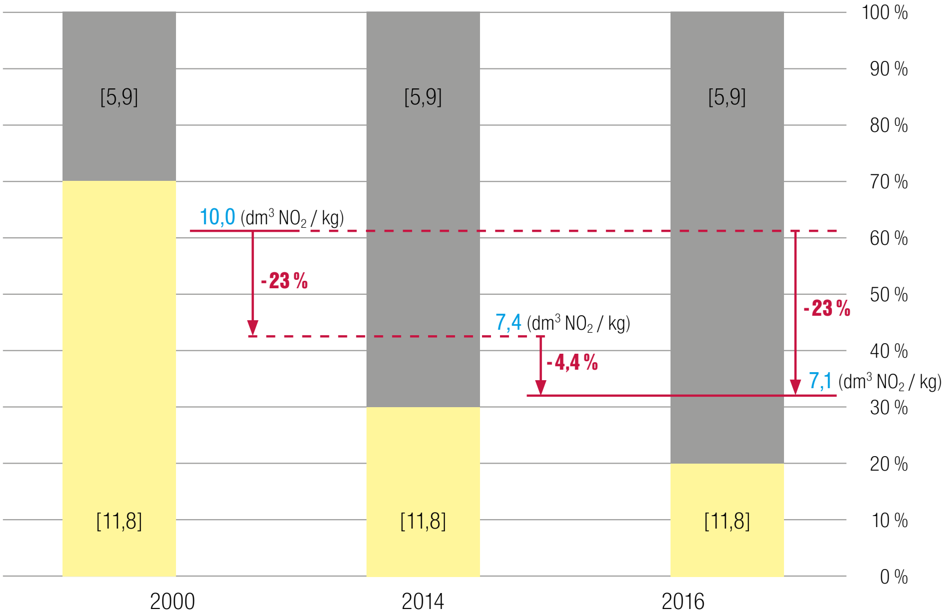
NO_x content converted to NO_2

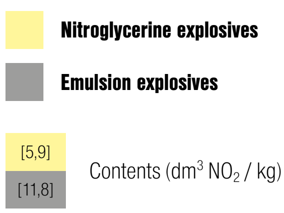
Source: Central Mining Institute Experimental Mine "Barbara" research unit notified in the European Union under the number 1453

The annual use of explosives
16 thousand tons

The daily use of explosives (24 h)
50 tons

The number of blasting works in the mine faces / daily (24 h)
600





Reduction of NO_x emissions

Organisational activities (measures):

1. Leaving of the machinery after work shifts in the area of exploitation front (faces) on specially dedicated points of machines interchange (technically efficient machines don't go to Heavy Machinery Chamber – thus we limit rides and reduce emissions).
2. Use of separation of the loading and transport of excavated ore phase from the drilling and bolting phase in the technological process in the operating areas, where it is possible.
3. Consideration of only one performance of blasting works throughout the day.

Planned actions:

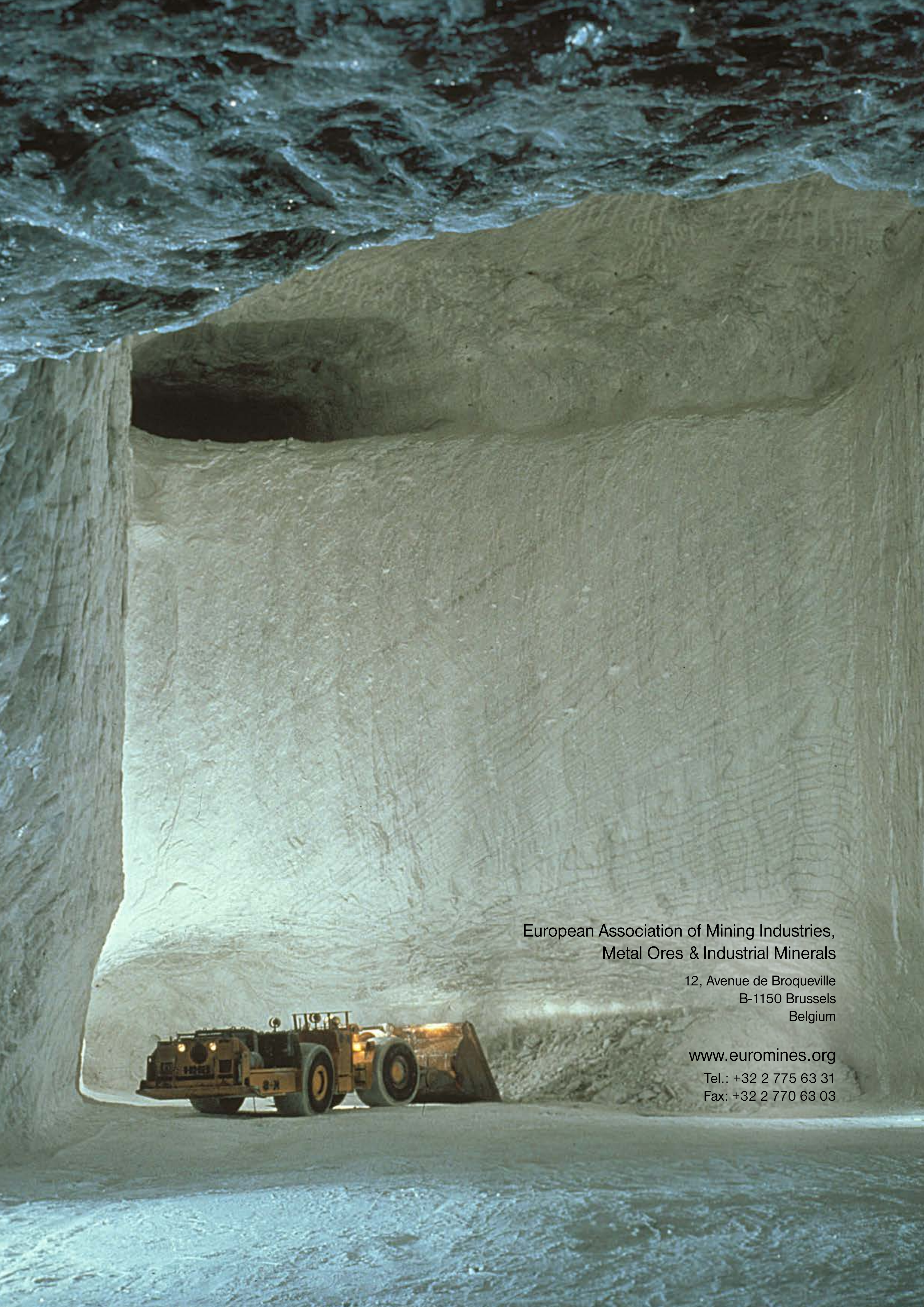
- Introduction of monitoring of combustion gases in mobile mining machines.
- Purchase of machines with diesel engines complying with higher emission standards.
- Development of a new emulsion explosive material with a detonation velocity approx. 6 thousand m/s (for the replacement of dynamite – nitroglicerine material).
- Introduction of fuel additive, aiming at reducing emissions of gases (NO_x, CO) during the combustion processes.

2. KALI + Steinsalz

The K+S Group is facing large challenges due to the release of new Occupational Exposure Limits (OELs) for nitrogen oxides in Germany with regard to underground mining operations. Additionally there will be more tightening of OELs with respect to carbon monoxide and Diesel Particulate Matter (DPM). In K+S underground potash and rock salt mines the extraction method is mainly drilling and blasting. In the mining cycle, in hauling, and for personnel transportation diesel driven mobile equipment is used. At this time, the new OELs for NO and NO_2 (as 8 hour shift average) cannot be maintained.

K+S is aiming to comply with the proposed OELs in the future. Therefore the goal is to make every feasible endeavour to meet the regulatory requirements for nitrogen oxides according to the transitional phase of five years applicable for the mining industry in Germany and to continuously safeguard health protection for the employees in correspondence to the new, tightened regulatory standards. The timed and technical effectiveness of measures in the fields of combustion engine technology, explosives, and ventilation cannot be finally assessed at this time. Besides the emission reduction from forced introduction of TIER IV final and EURO 6 diesel engines, new electric drives are tested.

Electric drives for underground mobile machine equipment and vehicles could play a more important role in the future. Possibilities of advanced ventilation optimization are investigated and promoted to dissipate the operational emissions from extraction with drilling and blasting and diesel engine operation more effectively and faster. New low emission explosives are developed, will be tested in practice and shall be introduced in case of success. The underground processes are analysed with regard to optimization potentials for emissions reduction. The K+S OEL measuring and monitoring concept for the underground mines needs to be adapted technically and from the organizational point so that the new OELs can also be maintained safely in the future. Finally, the systematic and intense medical prevention established in mining will be intensified on a high level. Furthermore an epidemiological study is planned which will contribute to extend the knowledge base regarding health effects.



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