1-7987638

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

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Canada Centre for Mineral and Energy Technology / Centre canadien de la technologie des minéraux et de l'énergie

MEASUREMENT OF DUST AND RADIATION CONCENTRATION IN MINES AND CONTROL STRATEGIES

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SEPTEMBER 1988

Presented at Seminar, CANMET, Partner with the Ontario Mining Industry, Timmins, Ontario, November 22 and 23, 1988
and published in the proceedings.

measurement
dust
dust control
radiation
mines

MRL 88-109 (OPJ)

15 pp

MINING RESEARCH LABORATORIES
DIVISION REPORT MRL 88-109 (OPJ)

Measurement of dust and radiation concentration in mines and control strategies

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ABSTRACT: Safety and health in mining is a priority and Canadian mines rank among the best when it comes to industrial hygiene. Such achievements are a result of constant efforts aimed at reducing exposure of workers to potential working hazards and dangerous substances such as noxious gases, respirable dust and ionizing radiation.

CANMET's Mining Research Laboratories, and more specifically the Elliot Lake Laboratory, are an essential tool in the evaluation of dust and radiation sources and concentrations in underground mines. The Elliot Lake Laboratory underground environment research team has been directly responsible for the development of techniques and instruments used to evaluate the impact of methods and control systems on underground contaminants.

Furthermore, the Elliot Lake Laboratory is equipped with unique and sophisticated facilities which are designed specifically for the comparison and calibration of dust, radiation and ventilation monitoring instruments.

RESUME: Bien que les mines canadiennes soient parmi les plus avancées au monde en ce qui a trait à la santé et la sécurité au travail, il n'en reste pas moins que l'industrie est toujours à la recherche de façons plus efficaces de réduire les risques à la santé des travailleurs du secteur minier.

Les laboratoires de recherche minière (LRM) du CANMET et plus particulièrement le laboratoire d'Elliot Lake en Ontario sont essentiels à

l'évaluation des sources et des concentrations de poussière et de radiation ionisante dans les mines. Depuis ses débuts, l'équipe de recherche de l'environnement minier du laboratoire d'Elliot Lake a su développer des techniques et des instruments de mesure qui servent à évaluer l'impact des méthodes et des systèmes de contrôle des contaminants dans les mines.

Le laboratoire d'Elliot Lake possède maintenant des installations d'étalonnage d'instruments de mesure de poussière et de radiation qui sont des plus sophistiquées.

INTRODUCTION

Mineral extraction processes produce large amounts of respirable dust which are irritants or may be the cause of serious lung diseases. Ionizing radiations are also known to be linked to lung cancer in uranium and non-uranium mines. Mine operators are responsible for the well-being of miners in the workplace through the implementation and maintenance of dust and radiation control programs.

In the beginning, the Mining Research Laboratory dust research team's mandate was the creation of a data base listing the types and concentrations of airborne dust found in several Canadian underground mines. Furthermore, the evaluation of mining regulations from other industrialized countries was undertaken in order to provide information which could help in the development of standards suitable for use in a Canadian context (1-3).

The radiation research group started in much the same way. At first, use was made of existing instrumentation to systematically establish the levels of radioactive contaminants found in various uranium mines. With time, this group has evolved and has been responsible for the development of several methods and instruments used to monitor radiation levels in mines. Finally, the radiation research group is now conducting a final evaluation of an environmental chamber destined to become a national calibration centre for radiation monitoring instruments. The dust, radiation, and ventilation groups are now integrated into an interdisciplinary group under the name 'underground environment' in an effort to tackle practical mining and research problems from a broader base and different perspectives

Presently, the Mining Research Laboratories (MRL) have at their disposal a wide variety of dust and radiation monitors and research is centered mainly on the evaluation and design of control methods for airborne respirable dust and ionizing radiation. As such, most of the work at MRL is conducted in close cooperation with the Canadian mining industry.

DUST SOURCES AND CONTROL METHODS

Dust sources are found at all stages of mineral extraction and a wide variety of methods may be used to eliminate or reduce dust concentrations by controlling dust emissions at the source and elsewhere in air. Blasting and drilling are primary sources of mineral airborne dust. Moreover, blasting releases large amounts of toxic and irritating gases. Dust produced during these operations may be reduced greatly by efficient use of water to knock down dust and by ventilation to dilute dust and other contaminants. In certain cases it is also possible to reduce dust concentrations, or worker exposure, by modifying extraction methods and schedules.

In several mines, ore transport and load, haul, dump (LHD) operations account for a large portion of the airborne dust production. Belt conveyors, vehicle traffic and ore transfer points are constant sources of mineral and combustible (diesel soot) respirable dust. In many cases, these sources are extended (as opposed to localized) which makes control and elimination more complex. In order to reduce concentrations at localized sources, dust must be captured and eliminated using a scrubber or a filter. Some examples of such sources include belt conveyor transfer points and ore passes. Conveyor belts must be cleaned during operation by wetting and scrubbing of the return strand. Ore to be transported should be wetted thoroughly and drifts where vehicle traffic is dense should be wetted using water sprays. These sprays may be charged electrostatically to enhance dust capture.

Ore breaking and crushing produces large amounts of mineral dust. Fortunately, these sources are localized which facilitates capture and elimination. A well designed capture system combined with an appropriate filter or scrubber will usually succeed in removing most of the dust produced by these operations. In many instances, however, efficient filtering units are not permitted to function at their full potential. There are several reasons for this lack of performance. Inadequate installation, incompatibility of the filter with the type of dust to be removed or the job to be performed, and lack of maintenance. To function in an optimal fashion, the dust collector must be built into the production system. The dust collector should not be thought of as an add-on, but rather as an integral and essential component at the working site. Several types of dust collectors are used to eliminate captured dust. "Bag house" type dust collectors operating on dry filtration principles are often used to eliminate mineral dust. Other options include wet dust collectors and electrostatic precipitators. The choice of dust collector to be used depends largely on the type, concentration and size of dust to be removed.

Finally, airborne dust settling in drifts and on roadways may be redistributed by vehicle traffic and by ventilation airflow. This phenomenon can be controlled directly by the use of water sprays in roadways, and indirectly by decreasing the amount of fugitive dust at the source (blasting, drilling, crushing).

In summary, the success of a dust control technique depends largely on how well it is adapted to the mining operation. The type, concentration and size of dust all have to be taken into consideration. The dust collector and the capture system must be designed in such a way as to obtain maximum efficiency. Finally, the dust collection apparatus must be inspected and maintained as rigorously as the machinery it is complementing (crusher, belt conveyor, etc.).

DUST SAMPLERS AND MONITORS

The Elliot Lake Laboratory makes use of several types of dust samplers. Gravimetric samplers used on personnel, or as area monitors, help us assess dust concentration before and after implementation of new, or improved, dust collection system. Continuous reading instruments are also used to quickly localize fugitive dust sources and dust concentration changes as a function of time or operation.

Two other instruments (one gravimetric, and the other continuous) allow us to measure the size distribution of airborne dust. These instruments serve two very important purposes. First, knowledge of the size distribution helps in the selection process of one type of dust collector over another. Secondly, sampling the intake and exhaust of a dust collector with these instruments helps determine the efficiency of filtration as a function of dust particle size. This test, when performed on line (when the collector has been installed in the field) shows whether or not the collector is operating optimally.

RADIATION SOURCES AND CONTROL METHODS

Underground airborne radioactive decay products may be divided into two groups. These are the short-lived decay products of radon and thoron, and the long-lived radioisotopes of the uranium decay series. The short-lived decay products are found in uranium as well as non-uranium operations. Short-lived radioactive particles in air arise from radon or thoron gas diffusion from the uranium ore in drift walls and muck piles. These gases are readily soluble in water. As a result, underground sources of water may cause radon or thoron gas emanations to contaminate non-uranium mine air. Serious concentrations of long-lived radioisotopes associated with airborne mineral dust are mostly a uranium mine problem.

Because uranium and thorium minerals are widely, and more or less evenly distributed over the crust of the earth, the occurrence of radon, thoron, and their short-lived decay products in non-uranium mines is much more common than previously anticipated. Very significant concentration levels of the above radioisotopes have been measured in a number of underground surveys, to the extent that attempts are presently being made by the pertinent regulatory bodies to limit exposure levels in non-uranium mines.

Another potential radiation health hazard in uranium mines is the emission of gamma-rays. Exposure to this type of radiation becomes important in high grade uranium mines. Because gamma-radiation sources are in the ore (and they do not diffuse and become airborne), mechanical ventilation is ineffective in reducing gamma-ray exposure levels. External gamma radiation presents health and practical problems of an entirely different nature to airborne radon and its decay products.

Radioactive respirable dust may be captured and controlled in the same manner as ordinary respirable dust. Short-lived decay products, however, are often associated with sub-micron size airborne particulate and removal or filtration becomes increasingly difficult as particle size decreases. Some attempts have been made to reduce radon and thoron emanations by coating the drift walls with a substance which is impermeable to gas. This method, however, has proven very expensive and results to date are not encouraging. Electrostatic deposition of radioactive contaminants is another technology that has shown promise. Research in this direction is presently underway at the Elliot Lake Laboratory. Presently, the most common method for controlling airborne radiation in mines is forced mechanical ventilation to dilute contaminants. This method is effective in a properly designed ventilation network, but the operating costs in a northern Ontario climate are high.

AIRBORNE RADIATION MONITORING EQUIPMENT

Several types of instruments are used to monitor airborne concentrations of radioisotopes in mines and for personal exposure determinations. Most of these operate on alpha-particle detection principles, and may be divided into two categories. The most common instrument used in mines is of the grab-sampling type. These allow the concentration of short-lived decay products to be measured at 5 minute intervals or longer if so desired. The Elliot Lake Laboratory also uses a variety of continuous radiation monitors (for radon and its decay products) to establish radiation concentration as a function of time. Many of these instruments have been designed and built by the laboratory's underground environment research staff, or by outside firms on contract. The Elliot Lake Laboratory has contributed significantly in the development of personal radon daughter dosimetry in Canada.

MINING RESEARCH - A COOPERATIVE EFFORT

Close collaboration with the mining industry ensures that the research performed by MRL is geared to the needs of industry and is applicable in the short-term. The following examples illustrate the type of work undertaken at the Elliot Lake Laboratory in cooperation with the mining industry.

a) **Evaluation of a wet dust collector used to control dust and radiation at an underground crusher station (4,5).**

A crusher station in an underground uranium mine was plagued with high dust and radiation concentrations. The bag-type filter and associated capture duct and hoods used in this area were not adequate. The bag-house filter was then replaced by a wet dust collector. The ducting system was re-evaluated, and two capture points were added to the existing layout, one closer to the crusher jaws, and a hood close to the ore pass where airborne dust was accumulating during crushing.

Further analysis and sampling after installation of the new system have shown that although the efficiency of the wet collector is theoretically lower than that of a bag filter, respirable silica concentration in the general area was reduced by 70% on average, up to a maximum of 79% at the crusher attendant's work station. Long-lived radioactive dust concentration was reduced by 68% in this same area. Short-lived radioactive contaminants were marginally affected showing a 10% decrease.

b) Evaluation of electrostatic water sprays (6,7).

It has been shown that most airborne dust particles are bearers of a significant number of elementary electrical charges. In light of this, several manufacturers offer equipment for producing electrically charged water sprays. This concept is not new, and is used in some surface plants. This technology, however, had never been rigorously tested in an underground setting.

A project was then elaborated which required the participation of an electrostatic water spray manufacturer, of a mining company, and the MRL underground environment staff. Electrostatic sprays were mounted in a drift near the exhaust airway of a crusher station. Results from this study have shown that two water sprays operating at a pressure of 350 kPa (50 psi) and a water flow rate of 130 mL/min (1.7 gallons per hour) succeeded in reducing respirable dust by 38% in a drift where air velocity was 0.06 m/s (0.2 ft per sec). Efficiency, however, was greatly reduced at higher air flow regimes. Results for long-lived radioactive dust were almost identical to those shown above for respirable dust. A significant effect on radon daughter concentrations was also noticed although highly dependent on air flow conditions.

c) Evaluation of a fan-filter system to reduce noise, dust and radiation in an underground uranium mine (8,9).

This test was conducted underground to evaluate a ventilation fan designed primarily to reduce noise emissions. In order to protect the noise insulating materials inside the fan body, the manufacturer designed and installed a cylindrical filter unit at the fan intake. By adding this module it was also possible to reduce the dust and radiation concentration of exhaust air, which would be an asset in secondary ventilation cases.

Results of the study show the filtration efficiency was low, in the range of 10% to 30% for dust in the 0.2 μm to 2 μm diameter range. Respirable dust concentrations were reduced by a maximum of 32% during one of the tests. Short-lived radioactive contaminant concentrations were reduced by 10% to 17% when the fan-filter unit was operated.

LABORATORY ANALYSES AND SERVICES

Facilities at the Elliot Lake Mining Research Laboratory are designed specifically to support the mining industry in a variety of fields. These services include X-ray diffraction analysis of respirable silica samples, dust, radiation, and ventilation instrumentation evaluation and calibration, as well as a gas chromatography laboratory for underground tracer gas ventilation studies.

The X-ray diffraction apparatus for silica analysis has been operating for several years. Constant refinements and upgrading in both hardware and software make it one of the most versatile and efficient systems of its kind in the country. Several thousand samples from internal projects, outside research initiatives and routine silica samples from dozens of Canadian mines and industries are processed every year.

The dynamic flow dust chamber is a wind tunnel where a fan circulates dust laden air through three chambers of different cross-sections. This layout allows three simultaneous operating conditions. Air velocity in each section may be adjusted at will by varying the fan's air volume displacement. Several types of dust may be injected into the chamber in order to reproduce, as closely as possible, dust conditions encountered in underground settings.

The dust tunnel is a very versatile research tool. Dynamic (under controlled air velocity conditions) testing and calibration of dust samplers and monitors may be performed in dust clouds whose size distributions are controlled in order to closely resemble those found in mines. The dynamic aspect of the chamber is also ideally suited for the calibration of anemometers used to measure air velocity in mine drifts. Finally, the chamber is used to perform more advanced research on the effect of ambient air velocity and direction on the sampling efficiency of dust samplers.

Another research tool which is quickly becoming an invaluable asset in ventilation research is gas chromatography used in tracer gas ventilation surveys. Indeed, tracer gas studies are finding an increasing number of applications in solving complex ventilation problems in Canadian mines. This technique has already been used with great success by our laboratory on collaborative projects with the mining industry.

The apparatus may be used to accurately establish the rates of flow in several branches of a ventilation network simultaneously. But its versatility extends far beyond this, enabling it to measure the rate of recirculation and residence times of gases and fumes in stopes with an ease and accuracy not available from conventional means of analysis.

Finally, the radiation group of the Elliot Lake Laboratory has designed and built a test facility of the walk-in type, for the calibration and testing of radiation monitoring instruments used in underground mines for AECB compliance purposes. The facility has been designed to maintain 'test' atmospheres of radon or thoron and decay products (or an arbitrary mixture of both), and long-lived radioactive dust. In addition, this

calibration.

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