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CONTROL OF RADIATION AND DUST IN UNDERGROUND MINES

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by

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ABSTRACT

Several areas of relevance in the control of air pollutants in underground mine environments were examined. The areas covered, of practical interest in the context of occupational workers health in underground mines, are primarily the monitoring and control of airborne radioactivity and dust contaminants in mine air. Other areas include design optimization of mining tools, machinery and vehicles, optimization of mining operations, methods, techniques and practices. Also discussed is the proposal of an Interactive Integrated Underground Environment/ Ventilation Program (II(U/G)EVP) to operate in conjunction with a Data Acquisition System/Automated Control System (DAS/ACS) for the monitoring and automatic control of environmental pollutants in underground mine atmospheres.

Key words: Control; Respirable dust; Radiation; Ventilation.

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CONTRÔLE DU RAYONNEMENT ET DE LA POUSSIÈRE DANS LES MINES SOUTERRAINES

par

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RÉSUMÉ

Plusieurs aspects du contrôle des polluants atmosphériques dans le milieu minier souterrain ont fait l'objet d'une étude. Les secteurs couverts, qui sont d'un grand intérêt par rapport à la protection de la santé des mineurs qui oeuvrent dans les mines souterraines, sont principalement la surveillance et le contrôle des polluants radio-actifs aéroportés et des concentrations de poussière dans l'atmosphère des mines. D'autres aspects comprennent l'optimisation de la conception des outils, des machines et des véhicules utilisés dans les mines et l'optimisation des opérations minières, des méthodes et des techniques ainsi que des usages. On a également étudié la proposition relative à un Programme interactif intégré de protection du milieu minier souterrain/ventilation (II(U/G)EVP) qui serait appliqué conjointement avec le Système d'acquisition des données/Système de contrôle assisté par ordinateur (DAS/ACS), pour la surveillance et le contrôle automatisé des polluants atmosphériques dans les mines souterraines.

Mots-clé : contrôle; poussière inhalable; rayonnement; ventilation.

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INTRODUCTION

In the course of mining operations potentially hazardous situations may develop due to the release into working sites of contaminants such as radiation, dust in the respirable range and coarse dust, mists, vapours, noxious gases, diesel particulates, sprays, and other aerosols in the submicron and micron size range. These contaminants are inhaled and deposited in lung tissue. The penetration into the respiratory system, and hence, the health risk associated with these contaminants, is highly dependent on the type of contaminant and its particulate size and size distribution. Other important environmental factors that should be taken into consideration include light, noise and vibration. The role of ergonomics in improving the working environment must also be emphasized.

Precise, real-time continuous monitoring of mine environments is, therefore, of paramount importance in identifying potentially hazardous situations and in facilitating rapid remedial actions.

This report examines some areas of relevance in the control of air pollutants in mine environments. This work is based on an earlier discussion of the subject published elsewhere (1). The areas covered are, therefore, of practical interest in the context of occupational workers' health in underground mines. The report deals primarily with the monitoring and control of radioactivity and dust contaminants in mine air.

ENVIRONMENTAL AND PERSONAL MONITORING

Monitoring of working areas and inactive areas in underground mine environments is carried out for the following purposes:

1. To acquire knowledge and information on environmental variables and environmental conditions;

2. To use knowledge and information obtained in 1) in order to identify potential and/or actual undesirable conditions which may pose a risk to health of personnel;
3. To correct undesirable environmental conditions by maintaining adequate control quality standards using items 1) and 2) through adequate control procedures, methodologies and techniques; and
4. To monitor production, tools, machinery and production/processing performance.

To collect data on environmental conditions in underground mines a monitoring system is required.

The need for a reliable multisensor Data Acquisition System to monitor underground environments in order to investigate, and understand, the complex relationships between different environmental variables, and to diagnose anomalous situations, cannot be sufficiently emphasized. Up to the present no truly coordinated effort has been made toward the solution of a relatively simple, in principle, and urgent problem, namely:

1) Integration of dust, ventilation, noxious gases and radiation sensors into an off-the-shelf commercially available, state-of-the-art data acquisition system (DAS); and
2) Installation of the system in an underground mine, even using conventional communications channels, e.g., telephone lines.

CONTROL AND SUPPRESSION OF AIRBORNE CONTAMINANTS IN UNDERGROUND MINE ENVIRONMENTS

Acquisition of underground environment data in real-time, and on a continuous basis, not only enables identification of anomalous and undesirable environmental conditions to be ascertained, but also permits quick action to be taken in order to suppress, reduce and control the concentration of airborne pollutants at working sites to acceptable levels, thereby preventing or minimizing the risk of inhalation of potentially hazardous air contaminants. Automated acquisition of data also allows optimization and improvement of engineering conditions.

Central to our discussion is the need for a powerful automated control system (ACS) to operate in conjunction with a flexible and versatile data acquisition system (DAS) in order to perform certain functions to control the environment. The ACS and DAS should operate in an interactive fashion for fully automated control of the environment.

Any automated control system should perform a wide range of operations to control the environment, such as: changing air flows; pressurizing, activating or shutting down of fans, air compressors, air injectors, and water sprays and; opening or closing doors, amongst other functions. All of these are done in order to control dust, noxious gases and radiation levels.

However, not in all cases can control of environmental factors be effected automatically, as indicated above. Control, optimization, and improvement of environmental quality can also be brought about by the optimization of mining operations and techniques, by improved design of tools, vehicles and machinery and by some special in situ physical control measures. In this respect, part of this research thrust should be focused on environmental improvements to those aspects of mining processes which have an impact on the environment such as cutting, materials breaking and transfer.

Broadly speaking, environmental control can be accomplished, in varying degrees, by the following methods, where selection of one method over another depends on economics, know-how, and technical feasibility.

1) Dilution by natural and forced mechanical ventilation;

2) Air recirculation and pressurization;

3) *In situ* physical control measures which require the application of

methods and techniques different from those indicated in items 1) and 2). Examples of these are filtration, electrostatic collection, and the use of charged and uncharged water sprays;

4) Design optimization of mining tools, machinery and vehicles, to reduce contamination and noise, and to improve efficiency and ergonomics.

5) Optimization of mining methods and techniques for the same purpose;

6) Personal control measures by adopting adequate protecting devices, combined with the implementation of certain routines and practices.

The choice of one method or technique over another should always be carefully weighed in terms of practicality, output productivity and associated potential health risks, and also by economic considerations.

IN SITU PHYSICAL CONTROL MEASURES

As indicated previously, there are methods to suppress or control environmental pollutants other than by conventional dilution by forced mechanical ventilation. Major mine air pollutants can be divided into three main groups:

1) Dust in the respirable range (<1-10 μm). Quartz, coal, asbestos and other kinds of dusts are found in different underground mines depending on the chemical composition of the rock formation;

2) Noxious gases, e.g., NO_x, CO, CO_2, CH_4, etc. For simplicity, diesel particulates (in the submicron size range) are also included in this category. Most of the above gases arise from the use of diesel equipment;

3) Airborne radioactivity, which can be associated with submicron aerosol, respirable dust, and coarse dust. It is also found in an unattached state, i.e., in an atomic state. Radioactivity in underground mines is mainly due to radon gas and its short-lived decay products, usually

referred to as radon daughters. In some mines, thoron and thoron daughters, and/or long-lived radioactive dust (dust containing long-lived radionuclides) are also important.

The contaminants in the first two groups are encountered in a vast majority of underground mines, whereas the third group plays an important role in uranium mines. Radiation is, however, not restricted to uranium mines, as has been amply documented. Likely candidates for potentially significant airborne radioactivity levels are 'wet' mines, i.e., mines with large influx of water through their walls. The water dissolves radon gas in the pore space of the rock which is then carried into mine openings.

A. NOXIOUS GASES

Noxious gases in air cannot always be removed from air by mechanical filtration. In fact, pure gases (molecules) are not removed by conventional filtration techniques. Noxious gases can be removed by adsorption onto activated charcoal beds or layers of other large surface area to volume organic materials. Other techniques to control noxious gases include dilution by forced ventilation, i.e., the conventional method of gas control, and by chemical reaction (combination) with other chemical substances to produce an inert or non-toxic end product. The latter technique requires more research.

Little is known about the detailed physico-chemistry of underground mine environments, except for the usually widespread contaminants such as CO, CO_2, NO_x, SO_x, etc., some of which are by-products of diesel combustion, blasting operations, and other sources. Complex organic molecules, however, are also generated. These might interact with dust, submicron aerosol and airborne radioactive contaminants. Complete analysis of mine air environments by gas analyzers using different detectors (e.g., electron capture, flame ionization, nitrogen phosphorous, hot wire) has not been conducted to any degree of satisfaction. The toxicity of the complex milieu of chemical compounds generated in underground environments has not yet been ascertained in detail. It is, therefore, an important project to undertake.

B. RESPIRABLE DUST

Methods of dust 'avoidance', control and suppression include:

1) Ventilation
2) Air recirculation
3) Mechanical filtration
4) Wetting
5) Electrostatic precipitation (e.g., charged water sprays)
6) Air 'curtains'
7) Scrubbing.

A great deal of work has been done on items 3, 4 and 5. However, a fair amount of the work has only been partly conducted underground, e.g., electrostatic precipitation. The use of charged water sprays is a relatively new technique on which there are only sparse data available. Apart from some inconveniences of a practical nature, mechanical filtration is known to work satisfactorily in virtually all cases. However, wet scrubbing is a technique which offers some advantages over filtration (2,3). Using wetting with water is known to work well for certain kinds of dust. Other kinds of dust require the use of fluids other than water. Hence, there is room for research work into wetting techniques and methods. In general, mechanical filtration, wetting, and wet scrubbing are widely used in underground mines during mining operations that generate large quantities of dust, e.g., mucking, rock crushing and ore transportation.

Charged water sprays deserve more attention, not only because they are effective in removing airborne dust but also because radioactive materials attached to dust particulates are also removed at the same time. (It should be noted that mechanical filtration also accomplishes this but presents a different type of problem.)

The underground environment group of the Elliot Lake Laboratory has made substantial contributions to items 1, 3, 4, 5 and 7 (2-6 and references therein). Air recirculation as a means of partially controlling airborne respirable dust is of practical interest from the economical standpoint. Air recirculation is an area in which not much work has been done and which deserves more attention. The Elliot Lake Laboratory will undertake a major ventilation/recirculation project as a means of reducing environmental pollutants in the near future.

Respirable dust is an important consideration from the health standpoint as it poses a twofold health risk, namely that associated with dust itself, and that associated with long-lived radioisotopes 'attached' or contained in it.

C. AIRBORNE RADIOACTIVITY

Airborne radioactivity in underground mines can be divided into two main groups: i) short-lived radioactivity associated with submicron aerosol, and long-lived radioactivity found in respirable dust and coarse dust.

The present methods (potential or widely used) for radiation 'avoidance' control and suppression include:

1) Ventilation
2) Air recirculation
3) Mechanical filtration
4) Electrostatic deposition
5) Air curtains

6) Plate-out on mine walls, e.g., thermophoresis and electrophoresis.

7) The use of sealants, which are usually colloidal dispersions of complex organic polymers. These are sprayed on mine walls to provide a coating impermeable to radon and to impede diffusion and transport mechanisms.

Ventilation constitutes the most general method used in underground mines to reduce airborne radioactivity to acceptable levels. Control of airborne radioactivity can be considerably enhanced by the use of mechanical filtration with suitable filter materials. Ventilation and mechanical filtration are extensively used in underground mines to control the concentration levels of radon (and thoron), and their decay products. These control methods are also useful in reducing airborne long-lived radioactive dust in the respirable range. In the latter case, the use of wet scrubbers has proved to be a very efficient control technique.

The use of radon gas sealants has been investigated extensively by the U.S. Bureau of Mines. However, the physical integrity of the coating and the economics of the method are major concerns.

Electrostatic deposition techniques including the use of electrostatic precipitators, charged water sprays, as well as plate-out on mine walls by electrophoresis are methods that have rarely been used in underground mines as a means of reducing radioactivity concentration levels. The same applies to the use of charged wire mesh screens and negative ion-generators which are both presently under investigation at the Elliot Lake Laboratory. Both methods look promising.

Items 1, 3, 4 and 6 are the subject of considerable investigation at the Elliot Lake Laboratory (2,7-13 and references therein). As for the case of dust, air recirculation is an area of much interest at present and an extensive program to investigate its merits in controlling radiation levels in underground mines is underway.

The concentration levels of certain pollutants in mine air could be further reduced, or at least avoidance strategies could be implemented, by optimizing the design of mine tools, machinery and vehicles, and also by optimizing operations, methods, techniques, and practices as indicated below.

DESIGN OPTIMIZATION OF MINING TOOLS, MACHINERY AND VEHICLES

Improvement in the design of tools, motorized machinery and vehicles (e.g., trucking and loading) such as jumbo drills and scooptrams, with a view to reducing contaminants and improving efficiency and ergonomics at the operator site, is of paramount importance.

A number of improvements could be added to already existing tools, machinery and vehicles by slightly redesigning the above to improve their environmental and operational performance. Hence, according to the type of tool, machine or vehicle, air deflectors or air 'curtains', charged and uncharged water sprays, and air filtering systems could be added to reduce and/or control some pollutants such as dust, diesels and radiation near and about the mine operator. Improvements can also be made in fundamental processes of rock cutting, breaking, loading, and handling with increased safety and efficiency in mind.

Design optimization of mining tools, machinery and vehicles is an area which calls for a close collaboration between government, environmental scientists, mine companies, mine equipment operators and the mine equipment industry.

OPTIMIZATION OF MINING OPERATIONS, METHODS, TECHNIQUES AND PRACTICES

The subject is too complex to deal with in a brief report of this kind. However, apart from mine layout and other considerations, there are a number of suggestions and recommendations with respect to improving the quality of mine environments.

Optimization of mining methods and operations can lead to improved dust, diesel, and radiation environmental conditions. In particular, rock fragmentation, by crushing and blasting, and other mining operations such as mucking, slushing, and ore transportation, should be examined as targeted areas for improvement.

A proper and in-depth study to improve methods and techniques to reduce contaminants in underground mine environments is a rather difficult task under present conditions. Only very rarely can an underground project be undertaken and carried through under conditions which meet all the requirements for successful completion.

Although mining companies have always been extremely cooperative and accommodating to research needs and requests, and every effort has always been made at the Elliot Lake Laboratory to undertake research projects of direct interest, benefit and value to the mining industry, there are serious difficulties in carrying out major projects which have an impact on production.

Mining companies are understandably concerned when it comes to altering schedules and/or introduce changes in their established methods and techniques in production areas. The reason for this concern is in the direct undesirable effect that any change introduces into tight production schedules. productivity and profitability. At the same time, however, these are often the only areas suitable for certain projects.

There is little doubt that, in order to improve mining techniques and operations some experiments and tests must adhere to specific protocols which. in many cases, interfere with production. This type of research should definitely be undertaken as a joint venture between government and the mining industry, and the costs involved should be shared accordingly.

MINE ENVIRONMENT, CONTROL AND SIMULATION STUDIES - TOWARD THE ESTABLISHMENT OF AN INTERACTIVE INTEGRATED UNDERGROUND ENVIRONMENT/VENTILATION PROGRAM

Ventilation is the most common method used for reducing and controlling air pollutants in mine environments. However, as previously indicated, there are a number of other techniques that can, in some cases, either enhance or altogether substitute the effect of forced ventilation. The remainder of this section discusses the control of the mine environment by means of an automated system that can determine pollutant levels and respond to these levels accordingly by either using mechanical ventilation or activating any other control system as appropriate, or both.

Proper use of forced mechanical ventilation in underground mines begins with the development of theoretical models to predict air flow and air mass in either a section of a mine or in the entire mine, followed by experimental verification of theoretical predictions based on field measurements.

Firstly, user-friendly models have been developed for predicting air flow and air mass. These take into consideration airway resistance and other relevant variables, suitable for the specific purposes of interest, e.g., harsh and extreme surface environmental conditions applicable to Canadian weather.

The next step consists of expanding simple ventilation models to deal stepwise and incrementally with the three main environmental pollutant groups; dust, noxious gases and radiation. As already indicated, however, each main group of contaminants needs to be dealt with independently at first. The reasons are: i) different air ventilation requirements for each group; ii) disparity in the nature and behaviour of the contaminants in each and all groups; iii) widely different physical processes and interactions of the contaminants with the environment; and iv) interaction of contaminants of one group with contaminants of another group.

The mutual interactivity nature of the contaminants in the three main groups should now be considered carefully in order to integrate them into the mine atmosphere. Lastly, the use of an Interactive Integrated Underground Environment Ventilation Program (II(U/G)EVP) for contaminant level prediction could be interfaced with a Data Acquisition System/Automated Control System (DAS/ACS) as discussed elsewhere (1), for experimental (field) control purposes after experimental verification of the model(s). Control of the mine atmosphere should be done in such a fashion as to minimize the contaminant concentrations to acceptable levels, each contaminant having its own acceptable level, through a process of economic optimization, i.e., by minimizing air requirements consistent with the reduction of personal exposure to acceptable limits.

Development of mine environment models would lead to mine layout optimization compatible with improved mining operations. Furthermore, the models should also address the problem of achieving and maintaining reasonably acceptable conditions (temperature and moisture) in order to improve workers comfort while not losing sight of economic constraints.

The Elliot Lake Laboratory is, at present, working on the first stages of radiation/ventilation, purely ventilation, and simple dust/ventilation models. However, there is still a great deal to be accomplished before the establishment of an interactive integrated underground environment/ventilation program, II(U/G)EVP, in conjunction with a reliable data acquisition system/ automated control system (DAS/ACS).

LONG RANGE IMPLICATIONS

Further extension of the mine environment monitoring program outlined above should include mine-wide monitoring (performance and status) of: i) engineering systems such as fans, compressors, heating and refrigeration systems; ii) tool and machinery performance; and iii) power consumption of mining operations under specific working and production conditions. All these could lead to significant improvement in worker safety, lower production costs and, hence, increased productivity.

Some of the benefits provided by mine-wide monitoring systems of the kind discussed above would include:

a) Reduction of production and development losses due to unexpected failure of vital support systems, such as compressed air, electrical power systems, and mine dewatering;

b) Improved maintenance planning and response;

c) Reductions in heating and electrical energy with corresponding reduction in energy costs; improved use of equipment, and hence, improved morale and safety;

d) Improved grade control;

e) Improved equipment utilization and maintenance response to failure;

f) Improved personnel safety and morale, and better coordination of manpower and equipment;

g) More efficient use of manpower as a result of the combined effects of mine monitoring, increased mechanization, and mine-wide voice communication. It should be noted that mine-wide voice communication is recognized by mine operators and mining authorities as one of the most promising and important technologies to improve worker safety, and increase over-all mine productivity;

h) Improved fire control.

In addition to items a) to h), mine-wide monitoring would provide operating and maintenance personnel with up-to-date information on the status of the equipment used in mining operations, and also with operating and maintenance report generation and historical trending.

Methods for the control of underground mine air pollutants is a major research activity of the underground environment group of the Elliot Lake Laboratory (CANMET). A number of dust and radiation control methods and techniques have been investigated or are being evaluated at present. The interested reader should refer to the published literature for more details on the work that has been conducted or is in progress.

Finally, because the accuracy of any measurement greatly depends on the instrumentation used, the technical performance and reliability of instrumentation is of paramount importance. This is particularly important under the harsh environmental conditions prevailing in underground mines under which instrumentation are mostly operated. The Elliot Lake Laboratory has designed facilities to test and calibrate radiation and dust instrumentation. In particular, the radiation calibration facilities will become the National Radon/Thoron Test Facility. This facility will be partly operated to provide calibration of instrumentation used by the uranium mining and milling industry, in their radiation monitoring programs to comply with the Atomic Energy Control Board licencing regulations, and partly for research.

In summary, major thrusts by the underground environment group at the Elliot Lake Laboratory are aimed at controlling mine air pollutants, as well as providing adequate instrumentation, and testing and calibration facilities, in order to minimize health risks to mine workers and to provide knowledge for a better working environment.

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