Radiological Health and Safety in Mining and Milling of Nuclear Materials

PROCEEDINGS SERIES

RADIOLOGICAL HEALTH AND SAFETY IN MINING AND MILLING OF NUCLEAR MATERIALS

PROCEEDINGS OF THE SYMPOSIUM ON
RADIOLOGICAL HEALTH AND SAFETY IN MINING AND MILLING OF
NUCLEAR MATERIALS
HELD BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
IN CO-OPERATION WITH THE
INTERNATIONAL LABOUR ORGANISATION, AND THE
WORLD HEALTH ORGANIZATION
IN VIENNA, 26-31 AUGUST 1963

In two volumes

VOL. I

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1964

RADIOLOGICAL HEALTH AND SAFETY
IN MINING AND MILLING OF NUCLEAR MATERIALS,
IAEA, VIENNA, 1964
STI/PUB/78
Printed by the IAEA in Austria
January 1964

FOREWORD

The mining and milling of nuclear materials present special hazards which should be dealt with on an international level. So far, however, this aspect of nuclear industry has been given relatively little attention in comparison to hazards arising from the use of radioisotopes and the operation of nuclear reactors.

Some of the relevant problems were recognized several decades ago, before man became acquainted with the uses of nuclear energy, and were investigated and studied to a certain extent by the experts of that time. The recommendations resulting from these investigations and studies do not, however, any longer provide solutions to the problems met today.

Safety standards which have been applied in the past need to be reviewed as a result of the extensive development of the nuclear mining industry. During the past ten years many surveys have been made and a great deal of research undertaken; in the light of this additional information, the health and safety problems of this industry must be assessed. Progress in this field can be substantially assisted by giving scientists an opportunity to exchange ideas and information. With this aim in mind the International Atomic Energy Agency, the International Labour Organisation and the World Health Organization sponsored the Symposium on Radiological Health and Safety in the Mining and Milling of Nuclear Materials.

The Symposium was held from 26-31 August 1963 in Vienna and was attended by participants from 24 countries and 5 international organizations. The 70 papers and a record of the discussions are published in these Proceedings. It is hoped that the information thus recorded summarizes the present situation in different parts of the world and will stimulate those efforts necessary for ensuring adequate health and safety conditions for the mining and milling of nuclear materials in the future.

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(Session 1)

INTRODUCTORY REMARKS CONCERNING HEALTH AND SAFETY IN URANIUM MINES*

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Abstract — Résumé — Аннотация — Resumen

INTRODUCTORY REMARKS CONCERNING HEALTH AND SAFETY IN URANIUM MINES. The historical development of the problems concerning health and safety in uranium mines is briefly reported. The efforts of different scientists engaged in the solution of these problems, and contributions of the team from the Federal Republic of Germany (Max Planck-Institute for Biophysics, Frankfurt/Main) are described.

INTRODUCTION AUX PROBLÈMES DE SANTÉ ET DE SÉCURITÉ DANS LES MINES D'URANIUM. L'auteur fait brièvement l'historique des problèmes de santé et de sécurité dans les mines d'uranium et décrit les travaux entrepris par divers spécialistes qui se consacrent à ces problèmes, notamment ceux d'une équipe de chercheurs de la République fédérale d'Allemagne (Institut de biophysique Max Planck, Francfort-sur-le-Main).

ПРЕДВАРИТЕЛЬНЫЕ ЗАМЕЧАНИЯ ОБ ОХРАНЕ ЗДОРОВЬЯ И ТЕХНИКЕ БЕЗОПАСНОСТИ НА УРАНОВЫХ РУДНИКАХ. Дается краткий обзор исторического развития проблем, связанных с охраной здоровья и техникой безопасности на урановых рудниках. Сообщается об исследованиях различных ученых, работающих над решением этих проблем, и вкладе группы ученых из Федеративной Республики Германии.

OBSERVACIONES PRELIMINARES ACERCA DE LA HIGIENE Y SEGURIDAD DE LAS MINAS DE URANIO. El autor expone brevemente los antecedentes de los problemas que plantea la seguridad y la protección de la salud en las minas de uranio. Describe los trabajos de diversos hombres de ciencia dedicados a resolver estos problemas y la contribución aportada en este terreno por el equipo de la República Federal de Alemania (Instituto de Biofísica Max Planck, Francfort del Main).

Due to illness, Professor Rajewsky was prevented at the last minute from attending this Symposium. As a co-worker of Professor Rajewsky, I will try to give a short review of the material he presumably would have reported in fuller detail.

Old scripts and tales about mining in the "Erzgebirge" area, the mountains in Saxony, reported that a large percentage of the miners, after having worked for 15-25 years, fell ill with a respiratory-tract disease called "Schneeberger Bergkrankheit". The symptoms of this pulmonary disease increased with time, and on an average the miners died many years earlier than their colleagues in similar mines of other areas.

As early as 1879 Härting and Hesse published their first paper as a result of their pathologic-histological studies on 20 deceased miners. Far more than 50% of all cases showed malignant changes of the respiratory tract, called by the authors "lymphosarcomata"; later on they were correctly diagnosed by Arnstein (1913) as "primary carcinomata of the lung".

However, warnings were ignored until the 1920's when the problem was dealt with again. Formerly, Härting and Hesse had already enquired from

* In this paper Professor Schraub presents the introductory remarks he made to replace the paper by Dr. Rajewsky who was unable to be present because of illness.

the administrative authority of the mines on the eastern side of the Erzgebirge, which belonged then to Austria, as to whether similar cases were known there. The answer was in the negative. Margarete Uhlig made a similar enquiry in 1921 of the Czechoslovakian mine authorities; the answer was also negative. Nevertheless, Mrs. Uhlig's initiative resulted in scientists (mostly pathologists and roentgenologists) beginning to work from that time on this problem by systematically investigating the case histories of both living and deceased miners as well as studying conditions in the mines themselves. They tried to discover to what extent this disease was occurring, and what were the reasons for it. Arnstein, Uhlig, Löwy, Sikl, Rostoki, Saupe, Pirchan, Woldrich, Tschelnitz, Peller, Behounek and others should be mentioned in connection with this problem.

Because of these investigations and reports, between 1930 and 1940, the time came when official authorities were interested in solving this problem. An appeal of the then Czechoslovakian President, Masaryk, and an action of the so-called "Reichsausschuss für Krebsbekämpfung" in Germany, started intensified investigations in this field.

As the significance of an increasing rate of lung-cancer was no longer deniable two questions had to be answered: (1) What are the actual causes; and (2) what were the possibilities of preventing the occurrence of the disease?

From the German side the medical-clinical work was done by Brandt, Hueck, Buckup and Lange and others, whereas Rajewsky undertook the physical and biophysical part; the author of this report had the opportunity to participate in these investigations from the beginning. In Czechoslovakia very successful work was done in this field by Behounek and his colleagues.

The results of these studies can be found in published papers. Here only a few examples are given.

According to Hueck, over a three-year period (1936-1939) six out of 70 miners died and in five cases lung-cancer was diagnosed. Heiner, the roentgenologist, published the following results from 58 autopsies of Jachymov miners, who died within a 10-yr period;

Carcinomata of the respiratory tract	27 cases
Severe silicosis	13 cases
Lung-tuberculosis	12 cases
Other diseases and causes	6 cases

The causes of miners' deaths in earlier times were mostly unknown since permission to carry out an autopsy was generally refused by the miners' relatives. A roentgenological diagnosis of lung changes is not possible except in the late stages of the disease, only a few months before death.

Of the different possible causes for the origin of the disease, which had been discussed in earlier times, only a few were now considered further: radon and radioactive dust content of the air in the mines. Therefore, many special measurements were carried out to investigate the conditions in the different mines. According to these studies the radon concentrations in the Schneeberg area and, in agreement with the results found by Behounek, in the mines of Jachymov, amounted to values between approximately 5×10^{-11} and 5×10^{-9} c/l. But, it must be considered that these values were measured

at the end of the 1930's, at a time when a considerable effort had been made to reduce the concentrations by artificial ventilation. Furthermore, the radon content of mine-water was measured because this is also responsible for radon contamination of the air in the mines. Based on these results Behounek, on behalf of the Czechoslovakian, and Rajewsky, on behalf of the German mines, recommended that mines be provided with ventilation doors and additional ventilators in order to reduce the radon concentration.

According to the measuring equipment of that time no increased dust activity, which was collected from the air in the mines by cotton filters, was proved; also, the dust concentration was rather lower than that in comparable ore mines of other areas. These were the reasons why the prevailing significance of radon in the air of the mines as a cause of the Schneeberg lung-cancer was again considered, a suggestion that Tschelnitz had already made in earlier times.

Concerning this two remarks should be made:

(1) What is the reason that diseases of this kind did not also appear in other uranium and radium mines? The fact should be pointed out that, with surface mining, other conditions prevail, and also that, in other uranium mines all over the world, the turnover of personnel is much greater than in the mines of the Erzgebirge. The last point is due to the fact that, in this area where the soil is not very fertile, the male population was forced to make a living as miners. Therefore, in general a miner never changed his profession.

(2) If the radon were so important, it should be possible to create malignant changes in the lungs of animals which lived continuously in a radon atmosphere.

Rajewsky, together with his co-workers, proceeded to explore this hypothesis. Suitable inhalation chambers were built which, by a closed circulation method, allowed control of radon concentration, temperature and humidity and permitted the removal of the CO_2 produced and replacement of the oxygen consumed. At the highest applied radon concentrations (around 0.1 c/l) animals died from internal and external radiation damage after approximately one day, while the lowest applied radon concentrations (around 10^{-6} c/l) did not considerably influence the lifetime of the animals: A detailed description of the investigations, which included measurements of body-weight, blood-count, and pathologic-histological diagnosis, cannot be given here, but reference is made to our published papers*. Here we only note that frequent appearance of malignant changes in the lungs was especially noticed with those series of animals which lived a very long time. Unfortunately, due to war-time conditions, these investigations had to be suspended. Therefore, the results cannot be considered significant because the number of test animals was not sufficient. It is just as regrettable that, in the subsequent twenty years, similar tests have not been carried out by anyone else with the exceptions of Kushneva and Morken.

A few years later it transpired that such experiments should be carried out under somewhat changed conditions. Distribution studies, after injecting a radon solution in water into the stomach of a mouse (1952 Aurand/Schraub), revealed that the incorporated daughter products were very important with

* See Bibliography at the end of this paper.

regard to the radiation burden of the organism. The effect of inhaling air containing radon must be also influenced by this fact, to an even greater degree. A study of the published papers revealed, that a year previously William F. Bale and Rochester (New York, 1951) had expressed this idea in a memorandum. Therefore, W. F. Bale was the first to discover that, in a radon-containing atmosphere, the daughter products in the air are also inhaled and a considerable percentage is retained. This process is repeated in every breath and it is easy to show that, by this somewhat complicated interaction of different mechanisms such as inhalation, retention, transport and decay, the respiratory tract obtains - besides the radiation burden following the uptake of gaseous radon - a further, perhaps considerably greater burden by accumulated daughter products.

Stimulated by these new aspects there followed in the next years a number of very informative publications about investigations which aimed at a quantitative evaluation of the above-mentioned mechanism and an appraisal of the actual doses. Here there is not space to go into details and it is certain that some of the reports and discussions will deal with this question. Above all, research teams in the United States of America have made valuable contributions to the study of this problem: e.g., Bale, Shapiro, Harley, Tsivoglou, Ayer, Holaday, Cohn, Skow, Gong, Chamberlain, Dyson and Morken; and also some from other countries. Also the research team in Frankfurt (Rajewsky, Aurand, Jacobi and Schraub) has carried out several investigations about the behaviour of inhaled decay-products; this is mentioned here because, in general, these studies seem to be little known. Above all, I want to point to a series of animal tests (Schraub and Belloch-Zimmermann) which demonstrate, as far as I know for the first time, the different biological effects of inhaled air with daughter products and of that without daughters, tested by the lifetime after 6 to 8 h of inhalation.

If it has only been possible to give a rough description of the historical development of the problems under discussion, and this is due primarily to the extemporaneous character of this report, but another reason is the fact that a just appreciation of all efforts to solve these problems would take a great deal more time. Therefore I make my apologes to all the authors who were not mentioned in this report.

A considerable part of this Symposium is dedicated to methods of sampling, measurement and prevention. Without anticipating the final results of this Symposium we must already confess that these physical and technical aspects are far more developed than our biophysical and medical knowledge. Today we are able, by measurement, to determine whether or not the protection rules are kept with regard to the MPC; furthermore, it is possible - albeit in some cases with considerable technical efforts - to maintain the rules; but, up to now, we do not know if these rules are more rigorous than necessary, or if the MPC values will have to be reduced. As to this question we need more experience with miners themselves as well as further experimental studies. From the standpoint of our present knowledge it seems that we are on the safe side.

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ENVIRONMENTAL STUDIES IN THE URANIUM MINES

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Abstract — Résumé — Аннотация — Resumen

ENVIRONMENTAL STUDIES IN THE URANIUM MINES. A long-range study underway by the Public Health Service since 1950 seeks to define the effect of uranium-mining operations on the health of the miners and to derive data leading to the establishment of a healthful working environment. The environmental study is designed: (1) To measure the atmospheric concentration of radon and daughters; and (2) to obtain exposure data on the miners included in the medical study.

Uranium mines in the United States of America vary widely in size, ranging from two-man operations to those employing several hundred men. Environmental radiation measurements have been collected from over 800 mines and these are used to evaluate the exposure of the miners and to assist in control procedures. Since 1950, there has been a marked decrease in the radon-daughter concentrations, however, in many cases, the exposures are at present above the recommended levels. Continued efforts are being made to reduce the exposure of the miners to radiation. These efforts involve close co-operation with the State Health and Mining Departments, training courses for official agency and mining personnel, and continued surveillance and inspection. This paper traces the radon-daughter concentrations in the uranium mines for the past 12 yr and discusses those techniques which have been effective in reducing the concentrations.

At the start of the study, no standards were available which could be applied to uranium mines. Through conferences with all co-operating agencies, a working level of 1.3×10^5 MeV of potential alpha energy/l of air of radon-daughter products was suggested as a standard.

Uranium mines do not come under the jurisdiction of the Atomic Energy Commission but are subject to inspection or regulation by several other agencies. The States in which the mines are located have primary responsibility for establishing health and safety rules. A chaotic situation has been avoided by an agreement of all State agencies to use the American Standards Association Standard for Uranium Mines and Mills as a guide for their inspection and regulatory activities. This standard sets forth detailed recommendations on the management of radiation exposures in mines and, specifically, the methods of air sampling and analysis. Thus, results obtained by different groups are comparable and mine operators are not confronted with widely different standards in the various uranium-mining areas.

ÉTUDES SUR LE MILIEU AMBIANT DANS LES MINES D'URANIUM. Le Service de la santé publique se livre depuis 1950 à une étude de grande envergure destinée à déterminer les répercussions des travaux d'extraction de l'uranium sur la santé des mineurs et à obtenir des données permettant ensuite d'établir des conditions de travail saines. L'étude a pour object: a) de mesurer la concentration du radon et de ses produits de filiation dans l'atmosphère, b) de réunir des renseignements sur les doses d'exposition reçues par les mineurs examinés dans le cadre de l'enquête médicale.

L'importance des mines d'uranium aux Etats-Unis varie grandement: elle va de celles qui occupent deux hommes à celles qui emploient un effectif de plusieurs centaines de personnes. On a rassemblé les mesures de la radioactivité du milieu ambiant faites dans plus de 800 mines et on s'en est servi pour évaluer la dose d'exposition des mineurs et pour mettre au point des méthodes de lutte contre la contamination de l'air. Bien que l'on ait constaté depuis 1950 une nette réduction de la concentration des produits de filiation du radon, les doses d'exposition sont encore, dans de nombreux cas, supérieures aux niveaux recommandés. On s'efforce sans relâche de réduire l'exposition des mineurs aux rayonnements. On s'attache notamment à entretenir une coopération étroite avec les ministères de la santé publique et des mines, à organiser des cours de formation et à assurer une surveillance et un contrôle ininterrompus. Les auteurs donnent un aperçu des concentrations de produits de filiation du radon relevées dans les mines d'uranium pendant les 12 dernières années et ils examinent les procédés qui ont permis d'abaisser les taux de concentration.

Lorsque l'étude a été entreprise, on ne disposait encore d'aucune norme qui soit applicable aux mines