

HEALTH IN URANIUM MINING

Safety in mining radioactive ores, and in milling and treating them, has been a serious preoccupation for some thirty years. Much earlier than this, however, a high incidence of lung cancer had been reported among the miners of the Erzgebirge mountains in the German-Czechoslovak border region (places familiar under the names of Schneeberg and St. Joachimsthal). Investigations into deaths from radium poisoning began at these mines in 1937, and the results seemed to indicate a causal connection between the radioactive substances and the development of lung cancer and other diseases.

When uranium was first being sought with great urgency in a number of countries, new mines were opened without adequate health precautions. This neglect was caused partly by inherent difficulties. In regions like the Colorado Plateau in the United States, and parts of South Africa, water for dust control and power for ventilation were not readily available. Many of these operations were quite small, and if water had to be carted for long distances, or special equipment was required for ventilation, these things were simply left undone.

Partly, however, the lack of proper precautions - as we know them today - was due to lack of information. Little was known about the toxic substances likely to be encountered, their probable occurrence and concentration, and the scale of effort needed to control them. Nor were the physiological effects understood, nor the mechanisms by which radioactive substances attack the body.

About 1950, closer investigations of conditions in uranium mines and plants were begun in several countries. The initial result was to disclose a serious state of affairs in many places; exposures to radiation were often far too high. The combination of radon gas with excessive dust in a number of mines created particularly bad conditions. The first and most obvious remedy was to provide better ventilation, and stricter dust control, mainly by the use of water. Immediate improvement followed; but this stage was only in the nature of "first aid".

Good mining and plant practices still remain the essential basis of all health and safety precautions - ventilation, dust prevention, and personal hygiene. But it is necessary to know more than this; for example, one question to be answered by mine management is how much ventilation? The answer depends upon ability to measure accurately not merely the radioactivity present, but the concentration of those radioactive substances known to be particularly harmful. This in turn depends on knowledge of the biological effects

of the different substances, and of the forms which are most likely to enter the system. Having established a system of monitoring and control, further questions arise regarding the necessity for frequent medical checks of the personnel and the records to be kept; also wider questions such as prevention of contamination of the environment and systems of public regulation.

These matters were discussed in Vienna at the symposium on Radiological Health and Safety in Nuclear Materials Mining and Milling, 26-31 August 1963. The symposium was organized by IAEA and co-sponsored by ILO and WHO; some 70 papers were presented. The purpose of the meeting was to collect and compare the very widely scattered research results and practical experience in this field. One conclusion which emerged was that the milling of uranium ore involves no unusual problem. Provided standard controls - as applied to the treatment of other minerals - are strictly enforced, exposure to radiation can be kept to a minimum. In the actual mining of uranium, the problems are only beginning to be clearly defined, but it seems to be well established that exposure of miners to excessive levels of radon will have most serious consequences. In a complicated pattern there are many factors at work, ranging from the physical behaviour of sundry radioactive substances to the personal histories of individual miners. The need for considerably more research was stressed throughout the discussions.

Radiation or Cigarettes?

The principal radiation hazard encountered in mining uranium and thorium arises from the radioactive gases radon and thoron, and the further dangerous products to which they give rise. In uranium mines the gas radon is a decay product of radium; radon itself decays rapidly to a series of daughter products, which are solids. Describing this process, C. F. Smith (Canada) said that radon is released when ores containing radium are opened up, and by seepage of ground water containing the dissolved gas into the mine. Concentrations vary and are difficult to forecast. Airborne radiation levels do not conform to the grade of ore; some of the highest levels are found in waste headings. Small flows of radon-laden ground water can lead to very high concentrations when least expected, and the concentration varies rapidly with ventilation.

Primarily to determine whether this radioactivity involved an increased risk of lung cancer in uranium mines, the United States authorities in 1950 initiated a programme to evaluate the health problems by means of a long-term study. By the end of 1959, this had



Polythene duct for ventilation of development headings
(from paper by C.F. Smith)

furnished sufficient information to indicate that American uranium miners did run an enhanced risk of death from lung cancer.

The health study was conducted in two parallel phases, dealing respectively with environment and medical aspects. Dealing with the first, D. A. Holaday and H. N. Doyle (USA) described conditions in the United States, where most of the uranium mining is carried on in the Colorado Plateau. At the height of the boom, about 350 mines were working, most of them small and employing less than ten men. Roads were inadequate and most of the mines were in desert areas where water had to be carried; nor was electric power generally available, so that controls as used in other metal mines were not always applied. None of the mines had mechanical ventilation, and even in the small shallow mines natural ventilation could not reduce the radon concentration to acceptable levels. These concentrations caused some alarm, and steps were taken to have mechanical ventilation installed in all mines, which were effective. In 1952, it was found that about 45 per cent of the men were exposed to concentrations of radioactive substances more than ten times the present recommended level. Intensive efforts in inspection and control have brought about great improvement, but in many mines the concentrations are still too high.

On the medical side of the investigation, V. E. Archer, B. E. Carroll, H. P. Brinton and G. Saccomanno (USA) gave an analysis of the health of the miners in the field, based on examinations, tests and medical histories. The analysis - still

incomplete - is complicated by factors such as exposure to dust, cigarette smoking, altitude, race and age. Since these might affect the examination results, information was gathered on them also. Transient effects of radiation might be associated with the radiation level encountered by the miner; cumulative effects from chronic exposure to low-level radiation would more probably be related to the number of years spent in underground mining. Since it was apparent that cigarette smoking showed associations with some of the same symptoms as radiation, it was necessary similarly to take smoking into account. The number of cigarettes smoked per day was tested for association with transient effects, and the total number of cigarettes consumed over the years by the individual was tested for association with symptoms which might result from chronic low-level exposure. Thus shortness of breath was found to be associated with the radiation level, with age, and with the total of cigarettes smoked. Persistent cough was associated with the radiation level, the number of years spent in underground mining of uranium, age, and current cigarette smoking intensity. After considering the complications offered by these other factors, the authors found underground mining to be associated with "ambiguous and suspicious" cells in sputum, shortness of breath, persistent cough, lung disease, and possibly with wheezing and chest pain. There is evidence to connect these with the effects of radiation, but further studies are needed.

Assessing the Hazard

Knowledge of the concentration of radioactive material is not enough by itself for evaluation of hazards. V. S. Kusneva (USSR) reported on a study of combined effects of quartzitic dust and radon, to show how radiation affected the course of pneumoconiosis (a lung disease of miners). Experiments on white rats show that the most serious clinical symptoms are found in animals exposed simultaneously to siliceous dust and radon. The presence of dust in the lungs increases the danger of radioactive substances remaining in the body. Similar tests were described by L. Lafuma and M. Medjedovic (Yugoslavia), who concluded that dust and radon give greater contamination through inhalation of a larger quantity of short-lived radioactive deposit emitting alpha radiation, which is particularly damaging under these conditions. Although most radon daughter products have short half-lives, they are a considerable source of contamination in the mine, where workers have to breathe a contaminated atmosphere for periods of eight hours. The authors therefore concluded that it is not enough, in evaluating radiation hazard, to measure only exposure to radon and long-lived dusts; the dose from the short-lived active deposits must also be measured. W. J. Bair, B. O. Stuart, J. F. Park and W. J. Clarke (USA) pointed to another factor which must be taken into account, in the physical and chemical properties of inhaled particles, which influence the

subsequent behaviour of the material in the body after it is deposited. Small particles move much faster through the system.

Accurate measurement of the decay products of radon were considered by H. L. Kusnetz (USA) to be necessary in determining workers' exposures. Control methods depend on ability to measure ambient concentrations of radon, thoron and their daughters. Field measurements are not easy, because of the state in which the contaminants may exist in the atmosphere, because of the brief half-lives of some of the decay products, instrument contamination, and lack of knowledge of the exact mechanism of physiological damage. The contaminants may exist as parent gas, unattached daughter atoms, or dust particles carrying daughter products.

While recognizing that the daughter products are the main hazard, J. R. Stewart (Australia) pointed out that radon concentration in the air is the only quantity which can be measured without having to provide special equipment and trained persons at the mine. Radon concentrations have been determined in Australia at central laboratories from samples collected in metal cylinders under pressure and transported up to 2 000 miles.

A paper by F. Billard and J. Miribel (France) compared two control methods, based respectively on measurement of radon concentration, and of the activity of daughter products collected on a filter. They concluded that a true reflection of the hazard is given by the US method, based on the energy liberated by this material as it goes through successive disintegrations. Further measurements are desirable, and if the results are thereby confirmed the authors assume that the US method (which does not take into account the different behaviour of different particles) is quite acceptable. They considered that the measurement of radon used in France tends to over-estimate the hazard, but a correction factor can be applied for each section of the mine and the method can then still be used - it is easier and allows of a greater number of measurements.

Protective Measures

Dealing with the technique of protection in mines, M. Avril and J. Pradel (France) based procedures on four general procedures:

- Hermetic sealing of unused galleries
- Elimination of infiltrating water
- Powerful ventilation
- Normal dust-prevention techniques

These may need to be reinforced by individual protection. In France, trials were made of dust masks, gas masks (military), hoods with separate air-supply, and bottled oxygen or air systems. These have been abandoned as too cumbersome, except where the task is of short duration and involves no great physical effort.



Grinding uranium ore in a rod-mill, Yugoslavia
(from paper by M. Kacarevic)

Similar principles apply to ore processing and calcination plants. J. L. Saconney (France) described a plant delivering uranium concentrate containing 60-65 per cent metal. The crushing, milling and chemical sections of the plant involve a minor problem because of the release of small quantities of radon; the production and packing of the dried concentrate, on the other hand, calls for strict safety measures against active dust. S. R. Rabson (Republic of South Africa) described the same problem at a central plant where slurries of uranium concentrate are dried and calcined at a central plant and converted to the final oxide form, the material emerging as a dry powder. Some parts of the process were enclosed, or carried on under suction hoods. In some places a completely closed system was established, and maintained under suction. In addition, strict cleanliness was enforced in respect of floors etc. and clothing, and a marked improvement resulted. A uranium-steel plant, producing billets containing up to 0.5 per cent uranium, described by G. C. Eichholz (Canada) was found to have no hazardous concentration of uranium during casting and rolling under good ventilation. Surface treatment, required strong local ventilation and face masks.

Respirators are an adjunct to engineering control methods; the primary consideration should always be to prevent the air from becoming contaminated. But E. C. Hyatt (USA) pointed to situations where respirators are needed. These include:

- A new operation, until such time as adequate ventilation has been established
- Routine operation of crushers or ore transfer points, especially if the moisture content of the ore is reduced in dry weather

- Weighing and changing of barrels in the final product department
- Maintenance or mechanical failure of the ventilation system
- Handling of processing chemicals

He stressed that the selection of a respirator requires thorough knowledge, and that success of a respirator programme depends on selection, fitting and instruction, supervision, a centralized cleaning station, inspection and maintenance, storage, and medical checks.



Half-mask dust respirators provide satisfactory protection against uranium mill dust (from paper by E.C. Hyatt)

Dealing with the wider question of contamination of the environment, E. C. Tsivoglou and C. E. Sponagle (USA) described how, in the late 1940's, it was realized that the most dangerous radioisotope in uranium mill wastes was radium-226, and in 1950 river sampling began. Since then, there have been many detailed studies, which have taught much about the monitoring and surveillance of various environmental media. Methods used include monitoring of water, of sediments, of aquatic biota (algae, insects, fish), and of other media such as mill effluents, soil and crops.

Safety Standards Could Be Too Strict

In considering the necessity for routine medical checks, J. Chameaud (France) argued that, gas and dust protection being today highly efficient, there is no need to prescribe the regular conduct of tests the results of which are mostly negative. The system of protection, however - and especially the ventilation - encourages infection of the upper respiratory system and rheumatism, so that periodic examination is essential. G. C. Freed (Republic of South Africa) referred to a ten-year record of men employed in uranium reduction plants and a calcining plant. The results revealed were satisfactory, but he urged the importance of maintaining medical records of workmen occupationally exposed, because so little is known about the long-range effects of low-level radiation in employment situations.

Discussing regulations and the enforcement of standards, M. Dousset (France) considered that regulations should be based on general principles recommended by the International Committee for Radiological Protection. They should provide for the determination, in respect of each organ, of the permissible quarterly and yearly radiation dose-levels. The regulations should provide for a safety organization, to be responsible for such matters as ventilation and safety practices. They should provide for area and personnel monitoring and for the medical selection and supervision of personnel. G. Walinder (Sweden), in speaking of maximum permissible concentrations of radon and thoron, stressed that standards should be laid down with due regard to all the factors involved. The use of atomic energy implies not only the introduction of risks, but also an alternative with positive hygienic value. The use of fossil fuels involves pollution of water supplies and of the air we breathe, which leads to respiratory-tract diseases in highly industrialized areas. It would be most unfortunate, he urged, if unduly low tolerance-levels were to interfere seriously with the utilization of atomic energy. In setting maximum permissible concentration norms, purely physical or biologically one-sided estimates are not enough. He compared the establishment of an MPC value to walking on a tight-rope.