# RADIATION DOSE CONTROL IN THE MINING OF HIGH GRADE URANIUM ORES

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## Introduction

The control of radiation doses received by uranium miners is an unusually complex procedure, as three separate components of their total effective dose may be significant and may have to be evaluated separately. Apart from external and internal doses evaluated in the usual way, it is also necessary to evaluate the inhalation dose from radon progeny separately. Although this essentially forms part of the internal dose received, it is not evaluated in the conventional way since the associated dose equivalent must be derived from conversion factors based on epidemiological studies, instead of by the usual approach of calculating the dose to tissue from the inhaled activity and multiplying this by a recognised conversion factor to derive a whole body effective dose. Historically the traditional unit used for monitoring the concentration of radon progeny in a workplace is the Working Level (WL), this is now defined as a concentration such that the potential alpha emission from all the short lived progeny present in the sample will total 1.3 x $10^8$ MeV per $m^3$. The corresponding unit of exposure is the Working Level Month (WLM) and is the exposure that would be received by a reference man working in such an atmosphere for a standard working month lasting 170 hours. Unfortunately the relationship between exposures, measured in WLM, and the conventional radiation dose to the target tissues is complex and calculated values depend greatly upon the assumptions made in the lung model that must be used. Risks are therefore still controlled by limiting exposures in WLM on the basis of epidemiological studies of lung cancer incidence among miners employed at a time when the magnitude of the risk was not fully appreciated, and cancer incidence was high enough to permit reasonably accurate risk estimates to be derived directly from exposures in WLM.

## The Mining of High Grade Ores

Where the grade of the ores being mined is relatively low, the risk to underground workers is dominated by the inhalation of radon progeny; and frequently in the past the contributions to the worker's total radiation dose from gamma radiation, or the inhalation of ore dust containing uranium and its long lived decay products, was neglected in comparison. This is no longer acceptable, both because the majority of ores currently being mined are of far higher grade than was usual in the past, and because radiation dose limits for occupationally exposed workers have been reduced significantly. In other industries the introduction of lower dose limits has generally not led to serious difficulties, revised working procedures, coupled with better shielding, have ensured that the new standards can still be achieved. This can be much more difficult in the case of the mining of high grade uranium ores. Conventional mining techniques can result in the worker being surrounded by ore, this leads to an omnidirectional gamma flux from which it may be very difficult or impossible to shield the worker effectively. Radon concentrations are traditionally reduced to levels that are acceptable by ventilating the workings with fresh air brought in from outside. If the radon emission rate is too high this may require such massive ventilation systems that all operations have to be carried out in near gale force winds. Such high ventilation rates lead to very exhausting working conditions and will, in turn, also increase the resuspension of dust in the workings. When the grade of the ore is very high, this can also lead to a large potential dose to the miners from long lived radioactive dust inhalation. Ultimately, in the case of very rich ore deposits these problems become so severe that conventional mining methods cannot be attempted . Consequently in Saskatchewan, where several such very high grade deposits are currently under development, the approach has been for the development of new technologies in which the miners are excluded from the workface and operate from higher or lower stopes lying outside the main ore body, with all ore being extracted by means of remote boring operations.

Such automated mining methods need to be planned in detail right from the moment when the development of a new mine is first considered, they cannot usually be economically introduced into an existing mine. In such mines, meeting the more stringent standards required to comply with ICRP 60 recommendations may have to be accomplished without the introduction of fully automated mining methods. The provincial Occupational Health and Safety Branch has therefore been investigating the magnitude of the problems likely to be encountered, and the changes in working procedures which may be possible and may help in alleviating these problems. Since each mine is fundamentally different there is not a large body of existing data that can be accessed, and it was found to be necessary to conduct a series of studies in some of the existing mines which were designed to determine the relative importance of the three different components of the miner's dose for groups of workers in different categories.

## Contributions to the Miner's Effective Dose

The whole body dose limits for occupationally exposed workers recommended in ICRP 60 are 50 mSv effective dose in any one year with an average of not more than 20 mSv per year over any five year period. In the case of uranium miners, compliance with these recommendations requires that for both the one and the five year period the external gamma ray dose received by the worker, expressed as a fraction of the one or five year limit, added to the inhalation dose from long lived radioactive dust, expressed as a fraction of the ALI (or five times the ALI as appropriate), and to the separate inhalation doses from radon and thoron progeny expressed as fractions of the corresponding one or five year limits, does not exceed unity. Clearly maintaining records designed to provide both one and five year summation doses on an ongoing basis for every miner places complex requirements on the mine operator. Monitoring, recording and reporting all these components of the miners total dose also involves a number of very complex considerations, including the relative importance to be attached to personal and workplace monitoring. The recommended procedures for meeting these requirements are still being extensively studied and no final decisions have yet been made as to the procedures the mine operator will be expected to adopt, although it is recognised that the relative importance of the various contributions to the total radiation dose experienced will differ considerably between one mine and another. This will prevent agreed universal dosimetric protocols being developed and means that the procedures adopted by each mine will have to be agreed between the appropriate regulatory agency and the mine operator at an early stage. To enable realistic requirements to be formulated it will be necessary for all parties be very clear as to the relative importance of each contribution to the workers dose in each individual mine.

The only type of personal dosemeter which is currently available and which has the capability of being used to determine all these contributions to the workers total dose is the CEA track etch monitor which has been further developed in Canada and is supplied here through the Canadian Institute for Radiation Safety. Essentially this monitor employs an active filtration technique, it is worn on the workers belt and samples the ambient air in which he works. Alpha particles from the radon progeny collected on the filter paper pass through a mechanical spectrometer and impact on a conventional plastic foil where their tracks are displayed following etching. The alpha tracks in each energy group enable the radon and thoron progeny present to be individually identified. Subsequently the residual activity on the filter paper can be used to evaluate the long lived alpha emitting dust that was collected. If the external gamma dose is not being monitored by other methods, this can also be determined by incorporating a TLD chip into the dosemeter system. Personal dosemeters of this type have been in routine use in some Saskatchewan uranium mines for the evaluation of radon progeny dose for more than a decade, but until recently no attempt has been made to use them to determine the internal dose received from the inhalation of long lived radioactive dust. In 1991 the Saskatchewan Occupational Health and Safety Branch, in conjunction with the Canadian Institute for Radiation Safety, initiated a research project designed to determine what proportion of the dose received by workers in different categories was associated with each of the contributing factors that have been discussed above, and also what problems might be expected in attempting to meet the more stringent dose limits of ICRP 60 in some of the operating mines in Saskatchewan. Some of the results of this study can be seen on the two figures below which show the distribution of effective doses among different categories in the workforce both as they are under the present dose limits and as they would be under the new dose limits recommended in ICRP 60.

## Conclusions from this study

It is important to recognise that evaluating the risk from the inhalation of uranium dust involves consideration of chemical toxicity as well as radiological dose, and that both of these quantities will be strongly influenced by the solubility of the uranium in the dust. In this respect the dust inhalation risk for millworkers, which arises primarily from processed yellowcake, will be quite different to that for underground miners. Neither can be directly calculated in terms of the listed ALI without consideration of the solubility of the dust compared with the solubility of the compounds for which the ALI was determined. These considerations may warrant a re-examination of the absolute value of the dust component of the workers dose used in preparing the following figures, but nevertheless the data presented here is not generally available from other sources and provides a great deal of useful information about what are likely to be the principle problem areas when ICRP 60 limits are first implemented in existing Saskatchewan uranium mines. The most important conclusions to be drawn from this study are that mill workers already receive doses well below the intended new dose limits, and that this also applies to several other categories of the total workforce. It is only in the case of underground miners extracting high grade ore by largely traditional methods that there appears to be any significant likelihood of individual annual effective doses exceeding 20 mSv. With high grade ores, sufficient mill stock for an extended period of milling can be extracted in a relatively short time and these underground mines are therefore generally operated on a seasonal basis. This has led to a situation where the existing practice in Saskatchewan is for such mining to be carried out under contract and not by permanent members of the mine workforce. With careful monitoring, it would then be easy for the contractor responsible for the mining operation to divert members of the workforce who were approaching their acceptable dose limit into a non-uranium mine where no significant radiation dose was encountered. This makes it unlikely that there would be any intrinsic difficulty in implementing ICRP 60 in such mines. Whether it would be regarded by the regulatory agencies as acceptable to continue mining in working conditions where the permissible annual dose limit might well be approached after significantly less than a full years work, is a different issue. Ultimately ALARA and optimisation are best satisfied by operating mines under conditions where there is a maximum of product per unit of collective dose received by the workforce. With high grade ores, large volumes of yellowcake can be produced by a relatively small workforce; and, even though individual doses may be higher, this requirement is therefore much more likely to be satisfied than when mining lower grade ores.

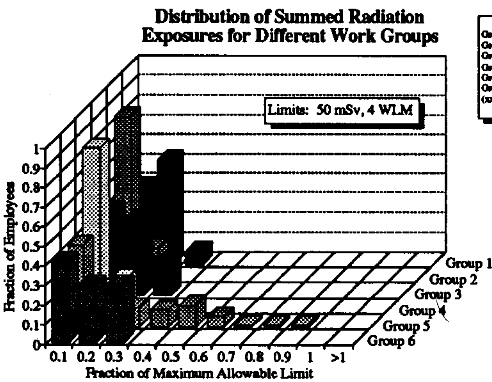


Figure 1

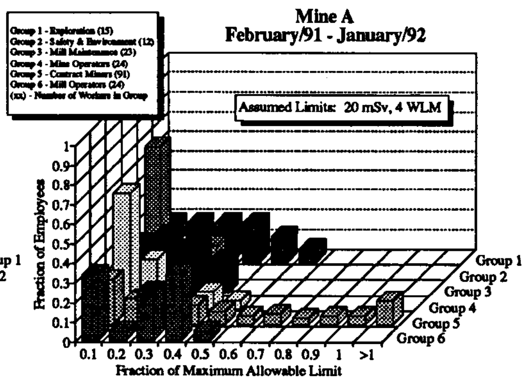


Figure 2

## References


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