Publication

# COMPARING PERSONAL ALPHA DOSIMETRY WITH THE CONVENTIONAL AREA MONITORING-TIME WEIGHTING METHODS OF EXPOSURE ESTIMATION: A CANADIAN ASSESSMENT

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by

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Paper

**RÉSUMÉ**

Un programme expérimental de dosimétrie alpha personnelle pour contrôler les expositions des travailleurs des mines d'uranium du Canada a été mené. Toutes les installations minières licenciées qui étaient en exploitation y participaient.

Les discussions portent sur les techniques de dosimétrie, la description des dosimètres qu'utilisent les titulaires de permis, le rendement et les problèmes liés à la mise en application du programme, ainsi que les avantages et problèmes techniques et administratifs.

On évalue et compare les méthodes de pondération du temps-contrôle de l'aire utilisées et les résultats obtenus pour déterminer les expositions personnelles aux produits de filiation du radon et du thoron et les résultats des expositions qui découlent de l'utilisation des dosimètres.

# COMPARING PERSONAL ALPHA DOSIMETRY WITH THE CONVENTIONAL AREA MONITORING-TIME WEIGHTING METHODS OF EXPOSURE ESTIMATION:

## A CANADIAN ASSESSMENT


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## ABSTRACT

An experimental personal alpha dosimetry program for monitoring exposures of uranium mining facility workers in Canada has been completed. All licensed operating mining facilities were participating.

Dosimetry techniques, description of dosimeters used by licensees, performance and problems associated with the implementation of the programme as well as technical and administrative advantages and difficulties experienced are discussed.

Area monitoring-time weighting methods used and results obtained to determine individual radon and thoron daughter exposure and exposure results generated by using dosimeters are assessed and compared.


## INTRODUCTION

Those radionuclides which are only alpha particle emitters are potentially harmful with possible biological effects when they are taken into the body by inhalation, ingestion or by absorption at the site of an open wound. Continuous activities in uranium mining and milling have resulted in the exposure of large numbers of workers to radioactive substances.

The current Atomic Energy Control regulations governing personal radiation exposure to radon daughters are very explicit for maximum permissible exposures; however, the uranium operator is free to select the method of measuring in order to comply with these limits.

Since 1976, the Atomic Energy Control Board (AECB) has been pursuing the development of a reliable personal dosimeter for monitoring exposures of uranium mine workers to radon and thoron daughters. The testing of personal dosimeters has been on-going in Canada for the past several years, and the AECB has sponsored research projects to evaluate various types (1). With full co-operation from mining companies in Elliot Lake, Ontario, various devices were extensively tested. Most of them could not tolerate the harsh mining environment, particularly underground, and were plagued by frequent mechanical failures. One of them, however, developed by the French Atomic Energy Commission (CEA) was extensively modified based on the experience from Elliot Lake testing and is now used in both French and Canadian uranium mines.

The initial conclusions, based on the laboratory and mine tests, were as follows:

(1) Under the controlled conditions the dosimeter results were in good agreement with the Kusnetz area monitoring average taken as far as practicable at the same place.

(2) The mean flow rate over one working shift could be estimated fairly well. (Arithmetic average of the daily mean flow was calculated).

(3) The need for further improvements in the mechanical design of the dosimeter pumps to provide greater flow stability, durability, and more convenient maintenance, was recognized.

(4) The dosimeter to be used in Canada should be modified to monitor working levels of daughters of both radon and thoron.

(5) With further modifications the personal dosimeter can be used to determine concentrations of long lived alpha emitting radionuclides in mine and mill atmospheres.

During the testing period, close contact was maintained with CEA, the manufacturer, and, as a result, a new model of the dosimeter was produced such that the working levels contributed by both radon and thoron daughters could be measured simultaneously (2). As mentioned earlier, modifications such as a light weight turbine made of plastic, a sintered metal screen support with a smooth annular surround, a protective separator over the detector, and a more convenient seating-mating arrangement for the motor were incorporated.

In 1981, the Board, decided that it was necessary to implement a limited scale personal radon and thoron daughter dosimetry program on an experimental basis, based on the state-of-the-art. It was recognized that further modifications to the dosimetry would be likely. In 1982, the program was implemented in all uranium mines in Canada for a period of three years.

A representative number of workers from each uranium mining facility were designated to wear a personal alpha dosimeter during this trial period. The method of individual exposure calculations for these workers, however, is continued in the traditional manner and reported quarterly to the National Dose Registry. The two sets of data were evaluated from time-to-time and since the end of the trial period in 1985 evaluations and assessments were carried out.

It should be noted that the implementation of the experimental alpha dosimetry program has not affected the continued Board-sponsored research program to further improve the existing personal dosimeters and to develop a semi-passive or passive personal dosimeter.

## PROGRAM OBJECTIVE

The main objective of the AECB in introducing the experimental program was to obtain the best possible radon and thoron daughter exposure estimates for Canadian uranium mine workers. This may be possible by assessing and comparing the correlation between the present method used to determine existing exposure data and values which will be generated by using dosimeters. The personal alpha dosimetry program was to provide technically sound data.

Secondary objectives were:

(1) to further determine technical or logistical problems if a full dosimetry program is to be developed;

(2) to determine any site specific problems in the development of a personal dosimetry program;

(3) to have licensees develop sampling strategies which would best serve the exposure program for their workers.

## THE PROGRAM & METHODOLOGY

The facilities chose the type of dosimeter to be used, but this choice was subject to Board approval.

Each company was requested to submit a program proposal which would at least address the four objectives outlined above.

The following three systems:

A) grab sampling technique,

B) full shift area sampling, and

C) personal dosimetry

used for calculating radon and thoron daughter exposures, were fully discussed with the licensees and worker representatives prior to implementation of the program: a partial list of criteria which could be used for the classification of employees, was discussed. Each stage of the program was to be designed in order that statistical techniques could be applied to the data:

System A - Grab Sampling Technique:

Application:

- This system was and still is continued for the evaluation of exposure estimates; the status quo at most facilities had been described in supporting documents in licence applications.
- A sample is taken at each work area as required, according to a Code of Practice which is part of the licence.
- AECB Regulatory Document R-4 provides "Guidelines for the Measurement of Airborne Radon Daughters in Mines" outlining the procedure which is used for the calculation of radon daughter concentrations.

The concept of expressing atmospheric concentrations of radon daughters in terms of latent alpha energy content was proposed by KUSNETZ. The KUSNETZ method, developed in 1956, is now generally accepted in its modified form as the "standard reference method", described in the guideline.

The atmospheric concentrations of radon daughters are measured by drawing a known volume of air through a filter media for a specified sampling period. The alpha particles are collected on the filter and activity counted between 40 and 90 minutes after sampling. From this data, the radon daughter concentration in working levels (WL) is calculated. For the purpose of Codes of Practice radon daughter concentrations of 1 WL is deemed equivalent to 21 $\mu J/m^3$, in SI units.

Sample locations are selected which are representative of the workman's exposure. Because the miner's range of activity in the workplace may vary greatly, consideration of the relative amounts of time spent in each work area is warranted.

However, no hard and fast rules can be given because too many variables are involved in determining what constitutes an accurate exposure evaluation. many proponents recommend that all samples should be taken at the breathing zone of workmen, or, for stationary job activities, at the work locations. In some cases the most representative sampling location may be the return air side of the work place. Because of the mobility of some workers, an average of several sampling locations in a mining zone might be appropriate.

The number of samples required depends on the radon daughter concentrations in the working environment, and the mobility of the miner. Present practices include sampling each work place at a frequency specified in the Code of Practice. Samples, should be at various times of the week and day in each work area to avoid biasing sampling results, due to systematic temporal radiation behaviour. Obviously, the grab sampling approach to estimating personal exposure is subject to a high degree of uncertainty. Errors may be introduced by three classical means.

1. Sampling, measuring and recording.

Inherent method errors - estimated to be 5-10%.

(i) The time factor used by Kusnetz only partially compensates for the fact that RaA, RaB and RaC are not ordinarily found in equilibrium.

(ii) Input errors resulting from keypunching of data.

Systematic errors - estimated to be 5-10%.

(i) Air sample volume errors (i.e. flow rate calibration, sample timing, filter holder leakage and flow meter scale reading).

(ii) Counting errors (i.e. counter calibration, sample counting error).

2. Fluctuation of the radon daughter concentration in the air.

Chiefly, this is controlled by the effectiveness and stability of the ventilation system. Ventilation dilutes radon and its daughters and also limits ingrowth time for the daughters.

3. Inaccuracies in estimates of occupancy time.

Occupancy time is taken from the daily supervisor's reports or individual's time card and normally forwarded to the computer center. Because of the uncertainty in job activity, some mines have devised an occupational ratio such as 80/20 or 90/10. It assumes the workman spends 80% of his time at the workplace and 20% in travel to and from workplace and for lunch in the lunchroom. This ratio varies between mines.

Consideration:

- development of a "statistically sound" sampling program, for example, obtaining unbiased exposure measurements that are mostly representative of employee exposure. This may require the design of statistical sampling plans required to adequately monitor these locations so that each of these location-occupation time periods will have equal opportunity of being sampled. C. Makepeace has discussed stratified radon sampling plans in a paper prepared under contract for the AECB in 1981. The subject is again under review.

System B - Full Shift Area Sampling:

Application:

- Work areas where radon and thoron daughter values remain relatively consistent, i.e. fresh air travel-ways, most mill locations, open pit;

- Radon and thoron daughter dosimeters are strategically located to determine the best estimate exposures for a group of workers;

- Another possible method discussed included one worker wearing the full shift dosimeter and his exposure then used to calculate the exposure of other workers located in the immediate vicinity.

Consideration:

- determine where the sampler should be located
- determine the working groups for whom this system would apply

System C - Personal Dosimeters:

Application:

- Ideal for workers whose work locations vary during the course of a shift;

- the employee wearing a personal dosimeter for the full shift and the exposure determined accordingly.

Two types of commercially available dosimeters were selected by the industry:

1. CEA Dosimeter

The CEA personal dosimeter is based on the Thermoluminesence (TL) principal. The track-etch film device is manufactured by CEA, the Atomic Energy Commission of France. The AECB purchased five dosimeters in 1976 to be tested. The contract was awarded to the University of Toronto in 1977, co-sponsored by the Department of Energy, Mines and Resources. The objective of the contract was to evaluate the CEA dosimeters in the laboratory and in an underground uranium mine environment including an attempt to correlate radon daughter estimates with those from the grab-sampling technique. The result of the evaluation, as earlier indicated, was favourable.

"In the CEA instrument, shown in figure 1, a turbine forces work-place air through a filter which traps all respirable aerosols, among them radioactive aerosols (radon daughters, long-lived radioactive dust). Inactive and long-lived dust remains attached to the surface of the filter which can be removed later for measurement in the laboratory. The short-lived radionuclides, which contribute most of the radiation dose to the lung, undergo radioactive decay while the filter is still in the instrument. The collimator selects alpha particles emitted in a direction perpendicular to the detector from the aerosols on the filter. Their path through the air and through absorbers E1 and E2 or E3 reduces the energies of the alpha particles emitted by the short-lived daughters of radon and thoron in such a way that the particles from $^{218}$Po (RaA), $^{214}$Po (RaC), and $^{212}$Bi (ThC) on the filter are recorded on distinct zones of the detector film. The detector used is Type II KODAK PATHE LR 115 film, 13 micrometers thick. After appropriate chemical processing, the impact of an alpha particle on the film is revealed by a hole several micrometers in diameter."(3) A photograph of the complete instrument is shown in figure 2.

Fig. 1.
Schematic diagram of the CEA personal alpha dosimeter

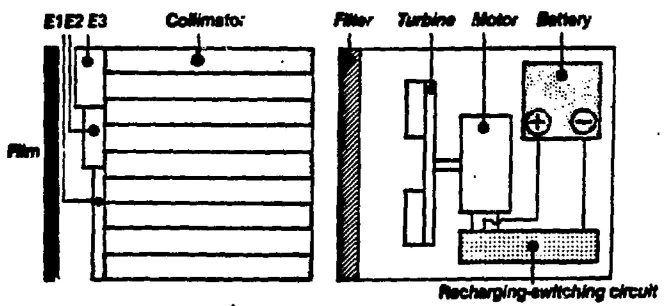
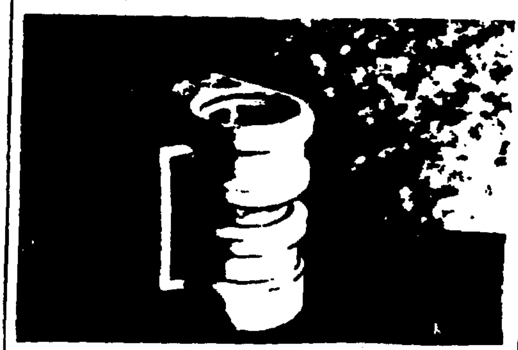



Fig. 2.
CEA Personal Alpha Dosimeter.

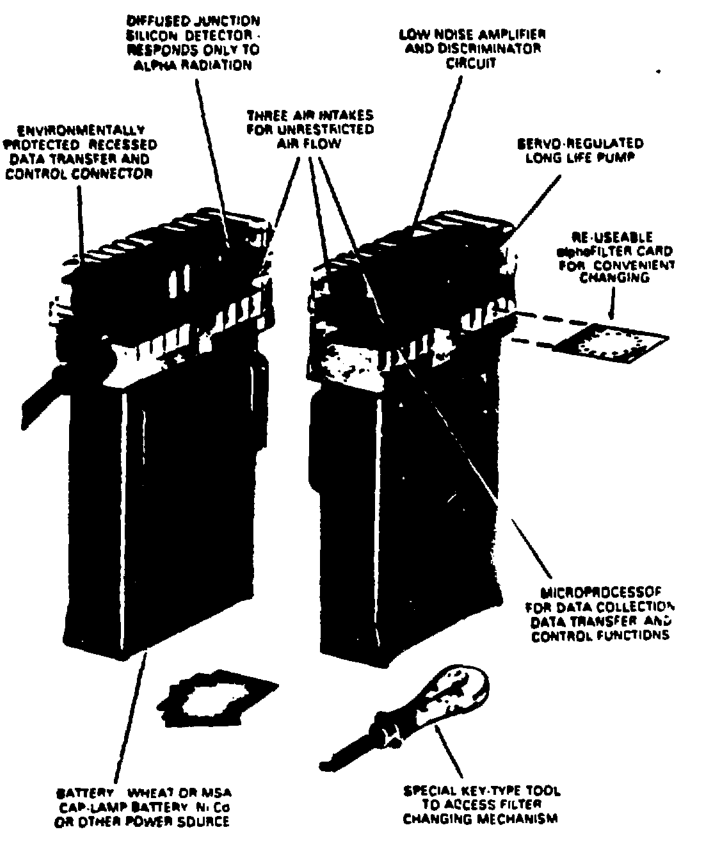


2. <u>alphaNUCLEAR dosimetry</u>

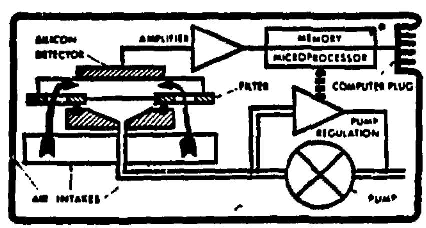
The alphaDosimeter instrument is manufactured by AlphaNUCLEAR Company. The alphaDosimeter is a complete, interpreted system designed to monitor radon and thoron daughters in the immediate work site of a mine. It is primarily designed for a direct attachment to the miners cap lamp battery. (see figure 3.)

The alphaDosimeter module houses a flow regulation pump, filter receptable with "O" - ring sealing, diffused junction silicon detector amplifier and microprocessor circuits (see figure 4). External access to the stored data in the microprocessor memory is via an environmentally protected pin corrector. The electronics is mounted on 3 printed circuit boards in a modular fashion for easy access and serviceability.

**SERIES 500 alphaDOSIMETER SYSTEM**




INTERNAL VIEW OF THE MODEL 500 alphaDOSIMETER MOUNTED ON A WHEAT CAP-LAMP BATTERY SHOWING THREE EASILY SERVICEABLE MODULES




alphaDOSIMETER SCHEMATIC CROSS SECTION

FIGURE 4:

FIGURE 3 : alphaDOSIMETER

A general purpose, commercially available computer is used to acquire and process data from the dosimeters. This results in convenient record keeping capability on a daily basis for both radon and thoron daughter exposures for many hundreds of miners.

Development could cover

- a cross section of all occupational groups
- workers for whom occupancy time is difficult to determine (anomalies to the present system)
- highly mobile workers
- worse case situations
- persons who work in locations with a history of erratic values

Consideration:

- determine differences between individual workers exposures that may have slightly different work assignments or habits.

Each company had the opportunity to review the applicability of each of the above (or any other) system to their work force.

A set of criteria was developed and employees slotted into a system for the test period.

The number of parameters considered in the experimental design of this project are many and varied. These include ventilation systems, mining methods, ore grade, size of mine, number of workers, location of workers, etc. For example, in some cases occupation may be the main factor for the grouping of workers participating in the program and in another case location may be the primary factor. The multiple involuntary variables incorporated into the design of this test project is recognized and a multi-variate statistic could be considered for final analysis.

ONTARIO OPERATIONS

The histogram shown in Figure 5 provided ranges of alpha exposure of uranium mine employees in four underground operations.

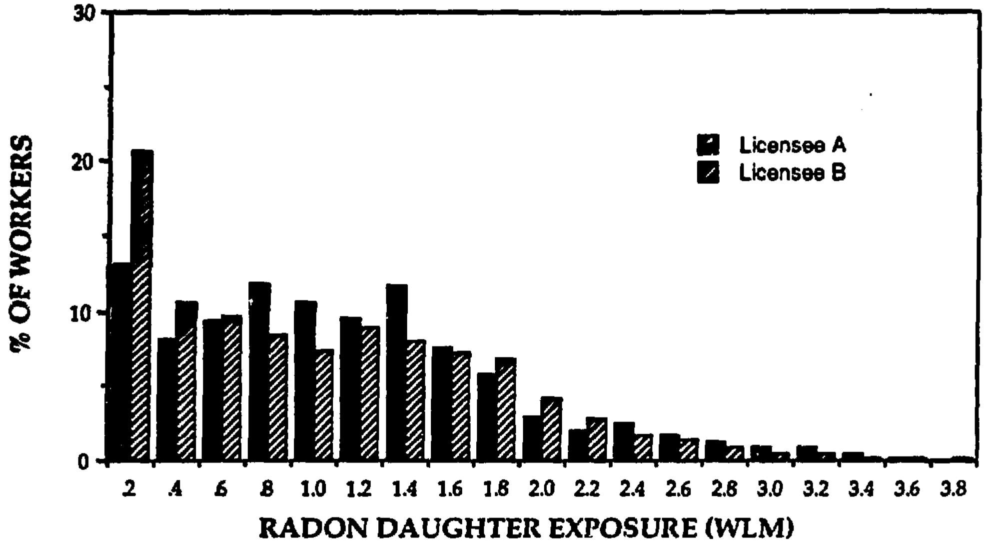
Licensee A: Represents 1868 employees of whom

990 (53.0%) are in the 0 to 1.0 WLM range
700 (37.5%) are in the 1.1 to 2.0 WLM range
178 (9.5%) are in the 2.1 to 3.8 WLM range
None surpassed 3.8 WLM

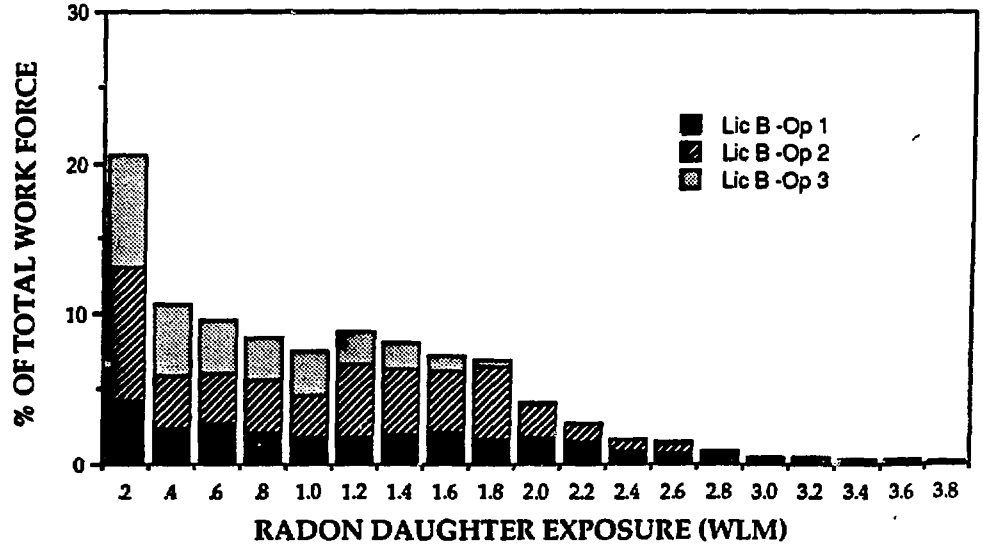
Licensee B: Represents 2218 employees of whom

1258 (56.7%) are in the 0 to 1.0 WLM range
776 (35.0%) are in the 1.1 to 2.0 WLM range
184 (8.3%) are in the 2.1 to 3.8 WLM range
None surpassed 3.8 WLM

## FIGURE 5A. RADON DAUGHTER EXPOSURES BY LICENSEE




## FIGURE 5B. LICENSEE B: DETAILED EXPOSURES



LICENSEE A (Figure 5)

This licensee has been actively involved in the co-operative efforts to evaluate dosimetric concepts in the uranium mining environment. A number of these devices have been extensively field tested at their principle underground operation since 1976. In their observation, the modified CEA-Tracketch unit demonstrated superior mechanical reliability in the mining environment and the licensee opted to use these dosimeters extensively in their program.

The licensee's program was to determine:

1) the practical viability of personal alpha dosimetry in the uranium mining environment;

2) the technical reliability of currently available instruments;

3) the need for personal dosimetry and the extent to which it is warranted in the mining industry; and

4) the variances in estimating worker exposure between the present method and personal dosimetry.

The licensee obtained the CEA dosimeters from CAIRS and retained the institute to read and service the personal alpha dosimeters for the three year program. The licensee also proposed to cover a representative section of all major underground occupational groups and groups having a special interest in the dosimetric model. Table-I provides a guide to the initial selection of workers in the programme.

TABLE 1

UNDERGROUND MANPOWER DISTRIBUTION AND THE NUMBER PARTICIPATING IN THE PROGRAM

| Division | Occupation Type | No. of Workers (Employed) | (Proposed Wearers) |
|---|---|---|---|
| Mine | Hourly | 627 | 61 |
| Maintenance | Hourly | 375 | 36 |
| Mine | Staff | 58 | 7 |
| Maintenance | Staff | 27 | 3 |
| Other | Staff | 72 | 3 |
| Mine & Maint. | Contractors - Staff & Hourly | 503 | 40 |
| TOTAL | | 1,662 | 150 |

The criteria for the selection of dosimeter wearers in the program were as follows:

a) the worker must consent to wearing the dosimeter;

b) a higher percentage of workers selected from a representative group that is very mobile and/or in numerous areas of the mine;

c) preference given to employees working in areas where the radon daughter concentration has a wider range of fluctuation;

d) a representative number of workers selected from each working zone;

e) Company and Department seniority given due consideration in the selection process; and

f) for initial assessment, have as many workers as possible wearing the dosimeter and to have all of types working areas covered.

At the end of 1983, the licensee reported as follows:

"The proposed dosimetry service with CAIRS called for 150 CEA dosimeters for a three-year period. However, as of January 1983, CAIRS was only able to supply 80 of the dosimeters. By April, 85 dosimeters were present (at the mine). It was not until the middle of November that the remaining 65 dosimeters were receive, completing the 150 dosimeters requested." The reason for the delay was shortage in supply of the units from the parent manufacturers in France.

"Initially, in January 1983, there were 55 assigned dosimeter users of which 50 wore their dosimeters regularly. By April, this was increased to 85 assigned dosimeter users, of which 78 wore their dosimeters regularly. Towards the end of the year, the number of a assigned dosimeter users declined for lack of volunteers. In December, there were 62 assigned dosimeter users of which 45 wore their dosimeter regularly.

During the 1983 year, 39 employees completed the 12 month participation period. Another 84 volunteer employees were requested to participate, but 10 declined when asked. In the course of the year 28 employees did not complete the requested 12 month period for various reasons; 12 users declined after using the dosimeters for a short period of time; 11 users stopped using the dosimeter for at least two months; 4 users transferred to surface jobs; and 1 terminated employment."

It is worthwhile to note that the licensee's original proposal did not preclude their negotiating with Canmet on a co-operative program for technical evaluation of alternative dosimeter devices.

In Table 2, the dosimeter readings versus area monitoring results by job groups are summarized for the data collected in the experimental alpha dosimetry program up to the end of May, 1984. Only data where dosimeters were worn on a regular basis for the full month are included to enable comparison with the area monitoring results shown in the table as "Computer Records". No mean of the dosimeter readings exceeds the means of the computer record by more than 0.03 WLMs.

In Figure 10, the data has been plotted by job group and a best fitted line drawn through the data points by linear regression. While good agreement appears to exist between personal dosimetry and the computer records in estimates of occupation groups, there may not necessarily be good agreement when comparing individual exposures within the groups. This was a conclusion of P.J. Duport's report "Integrated Personal Dosimeters for Uranium Miners" following a study of the CEA dosimeter in French mines.

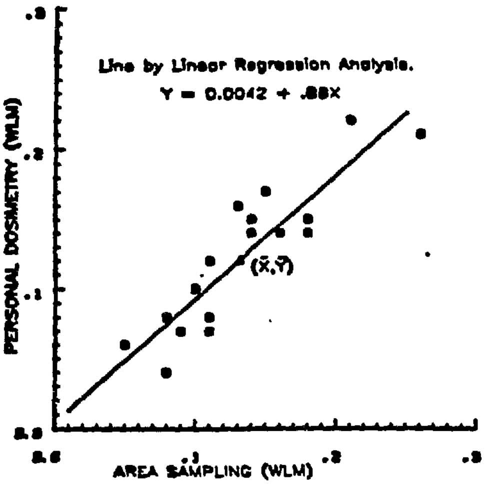



FIGURE 10

Average WLM Results by Job Group for Area Sampling versus Personal Dosimeter.

TABLE 2

SUMMARY OF THE DOSIMETER READINGS VERSUS EXPOSURES DETERMINED THROUGH AREA MONITORING RESULTS BY JOB GROUPS FOR THE DATA COLLECTED IN THE EXPERIMENTAL ALPHA DOSIMETRY PROGRAM UP TO THE END OF MAY 1984

| JOB GROUP | NO. OF SAMPLES | DOSIMETER READINGS (WLM) | | COMPUTER RECORDS (WLM) | |
|---|---|---|---|---|---|
| | | MEAN | RANGE | MEAN | RANGE |
| MINE DIVISION | 590 | .13 | .00 - .81 | .15 | .01 - .69 |
| JUMBO | 23 | .14 | .02 - .30 | .18 | .02 - .41 |
| JACKLEG | 347 | .15 | .00 - .47 | .14 | .01 - .51 |
| LONGHOLE | 25 | .16 | .07 - .44 | .13 | .02 - .41 |
| HAULAGE | 87 | .14 | .02 - .31 | .16 | .02 - .40 |
| ROOFBOLTING | 65 | .14 | .06 - .45 | .14 | .02 - .51 |
| LOADING | 25 | .08 | .01 - .20 | .11 | .02 - .19 |
| ROCKBREAKING | 25 | .04 | .01 - .14 | .08 | .01 - .23 |
| DIAMOND DRILL | 1 | .02 | | .08 | |
| ROADWAYS | 5 | .15 | .01 - .31 | .18 | .08 - .44 |
| CONVEYORS | 32 | .22 | .04 - .73 | .21 | .04 - .48 |
| LEACHING | 11 | .21 | .00 - .45 | .26 | .06 - .89 |
| VENTILATION CONSTR. | 62 | .14 | .01 - .53 | .16 | .02 - .44 |
| SERVICES | 5 | .07 | .01 - .20 | .11 | .05 - .21 |
| PIPEMEN | 37 | .10 | .01 - .23 | .10 | .02 - .36 |
| MAINTENANCE DIVISION | 234 | .08 | .00 - .34 | .10 | .01 - .25 |
| WELDER | 29 | .07 | .00 - .36 | .09 | .02 - .23 |
| INDUSTRIAL MECH. | 62 | .10 | .01 - .24 | .10 | .02 - .21 |
| HEAVY DUTY MECH. | 75 | .08 | .01 - .21 | .08 | .01 - .16 |
| ELECTRICIAN | 68 | .12 | .02 - .34 | .11 | .03 - .25 |
| STAFF | 132 | .10 | .01 - .88 | .10 | .00 - .41 |
| MINE STAFF | 67 | .17 | .02 - .88 | .15 | .01 - .41 |
| MAINTENANCE STAFF | 21 | .07 | .01 - .14 | .09 | .01 - .28 |
| OTHER STAFF | 44 | .05 | .01 - .11 | .05 | .00 - .11 |
| ALL GROUPS | 956 | .12 | .00 - .81 | .13 | .00 - .69 |

LICENSEE B (Figure 5)

In accordance with the requirement to develop a proposal for alpha dosimetry, the Company and the Union jointly submitted an acceptable proposal opting to deploy two types of alpha dosimeters for the duration of the programme: 50 Alpha-Nuclear and 100 CAIRS' CEA units.

The two main objectives listed in the joint proposal were:

1) to determine if dosimetry is technically, financially and administratively feasible; and

2) to assess the correlation between the present exposure record-keeping method and dosimetric data.

The total of 150 units deployed in the company's three licensed underground operations for the three year period would roughly cover 10% of the applicable work force, the same as Licensee A.

N° 1 Underground Operation: (Figure 5)

The personal alpha dosimetry program using 25 alphaNUCLEAR dosimeters was commenced in Oct 1982 and continued throughout 1983.

Actually, 21 dosimeters were usually distributed with 4 spares on the rack. There were many difficulties experienced during the first twelve months, however, about 50% of these problems have now been solved providing a yield of 85%. It should be noted that any problem could be observed on a daily basis, corrected and the dosimeter used as soon as available. The dosimeter is also useful for engineering work. The pumps have been performing particularly well. When working, the dosimeters were generally performing well; however, during 1983 the following problems, with frequencies shown, occurred:

| | PROBLEM | FREQUENCY |
|---|---|---|
| 1. | Failure to log in or out, or logging everything out on the charge rack | 18 |
| 2. | Blown fuses, shortening out or power drainage | 15 |
| 3. | Excessively high readings | 11 |
| 4. | *Pump failure, pump-holding wires broken, etc. | 6 |
| 5. | Receiving zero counts | 5 |
| 6. | Hole worn through casing | 2 |
| 7. | Constantly turning itself off | 1 |
| Cumulative number of units failed | | 58 |
| Cumulative number of units distributed | | 258 |
| 1983 failure rate | | 23% |

Compliance surveys: Actual number of units worn compared to possible number of units available: range 91.7%** to 100%.

* Actual pump failure has only happened twice.

** On only one occasion was an available dosimeter not worn, accounting for the 91.7% rate (during one shift 11 units worn out of 12 available).

The alphaNUCLEAR dosimeter unit and system have merit with many attractive features; for example, the print-out system and the unit being part of the cap lamp battery, daily read-outs, early detection of problems, the use of the instrument for engineering purposes, etc., to name but a few.

In figure 11 the maximum and minimum exposures are shown as well as the averages for both area monitoring and alphaNUCLEAR dosimeter results for the N° 1 underground operation. The PAD results definitely indicated a lower average exposure than those obtained by grab sampling means. The holiday shut-down period during July accounted for lower exposures. The twelve month means comparison between the two methods:

Dosimetry - .074 WLM
Area Monitoring - .148 WLM
Difference 50%

It is worthwhile to compare the N°. 1 underground operation's frequencies of failures and compliance with those at N°. 3 underground operator, when 25 CEA dosimeters were deployed with a minimum availability of 18 units per day over a two-month period, but where compliance percentages were much less than at N°. 1's operation.

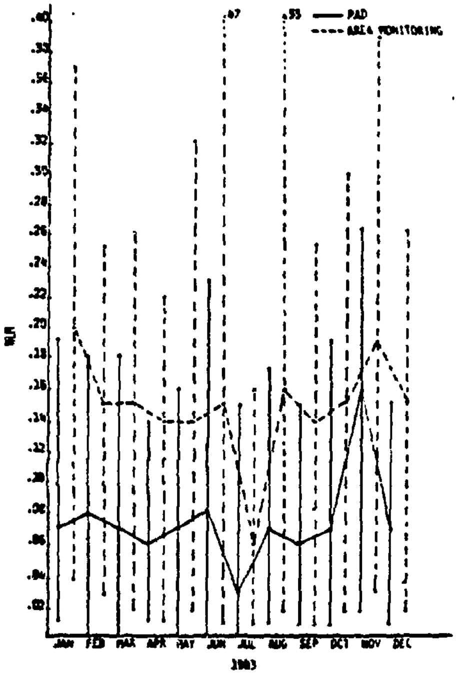



FIGURE 11
alphaNUCLEAR
PERSONAL ALPHA DOSIMETRY (PAD) RESULTS
FOR RADON DAUGHTERS VS EXPOSURES DETERMINED THROUGH
AREA MONITORING RESULTS IN WORKING LEVEL MONTHS (WLM)

| PROBLEM | FREQUENCY |
|---|---|
| 1. Unreadable | 6 |
| 2. Faulty turbine | 1 |
| 3. Faulty battery | 1 |
| 4. Exhaust port holes plugged with muck | 1 |
| 5. Not specified | 3 |
| Cumulative number of units failed | 12 |
| Cumulative number of units distributed | 270 |
| 1983 failure rate | 4.4% |

Compliance surveys: Actual number of units worn compared to possible number of units available: range 50% to 100%.

The 100% compliance occurred only once (in February 1983). Compliance surveys during the year showed a rate of 77%. The better compliance rate of the alphaNUCLEAR dosimeter might be contributed to one major factor: the dosimeter being an integral part of the cap lamp battery, whereas a worker may forget to wear other dosimeters from time to time.

N°. 2 Underground Operation: (Figure 5)

"The CEA program commenced in February (1983) with 75 dosimeters deployed. Administration of the program continued to be a key element to its success or failure. Employee transfers and refusal to continue participation resulted in poor compliance with the program. The following action was taken to improve these deficiencies:

a) program co-ordinator (Canadian Institute for Radiation Safety (CAIRS) to re-train all participants

b) the health & Safety Committee from the Union was requested to strengthen its support of the program

c) program coordinator made personal contact with all wearers to explain the results of the program." (Excerpt from the Operator's Annual Report to the AECB).

Comparative Results

Some interesting comparisons were made at the N°. 2 underground operation.

1) During May 1983, area monitoring samples were taken (Kusnetz method results) at 15 minute intervals at the crusher operator's position. A total of 450 samples were taken. At the end of the sampling period the exposure to radon daughter concentrations was determined to be 0.0563 WLM, as compared to 0.0513 WLM derived from the CEA dosimeter.

2) Area monitoring samples were taken in September 1983 where a raise miner was developing a heading. Radon daughter concentrations were determined by area sampling every 15 minutes. A total of 565 samples were taken. The exposure of the raise miner was calculated to be 0.1145 WLM as compared to 0.062 WLM determined by the CEA dosimeter.

3) Of further interest is comparing two dosimeter results, based on the wearing of one in the inside and one on the outside of the coveralls. The two readings were as follows:

CEA dosimeter worn inside the coveralls: 0.060 WLM
CEA dosimeter worn outside the coveralls: 0.077 WLM

Comparisons of this nature should be encouraged to provide more conclusive results.

N°. 3 Underground Operation: (Figure 5)

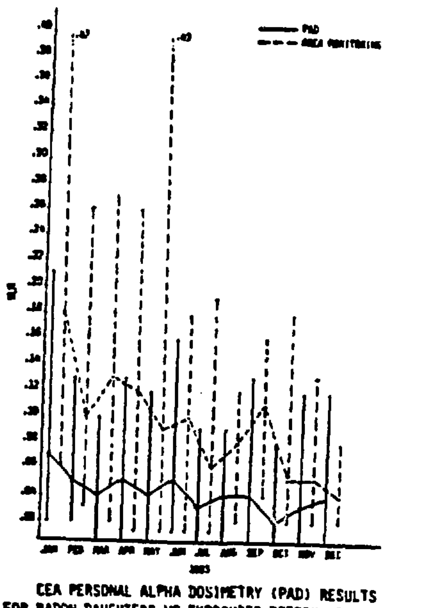
At the end of 1983, the operator reported as follows:

"The CEA program commenced in July 1982 with the deployment of 25 dosimeters.

Since commencement of the program in 1982, 179 employees have been asked to participate in the program of which 152 initially undertook to wear the dosimeter. Of these, 51 to date have withdrawn from the program before completion of the 12-month period. Volunteers to date have been selected from voluntary requests made to all underground supervisors."

Some discussion has been outlined under N°. 1 underground operation in comparing the CEA units with the alphaNUCLEAR system.

Figure 12 shows the:



CEA PERSONAL ALPHA DOSIMETRY (PAD) RESULTS
FOR RADON DAUGHTERS VS EXPOSURES DETERMINED THROUGH
AREA MONITORING RESULTS IN WORKING LEVEL MONTHS (WLM)

FIGURE 12

The maximum and minimum exposures are shown as well as the averages for both area monitoring and CEA dosimeter results for the N°. 3 underground operation. The PAD results definitely show a lower average exposure than those obtained by grab sampling means. Only in December were the means the same. The twelve month mean comparison between the two methods:

Dosimetry - .042 WLM
Area Monitoring - .093 WLM
Difference 45%

SASKATCHEWAN OPERATIONS

There are thee operating mines and mills in Saskatchewan.

N°. 1 Operator

This well established open pit mining and milling operation utilized CEA dosimeters from mid-1982 to the end of the test programme.

Six dosimeters were used with twelve heads. Due to the almost non-existent ranges of radon daughter concentrations in the pit, eight dosimeters were allocated to mill operators and four worn by mill maintenance personnel.

Three sets of exposure results were kept by the facility:

a) Working Level Months calculated manually;
b) Working Level Months calculated by the computer programs;
c) Working Level Months as established by CEA alpha dosimeters.

The following were the averaged exposure levels from 1982-1983 (seventeen months), quoted in Working Level Months:

| | Calculated | Computer | CEA Dosimeters |
|---|---|---|---|
| Mill Operations | 0.0267 | 0.0271 | 0.0265 |
| Mill Maintenance | 0.0159 | 0.0146 | 0.0276 |
| Combined | 0.0213 | 0.0213 | 0.0271 |

Some of the problems experienced during the experimental program were as follows:

- batteries were going dead without reason, resulting in the replacement of some units;

- results came back from units that were not worn for a whole month;

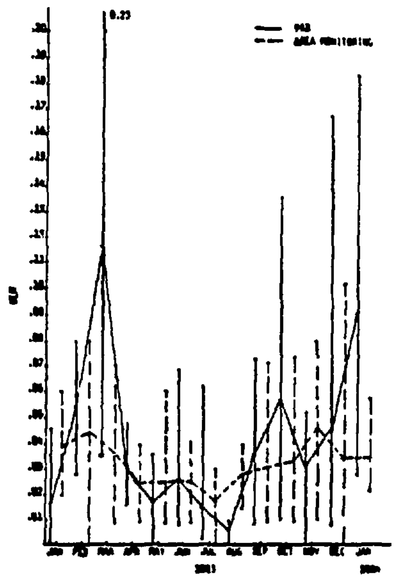
- many results came back marked as being contaminated, for which there had been no apparent reason; and

- there were several months of usage before receiving the necessary equipment allowing the calibration of the pumps.

Figure 13 shows the maximum and minimum exposures as well as the averages for both area monitoring and CEA dosimeters results. The twelve month mean comparison between the two methods:

Dosimetry - .038 WLM
Area Monitoring - .031 WLM

There is correlation in the mean result however, there were major differences in individual results.



CEA PERSONAL ALPHA DOSIMETRY (PAD) RESULTS FOR RADON DAUGHTERS VS EXPOSURES DETERMINED THROUGH AREA MONITORING RESULTS IN WORKING LEVEL MONTHS (WLM)

FIGURE 13

N°. 2 Operator

A full-scale alpha dosimetry program has been in place since 1979. Involved are open pit and underground mining and milling activities. In contrast with other operations, the Personal Alpha Dosimetry results, rather than the exposures calculated from grab sampling results have been used for official records.

Grades of ore in the open pit were significantly higher than at any facility anywhere. An example of the ore grades involved can be noted by the grades in the initial stockpiles:

1. low grade (0.3 percent uranium);
2. medium grade (0.3 to 20 percent uranium);
3. high grade (20 percent uranium). (4)

Ranges of concentrations of radon daughters in the open pit were measured between one and six times each day for a period of about two months. A total of 296 measurements were taken with the following recorded results:

| Level (WL) | ($\mu J/m^3$) | Frequency |
|---|---|---|
| <0.01 | <0.21 | 252 |
| 0.01 | 0.21 | 40 |
| 0.02 | 0.42 | 1 |
| 0.03 | 0.63 | 2 |
| 0.04 | 0.54 | 1 |

From the outset, concentrations of radon daughters were maintained in the lower ranges in the open pit as indicated above, and also in the underground and mill operations where the ranges were usually below 0.10 WL (2.1 $\mu J/m^3$).

Acceptance of personal alpha dosimeters by workers were initially found to be difficult, in contrast with no difficulties experienced in TLD (gamma dosimeter) badge acceptance. The older model alpha dosimeter was considered cumbersome and there was concern expressed by workers about the electrical connections. These concerns were overcome and the biggest problem now is to have a worker surrender his alpha dosimeter when no longer required in a particular work environment. This action is not considered popular with the workers. The strong sense of acceptance of monitoring and protection equipment is a direct result of the positive effects of training.

An initial difficulty experienced by the licensee was dosimeter contamination: it was and still is difficult to ascertain whether there are other factors involved. Contamination usually occurs around the edges of the filters. Another unusual occurrence is the higher levels of polonium-218 (Radium A) as compared to polonium-214 (Radium $C^1$). This matter is discussed elsewhere.

Regarding correlation between working level month results derived from grab sampling techniques and those obtained from the personal alpha dosimeters: there was none. The highs and lows do not average out even on daily frequencies.

Presently 90 CEA dosimeters are in use in the mill (40 per shift for all personnel who regularly work in there). For the underground operations (by contractor) 52 dosimeters have been made available.

N°. 3 Operator

This facility has only recently started production. Concentrations of radon daughters have not been significant.

Comments by Licensees:

Canadian licensees have identified the following additional difficulties which are presented without comment:

1) the flow rate of the CEA dosimeter has caused user concern:

- the equation used by CAIRS
- measuring strategy and techniques
- assuming flow;

2) doses recorded against workers who were not wearing dosimeters;

3) the turnaround time for Western operators was slow.

Other areas requiring consideration were:

- in comparing personal alpha dosimetry with exposures determined through area monitoring results, it will be necessary to evaluate the concentration values and times of exposure from the time a worker activates his dosimeter to the end of the shift, i.e. the 80/20 or 90/10 occupational ratio earlier discussed. In large operations the cumulative hours may be significant; also

- compliance were and - are dosimeters worn regularly and properly?

CONCLUSIONS

In this presentation the authors have discussed and compared the two methods of radon daughter exposure estimation in Canadian uranium mines. With the co-operation of mining companies and workers the experimental program continued until the end of 1985.

The problems experienced in the initial stages have, if not removed, been identified, and a determined effort is being made by licensees and the regulatory agency to thoroughly evaluate the programs, looking closely at the variables, costs and the generated data: the program was to provide technically sound data.

Thus far, the facts are:

- there is a discrepancy between area sampling and PAD results. Practical Canadian experience indicates that both the CEA and alphaNUCLEAR PADS most often read lower than the conventional area monitoring results.
- the technical evaluation of data may not be sufficiently comprehensive;
- application of site specific factors may at times be debatable; discriminatory factors must be identified;
- servicing the Industry requires improvements; and
- training programs are essential.

Other areas requiring further evaluation:

- decisions on further technical modifications to the dosimeters which will have an effect on which type may or may not be available, i.e. commercial viability;
- contamination of dosimeters; and
- both CEA and alphaNUCLEAR dosimeters have been modified since the program began and therefore the next period will be critical for evaluating the dosimeter and the ensuing results.

Final evaluation of the programme is expected in 1988.

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(3) CAIRS Radiation Safety Bulletin Vol. 2 N°. 1, February 1984.

(4) The Cluff Lake Board of Inquiry Final Report, Chapter II Page 22.

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