Commission canadienne de sûreté nucléaire
Canadian Nuclear Safety Commission

Protecting the Health of Uranium Mine Workers: The Situation from the 1930s to the Present Day

Canadian Nuclear Safety Commission

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Canada

Main Points of the Presentation

- The Canadian Nuclear Safety Commission's (CNSC) role in protecting miners
- Regulations and radiation protection programs
- Health effects – Cohort studies and observed effects
- Average doses of RDPs in workers prior to 1970
- Average doses of RDPs in workers from 1970 to 2000
- Average doses in current workers (2001-2013)
- Health of workers in modern uranium mines
- Conclusions

CNSC's Role in Protecting Miners

- Regulates radon, its decay products and other sources of exposure to ionizing radiation in Canadian nuclear facilities by enforcing the *Nuclear Safety and Control Act* (NSCA) and its regulations
- Regulates and authorizes all current and future uranium mining and milling activities in Canada
- Performs regulatory surveillance on workers' health

The Radiation Protection Regulations

- The *Radiation Protection Regulations*:
  - limit radiation doses for members of the public and workers in the nuclear sector
  - require licensees to implement radiation protection programs to keep radiation doses as low as reasonably achievable (ALARA principle)
- Canadian nuclear safety standards are based on international standards and protect the health of workers and the public
- When implementing its regulations, the CNSC relies on the work of the International Atomic Energy Agency (IAEA) and other organizations such as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Commission on Radiological Protection (ICRP)

Radiation Protection Program for Mine/Mill Workers

- Licensees must submit a radiation protection program with their licence application
- Using a risk-based approach, CNSC staff evaluate the program to ensure that it:
  - meets regulatory requirements
  - is appropriate for the authorized activity and the associated radiological hazards
  - is compliant with international and industry best practices
- Compliance activities are performed to verify that the radiation protection program has been implemented effectively to protect workers
- The CNSC issues an authorization when it is convinced that the activity is safe

Dosimetry Monitoring of Workers

- Authorized dosimetry monitoring service is mandatory if the annual dose > 5 mSv
- Monitoring radiation exposure:

… how?

Personal dosimeters

➔ gamma rays

Personal alpha dosimeters

➔ radon progeny, uranium dust

… why?

To ensure regulatory compliance and that radiation protection, dose control and planning are effective

Workers' Condition Before Today's Standards – Effects Observed

- Around 1950, radio-epidemiological studies on miners working underground showed that an increased risk of lung cancer was linked with certainty to radon decay products (radon progeny)
- There is little evidence that PDRs are responsible for an increased risk of contracting other diseases
- Before 1950, workers were exposed to high doses of radon progeny and died of lung cancer at a much higher rate than the rest of the male population

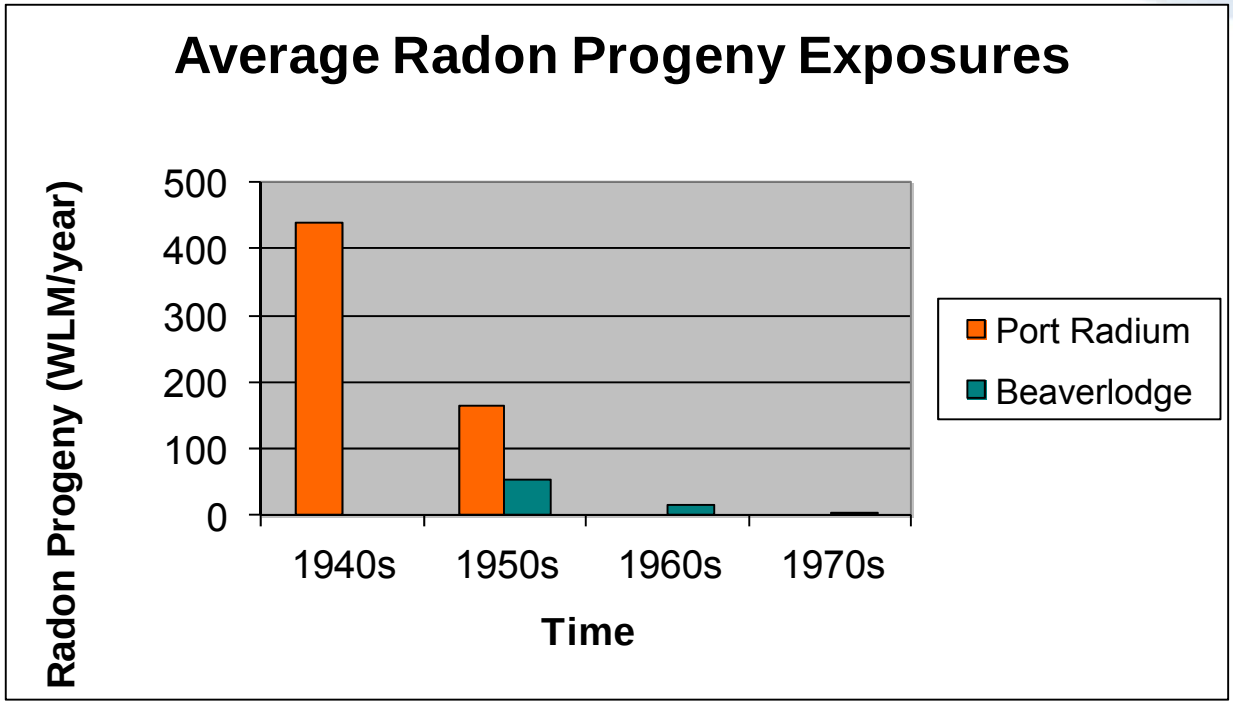
Workers' Conditions – Cohort Studies

- Radon was designated a carcinogen in 1988
- According to studies combining cohorts of workers conducted with the first raw data of miners working underground: the excess relative risk (ERR) per unit-alpha-month (WLM) for death by lung cancer is directly proportional to the cumulative dose of radon progeny
- The use of tobacco combined with exposure to radon progeny had an additive to multiplicative effect
- According to a study of 11 cohorts of miners: high concentrations of radon in the air could not be associated with deaths other than deaths by lung cancer

Workers' Conditions – Cohort Studies (cont'd)

- Additional studies conducted on miners exposed to radon progeny doses ≤ 100 WLM
- Conclusion: linear relationship between the EER model and cumulative exposure to radon
- Variation in response depending on age, time elapsed since last exposure, the level and duration of exposure as in studies using raw data
- Based on these studies, BEIR VI concluded that lung cancer was directly proportional to cumulative exposure to radon, as in previous studies
- Risk of lung cancer for low cumulative doses could be extrapolated from high cumulative doses

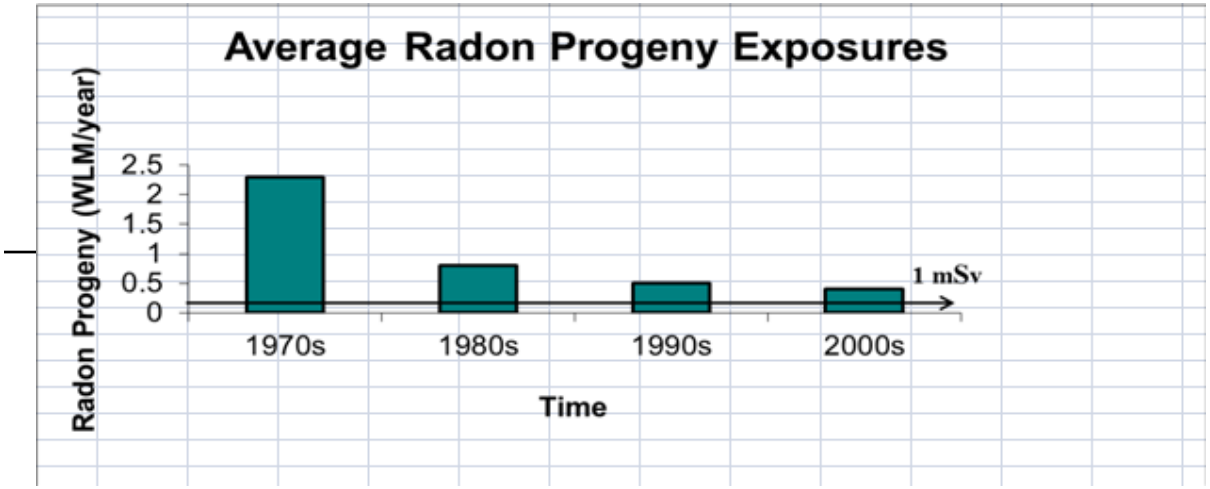
Average Radon Progeny Doses in Workers (1940-1970)



Average radon progeny doses went from more than 400 WLM, or 2000 mSv, in 1940 to less than 2.3 WLM, or 11.5 mSv, in 1970

Average Radon Progeny Doses in Workers (1970-2000)

Change in exposure levels of miners at the Beaverlodge mine (until June 1982) who continued to work as miners in Saskatchewan and were monitored during the update of the Eldorado study until 2000:



1 mSv = 0.2 WLM (1 WLM = 5 mSv)

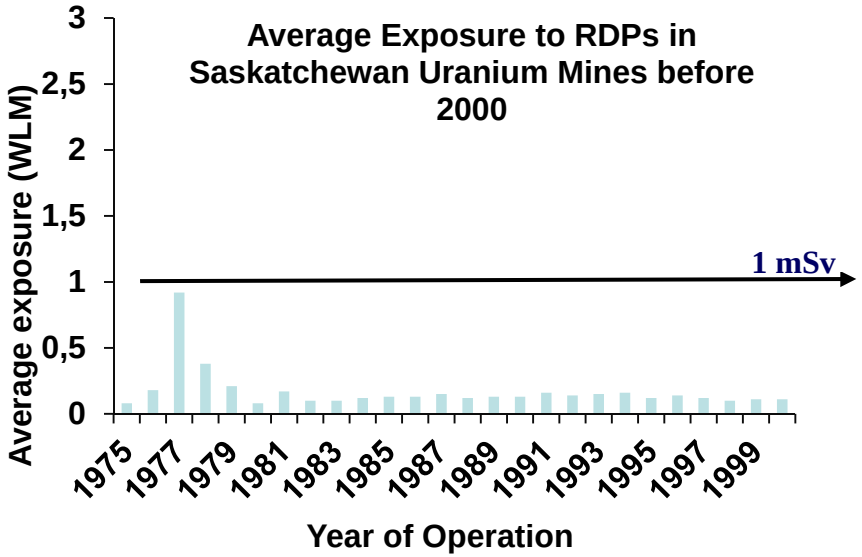
Exposure to radon progeny was reduced by more than four times from 1970 (≤2.3 WLM or 11.5 mSv) to 2000 (≤0.5 WLM or 2.5 mSv)

Feasibility Study on Saskatchewan Workers from 1975 to 2000 and Risk Prediction to 2030

- At the request of the Joint Federal-Provincial Panel on Uranium Mining Developments in Northern Saskatchewan, the CNSC conducted a study to determine whether there was an increase in cases of lung cancer attributable to radon progeny in modern mines
- The study evaluated the risk of lung cancer due to radon progeny exposure in minors who worked, are working and will work in Saskatchewan mines between 1975 and 2030
- The study used the provincial cancer rates distributed according to age and sex of the miners, their rate of employment, level of exposure to radon progeny and other factors
- The excess number of lung cancer cases was calculated based on the linear projection model of relative risk produced by the BEIR VI committee, which takes into account tobacco use and exposure to residential radon

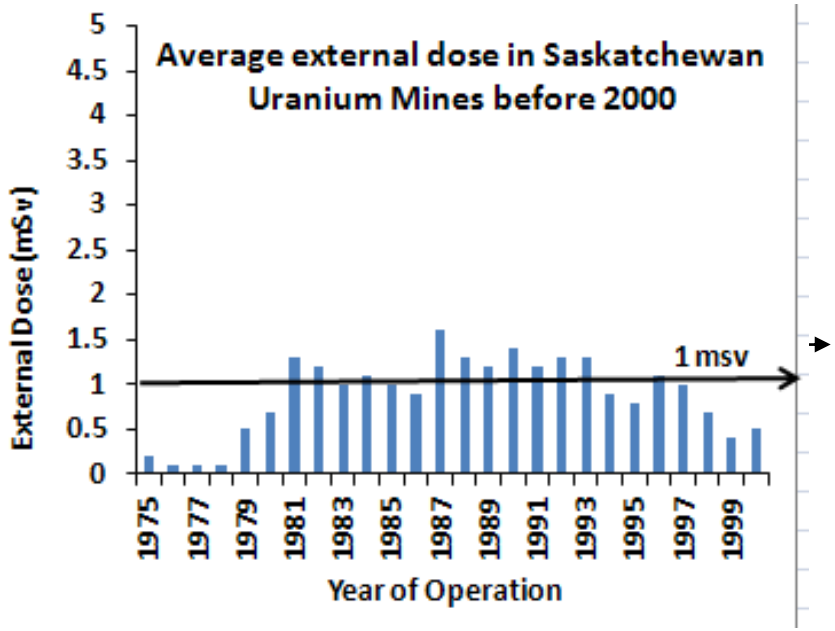
Average Radon Progeny Doses in Saskatchewan Workers – Feasibility Study

Exposure to radon progeny from 1975 to 2000 for all mining facilities in Saskatchewan: Beaverlodge, Rabbit Lake, Key Lake, Cluff Lake, McArthur River, Cigar Lake and McClean Lake:



Beginning in 1979, the average radon progeny dose was maintained below 0.2 WLM or 1 mSv at all times

Average External Doses in Saskatchewan Workers – Feasibility Study (cont'd)



The average external dose since 1975 has been maintained below 2 mSv and reduced to less than 1 mSv since 1994

Feasibility Study – Conclusions

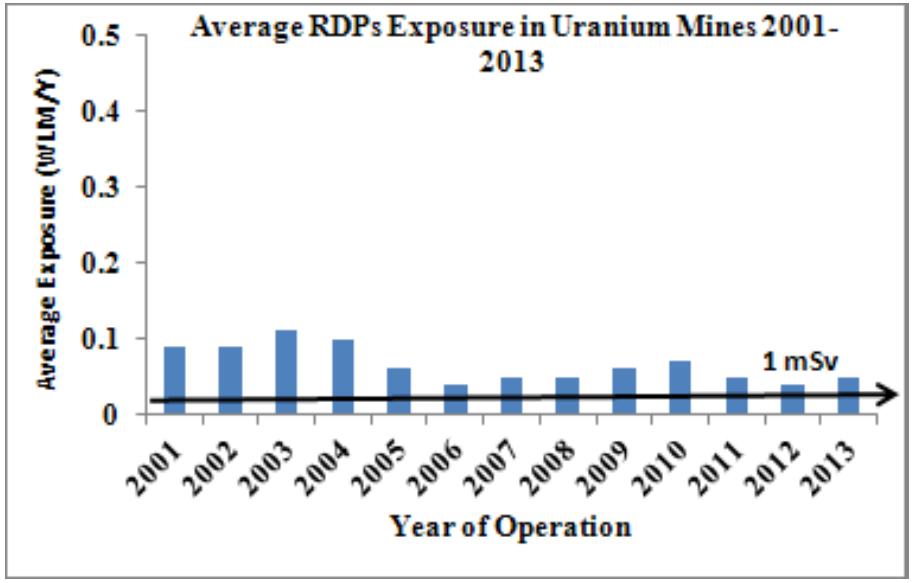
- Current workers in Saskatchewan uranium mines are exposed to radon progeny doses much lower than those experienced by former miners (less than 0.2 WLM or 1 mSv since the late 1970s)
- Approximately 24,000 miners will work at some point or another in a uranium mine by 2030. During this period, **141** miners would be expected to develop lung cancer, primarily due to smoking. Only **1** miner would develop lung cancer due to occupational exposure to radon progeny, which would increase the number of lung cancer cases from 141 to 142

Feasibility Study – Conclusions (cont'd)

- In 2014, 26,100 Canadians will be diagnosed with lung cancer. This represents 14% of all new cancer cases
- It would be impossible to conduct a study of the risks incurred by modern miners due to their exposure to radon progeny being too low (0.13 WLM/year in 2000; this is 100 to 1,000 times less than in older mines)
- It would be almost impossible to correct the estimates to take into account tobacco use and residential radon, two factors that could have a major influence on estimates

Average Radon Progeny Doses in Current Uranium Mine Workers (2001-2013)

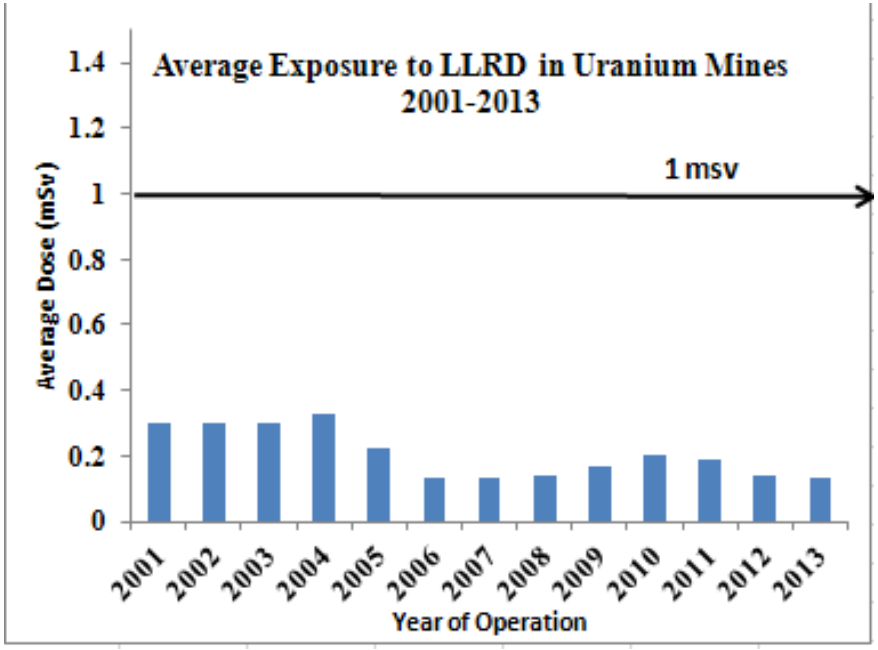
Average radon progeny exposure in Saskatchewan uranium mines from 2001 to 2013:



Average radon progeny doses for the years following 2001 have remained below the threshold of 0.1 WLM or 0.5 mSv, which is completely comparable to doses taken into consideration in the feasibility study (0.05 WLM or 0.25 mSv in 2013)

Average Doses of Radioactive Dust in Current Uranium Mine Workers (2001-2013)

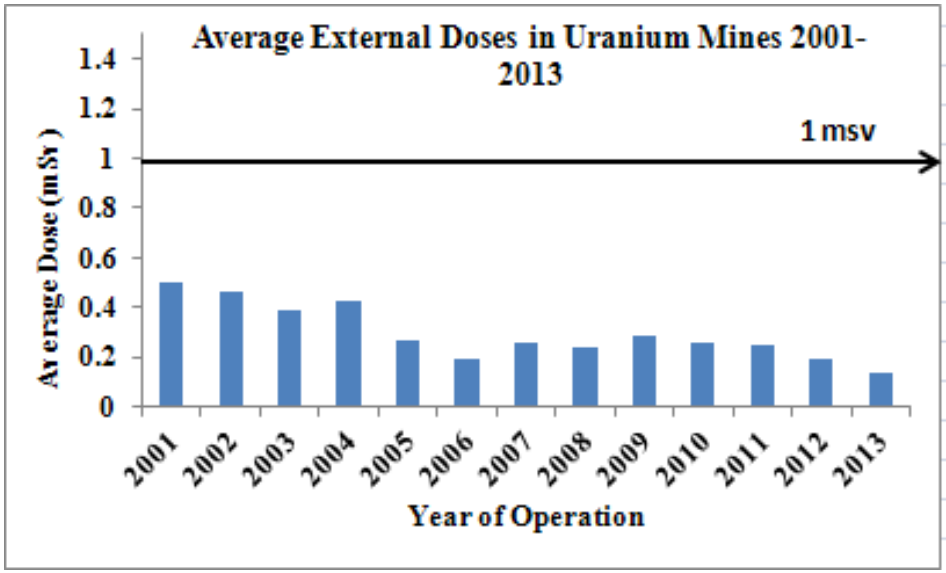
Average long-duration exposure to radioactive dust in Saskatchewan uranium mines from 2001 to 2013:



The average dose has been maintained well below 0.3 mSv since 2001 and was 0.13 mSv in 2013

Average External Doses in Current Uranium Mine Workers (2001-2013)

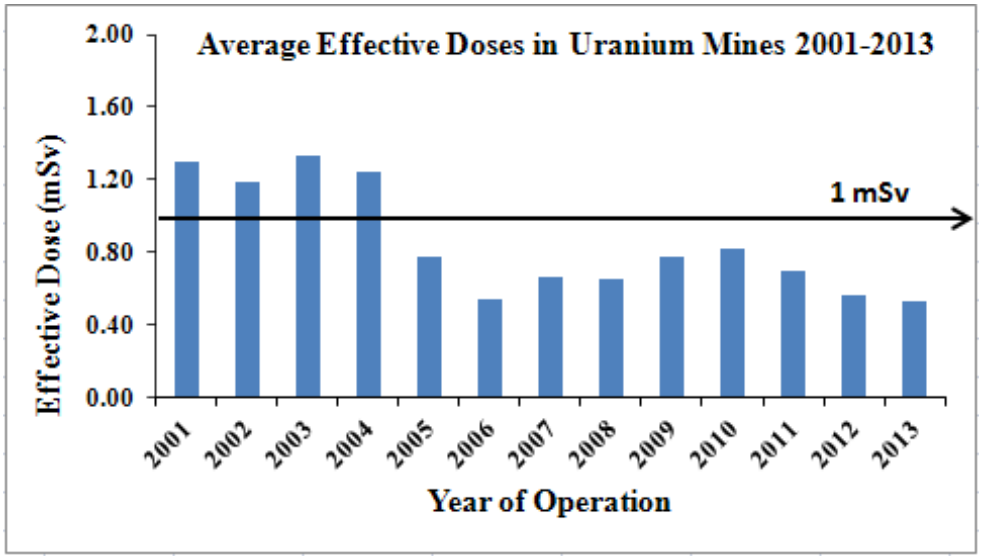
Average external doses in Saskatchewan uranium mines from 2001 to 2013:



External doses, primarily due to gamma rays, have been maintained below 0.5 mSv since 2001, and were 0.14 mSv in 2013

Average Effective Doses in Current Uranium Mine Workers (2001-2013)

Average effective doses in Saskatchewan uranium mines from 2001 to 2013:



In 2013, the effective dose (the sum of external doses, radon progeny and radioactive dust) in workers was 0.53 mSv and average exposure to radon progeny was 0.05 WLM (0.25 mSv), which represents approximately 50% of the effective dose

Worker Protection in Modern Uranium Mines

- Today's workers wear personal dosimeters that measure their radiation exposure. The measurements obtained are studied regularly by the CNSC and sent to the NDR
- In 2013, the average annual effective dose was 0.53 mSv, and the maximum dose observed was less than 15 mSv, which is well below workers' annual limit of 50 mSv established by the CNSC
- The doses measured in 2013 are similar to or even lower than those predicted in the feasibility study
- Therefore, the conclusions of the feasibility study remain applicable today

Conclusions

- International radiation safety criteria have been applied in Canadian uranium mines for more than 40 years
- Improved ventilation systems in mines, strict enforcement of international standards and the introduction of radiation protection programs have significantly reduced the doses of radiation to which underground mine workers are exposed
- Open-pit uranium mines have virtually eliminated exposure to radon progeny
- No cases of disease, including the potential increased risk of lung cancer in miners related to radon progeny exposure, have been reported in Canada since modern protection measures have been put in place

Conclusions (cont'd)

- The increased risk of lung cancer in miners working in underground uranium mines today is similar to or even lower than the risk estimated by the feasibility study
- The mortality risk for lung cancer in modern mines is similar to the risk for the rest of the Canadian population
- Miners' additional exposure to radon progeny in 2013 was very low (0.05 WLM or 0.25 mSv) in comparison with the residential radon threshold recommended by Health Canada in its guideline: 200 Bq/m^3 or 2 mSv/year

Questions?

For more information, please refer to these two CNSC documents on uranium mines:

1. Uranium Mine Workers' Exposure and Incurred Risk Since the Coming Into Force of the *Nuclear Safety and Control Act* (NSCA) in 2000
2. Health Risks of Past Mining Activity (Uranium)

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Thanks!

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