Canada's Nuclear Regulator

Health Risks of Past Mining Activity (Uranium)

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1 INTRODUCTION

Memories of the harmful health and environmental effects caused by the old methods used in the uranium mining industry in the early 20th century are hard to shake. The mining industry at that time was almost entirely unregulated. This historical context is often used to draw conclusions about the level of protection for the environment and the health of workers and the public provided by the mines and mills operating today.

The regulatory framework in the uranium mining industry has changed greatly in the period from 1930 to today. The purpose of this document is to present a brief overview of uranium mining regulation in Canada, and to review the knowledge acquired on the relationship between exposure to radon and its decay products (progeny) and the incidence of lung cancer observed in cohorts of miners – such as those of Beaverlodge and Port Radium, from 1930 to 1975.

2 BRIEF OVERVIEW OF URANIUM MINE REGULATION IN CANADA

The conditions in which miners used to work in do not resemble the working conditions of today. The radiation protection programs now in place in the mines are based on strict regulatory standards and requirements. The Canadian Nuclear Safety Commission (CNSC) has produced a second document [1] that relates the changes in radon and RDP exposure and in the risk incurred by uranium miners since the *Nuclear Safety and Control Act* (NSCA) came into force. This document highlights the current high level of protection in uranium mines, which will be maintained in future uranium mines and mills in Canada.

Between 1930 and 1975, the Atomic Energy Control Board (AECB) – the Canadian nuclear energy regulatory agency that preceded the CNSC – did not have the legislative mandate to regulate uranium mines and mills. It was not until 1975 that the AECB began to regulate this sector under the *Atomic Energy Control Act* (AECA), which came into force in 1946. In 2000, the *Nuclear Safety and Control Act* (NSCA) replaced the 1946 legislation and confirmed the CNSC’s expanded mandate to regulate nuclear activities, to protect the environment and to preserve the health and safety of workers and the public. The current performance of the uranium mines and mills, as well as the tailings sites licensed under the NSCA, reflects the CNSC’s strict regulatory framework.

Modern uranium mines use improved techniques, and take worker and environmental protection measures completely different from past practices. The practices followed in modern mines are designed to minimize worker exposure to radon decay products (RDPs). These practices include modern drilling techniques, mandatory personnel training and the incorporation of high-capacity ventilation systems that continuously evacuate radioactive particles from the at-risk work areas in mines and mills. All the miners are monitored for exposure with dosimeters, to ensure that their cumulative dose is kept within the international acceptable limits [2] and that the “as low as reasonably achievable” (ALARA) principle is respected. Through planning and continuous regulatory monitoring and protection of the environment, the Commission is assured that the mines comply with the regulatory requirements set out in their licences and apply stringent performance standards to reduce their environmental impact until they are decommissioned.

All these improvements, which make modern mines safer and cleaner, result from lessons learned in the past and the implementation of strict regulatory control in the industry. The new sites being developed will have specific policies covering tailings management, mine closure, remediation and decommissioning, and will have to provide governments and regulatory bodies with proof of sufficient funds (financial guarantees) available for these activities. These strict conditions for the establishment of new mine sites should guarantee that the facility is managed safely and sustainably for the people living around the sites.

When the NSCA came into force in 2000, the unlicensed sites were required to obtain a licence and comply with the new regulations: they were uranium mine sites, their tailings contained licensable material (uranium and RDPs), and the nuclear substances onsite were present in volumes and concentrations subject to control under the new legislation.

By 2006, only three historic mining facilities remained unlicensed: Port Radium, the Lorado mill and Gunnar. The process for licensing the Port Radium remediation had begun, and the licence was issued on January 1, 2007. The site is now remediated, closed and licensed for monitoring and maintenance.

The Lorado mill tailings site was licensed in 2013, and the remediation work will proceed over the next two years. The site will be licensed for monitoring and maintenance after its closure in 2016.

The Gunnar site is expected to be licensed by the end of 2014. Remediation work will be performed over a period of three to five years; after its closure, the site will be licensed for monitoring and maintenance.

All these sites will remain under CNSC licensing until they are transferred to a province or territory as part of an institutional control regime. Several scientific studies have enabled us to assess the health consequences of historical practices and establish strict health and environmental protection regulations.

3 WHAT HAVE WE LEARNED FROM THE BEAVERLODGE AND PORT RADIUM COHORTS?

In 1994, an important combined study [3] of eleven large miner cohorts – including four from Canada (Beaverlodge, Port Radium and Ontario uranium miners, and Newfoundland fluorspar miners) – assessed the relationship between RDP exposure and lung cancer. The study (which also looked at miners from the United States, Sweden, Australia, the Czech Republic, France, Germany and China) revealed the following:

- There was an excess risk of lung cancer mortality attributed to RDP exposure.
- The increase in the lung cancer risk was linear and parallel to the increase in RDP exposure.
- Several modifying factors affected this risk. The risk of lung cancer mortality per unit of RDP exposure was inversely proportional to the time since exposure and to attained age, and was directly proportional to the exposure rate.

- Tobacco had an important impact on the relationship between RDPs and lung cancer risk; it increased this risk by having an effect between an additive and multiplicative effect.
- Lung cancer was the only established health effect of RDPs.

These findings form the basis of today's radiation protection programs for uranium miners. On the basis of this study, a model for assessing the risks associated with RDPs was adopted by the Biological Effects of Ionizing Radiation Committee (BEIR VI Committee) [4].

Recent updates of the French, German, Czech Republic, Colorado Plateau and Canadian (Newfoundland fluorspar and Beaverlodge and Port Radium uranium mines) miner studies [5-14] have increased the statistical power and precision of the risk estimates and largely support the BEIR VI RDP risk model [4].

4 PAST MINING ACTIVITIES ON THE PORT RADIUM SITE AND THEIR CONSEQUENCES

The mining activities at Port Radium in the Northwest Territories began when pitchblende (uranium), silver and cobalt ore were discovered in 1930. Underground mining to extract radium began in 1932, while uranium extraction took place from 1942 to 1960 (when the mine was closed). Silver mining at Echo Bay began in 1964 and ended in 1982.

The Deline Dene Band was long associated with the Port Radium mine activities and with the transporting of the ore and uranium concentrate from the mine.

In the early 1990s, the Northwest Territories Cancer Registry was put in place. This registry revealed that, in the late 1980s, 14 men in the Dene Band who had been associated with the Port Radium mining activities died of cancer, mainly lung, bone and throat cancer, which were then linked to radiation exposure. This observation generated much concern in the community.

The Deline Uranium Team (DUT) was formed to try to clarify how the Port Radium mine had affected on the Dene Band. In 1998, the DUT sent a delegation to Ottawa, asking the federal government to establish a study to clarify the local health and environmental effects of the mining activities in the Deline area from 1932 to 1960. A year later, the DUT agreed to work with the federal government, to carry out such a study.

SENES Consultants was hired to do a study to reconstruct the doses to which the Dene Band members had been exposed during this period.[15]

The Dene Band Chief and the Deline Band Council expressed great interest in the reconstruction of the doses to which the band members had been exposed. This covered workers who had transported uranium concentrate, those who had lived near the uranium mine or along the route used for the transportation of the concentrate, as well as those who had worked in the Echo Bay silver mine.

The initial objectives of the study were to:

- determine whether there was sufficient data to estimate reliably the doses to which those who had transported uranium concentrate had been exposed
- determine the possibility of estimating the doses to the other worker groups (i.e., the Dene Band members who had worked at the Echo Bay mine or had lived along the route used for the transportation of the uranium concentrate)

This feasibility study determined that it was possible to estimate the probable doses to those who had transported the uranium concentrate, while also taking into account the uncertainties related to such estimates. SENES Consultants produced preliminary exposure dose estimates for the Dene Band members who had transported uranium concentrate.

During the pilot dose reconstruction study, a large quantity of information from various sources was taken into account, including the historical reports on site activities, along with production reports, the data on the transportation system and oral information from Dene Band members and their families. This information shed light on the activities to which the band members at Port Radium and in the surrounding area participated.

The review of this information confirmed that the workers' exposure was limited to activities associated with the handling of the uranium concentrate along the route. Several exposure scenarios taking into account the information collected were considered.

Dose conversion factors developed for the various scenarios applied to the transportation of uranium concentrate from Port Radium were used in the dose reconstruction models, to estimate the potential doses to which the Dene Band transport workers had been exposed.

4.1 Pilot study results

The results of the pilot dose reconstruction study indicated that a Dene Band member who had been a transport worker could have been exposed to an average dose of 87 millisieverts (mSv) a year. For the reasons specified in the report, this dose must be considered the estimated upper dose limit.

The pilot dose reconstruction study also concluded that the doses for the other Dene Band groups who had lived and worked in this area could be estimated hypothetically but would, in any case, be distinctly lower.

4.2 Study results

Following discussion with the DUT, it was decided to assess the doses to which the Dene Band members who had transported uranium concentrate had been exposed, as well as the dose to which those who had lived along the route used to transport the concentrate had been exposed. The preparation of these assessments allowed for the gathering of further information from other sources (such as the Port Radium Fact Finder Report[16] prepared for Natural Resources Canada and the Deline Dene Band).

In general terms, the study concluded the following:

1. For the uranium concentrate transport workers:

- The highest annual exposure doses were estimated for the deck hands who travelled from Port Radium to Great Bear River during the 1930s and early 1940s. Although the quantities transported were larger in the 1950s (when larger boats and barges were used to haul the uranium concentrate), the lower uranium content of the concentrate and the use of cranes helped reduced the doses to which the deck hands and boat captains were exposed.
- The doses for all transportation activities were made up for the most part (≥80 %) of external gamma radiation. These individuals' annual exposure rate was estimated at 76 mSv.

2. For the Dene Band members living along the concentrate transportation route:

- The study estimated the doses to which the Dene Band members living along the concentrate transportation route were exposed. The estimated annual dose for a hypothetical person varied from 0.9 mSv for an adult to 5.5 mSv for a child between 5 and 10 years of age. For the most part (≥90 %), the doses came from external gamma radiation.

The International Commission on Radiological Protection (ICRP) estimated at 0.005% per millisievert the increase in cancer risk due to radiation [17]. The dose of 76 mSv to which the Dene Band uranium concentrate transport workers were exposed would contribute today to increasing the potential risk of death from cancer for Canadians from 25% to 25.38%; this value is much too small to explain the increase in deaths from cancer among the Dene Band in the late 1980s. The RDP exposure, which, according to SENES Consultants, accounted for 20% of this dose – i.e., 15 mSv (3 WLM)[1] – is much too small to explain an increase in lung cancer in the community. The exposure levels that were related to an increase in lung cancer among the miners who worked underground in the 1940s were approximately 2,000 mSv (400 WLM) [18]. For the people living along the concentrate transportation route, the RDP doses of 0.09 mSv for an adult and 0.55 mSv for a child are much too small to explain an observable increase the number of cancers.

Note also that the natural background radiation dose in the area is much higher than the Canadian average. It is approximately 3.1 mSv/year compared with 1.8 mSv/year [18] for the average Canadian. Again, according to the ICRP, the difference of 1.5 mSv/year can explain only a 0.0075% increase in the risk of death from cancer.

As indicated in the *Port Radium Fact Finder Report* [16], the Port Radium mine operated several decades before the health effects of radiation exposure were understood. Therefore, a number of miners and workers who handled the products from the mining may have been exposed to higher radiation doses than the current standards allow. The acts, regulations and standards that existed in Canada at that time to protect workers from radiation exposure were comparable to what was in place elsewhere in the world. It was not until the 2000s that the current Canadian exposure limits were adopted.

[1] The most common measurement of radon in mines is the working level (WL) or working level month (WLM). 1 WLM is equivalent to a 5 mSv dose.

5 CONCLUSION

The study of Lubin et al. [3] showed that there was an increased risk of death from lung cancer due to RDP exposure among the Port Radium and Beaverlodge underground uranium mine workers, and that this increase was directly proportional to the RDP exposure dose. Several modifying factors can also affect this risk. The risk of death from lung cancer per unit of RDP exposure decreases with time since exposure, age and exposure rate. The important role of tobacco in the relationship between RDPs and lung cancer risk must also be taken into account. As already stated, the use of tobacco among the miners exposed to the RDPs would increase the risk of lung cancer, through an effect ranging from additive to multiplicative. However, it was shown that lung cancer is the only established health effect for RDPs [5-14].

For the members of the Deline Dene Band who were associated with the Port Radium mine activities and the transportation of the ore and uranium concentrate extracted from the mine, the exposure doses (76 mSv, 80% of which was external gamma radiation) were much too small to explain the cancer deaths increase in the Dene Band in the late 1980s [15]. The same is true for RDP exposure, which accounted for approximately 20% of this dose (i.e., 15 mSv). This dose is much too small to explain an increase in lung cancer in the community. The RDP exposure doses that were related to an increase in lung cancer among miners who worked underground in the 1940s were 150 times larger – i.e., approximately 450 WLM or 2,250 mSv [19].

The behaviour and health effects of radioactive particles were poorly comprehended in the past. The level of understanding of the health effects of RDPs on miners working underground has greatly improved. The implementation of effective radiation protection programs, the existence of strict regulatory controls and the improvement of drilling practices have contributed greatly to significantly reducing radiation exposure for miners.

The general improvement in working conditions, dose control and exposure management are today helping to reduce worker exposure levels in modern mines to ALARA levels.

A 2003 feasibility study to which the CNSC contributed [20] revealed that it was not possible to demonstrate the risk of an increase in lung cancer among modern miners, given the current exposure levels. At low exposure levels – i.e., less than 0.05 WLM (0.25 mSv) in 2013 – no health effect can be anticipated. The study also showed that it was nearly impossible to correct the risk to take into account the effect of tobacco use and residential radon exposure. These factors had too large an impact on the results of such a study, meaning that the very low level of risk resulting from exposure at work would be masked [1].

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