ANALYSIS ON THE RADIATION EXPOSURE OF URANIUM TRANSPORTERS AT THE PORT RADII MINE

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ABSTRACT
This research paper describes how the handling of radioactive ore by indigenous transporters in Canada for the Manhattan Project of the United States in the early-mid 20th century has affected the health of the indigenous population of the time. These Sahtu Dene people resided in Déline, NWT, Canada and from the 1930s through 1940s were hired to carry cloth sacks of radioactive ore at Port Radium, NWT without appropriate personal protective equipment. This resulted in the spreading of radioactive contamination to the transporters as well as their families and community. In this report, we estimate the radiation exposure of a uranium ore transporter and analyzed the corresponding health effects. The objective of this investigation is to reconstruct the dosage received by Dene uranium transporters in the early-mid 20th century. Specifically, this research paper includes information on the uranium supply for the Manhattan Project, possible hazards from transporting radioactive material without proper protective equipment, and a quantitative estimation of radioactive exposure received by an average indigenous transporter. The information presented in this paper aims to provide readers with knowledge of nuclear history and indigenous health history related to this event.

Cet article de recherche décrit comment la manipulation du minerai radioactif par les transporteurs indigènes au Canada pour le Projet Manhattan des États-Unis au début du 20e siècle a affecté la santé de la population autochtone de l'époque. Ces personnes de Premières Nations, qui résidaient à Déline, dans les Territoires du Nord-Ouest au Canada, ont été embauchées entre les années 1930 et 1940 pour transporter des sacs en tissu de minerai radioactif à Port Radium, dans les Territoires du Nord-Ouest, sans équipement de protection approprié. Cela a entraîné la propagation de contaminants radioactifs aux transporteurs, ainsi qu'à leurs familles et à leurs communautés. Ce rapport fournit une estimation de la quantité de rayonnement auquel un transporteur moyen a été exposé et analyse ses effets sur la santé. Ces risques pour la santé prévus ont ensuite été comparés aux statistiques rapportées dans le rapport de la Commission canadienne de l'uranium de Déline. L'objectif de cette enquête est de comprendre l’impact de la manipulation du minerai radioactif au début du 20e siècle sur la santé de la population autochtone. Plus précisément, ce document de recherche comprend des informations sur l’approvisionnement en uranium du projet Manhattan, les risques possibles liés au transport de matières radioactives sans équipement de protection approprié et une estimation quantitative de l'exposition radioactive que le transporteur indigène moyen a reçue. L'information présentée dans cet article vise à fournir des connaissances sur l'histoire de la santé nucléaire et autochtone liée à cet événement.

KEY WORDS
Port Radium; Déline; uranium transporter; radiation exposure; Indigenous health.

INTRODUCTION
In the early 1930s, when long-term radiation health effects were yet to be fully understood by scientists, radium – a radioactive element formed naturally as a radioactive decay product from uranium was thought to be a cure for cancer (Simmons, 1999). The ore body near Great Bear Lake, NWT was one of the richest known deposits of uranium (Gray-Cosgrove, 2013). Even before nuclear fission was discovered and the value of uranium was understood, uranium was mined and refined in order to yield radium (Keeling et al., 2015). Déline, as the only inhabited community on the Great Bear Lake, became of significant value to uranium mining (Simmons, 1999). The inhabitants of Déline were hired to carry cloth sacks of radioactive
ore from Port Radium mine, NWT to shipping sites, where the ore would be delivered to southern Ontario to be refined (Simmons, 1999). These transporters of radioactive ore were neither warned of the inherent danger of their jobs, nor provided with personal protective equipment (Simmons, 1999). As a consequence, we expect these activities to have had a negative impact on the health of ore transporters as well as their families. Originally when the mine opened, ore was mined in Déline to yield radium for medical purposes; however, after the lethal application of uranium was discovered and tested in the early 1940s, Great Bear Lake uranium ore was refined and sent to the United States to create nuclear bombs (Henningson, 2005).

Researchers have since studied the radiation dosage and long-term health effects of uranium miners working in similar conditions; however, the working hours and tasks of radioactive ore transporters are different from that of the miners, yet the chronic health effects of ore transporters have not been analyzed. Compared to miners, transporters are in closer contact with large quantities of radioactive ore more regularly. Moreover, some transporters such as ship crews are required to share living spaces with radiation contamination – which could result in them having high exposure to radiation through the absorption and inhalation of fine ore dusts.

Since uranium ore is radioactive and is hazardous to the human body, it is crucial to understand its impact on the health of indigenous people of Déline. Specifically, it is important to quantify the radiation dosage that was received by an average Dene transporter and to understand the possible radiation-related health concerns that they faced.

**Knowledge of Hazards**

In 1942, U.S. scientist Wihelm Hueper predicted an epidemic of lung cancer among miners at Port Radium unless better protection is provided (Henningson, 2005). In 1945, U.S. Government officials confirmed the validity of the health concern (Henningson, 2005). However, even after the first Port Radium miner died of cancer in 1953, Canadian government still declared uranium mining safe in 1958 (Henningson, 2005). Until 2005, there was no evidence that the transporters were informed about the potential hazards of the products they were handling (Canada-Déline Uranium Table, 2006).

Not providing the workers with insights regarding the effects of radiation makes their work more dangerous. Due to the lack of knowledge, the transporters could not avoid wearing contaminated outfits back home, thus exposing their families to radiation; neither could they avoid eating food that was contaminated with radioactive material, thus ingesting sources of radiation-emitters. All these factors contribute to increased radiation dosage for transporter at Port Radium.

**MATERIALS AND METHODS**

Radiation dose received by Dene transporters is divided into three categories based on method of which it was received: namely inhalation, ingestion, and absorption; effects on the health of the transporters from each category are analyzed. Whereas, the dosage from each category is then quantified in the results section.

**Inhalation**

Inhalation of radioactive dust and alpha emitter (i.e., radon gas) would have contributed to radiation sickness in indigenous miners who were not aware of radiation hazards when handling uranium ore. Ionizing radiation is emitted when radiation sources enters human body; whereas, radiation creates many orders of magnitudes more damage when the source is inside human organ (Bertell, 1985). For example, radon does not affect health when it is present outside of human body, however, when inhaled, can cause an increased risk of lung cancer.
Ingestion

A significant amount of radiation dosage is accumulated through ingestion. As most uranium transporters did not have a specific set of clothing that they wear strictly for work, they contaminate their food with radioactive particles brought back from work. According to the United States Environmental Protection Agency, the toxic nature of uranium metal contributes to kidney damage and cancer more than the radioactivity of uranium (United States Environmental Protection Agency, 1992).

Absorption

Although alpha particles could be absorbed through open wounds and beta particles could penetrate human tissues, the major health concern is absorbing extreme high energy ionizing gamma rays emitted by radioactive ore during the decaying process.

In 1930s and 1940s, large amounts of uranium ore were carried from Déline to the shipping site on a regular basis, using a single route. Year after year, the amount of radioactive materials which leaked through the cloth sacks or were left along the route built up (Simmons, 1999). When the mine closed down, an estimated 1.7 million tons of radioactive tailing were left behind (Tilman, 2009). These improperly treated radioactive wastes added to the background dose and continue to be a hazard for the uranium transporters, their families, and their descendants.

RESULTS

In order to provide a quantitative estimation of the radiation dosage an average indigenous transporter would receive, we quantify the contribution from each of the three aforementioned categories. By summing up the individual dosages, we could compute the average per annum radiation dosage received.

Calculations

Since the indigenous uranium transporters come into close contact with radioactive ore every day, it is estimated that their external radiation dose is similar to workers in some East German mines during the time period, since the working conditions protective equipment in Germany at the time were similar to that of Canada (Enderle et al, 1995).

The mean exposure for workers in some East German mines from 1946 to 1954 was 750 mSv/a (World Nuclear Association, 2014).

Additionally, uranium transporters would receive dosage from inhalation of radioactive particles at a level similar to that of a worker at a uranium mill: where the concentration of radioactive uranium dust is high in spite of the well ventilated conditions.

An average worker at uranium mill receives 6.3 mSv of radiation per annum with protective gear, in which inhalation of radon gas represents 37% of the total dose and inhalation of concentrated uranium gas represents 47% of the total radiation received (Diehl, 2010). Thus we can get the dosage received by an average uranium transporter from inhalation:

\[6.3 \text{ mSv/a} \times (37\% + 47\%) = 5.29 \text{ mSv/a}\]

Radiation received by workers without protective equipment is 100’s of times greater than modern workers (Chambers et al, 2013). Thus, we multiply the dose by a factor of 100:

\[5.29 \text{ mSv/a} \times 100 = 529 \text{ mSv/a}\]

The amount of uranium ingested is calculated with respect to the amount of uranium a person came into contact with – this is based on the assumption that the amount of uranium one ingests grows proportionally and linearly with the amount of uranium the one comes into contact with.

In an average adult weighing 70kg, 2.3Bq of radioactivity originates from uranium within the body, even when they only come into contact with a few grams of uranium per day (Canadian Nuclear Safety Commission, 2015).

Contact with 20 bags of uranium ore (roughly 1 ton) per day will result a radiation of:

\[2.3 \text{ Bq/g} \times 1000000 \text{ g/ton} \times 365 \text{ days/a} = 840 \text{ MBq/a}\]

With an effective dose coefficient (for U-235 with f1 of 0.002) of ingestion of 8.3×10^{-9}, yield a dose of:

\[840 \text{ MBq/a} \times 8.3 \times 10^{-9} = 101 \text{ mSv/a}\]
The amount of radiation received through background radiation could be modeled through a growth function during the time when the uranium was produced, since the amount of radiation contained per unit volume of air or unit area of land increases with time; on the other hand, when the mine closed and uranium production stopped, the amount of background radiation could be modeled with a decay function. The WISE Uranium Project Uranium Radiation Individual Dose Calculator provided an estimation of 172 mSv/a for the following parameters (Diehl et al, 2010):

1.7 million tons (radioactive wastes left behind) of 10% grade uranium ore (approximate ore grade) with the exposed person 2 kilometers (distance across the mine) away for 2000 hours a year (working full-time), using dose coefficient of 700 mSv/Gy.

Summing up all the radiation doses by category to get the total estimated amount of per annum radiation dosage received by an average Dené uranium transporter working at Port Radium mine in the 1930s through 1940s:

750 mSv/a + 529 mSv/a + 101 mSv/a + 172 mSv/a = 1600 mSv/a

DISCUSSION

Even though cancer is the predominant health concern in Déline, sources still cannot reach a consensus about the effect of radiation on Dene workers. CDUT found that “the overall cancer rates for Déline are not statistically significantly different from the Northwest Territories” (Canada-Déline Uranium Table, 2006). Dr. David Bates, an environmental health analyst and chair of British Columbia’s royal commission on uranium in 1980, believes “[the radiation] might be comparable to taking a chest X-ray every week for a year with an old machine”; others claim blood tests conducted in 1930s revealed that “the blood counts of these men [Dené workers] had been altered”, and the Canadian Government was “well aware of the lethal properties of uranium” (Nikiforuk, 1998; Leghari, 2015).

This report quantified the dosage received by an average transporter to be three orders of magnitudes higher than that of a regular person. To put in perspective, the current averaged limit for nuclear industry employees and uranium miners is 20 mSv/a; the long-term safe level of exposure for public after a radiological incident is 130 mSv/a; the highest recorded level of natural background radiation is 800 mSv/a (World Nuclear Association, 2016). Also, a dose above 500 mSv causes some changes in blood cells; but the blood circulatory system will quickly recover. A dose above 1000 mSv received in a short time or over many years will increase the chances of getting cancer and cause symptoms of radiation sickness (Idaho State University).

On Canadian Broadcasting Corporation News, Dr. Douglas Chambers, a radioactivity expert, compared the risk of cancer associated with carrying uranium ore to that of smoking (CBC News, 2005). A radiation dose of 0.1 mSv increases an average adult’s risk of death by the same amount as that of 1.4 cigarettes (Post, 2011). From the aforementioned ratio, it could be determined that the risk of death associated with a dose of 1600 mSv is equivalent to that of 22400 cigarettes – averaging roughly 3 packs a day:

1600 mSv × 1.4 cigarettes/0.1 mSv = 22400 cigarettes

After CDUT published their report, the Government of Canada initiated the Port Radium Remediation Project in 2007 in attempt to make the site safer for people, animals, and the environment (Contaminants & Remediation Directorate, 2009). The project demolished old structures, covered mine openings, and removed scrap metal; however, contaminated materials and radioactive tailings were untouched, since they were considered “stable” and “contained” (Contaminants & Remediation Directorate, 2009). When the project was in progress, roughly a half-century after the mine closed, the radiation level at the mine site was only safe for humans to visit for up to three months per year (Contaminants & Remediation Directorate, 2009).

Not only was the Dene uranium transporters’ physical health compromised by radiation exposure, their mental health was also affected: after the nuclear workers has learned the purpose of the uranium they extracted and realized their contribution to the war
efforts, they were overwhelmed by guilt and many suffered from depression (Canada-Déline Uranium Table, 2006). In 1998, a Dené delegation went to Japan to formally apologize to the bomb survivors for contributing to the development of nuclear bombs that took away many lives in Japan (Henningson, 2005).

CONCLUSION

This paper has briefly explained the background of the Port Radium mine as well as the involvement of indigenous population that resided in Déline. The working conditions of Dené workers as well as risks and hazards associated with transporting radioactive ore have been investigated. Estimations and calculations were performed to quantify the radiation exposure received by an average uranium transporter, and the number was then compared with that reported by CDUT. It was found that the radiation received by uranium transporters is three orders of magnitudes high than that of a regular person, which increases the risk of death in equivalence to that of 22400 cigarettes. The impact to the indigenous transporters and the effects on their health was understood in terms of radiation exposure amount.

It is believed that quantifying the radiation exposure and its associated health effects of these indigenous nuclear workers is of significant importance. Therefore, work presented in this paper is only viewed as the beginning of a large project. Further work should thoroughly understand the working conditions and mental health conditions of the uranium transporters through oral history. It is also measure the current background radiation levels at Déline in order to learn the long term effects done to the community and the environment. Lastly, it should quantify the radiation exposure to the immediate family members of the Indigenous nuclear workers through estimations and measurements.

ABBREVIATIONS

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<td>a</td>
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<td>NWT</td>
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<td>CDUT</td>
<td>Canadian-Déline Uranium Table</td>
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<td>NTCL</td>
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<td>mSv</td>
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REFERENCES


