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30 April 2002

NIOCAN Inc.
2000 Peel Street, Suite 560
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VIA Email:
c/o rfournier@jeffreymine.com

Attention: **Mr. Richard R. Faucher**
President & CEO

RE: **Expert Advice Concerning Radiological Aspects of Proposed Niocan Project at Oka, Quebec**

Dear Mr. Faucher:

Further to our discussions, I have prepared expert opinions concerning several radiological issues for which some clarification may be helpful. Brief commentaries are provided in the following papers:

Appendix A:	Coefficient of Radioactivity
Appendix B:	Radon Context
Appendix C :	Radon : Occurrence & Risk
Appendix D :	Water Quality
Appendix E	Naturally Occurring Radioactivity in Agriculture

Overall, my opinion is that any potential impact that the proposed Niocan project might have on the environment would be very small; not distinguishable from variability in natural background radiation levels; and of no consequence.

I, base my opinion on more than twenty-five years of experience in this area as briefly outlined in the attached profile and documented in my curriculum vitae which has been send to you under separate cover.

I would be pleased to try to answer any questions you may have. I appreciate the opportunity to work in this very interesting project.

Yours very truly,

SENES Consultants Limited

DB Chambers

Douglas B. Chambers, Ph.D.
Principal, Director of Risk and Radioactivity Studies

/attch.

PROFILE - Douglas B. Chambers, Ph.D.

Dr. Douglas Chambers was born in Kingston, Ontario and raised in Owen Sound, Ontario. He received his B.Sc. (Physics) from the University of Waterloo in 1968 and his Ph.D. (Physics) from McMaster University in 1973.

Dr. Chambers has been working in the area of environmental radioactivity and risk assessment for more than 25 years and has studied both radioactive and non-radioactive substances. Dr. Chambers has worked on projects across Canada, throughout the United States and overseas.

In 1980, he and colleagues founded SENES Consultants Limited, in which he holds the position of Vice-President and Director of Radioactivity and Risk Studies. In 1990, SENES Oak Ridge Center for Risk Analysis was formed. Dr Chambers current interests include the methods and applications of risk assessment, uncertainty analysis (including the role of exposure uncertainty in epidemiology), risk management and risk communication.

Among other activities, Dr. Chambers was instrumental in the development of probabilistic tools of pathways analysis and risk assessment for uranium mill tailings. He has directed or carried out evaluations of all stages of the nuclear fuel cycle, including uranium mill tailings, uranium refining and conversion, nuclear power reactors and the McMaster University research reactor. Dr. Chambers has also carried out numerous studies on radioactive wastes including: uranium mining wastes, low level fuel cycle wastes and "historic" wastes in Port Hope Ontario, Chicago Illinois, eastern Germany and elsewhere.

In addition, Dr. Chambers has directed out many studies related to air dispersion and air quality including, for example, the development of a meteorological emission control system for a large thermal generating station, a detailed model for the transport of carbon-14, and the development and application of models for assessing the dispersion of denser-than-air gases from accidental releases of anhydrous hydrogen fluoride, anhydrous ammonia, chlorine, hydrogen, liquid natural gas (LNG) and uranium hexafluoride (UF_6).

Examples of recent work include assisting the Federal German Environment Ministry (BMU) and the State of Thüringen with the decommissioning of former uranium mining and processing facilities, licensing of remedial actions of a former uranium mill at Moab Utah, the re-evaluation of radon progeny exposures to underground miners, the development of a regulatory guide for UF_6 dispersion models for the U.S. Nuclear Regulatory Commission, evaluating the effects of uncertainty in exposure on the derivation of dose-response relations from epidemiological data, the development of metrics for risk comparisons, and the evaluation of risks to non-human biota.

Dr. Chambers is a member of numerous professional societies and was a founding member of the Canadian Radiation Protection Association. He became a member of the Canadian Standards Association (CSA) Committee on Environmental Radiation Protection in 1978, and subsequently was chairman to 1989. He is also a member of other CSA committees on Risk Analysis. Dr. Chambers was a member of the U.S. National Council on Radiological Protection and Measurements Scientific Committee 85 on the Risk of Lung Cancer from Radon, and has participated on a committee of the Science Advisory Board of the US Environmental Protection Agency concerning radon research initiatives. He was first appointed to the Canada's Atomic Energy Control Board's (former) Advisory Committee on Radiological Protection (ACRP) in 1993 and was vice-chairman in 2001. Dr. Chambers has participated on the UNSCEAR Committee since 1998 as a member of the Canadian delegation. Dr Chambers is currently a consultant to UNSCEAR with responsibility for preparing the next UNSCEAR assessment of radon. Dr. Chambers was the recipient of the 1997 W.B. Lewis award of the Canadian Nuclear Society for his achievements in environmental radioactivity. In February 2002, Dr Chambers was the Morgan lecturer for the healthy Physics mid-year symposium in Orlando.

April 2002

APPENDIX A

COEFFICIENT OF RADIOACTIVITY

There has been much discussion concerning the definition of “hazardous” radioactive materials on the Niocan and former St. Lawrences Columbium (SLC) sites, and the use of the “Coefficient of Radioactivity” for this purpose. The discussion below presents some perspective on this issue to show that the use of the limits in the Quebec Regulation Respecting Hazardous Materials (QHRM) (Quebec 1997) is extremely conservative when defining the hazard potential of radioactive materials.

The Regulation (Quebec 1997) defines what is considered to be “hazardous material”. A material is hazardous “radioactive material” if the concentration (C) of any radionuclide in the material in kilobecquerels per kilogram (kBq/kg) exceeds the maximum activity levels (A) for that radionuclide. The material is also defined as hazardous if the sum of the C/A ratios for all radionuclides in the material (the “coefficient of radioactivity” as used in the Roche report) exceeds “1”. Based on the limits in the Regulation, waste materials containing more than 37 ppm (parts per million, or mg/kg) of natural uranium or more than 352 ppm of natural thorium have coefficients of radioactivity greater than 1 and are defined as radioactive hazardous materials by the Regulation.

According to the limits in the Regulation, the slag from the proposed Niocan facility would have a coefficient of radioactivity greater than 1 (as does the slag from the previous SLC operations). (Based on data I have seen, the coefficients for the Niocan ore and tailings do not exceed 1.) However, the Regulation on hazardous materials does not apply to slag, waste rock and mine tailings which are considered as mine residues, irrespective of its radioactivity content. Despite this, it is still informative to look at the basis for the Quebec Regulation.

Although not indicated in the QRHM, the radionuclide limits are the same as those in the previous Quebec Hazardous Waste Regulation (1985), but converted to metric units. The 1985 Quebec regulation adopted the “scheduled quantities” per kilogram specified in the Atomic Energy Control Regulations of Canada (AECR). The AECR, which were promulgated under the authority of the Atomic Energy Control Board (AECB) of Canada, have now been superseded. Under the most recent regulations, the AECB has changed its name to the Canadian Nuclear Safety Commission (CNSC). The most recent CNSC regulations have different limits (for licensing of radioactive sources) and no longer refer to these “scheduled quantities” per kilogram.

It is important to understand that the original purpose of the scheduled quantities was to determine the need for the licensing of small, discrete radioisotope sources, such as used in medicine or research. They were meant to be a starting point above which a licence would be required for possession. They were <u>not</u> meant as a classification method for determining if large volumes of a specific waste or material were hazardous or not. Thus,

the use of these same limits in the QRHM is not as originally intended. Perspective on how conservative (i.e. low) the QRHM limits are can be illustrated by the following examples.

Under the QRHM, phosphate fertilizers, such as triple superphosphate (TSP), which are used to grow food for human consumption, would be classified as radioactive hazardous materials. It is difficult to understand how such radioactive materials, which are freely distributed on farmers' fields, should be considered "hazardous" if they were wastes instead of fertilizers.

As another example, the recent Canadian Guidelines on the Management of NORM (Health Canada (Santé Canada), 2000) gives limits for material that can be distributed in the environment without restrictions. For natural uranium, the limit is equivalent to 24 ppm. Again, it is difficult to understand how materials containing 24 ppm of uranium could have placed in the environment with no restrictions or controls according to the NORM Guidelines, but materials containing only 37 ppm of uranium are classified as "hazardous" under the QRHM. It should be noted that Quebec or other provinces have not formally adopted the NORM Guidelines as regulations. However, the Ministry of Environment of Quebec has indicated that they would use the Guidelines as a reference when dealing with NORM (personal communication with SENES Consultants Limited, February 2002).

As a final example, a worker could stand for a full year (2000 h) directly on materials classified as "hazardous" by the QRHM without exceeding radiation limits for workers or for members of the public. A worker could also inhale or ingest such material without receiving a radiation dose above the limit considered safe for members of the public. Why should such material be classified as "hazardous"?

In summary, the radioactivity limits in the Quebec Regulation respecting hazardous materials are extremely conservative for bulk quantities of radioactive material, such as mine residues, and are not appropriate indicators of the potential radiological hazard of such materials.

Relevance to Niocan Project

The QRHM does not apply to the Niocan Project. However, if it were applied, the mine ore and residues would have a radioactivity coefficient < 1. The slag (scorie) would have a coefficient > 1. The Niocan Project includes improvement to the Saint Lawrence Columbium (SLC) site. Part of the Niocan Project is to place the SLC slag underground along with the slag which will be produced by Niocan. The slag will be encased cemented backfill as part of Niocan's mining plan. The slag will thus be isolated from the environment.

Overall, I am of the opinion that the QRHM is not applicable to the Niocan Project, and placing the slag from SLC and Niocan underground as proposed is environmentally safe and is the preferred management approach.

References:

Health Canada 2000. *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM).* Prepared by the Canadian NORM Working Group of the Federal Provincial Territorial Radiation Protection Committee, First Edition, October.

Santé Canada 2000. *Lignes directrices canadiennes pour la gestion des matières radioactives naturelles (MRN). Rédigées par le Groupe de travail canadien sur les MRN du Comité de radioprotection fédéral-provincial-territorial, Première édition, Octobre.*

Quebec 1985. *Hazardous Waste Regulation.* Environment Quality Act, O.C. 1000-85.

Quebec 1997. *Regulation Respecting Hazardous Materials.* Environment Quality Act, O.C. 1310-97.

APPENDIX B

RADON CONTEXT

Niocan plans to mine a niobium deposit in the Municipality of Oka Quebec. Niocan plans to mine 2500 tonnes of ore per day. Niocan estimates that the ore contains niobium pentoxide at 0.614%, uranium at 19 ppm and thorium at 160 ppm. Both uranium and thorium are naturally occurring radionuclides that are found in all soils and rocks in variable concentrations which depend on the mineralogy and geology of the local area.

The niobium ore will be mined underground, which will minimize the surface disturbance. During processing to concentrate niobium through a flotation process, about 25% of the radioactivity goes with the tailings and about 75% remains with the product stream. Subsequently, during thermal processing of the concentrate to produce ferro-niobium, the radioactivity in the concentrate becomes part of the waste slag (scorie) from this process.

The tailings from the concentration process will contain uranium and thorium at about 10 ppm and 40 ppm respectively. The radioactivity is concentrated in the slag by about a factor of 80 [i.e. 75 % of the radioactivity is transferred to about 1% of the initial mass of the ore.]

There has been much discussion of how much radon would be added to the atmosphere through the mine ventilation shaft by the Niocan project. This subject is the focus of this Attachment.

How Much Radon would the Niocan Project add to the Existing Environment?

There are three major sources of radon associated with the mining and processing of the niobium ore. They are the radon, which is trapped in the pore space of the ore and released to the mine environment as the ore is mined; the radon coming into the mine with minewater; and radon from exposed surfaces in the mine.

- Based on an ore production of 2500 tpd, a uranium-238 [series] content of 0.23 Bq/g and assuming the widespread convention that about 20% of the radon produced within a rock or soil matrix is released to the pore space, I estimate that this source contributes about 1.3×10^3 Bq/s of radon to mine air.
- Assuming a minewater inflow of 2500 m^3/day, that the radon in the pore space is dissolved in the minewater and that the radon in the minewater is released to the mine air as the minewater enters the mine, I estimate that this source contributes about 8.0×10^4 Bq/s to mine air.
- Finally, I estimate, based on the assumption that radon will be released at the rate of 1 Bq/m^2s per Bq/g of radium-226 and assuming the surface area of mine openings is about 100,000 m^2, I estimate a further radon contribution of about 2.3×10^4 Bq/s to mine air.

Thus, I estimate a total radon release of about 1 x 10^5 Bq/s to mine air which would be removed to the surface via the mine shaft. This can be compared to the radon, which has always been released from the local environment. Based on data from the Geological Survey of Canada, the average uranium content of the soils within the carbonatite intrusion is about 5.3 ppm. Using the same unit release rate for radon per unit radium in the soil, I estimate the day in and day out the average radon release from the area within the carbonatite intrusion (about 1317 hectares as shown in Figure 1) is about 8 x 10^5 Bq/s or about 8 times the incremental contribution from the Niocan project.

Other potential radon sources are inconsequential. The tailings will contain about 10 ppm uranium which is within the range of background for the carbonatite and therefore, there is no possibility of incremental radon from this source. The radon released from 10 ha of Niocan tailings would be less than 1/60th of the radon released from the carbonatite. Moreover, radon from the 20 ha of SLC tailings release about 1/10th of the radon released from the carbonatite. Second, while the uranium content of the scorie is elevated, there is strong evidence that radon is not released from this material in appreciable quantities. Moreover, the scorie from Niocan along with the scorie from the SLC site will be placed underground in worked out portions of the Niocan mine and encased in the concrete backfill, thus isolating these materials from the environment.

How Much Will the Niocan Project increase Exposure to Radon?

In order to estimate the potential contribution of the radon from the Niocan project to ambient air, I have used an atmospheric dispersion model to assess how the radon released from the upcast of the Niocan mine will disperse in the environment. In order to do this calculation, I have used meteorological data from the Dorval Airport and the ISC3 atmospheric dispersion model. The ISC3 atmospheric dispersion model is widely used by the U.S. EPA and others to perform these kinds of calculations (*"User's Guide for the Industrial Source Complex (ISC3) Dispersion Models – Volume I – User Instructions"*, EPA-454/B-95-0030, September 1995). The wind patterns for the Dorval airport are shown on Figure 2. The results of the air dispersion calculations are shown in Figure 3 for two directions, which bound the predicted ambient radon concentrations. Since the point of release is elevated about 40 m above grade, the maximum concentration occurs downwind.

In considering the results shown on Figure 3, it is important to note that the predicted incremental concentration of radon in the ambient environment is well within the variation in natural background levels which in my opinion is most likely to be in the range of 10 to 30 Bq/m^3 (or higher). To illustrate this, I have plotted the predicted incremental radon contribution from Niocan on top of natural background. It is clear that the Niocan contribution is very small, well within natural variation, and of no consequence.

Relevance to Niocan Project

Overall, I conclude on the basis of my analysis that the incremental release of radon from the NIOCAN project and the consequent incremental ambient radon levels will be very small, well within normal variation, and of no consequence.

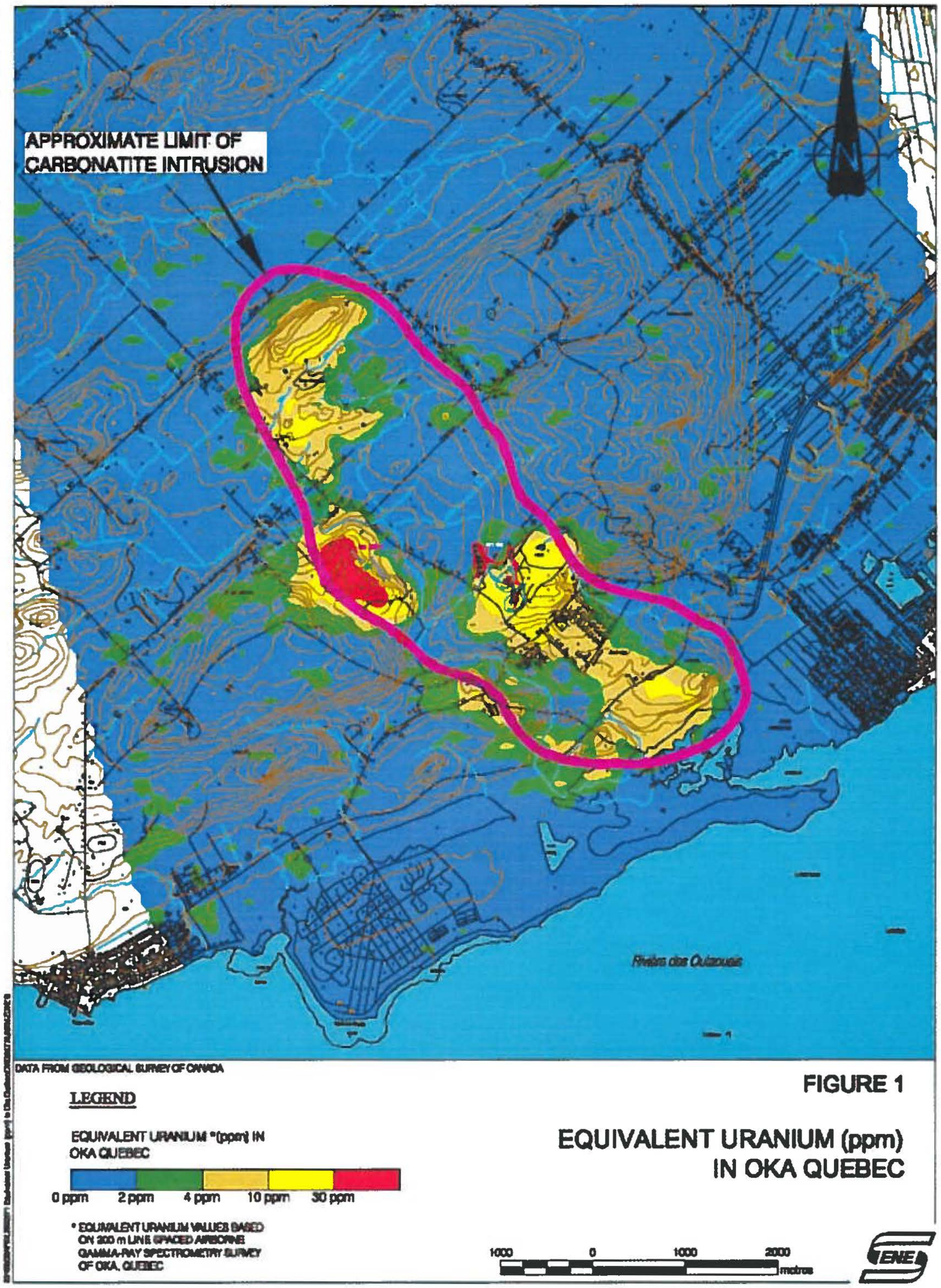
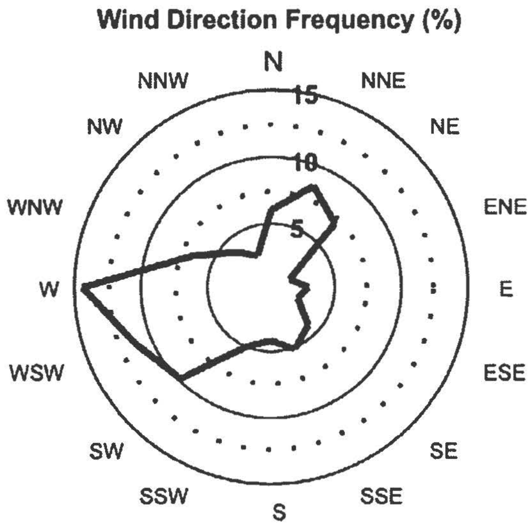


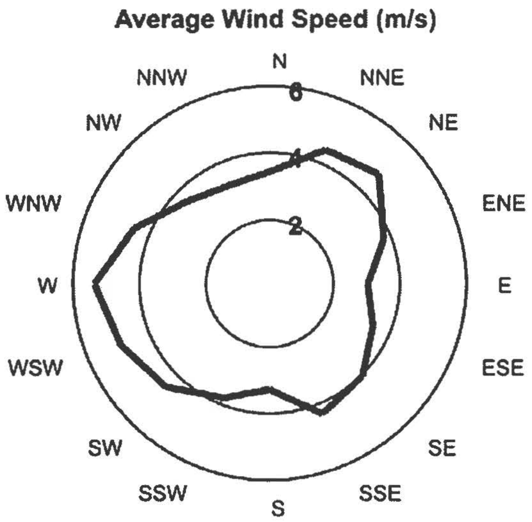
FIGURE 1

EQUIVALENT URANIUM (ppm) IN OKA QUEBEC

FIGURE 2

ANNUAL WIND ROSE
FOR MONTREAL - DORVAL INTERNATIONAL AIRPORT, 1997-2001



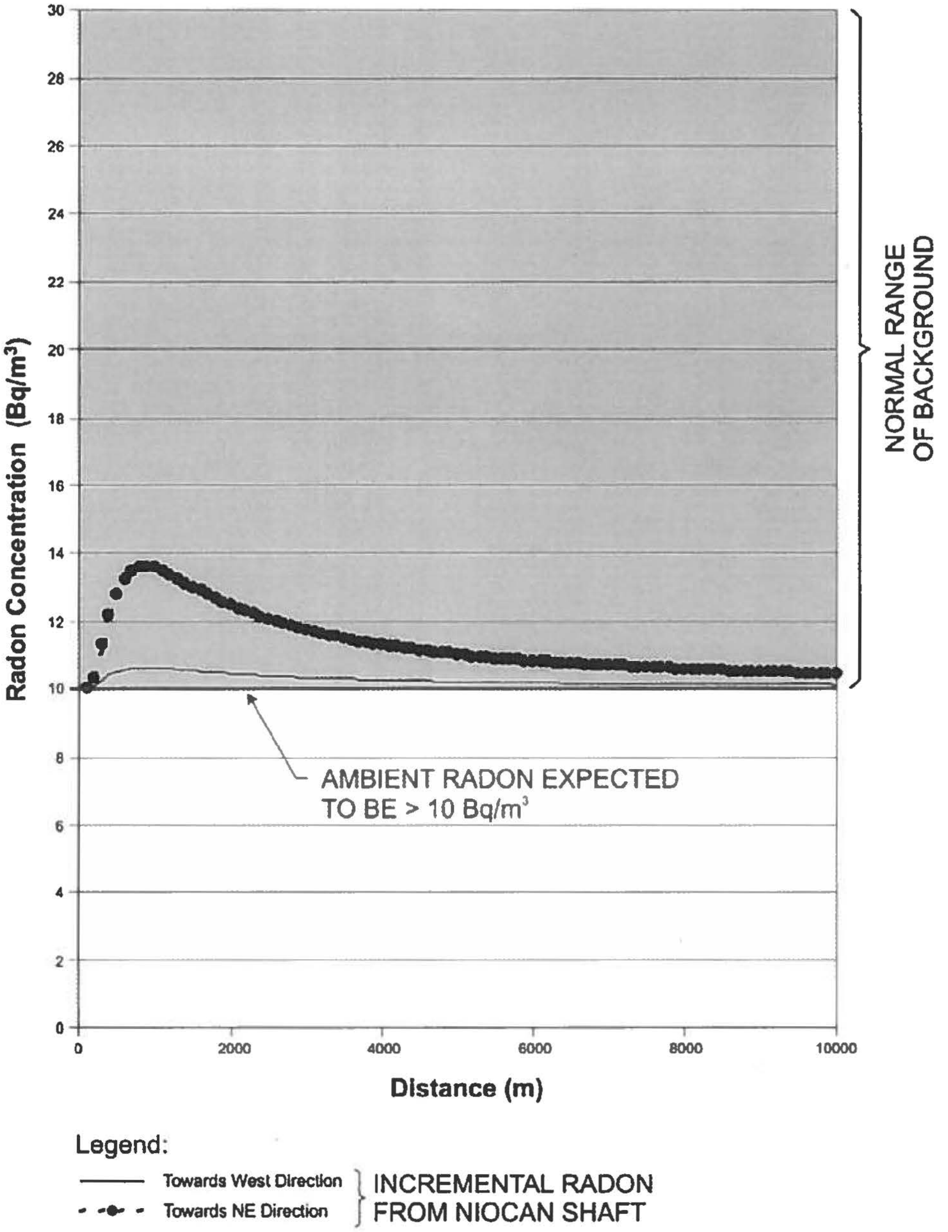


NOTE:

1. WIND SPEED MEASURED IN m/s
2. CALM WINDS MEASURED AT 3.36 %
3. FREQUENCIES FROM WHICH WIND IS BLOWING

FIGURE 3

RADON CONCENTRATIONS FROM NIOCAN SHAFT FOR A RADON EMISSION OF 100,000 Bq/s



APPENDIX C

RADON: OCCURRENCE AND RISKS

What are the natural levels of Radon in the Environment?

Radon-222, an inert radioactive gas, is usually simply referred to as radon. Radon is a natural component of the earth's atmosphere and is naturally present both outdoors and indoors. Radon arises from the radioactive decay of radium-226 which is in the radioactive decay chain of naturally occurring uranium –238 (uranium). Uranium occurs in varying levels in all rocks and soils. Since some fraction of the radon that is produced in the rocks and soils escapes to the air, radon is present everywhere.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports that the <u>outdoor</u> levels of radon vary widely from about 1 to more than 100 Bq/m^3 "with the former perhaps more typical of isolated small sites or coastal regions and the latter typical of sites with high radon exhalation over large areas." (UNSCEAR 2000, para 121) The United States Environmental Protection Agency (U.S. EPA) has carried out a national survey of ambient radon levels in the United States (Hopper et al 1991). Theses authors report an average outdoor level of about 15 Bq/m^3 with values ranging upwards to well over 30 Bq/m^3. A 1994 paper reports a range of outdoor radon data for Canada with levels as high as 103 Bq/m^3 (Grasty et al 1994). Average levels reported for Quebec in the same paper ranged between 12 to 17 Bq/m^3 in the summer of 1990, generally comparable to the mean values for the U.S. The ambient outdoor radon levels are seen to vary widely and depend on various factors, among them, the uranium (and radium-226) content of the soil, the soil type and the soil moisture content. Overall, it seems reasonable to assume that ambient outdoor levels in the Oka region of Quebec are likely to be in the range of perhaps 10 to 30 Bq/m^3, and perhaps higher since levels of radon in the air tend to reflect the level of radium-226 (from the uranium-238 decay chain) in the local soils (NRCan 2002).

<u>Indoors</u>, the radon levels are determined largely by the radon coming into the home from the soil underlying the home. Indoor radon levels are determined by factors such as the concentration of radium-226 in the underlying soil, the soil type, (e.g. sand or clay) the method of heating the home, and the habits of people who live in the homes. The indoor radon levels are typically higher than those outdoors and in the order of 40 Bq/m^3 or so. Indoor radon levels are even more variable than outdoor levels. Data from studies of homes in the United States shows that indoor radon levels can range from a few Bq/m^3 to more than 100 Bq/m^3 (Marcinowski et al 1994). In addition, radon levels can vary greatly from home to home, even for homes that are on adjoining properties. Levesque et al. (1997) also indicate the difficulty in predicting radon levels in individual homes. The large home to home variability is clearly illustrated in data provided by Natural Resources Canada for Oka Quebec (NRCan 2002).

What are the Potential Health Risks from Breathing Radon?

For many years, radon has been known to present a risk of lung cancer to underground miners, especially uranium miners, who were exposed to high levels in the past. Epidemiological studies of miners continues to provide the main basis for estimating the potential risks to people exposed to high levels of radon. An increased lifetime risk of lung cancer is the only health effect demonstrated in underground miners due to exposure to radon and its decay products (NAS 1999). Studies of miners exposed to radon are continuing today. However, in addition, the potential risks to people living in homes with high radon levels indoors is of considerable interest to both scientists and regulators in many countries and various investigations of residential risk to radon have been carried out or are currently underway (Lubin et al. 1997). The UNSCEAR 2000 report describes many of these studies and is a comprehensive source of information on both the levels of radon in the environment and the potential risks to people breathing radon are its short-lived decay products.

Miners exposed to high concentrations of radon and its decay products show a continued reduction of risk with time since last exposure once their occupational exposure ceases. For example, the BEIR VI (NAS 1999) committee risk model provides for a decline in risk with increasing time since exposure; which in the exposure, age duration would has a time since exposure factor of 1 for 5 to 14 years after the exposure, 0.72 for the 15 to 24 years after the exposure and a factor of 0.44 for more than 25 years after the exposure (NRS 1999).

There are many factors, such as smoking (the largest cause of lung cancer), which influence the risk of lung cancer and it is not clear that even large-scale, well-designed epidemiological studies will be able to determine precisely the lung cancer risk from radon exposure in homes (Lubin et al. 1997). Therefore, as noted previously, for the foreseeable future, the lung cancer risk to members of the public due to indoor radon will be estimated based on the miner studies.

The differences between indoor and mine exposure conditions have been studied. The authors of BEIR VI (NAS 1999) concluded that the radiation dose to the lung for a given radon decay product exposure is about the same regardless of whether the exposure is in the home or a mine. They also concluded that childhood exposure does not result in a higher risk during later years then does exposure as an adult. Since the lung cancer risk is believed to be proportional to the dose, the risks to members of the public can be estimated based on the risk to miners. However, the U.S. National Academy of Sciences in its BEIR VI Report (NAS 1999) has acknowledged that there may be a level of exposure below which radon does not cause any effect.

A study of lung cancer risk from indoor radon measured in a representative sample of homes in the Province of Quebec, concluded that radon-induced lung cancer risks, are generally of relatively minor importance in Quebec. (Ayotte et al 1998). These authors also argue that from a public health perspective, that most efforts should focus on smoking reduction rather than on reducing naturally occurring radon.

In the Oka area, a study in 1995 – 1996 showed that a higher than expected proportion of houses exceeded Health Canada's guideline value of 800 Bq/m^3. Subsequently, a detailed airborne gamma-ray spectrometry survey was carried out for the Geological Survey of Canada and the DRSP to further assess the risk of residential radon and to accurately define the geographic extent of high-risk areas (NRCan 2002). This analysis showed strong associations between increasing naturally occurring uranium concentrations in soil and the percentage of homes with increasing radon concentrations.

Relevance to Niocan Project

Overall, potential radon releases from the NIOCAN Project are of no significance in this regard as they are both small and indistinguishable from natural background levels.

References:

Ayotte, P., B. Levesque, D. Gauvin, R.G. McGregor, R. Martel, S. Gingras, W.B. walker and E. G. Letourneau 1998. *Indoor Exposure to ^{222}Rn: A Public Health Perspective.* Health Physics Society, 75(3):297-302.

Levesque, B., D. Gauvin, R. G. McGregor, R. Martel, S. Gingras, A. Dontigny, W.B Walker, P. Lajoie, and E. Letourneau 1997. *Radon in Residences: Influences of Geological and Housing Characteristics.* Health Physics 72(6):907-914.

Grasty, R.L. 1994. *Summer Outdoor Radon Variations in Canada and Their Relation to Soil Moisture.* Health Physics 66(2):185-193.

Hopper, R. D., R.A. Levy, R. C. Rankin and M.A. Boyd. 1991. *National Ambient Outdoor Radon Study.* (U.S. Environmental Protection Agency), in proceedings of the International Symposium on Radon at Radon Protection, Philadelphia, P.A. April 1991.

Lubin, J. H. And J. D. Boice. 1997. *Lung cancer risk from residential radon, metal-analysis of eight epidemiologic studies.* J. Nat. Cancer Inst. 89:49-57.

Marcinowski, R. et. Al. 1994. *National and Regional Distributions of Airborne Radon Concentrations in U.S Homes.* Health Physiscs, 66(6):699-706.

National Academy of Sciences (NAS). 1999. *Health Effects of Exposure to Radon, BEIR VI Report*. National Academy Press. Washington, DC.

Natural Resources Canada (NRCan) 2002. *Radon* Natural Resources Canada. http://gamma.gsc.nrcan.gc.ca:80/radon_e.html.

United Nations Scientific Committee on the Effects of Atomic Radiation 2000. *Sources and Effects of Ionizing Radiation.* UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes. United Nations 2000.

APPENDIX D

WATER QUALITY

Various data on background water quality are available for the Oka area of Quebec. A 1999 study by the Regie Regionale de la Sante et des Services Social, studied uranium in domestic wells in Oka. The study measured uranium levels in 57 of the 150 domestic wells that existed at the time. Most wells, 48 of the 57 studied were referred to as deep wells several 10's of metres in the ground. In a preface to their report, the authors indicate that while most groundwater sources have low uranium values, that some wells can have very high levels. They also note that the Quebec limit for uranium in drinking water is 20 µg/L. In brief, these authors divided the samples they collected into 4 zones. Zone 1 was for residents using the municipal aquaduct; zone 2 was from wells directly over the "Oka" formation [i.e. the carbonatite]; zone 3 for wells that were not directly over the Oka formation and zone 4 was for wells away from the influence of the carbonatite. For zone 2, (27 wells) the average uranium value was 17 µg/L with 1 in 4 wells exceeding the Quebec limit of 20 µg/L. For Zone 3 (25 wells), the average level of uranium was 11 µg/L. The authors of this report encourage the use of alternative water supplies if the uranium concentration exceeds 20 µg/L.

Data from the environmental study for the NIOCAN project (Table 3.12 Roche 1999) shows that the natural levels of uranium in well waters range from below the limits of detection to a maximum of about 51 µg/L. Roche also report a measurement of < 5 µg/L for the municipal aqueduct. Data reported by Roche (ibid Table 3.5) show that current levels of uranium in surface waters are consistently low even for measurements in open pits at the Saint Lawrence Columbium site. The only level of uranium reported at levels above the detection limits is the value of 6 µg/L in the Ruisseau Rousse.

Actual, measurements of uranium in a slurry of water and crushed ore are available from metallurgical testing that has been done in support of the NIOCAN project. These data show that for processing of ore with 19 ppm (Lavoie 28 Mar 2002) that the liquid part of the slurry shows dissolved uranium levels of 8 µg/L (Roche 1999, Table 6.2). This value is low, well within the range of natural levels, and moreover, is below the Quebec drinking water level of 20 µg/L.

In considering these numbers, it is important to understand that it is very difficult to dissolve trace elements present in natural minerals. In the mining of uranium ores for example, which contain much higher concentrations of uranium, it is necessary to crush the ore, grind it to a sand like or smaller size and to aggressively digest the ground up ore in strong acidic solutions [usually sulphuric acid] with oxidizing agents and often with the help of heat and pressure. None of these conditions apply to the NIOCAN project. It is also important to note that while acid can be naturally generated at some mining sites through the biologically aided oxidation of sulphur containing minerals, that such a situation is not possible at NIOCAN where the very large excess on of carbonate minerals over sulphur minerals (Roche 1999, p. 6.6) ensures that acid generation can never occur.

In the underground mine, the same excess of alikalinity will ensure that the minewater can never become acid. This combined with the backfilling of the mine will ensure that the potential flow of groundwater through the mine will be low and that groundwater which passes through the closed out mine will only contain low levels of uranium within the range of natural background.

Overall, my opinion is that any seepage that might occur in the future either from the mine or from the tailings which will be placed in pits at the SLC site will be at low levels, well within the range of current natural levels and likely within Quebec's 20 µg/L limit.

References:

Lavoie S., 28 March 2002. *Géologie des minéralisations de la propriété NIOCAN.* Oka, Quebec 2002.

Régie Régionale De La Sante Et Des Services Sociaux. 1999. *L'Uranium Dans L'Eau Des Puits Domestiques à Oka, 1999. La Radon à Oka.* 3 November 1999.

Roche 1999. *Etude de Repercussions Environment Oka Project Miniere NIOCAN.* October.

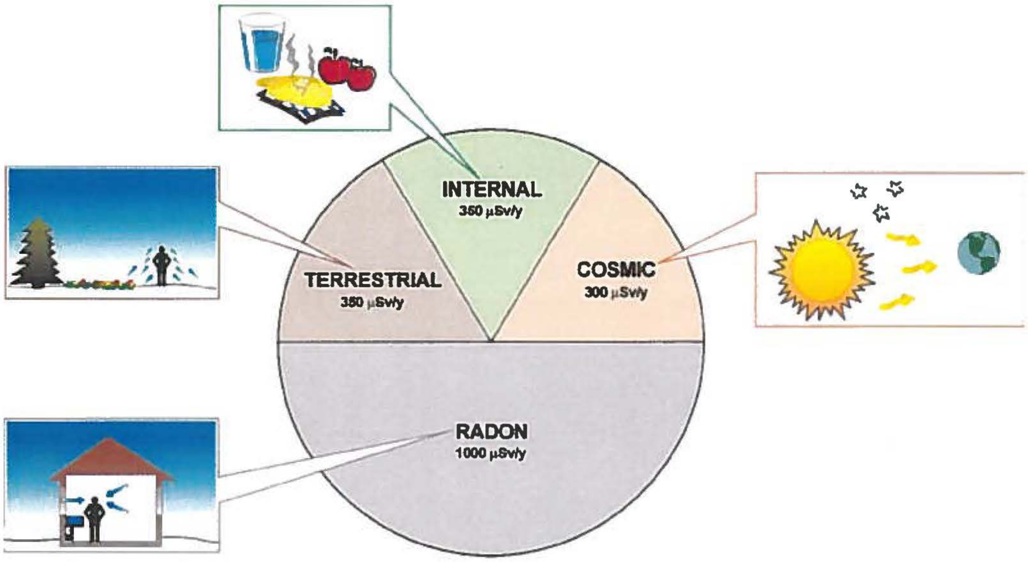
APPENDIX E

NATURALLY OCCURRING RADIOACTIVITY IN AGRICULTURE

Naturally occurring radioactivity is ubiquitous and provides radiation exposures to all people at all places and at all times throughout the world. The exposure rate varies over a wide range both temporally and spatially. The main pathways to human exposure from natural background radiation are:

- inhalation of radon gas (actually radon decay products);
- terrestrial radiation from rocks and soil;
- internal radiation from ingested and inhaled radioactivity; and
- cosmic radiation.

The approximate magnitudes of average exposures in Canada from these pathways shown in the following figure total 2000 µSv/y (2 mSv/y) (AECB 1995).



Exposures from the first three pathways are directly attributable to long-lived naturally occurring radioactivity in the earth's crust, and to a minor extent from radionuclides produced in the earth's crust by cosmic-ray bombardment.

Several dozen naturally occurring nuclides are radioactive with half-lives of at least the same order of magnitude as the estimated age of the earth (4.5 x 10^9 years), and are consequently assumed to represent a primordial inventory (U.S. NCRP 1987). The most significant members of this group are series radionuclides (uranium series and thorium series) and potassium-40.

The ultimate sources of the uranium and thorium series radionuclides and potassium are the earth's crust and underlying mantle. The chemical and chrystalographic characteristics of uranium, thorium and potassium result in a wide range of concentrations in crystal rock depending upon its type see the following table. Weathering of rock plays a key role in the creation of soil. So it is not surprising that different soil types in various locations exhibit a wide range of radionuclide concentrations representative of the original rock. For example, there are elevated exposure levels in large areas of Brazil and India because of very high levels of thorium in the monazite sand deposits on which large numbers of people live. The central massive in France and other areas of the country have elevated uranium minerals in the granite rocks and soils (UNSCEAR 2000). In some areas of Iran, people receive doses from background radiation up to 260 mSv/y (Ghiassi-nejad et al. 2002), or more than 100 times the average dose people receive in Canada. People have been living in these very high background radiation areas for generations without any apparent health impacts

Plants exchange oxygen and carbon with surrounding air and incorporate nutrients, important trace elements and water from the soil in which they grow. Also, plants transfer uranium and thorium series radionuclides and potassium-40 from the soil into their leaf, root, reproductive and supporting structures. Consequently, all plants contain naturally occurring radioactivity at concentrations that are representative of the corresponding concentrations in surrounding soils (UNSCEAR 2000). Radon gas dissolved in water can also be transported through plants but is chemically inert and does not accumulate in plants.

Animals consume vegetation as sources of energy, nutrients and trace elements that are critical to their health. Consequently, all animals and their products (e.g. milk) contain naturally occurring radioactivity at concentrations that are representative of the corresponding concentrations in feed and water they consume.

Finally, humans consume vegetables, fruits, animal products and drinking water that contain trace levels of naturally occurring radioactivity. These radionuclides accumulate and deliver an internal radiation dose as indicated in the above figure.

The average value and ranges of concentrations of selected radionuclides in the uranium series (uranium-238, thorium-230, uranium-234, radium-226, lead-210 and polonium-210), the thorium series (thorium-232, radium-228, thorium-224, radium-224, and potassium-40 are shown in the following table for selected environmental media.

The average concentrations in the surface expression of the carbonatite have been estimated based on data reported for a GSC Airborne Survey [NRCan 2002] as 5.3 ppm uranium and 23.8 ppm thorium. The former converts to an average activity concentration of 65,000 mBq/kg uranium-238 (and each of its decay products), within the range of 4,000 –140,000 mBq/kg reported for North American soils in the following table. The latter converts to an average activity concentration of 97,000 mBq/kg thorium-232 (and each of its decay products), also within the range of 4,000 –130,000 mBq/kg reported for North American soils in the following table. Thus, on average, radioactivity in plants growing on the carbonatite are expected to contain radioactivity in the same range as that found elsewhere.

Range of Concentrations of Naturally Occurring Radioactivity

In North America	Units	Potassium-40	Uranium-238	Radium-226	Lead-210	Polonium-210	Thorium-232
rock[b]	mBq/kg	70,000-1,500,000	7,000 – 60,000	7,000 – 60,000	7,000 – 60,000	7,000 – 60,000	7,000 – 80,000
Soils[a]	mBq/kg	100,000 – 700,000	4,000 – 140,000	8,000 – 160,000	-	-	4,000 – 130,000
Air[a]	µBq/m³	-	0.9-5	0.6	100-1000	10-40	0.4
Milk products[a]	mBq/kg	-	0.7	5.7	11	-	0.27
Meat products[a]	mBq/kg	-	0.8 – 2.3	20	18	-	0.3 - 2
Grain products[a]	mBq/kg	-	3 – 2.3	7 – 100	33 – 81	-	0.1 – 2.8
Leafy Vegetables[a]	mBq/kg	-	24	56	41	-	18
Root vegetables[a]	mBq/kg	-	0.9 – 7.7	7 – 47	8 – 150	-	0 08 –1.4
Fish products[a]	mBq/kg	-	13 – 1,900	30 – 59	14 - 1,800	150 – 55,000	1.2 - 30
Drinking water[a]	mBq/kg	-	0.3 – 77	0.4 – 1.8	0.1 – 1.5	-	0.05

[a] UNSCEAR (2000).
[b] US NCRP (1987).

Relevance to Niocan Project

Overall, it is my opinion that on the basis of radioactivity, there is no reason to restrict agricultural activities on the carbonatite.

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