Nunavummiut Makitagunarningit

Comments on the Draft Guidelines for AREVA Resources Canada Inc's preparation of the Environmental Impact Statement (EIS) for the proposed 'Kiggavik' Project

Submission to the Nunavut Impact Review Board

January 24, 2011

1. About Nunavummiut Makitagunarningit

Nunavummiut Makitagunarningit ('Makita') is an independent, non-governmental organization with members in Iqaluit and Baker Lake.

We are aware that as one of the few 'civil society' groups in Nunavut, we are sometimes viewed as being negative and adversarial. But we view what we do in *positive* terms. We are *in favour* of a clean environment, *in favour* of future generations being able to enjoy healthy wildlife, and therefore *in favour* of energetic citizen participation in the review of proposed developments. We are *not* anti-mining per se, but we *have* concluded that opening Nunavut to uranium mining is not in the best interest of Nunavummiut.

The participation of intervening organizations like Makita is an essential feature of environmental assessment in Canada. Bodies like the Canadian Environmental Assessment Agency (CEAA) and the Nunavut Impact Review Board (NIRB) *assume* that there will be groups like ours coming before them as intervenors, raising community concerns and asking tough questions. The role of intervenors is to ensure informed decision making. We're an important part of the process, and we hope that our comments are understood in that light.

These are our preliminary comments on NIRB's approach to issuing EIS Guidelines for the proposed Kiggavik project. More detailed comments will follow after NIRB releases the Revised EIS Guidelines, and Makita holds community consultations are held using a NIRB document translated into Inuktitut.

2. Lack of essential documents translated into Inuktitut

These comments are *not* the result of the community workshops we had intended to hold by this point. Proper community consultation is not possible without essential documents being made available in Inuktitut. Makita raised this matter with NIRB on November 18, 2010, and on November 23rd NIRB stated that it "is currently endeavouring to translate … key provisions of the Draft EIS Guidelines for the Kiggavik Project, and we will make these documents available for information purposes as soon as meaningful translations have been completed." We have not yet received the "key provisions" in Inuktitut.

3. Failure to acknowledge the 'basin opening' nature of the proposed project

The Draft EIS Guidelines limit the definition of 'reasonably foreseeable future development' to "Projects or activities that are currently under regulatory review or that will be submitted for regulatory review in the near future, as determined by the existence of a proposed project description, letter of intent, or any regulatory application files with an authorizing agency." A very different perspective was presented at NIRB's "community scoping sessions" in April 2010:

> Perhaps the most far-reaching question was asked by a hunter on the third night, after the NIRB facilitator stated that NIRB defines "cumulative effects" as "effects resulting from incremental impact of the action when added to other past, present and foreseeable future actions."
>
> This is what the hunter said:
>
> "Everyone knows that this review is not really about the Kiggavik proposal, yes or no. This review is about opening the Kivalliq – and Nunavut as a whole – to uranium mining, yes or no.
>
> "We know that there's a lot of uranium around Baker Lake, which is why this community is surrounded by uranium exploration. AREVA has already spoken publicly about the possibility of the mill at Kiggavik being used to process uranium from other mines to be built in the future. In 20 years there could be several or many mines, with several or many roads between them, and everything else that comes with additional mines.

> "For this review to be intellectually honest, you are going to have to model a realistic 'likely scenario' of what could very well happen if this region is politically opened up to uranium mining.
>
> "I believe that "foreseeable future actions" resulting from approval of the Kiggavik could be six or 12 or who knows how many uranium mines. How are you going to model their cumulative effects on the caribou, on the environment and on the people of Baker Lake?"[1]

Real 'cumulative impact assessment' in this situation requires modeling what the uranium industry might look like in the Kivalliq industry in 20 years time, and assessing what the cumulative impact of the entire development scenario might be.

A broader definition of cumulative effects is not without precedent in Canada. The *Canadian Environmental Assessment Act* defines cumulative effects as "any cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out."[2] The Canadian Environmental Assessment Agency (CEAA) interprets this to include assessment of "the most likely future scenario", which may include consideration of hypothetical projects.[3] The CEAA states:

> The Agency's 1994 Reference Guide advised that the assessment of cumulative environmental effects in relation to future projects should focus exclusively on imminent projects, that is, projects that have been approved but not yet implemented or proposals awaiting planning or other formal approval. It is now recognized that this approach may not always be adequate to understand the implications of development activities on the future well-being of the environment. Also, it may limit the ability of cumulative environmental effects assessment to contribute to informed environmental planning and decision making in the future in the project area.

The Report of the Joint Review Panel for the Mackenzie Gas Project, *Foundation for a Sustainable Future*[4] (December 2009), has put this higher standard into practice. Chapter 3 of the JRP's report outlines their approach to potential future projects. Here, a distinction is made between the project under review and the "Project as Filed" (p.54). The project under review includes additional infrastructure deemed hypothetical by the project proponent, but which the JRP believed to be reasonably foreseeable "notwithstanding that it is not possible to identify specifically what those developments would be or, more importantly, where they might be located" (p.54).

Cumulative effects assessment in Nunavut should reflect, at a minimum, the minimum standards of best practice in the rest of Canada. We note that such an approach would contribute to proper environmental planning for a 'basin opening' project like Kiggavik.

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1 www.nunatsiaqonline.ca/stories/article/98789_nirb_uranium_firm_governments_look_like_part_of_same_team/

2 See CEAA's Operational Policy Statement, http://www.ceaa.gc.ca/default.asp?lang=En&n=1F77F3C2-1

3 Ibid.

4 http://www.ceaa.gc.ca/default.asp?lang=En&n=71B5E4CF-1

4. Comparison of NIRB's Draft EIS Guidelines with the 'Environmental Impact Statement Guidelines and Government Information Requirements' released by the Federal Environmental Assessment Review Office (FEARO) in June 1989 for the first review of a proposal to open a mine and mill at the Kiggavik site

The EIS Guidelines released by the FEARO back in 1989 are attached as Appendix 1. We urge NIRB to review them thoroughly because we feel that in some critical aspects the FEARO Guidelines are superior to the Draft Guidelines that we are commenting on.

5. The role of government

NIRB's Draft Guidelines are silent on the question of the capacity of government (both federal and territorial) to regulate a uranium mine in Nunavut. The FEARO Guidelines were not. Among other things, they asked:

2.2.2

- What is the expected departmental cost for each government office that would have a regulatory or monitoring responsibility should the project proceed? Include costs from exploration to long term post-project monitoring. Is the expertise, manpower, infrastructure and equipment available within these offices at the present time? If not, from where would these resources be drawn and at what cost? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, LC)

part of 2.4.1

- How would regulation of the proposed project be coordinated between and within government agencies at all levels of government? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)
- How would compliance with regulations be enforced by responsible government agencies? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)
- How would information required by regulation be recorded? Would it be publicly available? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

In addition, we believe a cost benefit analysis must be done for the construction, operation, closure, and long term care and maintenance phases of the project from a public accounts perspective. This work should include consideration of both revenues and public expenditures to support an appropriate compliance and effects monitoring regime that meets NLCA Article 23 requirements. We argue that this information is necessary for NIRB to make an informed judgment regarding the socio-economic effects of this project and reasonably foreseeable future projects. These are questions that government should answer, and questions that we hope NIRB will require the government to answer.

6. Concerns about exposure to radiation

One of the characteristics of the FEARO Guidelines was that they were developed specifically for the review of a proposed *uranium* mine. There were no references to iron ore, as there are in NIRB's Draft Guidelines. There were, however, a significant number of sections in FEARO's Guidelines where the proponent is required to explain how radiation may impact on plant life (3.1.1), wildlife (3.1.2), and public health (5.2). They were very clearly worded and easy to understand. Given the almost complete lack of reference to radiation or radioactivity in NIRB's Draft Guidelines, NIRB may wish to simply incorporate these sections of the FEARO Guidelines into its Revised Draft Guidelines.

7. A monitoring system worthy of the land, the people and the wildlife

If the Kivalliq region is to be opened to uranium development, future generations deserve to know *with certainty* what the impacts of that development have – and have not – been. A scenario of (for example) five uranium mines each with its own project-specific monitoring system would be a travesty. NIRB has shown a willingness to approve projects in the absence of a co-ordinated system of monitoring socio-economic impacts across Nunavut. Makita calls for a well-designed 'general monitoring program' for the Kivalliq, to be operated by *an independent body* with sufficient funding to do the job well – and not by the proponents/operators themselves. This program, including its effects monitoring methodology and organizational structure, should be designed and agreed upon by intervenors prior to the issuance of NIRB's final hearing report.

8. A note on the 'nuclear sector'

The importance of having an *independent* monitoring system cannot be overstated, especially given the nature of the relationship between (A) the nuclear industry and (B) the Canadian Nuclear Safety Commission (CNSC). The President of the CNSC has himself described the two together as Canada's "nuclear sector."

Appendix 2 is an article from a respected scientific journal, Environmental Health, entitled "Childhood cancer near nuclear power stations". It was written by Dr. Ian Fairlie, a Canadian scientist who lives in Britain, about the findings and implications of a German study with the acronym KiKK (Kinderkrebs in der Umgebung von KernKraftwerken, or Childhood Cancer in the Vicinity of Nuclear Power Plants). Fairlie describes how:

> In 2008, the KiKK study in Germany reported a 1.6-fold increase in solid cancers and a 2.2-fold increase in leukemias among children living within 5 km of all German nuclear power stations. The study has triggered debates as to the cause(s) of these increased

> cancers. This article reports on the findings of the KiKK study; discusses past and more recent epidemiological studies of leukemias near nuclear installations around the world, and outlines a possible biological mechanism to explain the increased cancers.

How can it be that this relationship was not discovered until 2008? (One possible explanation: you're unlikely to find something that you weren't carefully looking for in the first place.) And how can it be that this research doesn't seem to trouble Canada's nuclear sector in the slightest?

When the President of the Canadian Association of Physicians for the Environment referenced the KiKK study in an op/ed published in the Windsor Star on January 6, the President of the CNSC wrote a remarkable letter to the editor in reply. It deserves to be read in its entirety:

> Nuclear power plants safe
>
> letter to the editor
> Windsor Star
> January 13, 2011
>
> I'm compelled to respond to Gideon Forman's groundless statements on the health impacts of nuclear energy in his Jan. 6 column, 'Wind power is healthy'.
>
> Studies have shown over and over that people living near nuclear power plants are as healthy as the rest of the population.
>
> When Forman mentions the 2008 German study, he fails to tell you that both its authors and the German Radiological Protection Commission specifically ruled out radiation as a reason for the presence of some clusters of childhood leukemia near the nuclear plants.
>
> Recent British and French epidemiological studies that used the same methodology as the German study did not find any increase in risk of childhood cancer in people living near their respective nuclear facilities.
>
> All industrial activities have some form of releases to the environment; nuclear has a regulator that ensures operations are safe.
>
> I would like to reinforce that the very small controlled releases of nuclear facilities do not pose any risk to people and the environment.
>
> Finally, nuclear waste is not a burden for future generations.
>
> In fact, it is safely stored and managed.
>
> Furthermore, Canada's nuclear regulator requires nuclear facility operators to maintain adequate financial guarantees to cover the costs associated with the long-term management of the waste they produced.

Guarantees are an important condition of the companies' licences and the CNSC would never grant a licence without having that in place.

I invite your readers to visit our website at nuclearsafety.gc.ca to get the facts about Canada's nuclear sector.

Michael Binder, President
Canadian Nuclear Safety Commission

The Windsor Star did not publish the following comment by Dr. Fairlie, which was submitted on January 12:

Mr Binder's letter (January 6) has just been brought to my attention. It contains inaccuracies and I'd be grateful if you would allow space for corrections. I'm an independent scientist who has written extensively on the health risks of radioactive releases from nuclear facilities.

Mr Binder states that studies have shown that people living near nuclear power plants are as healthy as the rest of the population. On the contrary, about 40 studies worldwide over the past few decades have consistently demonstrated increased incidences of child leukemias near nuclear power plants.

Second, he states that the KiKK study authors and the German Radiological Protection Commission ruled out radiation as a reason for clusters of childhood leukemia found near their nuclear plants.

The KIKK authors were unsure as to the reason(s), and readers are justified in querying the German Radiological Protection Commission's assertion, as it is pro-nuclear in outlook. This is because in making its claim, the German Commission made the following assumptions:

(a) its dose estimates from nuclear plant releases were 100% reliable, ie they contained no uncertainties;

(b) exposures were averaged over a whole year, instead of the large spikes occurring about once a year;

(c) radionuclides from nuclear plants were homogeneously dispersed throughout the body (instead of heterogeneously);

(d) a linear dose/risk relationship exists for radiation; and

(e) it's safe to use Japanese bomb survivor data (instantaneous blast with high doses of neutrons and gamma rays) to establish risks from environmental exposures (long term exposures to low doses of beta and alpha particles).

Independent radiation scientists dispute most of these unsafe assumptions.

Third, Mr Binder states that recent British and French studies used the same methodology as the KiKK study but did not find increases in cancer near their nuclear facilities. In fact, the KiKK study used a more careful and dependable methodology (the case-control type) than the British and French studies which just used cancer data from national records. And the British and French studies actually found cancer increases but their datasets were too small to rule out chance findings. It's poor science to claim no association when in fact one may exist: it's called a type II error or a false negative.

Fourth, Mr Binder asserts that radioactive releases pose "no risk" for the public near nuclear reactors. It is more accurate to state that the existing risks are considered acceptable by the regulator: quite a different matter.

I invite interested readers to download (free of charge) a highly-accessed commentary on the radiation risks near nuclear facilities from the peer-reviewed US journal Environmental Health http://www.ehjournal.net/content/8/1/43

Yours sincerely,

Dr Ian Fairlie

We have included this exchange not just to shed light on the nature of the 'nuclear sector', but also to make a point about monitoring. An absence of evidence is not the same thing as evidence of no ill effect. Whatever the impacts of opening the Kivalliq to uranium mining (if that happens) may be, the people of the region deserve nothing less than a substantial and sufficient evidence base with which to assess what those impacts have been.

9. End use

AREVA has stressed in its' public relations material that uranium mined in Nunavut will only be used for the production of electricity – and will not find its way into nuclear weapons. The proponent should be required to show how and why, with certainty, the latter cannot occur.

AREVA recently signed significant nuclear contracts with India.[5] The government of Australia has recently refused to allow the export of uranium to India because the Indian government refuses to sign the Nuclear Non-Proliferation Treaty.[6] That being the case, how can Canadian uranium be guaranteed not to end up in India's nuclear weapons program once again?[7]

We would also like to know where the uranium used in the production of nuclear weapons *does* come from.

5 http://www.guardian.co.uk/environment/2010/dec/28/india-areva-nuclear-power-bouissou
6 http://news.bbc.co.uk/2/hi/asia-pacific/7188835.stm; http://news.ino.com/headlines/?newsid=11920110216
7 http://en.wikipedia.org/wiki/Smiling_Buddha

APPENDIX 1: FEARO's Kiggavik EIS Guidelines (1989)

Federal Environmental Assessment Review Office

KIGGAVIK URANIUM MINE ENVIRONMENTAL ASSESSMENT PANEL

Environmental Impact Statement Guidelines and Government Information Requirements

June, 1989

TABLE OF CONTENTS

Table of Contents (continued)

KIGGAVIK URANIUM MINE ENVIRONMENT ASSESSMENT PANEL

Draft Environmental Impact Statement Guidelines and Government Information Requests

1.0 INTRODUCTION

Urangesellschaft Canada Ltd. is proposing to develop an open pit uranium mine located about 75 km west of Baker Lake in the Northwest Territories. In order to ensure that a comprehensive environmental impact assessment is carried out with full opportunities for public involvement, an Environmental Assessment Panel has been appointed by the federal Minister of the Environment. The appointment of the Panel has the support and concurrence of the Government of the Northwest Territories. The role of the Panel is to publicly review and assess the environmental and socio-economic effects of the project (including consideration of issues relating to community health, worker safety and regulatory procedures).

As one of the first steps in the Panel review process, the Panel has developed guidelines for the preparation by Urangesellschaft Canada Ltd. of an Environmental Impact Statement (EIS). In recognition that some of its information requirements can best be met through means outside of the proponent-prepared EIS, the Panel has also developed information requirements to be responded to by federal and territorial government agencies.

The EIS Guidelines and Government Information Requirements have been prepared through consultation with the public; local, regional, territorial and federal agencies; interest groups: and the proponent, through an issues scoping process which included workshops in Baker Lake, Rankin Inlet, and Yellowknife. The length of this document increased significantly as result of consultation with review participants. In most instances, the increased size of this final version of the guidelines serves to provide the necessary focus and detail to more general questions already posed in earlier versions.

The responses provided to this document will collectively provide the Panel and review participants with the main information base to be discussed and examined during the public hearings. In addition to examining these responses, the public hearings will also provide an opportunity to discuss other submissions to the Panel from public groups, native organizations and government agencies.

1.1 Format of Guidelines

These guidelines are organized by groups of issues that are of concern to local communities and interested government and non-government organizations. The sections on potential impacts are broken down into baseline data, potential agents of change and potential consequences. The EIS should make clear distinctions between these types of information. Each section begins with a statement on the focus of concern and the spatial and temporal boundaries. Mitigation and monitoring, and the regulatory framework form separate sections but clearly apply to all potential impacts. Rather than repeating requests for mitigation plans and regulatory requirements, the request is made once in each of the appropriate sections.

The issues addressed in this document are organized into the following categories: ecosystem impacts, including plant life, wildlife, physical environment, surface and groundwater, and atmospheric environment; socio-economic impacts; human health and safety, including worker and public health; risk management; tailings management and decommissioning; and mitigation and monitoring.

1.2 Organization and Content of Responses

The Panel expects the responses to the finalized version of these EIS Guidelines and Government Information Requests to be prepared and submitted in the following manner:

1. Project Description prepared by Urangesellschaft Canada Ltd
   Due August l, 1989

2. Government regulatory requirements prepared by relevant government departments.
   Due September 1, 1989

3. Environmental Impact Statement (EIS) prepared by Urangesellschaft Canada Ltd.
   Due November 1, 1989

4. Document containing all other federal government responses.
   Due November 1, 1989

5. Document containing all other Government of the Northwest Territories (GNWT) responses.
   Due November 1, 1989

The following information requirements, are structured around the main, issues to be addressed during the review. The EIS, in particular, should focus on a thorough examination of the identified issues, their significance and what can be done to minimize or mitigate them. As the Panel plans to structure its hearings around these issues, it is important that the EIS contain sufficient information on the issues and their significance to allow for an informed and productive discussion at the hearings.

In order to facilitate public involvement in the EIS review and public hearings, a non-technical summary of the full EIS should be produced in both English and Inuktitut. This summary should be written in plain, non-scientific language and contain a glossary of terms. It should briefly describe the existing environmental and socio-economic setting, the major positive and negative effects associated with the project, the proposed mitigation, enhancement and compensatory measures, and the proposed monitoring programs. Those aspects of project effects which are of greatest interest and concern to communities should be highlighted. The project description, EIS summary and the full EIS will help to ensure that all review participants from government scientists to community residents will have available to them appropriate information to enable them to effectively take part in the hearings.

1.3 Methodological Considerations

The following methodological considerations should be taken under advisement by the proponent in preparation of the EIS. They are based on Section 1.2 of An Ecological Framework For Environmental Impact Assessment in Canada, Beanlands and Duinker, 1983. Reference should also be made to the "Ethical Principles for the Conduct of Research in the North", Association of Canadian Universities for Northern Studies, 1977. Copies of these documents are available from the Panel Secretariat.

1. Identify Valued Ecosystem Components to Provide a Focus For Subsequent Research Activities.

   In these guidelines the Panel has begun to identify valued ecosystem components as brought forward in the scoping workshops. Further focussing may be necessary on the part of the proponent. The EIS must also identify ecosystem components that are expected to be impacted but are not sufficiently valued to be studied in detail.

2. Set Explicit Spatial and Temporal Boundaries For Study and Analysis of Changes in the Valued Ecosystem Components.

   When assessing impacts, the proponent is asked to define the maximum spatial and temporal extent of potential impacts, provide rationale for this delineation, and then carry out impact assessment within these boundaries. Where impacts may be felt outside the Northwest Territories, such as in transportation of dangerous goods by air and water, information must be included. Due to the long-term persistence of radioactive materials, there is clearly a need for temporal boundaries to be extended into the long-term.

3. <u>Define the Criteria For Determining Impact Significance</u>

When defining the significance of potential impacts the proponent must take into consideration the following three factors:

- statistical significance (related to the problems of isolating project-induced changes from natural variation);
- ecological considerations (related to the importance of project-induced changes from a purely ecological perspective, independent of social values); and
- social importance (related to the acceptability of project-induced changes in valued ecosystem components).

Terminology used to represent the level of significance (eg. negligible, minor, major, etc.) must be clearly defined.

4. <u>State Impact Predictions Explicitly and Provide Rationale For Predictions</u>

To be most useful, impact predictions must:

- fulfill the environmental assessment objective of contributing to informed decision-making,
- contain an estimate of the uncertainty expected, and
- be testable through a monitoring program.

The predictive analysis should strive to ascertain the nature, magnitude, duration (timing), extent (geographic distribution), level of confidence, and range of uncertainty of the predicted changes. Reasons should be given if any of the above cannot be ascertained. All strategies and methodologies used for predicting the potential effects of the project on each valued ecosystem component must be shown explicitly, providing details of all models, assumptions, simplifications and generalizations used.

5. Design and Undertake a Monitoring Program

A monitoring program must be designed to monitor change during the construction, operation and abandonment phases of the proposed mine. This program must test impact predictions and hypotheses, thus contributing to the body of knowledge for future assessments, and test mitigative measures, thus ensuring protection of valued ecosystem components.

6. Undertake Rigorous Data Collection

The EIS should use the most recent information available, drawing on international experience where relevant. The proponent should undertake fieldwork or original research whenever possible to verify or collect data that are not already available. Any information gaps should be identified and where information is not available, the proponent should demonstrate what efforts were made to acquire such information and what additional efforts would be required to obtain the information.

7. Make Use of Graphic Material

Wherever possible, maps, illustrations and graphs should be used to assist in the display of information. Where possible, maps should be of the same scale to allow for comparison of the distribution of mapped features.

8. Make Use of Local Knowledge

In order to contribute information that is otherwise unavailable and to enhance existing information, local knowledge and expertise should be incorporated in all possible aspects of the EIS. All local knowledge incorporated into the EIS should be identified as such.

9. Collection of Relevant Baseline Information

In preparing the EIS, the Panel expects that the proponent will collect all baseline data necessary for estimating the potential impacts of the proposal. More detailed baseline data, necessary for a comprehensive monitoring program need not be collected at this time. However, the proponent must indicate what, how and by what schedule monitoring baseline data would be collected if approval for the project were granted.

1.4 Information Requirements

In developing the following information requirements, the Panel has designated whom it expects to respond to each of the requirements. The majority of the information requests are directed to Urangesellschaft. Where noted in brackets, information requests are also directed at federal and/or territorial government agencies. Also, some information requests are directed at more than one respondent. In some instances the proponent will likely draw upon government documents, data or expertise. All federal and territorial government agencies involved with uranium mining are asked, in addition to the other information requests, to forward a listing of research carried out for or by the agencies regarding the potential socio-economic and environmental impacts of uranium mining. The Panel would like to receive this information by September 1, 1989.

The government agencies that are expected to have a role to play in uranium mining in the Northwest Territories are:

Government of the Northwest Territories (GNWT)
NWT Water Board
Atomic Energy Control Board (AECB)
Department of Energy, Mines and Resources (EM&R)
Department of Indian Affairs and Northern Development (DIAND)
Department of Fisheries and Oceans (DFO)
Health and Welfare Canada (HWC)
Environment Canada (DOE)
Transport Canada (DOT)
Labour Canada (LC)

2.0 BACKGROUND INFORMATION

Responses to the following requests for background information will help set the scene for the detailed assessment and analysis of project impacts. Responses to the following requests should provide a complete description of the project, information on its economic rationale, background on the proponent and details on the government regulatory framework under which the project would operate.

2.1 Project Description

The proponent must provide a complete and detailed description of all aspects of the proposed development, including the setting, design, construction, operation and transportation. As outlined above, the Panel has requested that the project description be submitted by August 1, 1989. Submission of the project description in advance of the EIS will allow the Panel and other review participants to fully familiarize themselves with the proposal prior to examination and review of the potential environmental, socio-economic and health impacts.

2.1.1 Setting

- Provide information on existing, planned or probable developments in the region in sufficient detail to provide insight into cumulative impacts or interactions that may arise. Include information on current or proposed uranium exploration programs. (UG in consultation with GNWT, DIAND and EMR)

- Outline any future plans that the proponent may have to expand the proposed facility or to develop other mineral deposits in the Keewatin.

- Using comparative historical data from similar projects elsewhere, indicate whether proceeding with the project would be likely lead to its further expansion or might attract other developments, whether of a similar nature or not. (UG in consultation with DIAND and GNWT)

- How have arctic conditions been taken into consideration in the design and selection of equipment for construction, operation and decommissioning plans for the proposed mine?

2.1.2 Design

- Provide rationale and criteria used to justify the selection of approaches, designs and strategies used in the construction, operation and decommissioning phases of the project. Where alternatives were examined, provide rationale used to select a particular alternative and reject others. Engineering, economic or operational constraints which preclude certain options should be described. Significant differences in impacts among the alternatives considered should be described. Emphasis should be placed particularly on alternative methods of long-term tailings management. Where project options are still being considered, identify all alternatives and clearly set out the factors being considered and any information must be obtained before a decision can be made.

- What is the total land area required by the proposed project?

- What is the total land area that the public and wildlife would be prevented from making use of? Would this change over time?

- What measures would be taken, such as constructing a fence, for the purpose of limiting access of people and wildlife to the proposed mine facilities?

2.1.3 Construction

Describe the following:

- location, method and timing of construction;

- types, approximate quantities, sources, timing and means of acquiring construction materials, equipment and services; and

- expected quantities-and characteristics of toxic wastes, debris, effluent and emission, including noise caused by or attributable to construction.

2.1.4 Operation

- Provide details of the design and operation of the following aspects of the proposal:

    - open pits
    - ore storage pads
    - waste rock disposal
    - uranium tailings treatment and disposal
    - mill
    - sulphuric acid plant
    - lime plant
    - power plant
    - fuel storage
    - solid waste management
    - liquid waste management
    - facility decommissioning
    - site reclamation

- Provide a breakdown of the composition, disposition and tonnage of the material to be mined, including waste rock, mill tailings and uranium.

- What is the depth and size of the ore body?

- What is the proposed rate and method of mining?

- Outline the proposed use of explosives.

- Outline in detail the proposed waste rock disposal process, including the potential for trace metals and low levels of radionuclides leaching from the waste rock.

- Outline plans for the removal and treatment of snow which may accumulate in the open pits during the winter months.

- Outline plans for the removal and treatment of excessive volumes of water which may accumulate in the spring melt season.

- Identify all input resources required, including process chemicals, water and energy.

- Identify all liquid outputs including sanitary wastewater, process waste water, surface runoff. Outline all radioactive and non-radioactive contaminants of these outputs.

- Identify all gaseous emissions and the chemical composition of these emissions.

- Describe the mill process, including ore preparation, grinding, thickening, leaching and washing, solvent extraction, uranium recovery and process control.

- Describe the tailings disposal and effluent treatment, including the lime plant, sulphuric acid plant, fuel storage, service buildings, water supply and balance.

- Provide details of construction and permanent camps, including: potable water systems, waste treatment and disposal, accommodation, wash facilities, and medical and surgical care facilities.

- Provide details of the nature and timing of operations and supporting transportation systems associated with the limestone quarry.

- Provide details of the proposed decommissioning plans, giving rationale for the chosen approach.

- Describe any plans for reclamation and outline the expected state of the environment after mine abandonment.

2.1.5 Transportation

- Outline the entire transportation infrastructure, including surface, air and marine transport facilities.

- Identify any changes that may be required in the existing infrastructure of nearby communities.

- Outline the pattern, frequency and seasonal trends of surface transport, aircraft flights and marine shipments in sufficient detail so as to identify possible interactions with wildlife.

- Specify the transportation equipment to be used and the training of the transportation personnel.

- Outline the frequency and volume of dangerous goods to be stored; and transported into, out of and within the project site.

- Provide details of spill containment designs for all areas where hazardous materials are stored, handled or utilized, including along transportation routes.

- Describe any power or other service corridors required.

2.2 Project Justification

2.2.1 Economic Rationale

- Based on factors such as market supply and demand, pricing and future projections, display economic rationale for the project. Outline the historic, existing and projected market characteristics, including the geographic context. Methodology used in deriving estimates of supply and demand and the qualifications and assumptions attached to them should be clearly stated.

- What changes in the market for uranium might affect the viability of the proposed mine?

2.2.2 Costs

- What is the expected departmental cost for each government office that would have a regulatory or monitoring responsibility should the project proceed? Include costs from exploration to long term post-project monitoring. Is the expertise, manpower, infrastructure and equipment available within these offices at the present time? If not, from where would these resources be drawn and at what cost? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, LC)

- Would there be any government assistance to fund the project?

- What is the estimated cost to the proponent of producing uranium from the proposed Kiggavik project? include the cost of:

    - design
    - construction
    - site infrastructure
    - mine/mill operations
    - decommissioning
    - reclamation
    - mitigation
    - monitoring

2.2.3 Benefits

- What are the potential economic benefits of the project to the Keewatin, Northwest Territories, and Canada? Of particular interest is potential tax revenue (not including personal income tax). What is the expected income, through taxes and royalties, to each level of government? Provide a breakdown for each type of income for each year of production. How would the revenue generated be utilized and distributed? (Urangesellschaft, GNWT, AECB, EMER, DIAND)

- Is there any possibility of establishing a fund, based on royalties from the proposed mine, for the Inuit similar to the "Heritage Fund" in Alberta? (DIAND, GNWT)

- What would the proposed mine contribute permanently to the infrastructure of the region as opposed to any temporary contributions (ie. what services and opportunities, if any, would remain after mine closure)?

- After mine closure, would the region lose a variety of services on which it had come to depend?

2.3 Background on Proponent

- What financial security does Urangesellschaft have to ensure that the project is carried through in compliance with all regulations?

- What experience does Urangesellschaft have in uranium mine construction, operation and decommissioning?

- What experience does Urangesellschaft have in introducing industrial development to isolated northern and native communities?

- What experience does Urangesellschaft have with development in arctic regions, particularly in continuous permafrost regions?

- What experience has Urangesellschaft had in incorporating environmental and health considerations into project construction, operation and abandonment (include uranium mining and other experiences). How successfully have impacts been avoided or mitigated?

- Where the proponent does not have expertise required to successfully carry out the proposed project, outline how this expertise would be acquired.

Does the proponent have the financial resources to post bond to ensure adequate clean up in the event of a major spill as well as for decommissioning?

2.4 Regulatory Framework

2.4.1 Structure

- Identify all siting, design, construction, operating and monitoring and decommissioning standards, regulations and requirements set out by various government departments that apply to the proposed uranium mine and potential impacts on humans and the environment. Include identification of responsible government agencies and the reporting requirements for each of the regulations or standards. Identify any overlaps or gaps in the regulatory framework. (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC) Include standards and regulatory requirements relating to:

  - construction phase, open-pit mine, mill, ore storage bins, waste ore piles, chemical and power plants, tailings piles and tailings ponds, transportation infrastructure, ongoing operation of the proposed mine, decommissioning of the mine and all other aspects of the proposal;

  - potential impacts to plant life, fish and wildlife, surficial geology, surface and ground water, the atmosphere, and all other potential environmental impacts; and

  - health and safety of workers and the general public, socioeconomic impacts on the local communities, and all other potential human impacts.

- What processes and/or bodies are likely to be established as a result of the final settlement of the Tunngavik Federation of Nunavut land claim? (GNWT)

- What authority would these processes and/or bodies have in authorizing aspects of or enforcing compliance and effects monitoring aspects of the proposed project? (GNWT, AECB, EM&R, DIAND)

- How might authority over mining be devolved to a greater extent to the GNWT over the course of the review, construction, operation or decommissioning of the proposed mine? (GNWT, AECB, EM&R, DIAND)

- How would regulation of the proposed project be coordinated between and within government agencies at all levels of government? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

- How does Urangesellschaft propose to comply with each of the regulations and standards?

- How would compliance with regulations be enforced by responsible government agencies? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

- How would information required by regulation be recorded? Would it be publicly available? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

2.4.2 Legislation

- Is there a need for the creation of new legislation to effectively regulate the proposed project? If so, what legislation is required and by what process would it be put in place? What time frame is required to develop and enact such legislation? (GNWT)

- What leases, licenses, or permits would be required if approval were granted for the proposed mine? Through what processes would applications be considered? (GNWT, AECB, BM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

2.4.3 Compensation

- Do legal provisions exist to require the proponent to post a bond to cover the costs of decommissioning as well as containment and clean up of spills or other accidental releases of contaminants. (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

- What amount of bond, if any, should be posted to protect against the possibility of damage to the environment, wildlife or humans? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

- Which government agency or non-government organization should be responsible for the administration of such a bond? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

- What requirements are there for the provision of compensation? What criteria would be used for awarding compensation? Who would administer a compensation program? Who would fund the program? How would the criteria incorporate the provisions of the Wildlife Compensation Agreement-in-Principal initialed 19 June, 1988 by the Government of Canada and the Tunngavik Federation of Nunavut? (GNWT, ABCB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

2.4.4 Expertise

- What experience has each government agency involved have in regulating projects of a similar nature? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

- Are there any conflicts of interest or apparent conflicts of interest within government agencies which play a role both in the regulation and promotion of uranium mining? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

- What long term commitments are the government monitoring agencies prepared to make in terms of frequency and adequacy of inspection to ensure the level of monitoring would not be affected by budgetary constraints? (GNWT, AECB, EM&R, DIAND, NWT Water Board, DFO, HWC, DOE, DOT, and LC)

3.0 ECOSYSTEM IMPACTS

This section includes requests for information that relates to the effects of the project as a whole, on the entire ecosystem. The objective of this ecological approach to environmental impact assessment is to ensure that all potential impacts resulting from the project are examined as part of an interrelated system rather Than as isolated units.

3.1 Biological Impacts

3.1.1 Plant Life

3.1.1.1 Focus of Concern

Concerns expressed over potential impacts to the plant life in the Keewatin region focussed on plant life (particularly lichen) as a food supply for wildlife (particularly caribou). Plant life is seen as an important element of the food chain which eventually includes humans as the consumer of wildlife and plants (particularly berries).

3.1.1.2 Spatial and Temporal Boundaries

In establishing a study area for data collection and analysis, the proponent must first define the maximum spatial and temporal extent of potential impact. This boundary must take into consideration air and water pathways by which contaminants may be dispersed over time.

3.1.1.3 Baseline Data

- Identify and illustrate the extent and distribution of all significant plant species in the study area as defined above. Significant plant species include those which, in isolation or as part of a plant community:
    - are rare or unique to the Keewatin region;
    - are important food sources to humans and/or wildlife;
    - tend to bioaccumulate contaminants;
    - are particularly sensitive to contaminants;
    - are "indicators" of various potential impacts;
    - play an important role in the ecosystem structure and function; or
    - play an important role in permafrost integrity and slope stability.
- Identify those "keystone species" which play a particularly important role in maintaining the balance of the ecosystem. What role do these important species play in maintaining the structure and function of the ecosystems?
    - include such factors as consumption by wildlife and humans, slope stability and permafrost degradation

- What is the potential for bioaccumulation of radiological and non-radiological contaminants in the significant species as defined above? What is the long-term persistence of these contaminants?

- Identify any pathways through which radiological and non-radiological contaminants could pass from plant species to wildlife and humans.

- Are any of the significant (see above) plant species currently contaminated with radiological or non-radiological contaminants? Identify the source, degree, distribution and means of contamination. Include all contaminants which could potentially increase with impacts from the proposed mine, and any chemical, physical or biological characteristics of the existing plant life which may affect the rate of uptake, persistence or susceptibility of plants to future contaminants.

3.1.1.4 Potential Agents of Change

- What radiological and non-radiological contaminants associated with the proposed mine project could potentially contaminate plant species? What are the sources of these contaminants? Are there any seasonal variations to the distribution of these contaminants?

    - include contaminants arising from construction, open-pit, mill, ore storage bins, tailings, sewage disposal, sulphuric acid and lime plants, power plant, camp, transportation infrastructure, decommissioned facility and all other potential sources of contaminants

- By what means could contamination occur?

    - include air deposition (fallout), rainfall, uptake from groundwater, soil contamination and all other potential means of contamination

- What is the potential distribution and degree of contamination?

- By what means could plant life undergo physical disturbance?

    - include road construction, quarrying, backfilling and all other potential means of disturbance

3.1.1.5 Potential Consequences of Change

Given the agents of change identified above, what are the potential impacts of contamination and disturbance on the plant species themselves and on maintenance of the ecosystem balance? Include various degrees of impact from least to greatest significance.

3.1.2 Wildlife

3.1.2.1 Focus of Concern

Concern expressed for the wildlife focussed primarily on the fish and caribou which make up a significant portion of the local diet. Contamination of these human food sources and habitat disturbance (particularly the limestone quarrying activities in caribou calving grounds) are seen in the context of the entire food chain.

3.1.2.2 Spatial and Temporal Boundaries

In establishing a study area for data collection and analysis, the proponent must first define the maximum spatial and temporal extent potential contamination or disturbance. This boundary must take into consideration air, water and food supply pathways by which contaminants may be spread, and migratory routes by which wildlife travel over time.

3.1.2.3 Baseline Data

- Identify and show the extent and distribution of all significant species of fish, birds, insects, and small and large mammals that permanently or temporarily make use of the habitat in the study area as defined above. Identify important habitat areas, migratory routes and patterns, breeding patterns and calving grounds (specify intensity and timing of land use). Significant species include those which:
    - are rare or unique to the Keewatin region;
    - are important food sources to humans and/or other wildlife;
    - are important to the local culture;
    - are important to the local economy;
    - tend to bioaccumulate contaminants;
    - are particularly sensitive to contaminants;

- o are "indicators" of various potential impacts; or
- o play an important role in the ecosystem: structure and function.

- Identify those "keystone species" which play a particularly important role in maintaining the balance of the ecosystem. What role do these important species play in maintaining the structure and function of the ecosystems?

  - o include such factors as food supply, competition, predation, habitat and consumption by humans.

- What is the potential for bioaccumulation of radiological and non-radiological contaminants in the significant species as defined above? What is the long-term persistence of these contaminants?

- Identify any pathways through which radiological and non-radiological contaminants could pass from one wildlife species to another or to humans.

- Are any of the significant (see above) wildlife species currently contaminated with radiological or non-radiological contaminants? Identify the source, degree, distribution and means of contamination. Include all contaminants which could potentially increase with impacts from the proposed mine, and any biological or chemical attributes of the existing wildlife which may affect the rate of uptake, persistence or susceptibility of wildlife to future contaminants.

3.1.2.4 Potential Agents of Change

- What radiological and non-radiological contaminants associated with the proposed mine project could potentially contaminate wildlife species? What are the sources of these contaminants?

- By what means would contamination occur?

  - o include air deposition (fallout), water, food supply and all other potential means of contamination

- What is the potential distribution and degree of contamination in wildlife species?

- What is the potential for bioaccumulation of radiological and non-radiological contaminants in all indigenous wildlife species?

- What is the potential for contamination of "country food" stored in caches on the land?

- By what means could wildlife habitat undergo physical disturbance? (Of particular importance is disruption of caribou calving grounds and wolf dens)

  - include road construction, winter roads, quarrying, backfilling and all other potential means of disturbance

- How might wildlife be disturbed by the noise and ongoing activity of construction and mine operation?

- How might fish and wildlife be affected by increased fishing and hunting with in-migration of population and increased access to fishing and hunting areas?

3.1.2.5 Potential Consequences of Change

- What are the potential impacts of animal contamination, habitat disturbance and other disturbances on the animal species themselves and on maintenance of the ecosystem balance? Include information on long-term, cumulative impacts given the current levels of contaminants in the wildlife, and degrees of impact at various age groups.

3.2 <u>Physical Environment Impacts</u>

3.2.1 Focus of Concern

The element of the physical environment which is of greatest concern is the permafrost. Uncertainty of how the integrity of the permafrost would be altered through the course of the proposed development and into the long term is of concern particularly in the face of global climate change.

3.2.2 Spatial and Temporal Boundaries

In establishing a study area for data collection and analysis, the proponent must first define the maximum spatial and temporal extent of potential contamination or disturbance. This boundary must take into consideration air, and water pathways by which contaminants and physical disturbances may be distributed.

3.2.3 Baseline Data

- Provide an inventory of the physical environment outlining all significant geomorphological features.
    - o include all surficial, geological, glacial and permafrost features
- What processes are active in the dynamics of these features? Of particular importance are permafrost dynamics.
    - o include role of climate, vegetation, wildlife, water, and all other factors which influence the state of the physical environment
- What are the current permafrost distributions, depths and variations in the proposed project site area?
- What is the pattern and depth of the active layer? What are the seasonal variations? What variations in active layer depth have taken place over time?
- Provide a comprehensive geotechnical study of the proposed tailings containment facility.
- What role does the surficial geology play in maintaining ecosystem balance?
    - o include soil-plant interactions and groundwater movement
- Is any of the surficial material currently contaminated with radiological or non-radiological contaminants?

3.2.4 Potential Agents of Change

- What radiological and non-radiological contaminants associated with the proposed mine project could potentially contaminate surficial material?
- What are the sources of these potential contaminants?
    - o include the open pit, mill, lime plant, sulphuric acid plant, ammonium nitrate fuel oil blasting, and any other potential sources
- By what means could contamination occur?
    - o include all air and water pathways (including acid precipitation)

- What is the potential for accumulation and concentration of radiological and non-radiological contaminants in surficial materials?

- By what means could the physical features undergo physical disturbance?

  - include permafrost degradation resulting from vegetation disturbance, and potential impacts of the tailings management plan on permafrost integrity

3.2.5 Potential Consequences of Change

- What are the potential impacts of contamination and physical disturbance of the physical features themselves and on maintenance of ecosystem balance?

3.3 Surface and Groundwater Impacts

3.3.1 Focus of Concern

The potential for contamination of the water and subsequently the wildlife, plants and humans supported by water was expressed as a broad concern. Recognizing that water is also a means of spreading contaminants, the position of communities downstream from the proposed mine site and the spring run off conditions were referred to frequently.

3.3.2 Spatial and Temporal Boundaries

In establishing a study area for hydrologic data collecting and analysis, the proponent must first define the maximum spatial and temporal extent of potential contamination. In the case of hydrologic boundaries, the spatial extent of impact must be defined for both surface and ground water (ie. surface area covered and depth of subsurface water). At a minimum, hydrological information must be collected for all receiving waters throughout the system to the marine confluence.

3.3.3 Baseline Data

- Identify all surface and groundwater features in the area defined by the boundary established above.

   - include details of drainage patterns, location and size of watersheds, precipitation, runoff and evapotranspiration, storage capacity, water quality, thermal patterns, discharge rates, velocity, sedimentology, lake morphometry, and channel morphology.

- What role does each component of the hydrologic environment play in maintaining ecosystem balance?

   - include support of plants, wildlife and humans, and role in the dynamics of surficial features

- Are any elements of the hydrologic environment currently contaminated with radiological or non-radiological contaminants? Identify the source, degree, distribution and means of contamination.

3.3.4 Potential Agents of Change

- What radiological and non-radiological contaminants associated with the proposed mine project could potentially contaminate elements of the hydrologic environment?

- What are the potential sources of these contaminants?

   - include construction, the open-pit, mill, ore storage bins and piles, waste rock piles, tailings, transportation system, marine terminals, fuel storage areas, chemical storage areas, decommissioned facility and all other potential sources

- By what means could contamination potentially occur?

   - include water and air pathways

- What is the potential distribution and degree of contamination of surface and groundwater? How might spring runoff and other seasonal variations in water volume and velocity affect the rate of potential contaminant dispersion?

- What is the potential for radiological and non-radiological contamination of downstream waters in the area of the communities of Baker Lake and Chesterfield Inlet?

- What is the potential for accumulation and concentration of radiological and non-radiological contaminants in the hydrologic environment?
    - include stream and lake sediment, groundwater channels and aquifers
- What is the potential for alteration of the sedimentation patterns in rivers and lakes?
- What plans, if any, are there for channel training, dredging or other engineering alterations to the Chesterfield Inlet waterway?
- What elements of the hydrologic environment might undergo physical disturbance?
    - include use of lakes for tailings, damming of streams and all other potential disturbances
- What is the potential for changes to water levels, and water movement patterns?
- What is the potential for alteration of surface drainage patterns?
    - include spring run-off, subgrade degradation, and ice-filling of culverts

3.3.5 Potential Consequences of Change

- What are the potential impacts of sediment and water contamination, sedimentation changes, water level changes and physical disturbance of surface and groundwater systems and on the maintenance of ecosystem balance?,
    - include potential on-site and downstream impacts

3.4 Atmospheric Environment Impacts

3.4.1 Focus of Concern

Given the distinctively strong winds in the Keewatin region, concern over air quality impacts focussed on the potential for widespread dispersal of radioactive gas and dust.

3.4.2 Spatial and Temporal Boundaries

In establishing the boundaries for the study area, the proponent must define the maximum spatial and temporal extent of potential air quality impact.

3.4.3 Baseline Data

- Provide a profile of the meteorological conditions for the area as defined above, including all parameters that would affect air quality and the airborne dispersal of radiological and non radiological contaminants. If the Baker Lake station is used as a standard for the Kiggavik site, provide quantitative rationale to support this extrapolation.

- What radiological and non-radiological contaminants are presently in the atmosphere in the Kiggavik area? What are the sources of these contaminants?

3.4.4 Potential Agents of Change

- What radiological and non-radiological contaminants associated with the proposed mine project could potentially enter the atmosphere?

    - include particulate matter, gaseous emissions and chemical emissions

- What are the sources of these potential contaminants?

    - include construction, open-pit, mill, ore storage bins, lime and sulphuric acid plants, power plant, limestone, quarry, tailings, transportation, decommissioned facilities, and all other potential sources

- How would contaminants be dispersed and deposited?

- How do site-specific and seasonal factors such as wind speed and direction, precipitation, atmospheric stability, temperature inversions, heavy fog and topography affect dispersal of particulates and gases?

- What are the potential patterns of contaminant dispersal and deposition for all potential contaminants?

3.4.5 Potential Consequences of Change

- What impacts would these contaminants have on ecosystem balance?
    - include potential contamination of water, soil, plants, wildlife and humans?
- What potential impacts would contaminants have on local, regional and global air quality?

3.5 Archaeological Impacts

- Identify all areas or features of archaeological or cultural importance in the area. Identify ancestral burial sites near the proposed mine site and transportation infrastructure. What arrangements are proposed to deal with situations where the proposed project may interfere with existing valued cultural and archaeological sites and features? (UG and GNWT)
- Identify any plans to protect sites by avoidance, excavation or company policies to discourage vandalism.
- What are the potential impacts of the proposed development on cultural and archaeological features?

4.0 SOCIO-ECONOMIC IMPACTS

Like the previous section, this section takes a broad-based approach to examining impacts as part of an interrelated system. In this case, the interrelated system is the socio-economic system that could be affected by the project. This system includes elements relating to community lifestyles, community character, culture, employment, and community-based enterprises. The responses to the following information requests are intended to provide a comprehensive picture of the socio-economic system in the project area and potential project impacts on this system. The Panel views socio-economic impacts to be of great importance and the responses to the following requests should not be treated as of secondary importance when compared to the ecosystem impacts.

4.1 Focus of Concern

The socio-economic concerns of the Keewatin communities-focussed on the potential negative impacts associated with in-migration of southern workers. Many questions also arose about the potential for native and northerner employment opportunities.

4.2 Spatial and Temporal Boundaries

Studies into the potential socio-economic impacts are expected to include all of the Keewatin communities. The temporal boundary should be extended into the long term, to the maximum future extent of potential impact.

4.3 Socio-Economic Structure

- Carry out a baseline study of the local communities to identify population distribution, levels of education, demographics, language, religious affiliation, ethnic background, household income, dependence on government assistance and employment patterns.

- Identify those aspects of the communities that are most important in defining the character and culture of the community and in maintaining the social structure and function of the community.

- What are the dominant institutional and economic activities in the Keewatin?

- What social problems are evident in the local communities?

- How might the proposed mine directly or indirectly alter the existing social structure?

    - include such factors as changes in household income, increased economic activity, separation of workers from family members, in-migration of non-northerners, change in subsistence economy patterns, etc.

- Given the current socio-economic structure of the Keewatin, what projections can be made about the future structure in the absence of the proposed mine development?

- How has industrial development affected the social and economic structure of similar northern communities?

- What is the potential for in-migration of people into the Keewatin Communities in both the construction and operation phases of the proposal? Provide a breakdown of anticipated in-migrants (ie. native/non-native, northern/southern.

    - o consider the potential for in-migration associated with the potential for increased economic activity through the provision of supplies and services to the proposed mine by local communities

- What are the potential impacts of population in-migration and other potential changes on the communities?

    - o include changes in the cost of living, boom/bust syndrome, cultural differences, increased pressure on service facilities such as schools and hospitals, demand and cost of housing, increased hunting, creation or exacerbation of social problems, alcoholism, drug abuse, prostitution, unwanted pregnancies, loss of language and culture, marriage and family breakdown and all other potential impacts that may occur throughout all phases of the proposed project

- How might in-migration of construction and mine/mill workers affect the rates of sexually-transmittable diseases such as venereal disease, herpes and AIDS?

- What long-term benefits would remain in the Keewatin after mine closure?

- Is there any possibility of there being an increase in home, life and health insurance in nearby communities due to the presence of the proposed mine?

4.4 Native and Northern Employment

- What is the current level of skill and training in the local communities that could be utilized for employment in the proposed mine?

- What needs of the proposed mine could be met by skills and capabilities currently existing in the local communities?

- What types of jobs would be available for northern and native people? How many? What criteria would be used to define northern and native people?

- How would native and northern employment be incorporated into the proposed mine hiring policies?

- Would these policies apply uniformly throughout all phases of the project?

- What total percent of northerners would the proposed mine employ?

- Would the management of the proposed mine ensure that contractors and sub-contractors were subject to the same policies?

- What type of commitment or guarantee would the proponent be willing to make regarding employment of native and northern people?

- Would natives and northerners acquire appropriate mining certification that could be used in other locations in the future?

- Would there be any cross-cultural programs between northerners and southerners and natives and non-natives?

- What policies would be in place regarding native and northern workers receiving equivalent pay to southern workers with the same experience and qualifications?

- How would the communities be consulted regarding work schedules?

- What programs are proposed to assist native employees with the transition to wage employment and matters of financial management?

- What is the willingness and interest amongst local people to work in an industrialized environment generally, and at the proposed mine specifically?

- Would the proposed mine employ union or non-union workers? How would this affect the ongoing prospects for native employment?

- Would native trainees and employees have native supervisors and native support personnel whom they can consult about personal and other problems related to their training or employment?

- How would local communities be informed about job and training opportunities?

4.5 Provision of Goods and Services

- Provide information on the type, volume and value of goods and services to be acquired locally and opportunities to diversify and increase local supply.

- How would the proponent assist local small businesses in order that they may successfully bid on business opportunities? (consider such options as dividing jobs up into small tasks, holding pre-bid workshops to explain the bidding process, post-bid workshops to explain deficiencies in unsuccessful bids, joint-venture programs, providing transport of materials into the site, etc

- Are any of the employment and business opportunities likely to remain after mine closure?

4.6 Non-northern Employment

- Would residents of regions other than the Northwest Territories be contacted with regard to employment opportunities? How and where would this be carried out?

- How would southerners apply to the proposed mine? (ie. would they arrive in Baker Lake to seek employment?

- Is there any legal mechanism by which non-local job-seekers can be limited in their access to Baker Lake?

- What contact would southern-hired mine employees have with Baker Lake while off duty? Would this contact be limited or controlled in any way?

4.7 Training

- How and where would pre-training and in-service training be carried out?

- Would there be management training and management positions for native and northern people?

- Would the proposed mine promote mining career training through such programs as scholarships for high schools, technical schools and universities?

- What pre-service and in-service training programs are proposed for native and northern employees?

- What would happen to employees after mine closure? What programs would be developed to assist employees?

- When would job training begin? Would this be for skilled labour and management as well as for laborers?

- What training would be required to prepare local residents for managerial and other positions of responsibility on the proposed mine site? Who would pay for this training?

- What rotational work schedule is proposed? What is the rationale for selection of this schedule?

4.8 Workers' Camp

- Questions regarding the workers' camp apply to all camps, including temporary camps for construction and more permanent camps for mine/mill operation.

- What accommodation arrangements would be provided to mine workers? Would arrangements be made to accommodate female workers?

- Would couples with or without children be accommodated?

- What arrangements would be made to control drugs and alcohol at the camp?

- Would any child care facilities be provided for children while parents are working? Where would such facilities be located? Who would staff such facilities?

- What access would workers have to fishing and hunting in the area? How would this be controlled and monitored?

- Would the proposed mine schedule be sufficiently flexible to allow for traditional hunting seasons?

- Who would pay for the air transport of workers from their homes to the proposed mine site?

- From what areas would the company fly workers in?

- What would happen if weather conditions were such that the airplanes could not bring workers in or take workers out?

Would workers unable to leave the mine site continue to be paid while waiting for the weather to change? How often is the Baker Lake airport closed? How often would there likely be air strip closure at the proposed mine site?

- What social and recreational programs would be provided at the camp?

- How would the camp be adapted to meet the particular needs of native employees? Would country foods be provided in the cookhouse?

- Provide rationale for use of the fly-in/fly out system of employment?

- What access would local people have to the mine and what access would mine workers have to the local communities? How would this be controlled?

4.9 Renewable Resource Use

- What are the current traditional uses of the area?

    - include hunting, fishing, trapping and all other traditional uses

- What is the economic value of "country food" consumption (ie. what is the replacement cost if another source of protein were required)?

- What are the commercial uses of the natural resources?

- What is the potential for commercial use of natural resources?

- What is the economic value of commercial resource use?

- What impacts could real or perceived contamination of these resources have on. the commercial use of these resources?

- How would transportation systems associated with the proposed mine affect access to renewable resources?

4.10 Tourism

- What is the present recreation and tourism use of the Keewatin region?
- What role does tourism play in the local economy?
- What features of the Keewatin attract tourists?
- Identify all significant recreation, sport, hunting, fishing and other tourism opportunities.
- What is the recreation and tourism potential for the Keewatin region?
- Are there any plans to expand traditional or recreational uses of the region?
- What impacts could the proposed mine have on existing or potential tourist industries, particularly those based on renewable resources?
- What are the potential impacts of the project on current and planned traditional and recreational uses of the area?
- How might transportation systems associated with the proposed mine affect access of the area to tourism and recreation?

5.0 HUMAN HEALTH IMPACTS

Responses to information requests in this section are intended to examine potential effects on worker and community health and safety.

5.1 Worker Health and Safety

5.1.1 Focus of Concern

The primary concern with regard to worker health and safety centered on potential for negative health effects associated with uranium mining, particularly on the incidence of cancer.

5.1.2 Spatial and Temporal Boundaries

In establishing the study area, the proponent must identify all potential groups of workers and define the maximum temporal extent of potential health impacts.

5.1.3 Information Requirements

All sources of hazards, radiological and non-radiological, must be identified and the means of controlling these hazards and of protecting the workers must be described. Without restricting the generality of this requirement, the following points must be addressed.

- Outline the potential long and short term effects of exposure to ionizing radiation. (UG, ABCE and HWC)
    - include potential effects to smokers and non-smokers
- What radiological and non-radiological contaminants associated with the proposed mine project could adversely affect the health of workers?
- What are the potential sources of radiation dose?
    - include construction, open pit, ore storage bins, mill, tailings area, surrounding area, transportation, decommissioned facilities, and all other potential sources
- What measures would be taken to limit workers' dose?
- Describe the planned distribution and use of respirators, protective clothing, etc. Has this equipment been tested and used in arctic conditions?
- What precautions will be exercised against the intake of uranium dust?
- Describe the provisions being made for workers' clothing, storage of laundry waste water, contaminated vehicles, equipment and containers, etc.
- What training is proposed to educate workers on matters of radiation protection, health instruction, and safety and emergency response?
- What health facilities are proposed to provide medical services to the mine workers?

- What consultative processes would take place between health professionals, the workers, and their families regarding screening and monitoring of body radiation levels and general health.

- Provide details of health surveillance programs which would be offered, to employees before, during, upon termination, and after employment? Would this include a biological sampling program?

- What special surveillance programs would be carried out for workers considered to be at special health risks?

- Where would health records be deposited and preserved?

- What provisions would be made to ensure confidentiality of individual worker's health records?

- Would regular independent audits of the worker health and safety program be carried out?

- To what additional non-radiologic hazards would workers be exposed? How do these hazards compare to other types of mining?

- What preventative/treatment programs are proposed for drug and alcohol abuse, sexually transmitted disease and other related illnesses that may' be associated with mining camps of the nature proposed?

- In the case of accidents where workers are seriously injured, how would they be transported and to what medical facility would they be taken?

- Would workers be provided with liability or life insurance? What terms and conditions would apply?

- Would a workers' safety committee be formed? What role would it have?

- Describe the means for monitoring and/or determining radiation dose, from all sources, external or internal, including bioassays.

- Who would decide on the appropriate parameters to monitor? How would these parameters be monitored? Who would monitor them? Who would pay for the compliance and effects monitoring? For how long? (UG and GNWT)

- What financial arrangement would be made to provide sufficient resources for the compensation of former workers for any damage to health, both pre- and post abandonment?

5.2 Public Health and Safety

5.2.1 Focus of Concern

Public health concerns focussed on the potential for negative health affects associated with radioactive contamination through ingestion of contaminated water and "country food" and through inhalation of contaminated air.

5.2.2 Spatial and Temporal Boundaries

As for socio-economic impacts, the study area for public health impacts should include all Keewatin communities, and extend into the long term, to the maximum future extent of potential impact.

5.2.3 Baseline Data

- Provide baseline data necessary for predicting potential impacts to public health. This may include the following information:
    - population size
    - fertility rates
    - live birth weights and rates
    - fetal and infant mortality rates
    - breastfeeding rates
    - expected life spans
    - cancer rates
    - major infectious disease rates
    - autoimmune disease
    - congenital disease or malformation rates
    - normal blood and urine parameters
    - nutrition patterns
    - existing levels of uranium, decay products and heavy metals

- What baseline information would be required for an adequate public health monitoring program?

- What baseline information would be required as a legal basis for compensation litigation?

- Would split samples of baseline and monitoring tests be provided for independent verification?

- What is the current level of background radiation in the local human population? What are the sources and pathways of this radioactivity?

5.2.4 Potential Agents of Change

- What radiological and non-radiological contaminants could potentially affect the health of Keewatin residents?

- What are the sources of these potential affects?

- What are the potential means of contamination?

    - o include air, water, soil, plant and wildlife pathways

5.2.5 Potential Consequences of Change

- What are the potential long and short term health impacts of exposure to radiation?

    - o include expected levels of exposure to permanent residents of nearby communities and to others such as hunters and trappers who may reside temporarily in the area surrounding the proposed mine

- How might presence of the proposed uranium mine alter the relative risks of these groups to health impacts such as cancers, birth defects and other illnesses? How does this vary by age and by sex?

- How does the rate of tobacco consumption affect the risk of potential negative health impacts associated with uranium mining? (UG, AECB, HWC, GNWT)

- How would the rate of tobacco consumption be incorporated into the estimation of potential health impacts?

- Have local characteristics such as body size and weight been taken into consideration in determining acceptable levels of exposure? How might these factors alter the acceptable levels? (UG, AECB, HWC, GNWT)

- What variation in inhalation of contaminants may exist between nose-breathing and mouth-breathing (which is more common in cold climates) people? Have these factors been taken into consideration? (UG, AECB, HWC, GNWT)

- What particular potential health risks are associated with radioactive exposure of pregnant women? Are the expected levels of exposure resulting from the proposed mine high enough to give rise to these risks? (UG, AECB, HWC, GNWT)

- How might presence of the proposed uranium mine affect the psychological health of Keewatin residents? (UG, AECB, HWC, GNWT)

    - include effects of stress and anxiety associated with fear of potential radioactive and non-radioactive contamination of the environment and humans and potential negative socio-economic impacts, including separation of family members, shift from traditional to wage economy etc.

- What health care facilities and programs would be offered to Keewatin residents? (UG, AECB, HWC, GNWT)

- What control measures would be undertaken to ensure that people are not exposed to contaminated waste through scavenging of contaminated building materials, equipment, etc.?

- What problems may arise from the lnuit's immunity to viruses and diseases from outside their communities that they may come into contact with? (UG and HWC)

- How would it be determined that a death, illness or condition is attributable to the mining operation? Who would determine this?

5.2.6 Consumption of "Country Foods"

- To what extent do the local residents depend on "country foods", particularly fish and caribou? Does this vary seasonally? Does this vary within and between the Keewatin communities?

- What are the potential health impacts of exposure to radioactive and non-radioactive contaminants through the consumption of caribou and other "country food" that may be contaminated? Illustrate how this may vary according to age of humans, rates of consumption, and levels of contamination in food. (UG, AECB and HWC)

- If the supply of "country food" were to decline, what would the potential health impacts be of switching from "country food" to store-bought food? (UG, AECB and HWC)

6.O RISK MANAGEMENT

An important component of managing a project with potential negative effects on the natural and human environments is the identification and assessment of risks associated with the project and the identification of procedures to deal with these risks. Responses to the following information requests are intended to address these issues and become the focus for a comprehensive environmental and health protection management plan.

6.1 Focus of Concern

Concern focussed on the preparedness of the proponent and region to respond to various accident scenarios, including a fuel spill in Chesterfield Inlet and a plane crash involving yellowcake. It was felt that accidents are inevitable, particularly given the harsh arctic conditions.

6.2 Spatial and Temporal Boundaries

In defining an area within with to consider risk management, the proponent must identify the maximum spatial and temporal extent of potential impact. In instances such as transport of dangerous goods, risk must be considered along the full route of transport.

6.3 Information Requirements

- Outline details of emergency response procedures for the mine and mill operation and the transportation system.

- Identify all areas that have a relatively high risk of an accident occurring. For these areas, outline emergency response plans for the most probable accident and the worst-case accident.

- What spill and fire contingency plans are proposed?
    - include reference to diesel, kerosene, uranium, thorium, ammonium nitrate and all other regulated dangerous goods to be used, stored or transported on site
- What particular plans are proposed for the safe transport, handling and transferring of dangerous goods?
- What physical barriers would be constructed at the mine, mill, storage, and transportation systems to allow for containment of spills?
- What measures would be undertaken to prevent accidents from occurring?
    - include worker safety training programs, monitoring and inspection
- What emergency response equipment is proposed?
- What experience and academic qualifications would be required of the person responsible for radiation protection and safety at the proposed mine?
- What communications network is proposed?
- Have the emergency response plans and equipment been specifically adapted to the arctic environment?
- What special adaptations have been made to plans and equipment for response to emergencies that may occur during severe arctic storms?
- Outline programs for training employees in emergency response procedures and accident prevention. How much "hands on" training would be carried out?
- What dangerous goods would be transported near communities? What contingency plans are proposed for these areas?
- What accident scenarios, if any, could potentially result in the evacuation, of Baker Lake or other Keewatin Communities?
- Outline programs for training members of the surrounding communities in emergency response and evacuation procedures.

- In the event of a hazardous materials release, how would clean up be carried out, by whom and who is responsible for the cost of clean up?

- Would manuals be prepared for use by workers in the event of an accident?

- For each regulated dangerous good used, handled, stored or transported on-site, provide the worst-case and most probable accident scenario. Outline the proposed emergency response plan for each of these scenarios.

  Specifically, provide details of a proposed response plan to the following situations (assuming worst-case weather conditions

  - an accident involving the release fuel from a barge in Chesterfield Inlet;

  - a breach (or burst) of the tailings dam; and

  - a plane accident involving the release of yellowcake near a settlement or important water course.

- In the event of a large-scale accident, who would be responsible for protection of wildlife?

- What packaging would be used in the air transport of yellowcake to prevent spillage in the event of an air crash?

- What compensation would be available in the event that a public water system or food source is contaminated to a degree where it is no longer fit for consumption?

- What particular problems do the wind, spring runoff, snow, ice and permafrost present for clean up in the event of a dangerous goods release?

- Have there been any barge or shipping accidents through the Chesterfield Inlet waterways? Provide location, conditions, consequence, cause, and any response measures taken.

- Is there, any equipment or expertise in the area to respond to a marine spill of fuel enroute from Montreal to Baker Lake? How would clean up be handled in different seasonal conditions? Where would clean up crews come from?

7.0 TAILINGS MANAGEMENT AND SITE DECOMMISSIONING

7.1 Focus of Concern

It is widely recognized that the tailings and waste rock would remain radioactive for a very long time. Concerns focussed on long-term management of the tailings and the decommissioned site.

7.2 Spatial and Temporal Boundaries

In defining the study area for consideration of the tailings management and site decommissioning, the proponent should define the maximum spatial and temporal extent of possible future impacts. Given the concern for long-term impacts of the site after mine closure, particular emphasis should be given to the long term.

7.3 Information Requirements

- Outline the proposed management scheme for waste rock and tailings in the decommissioning and abandonment stage.
- How long would the proposed mine site remain contaminated with radioactive and non-radioactive wastes? How might contamination vary seasonally and over time?
- What radioactive material would be left above ground after decommissioning? Describe the physical, chemical and radiological characteristics of this material.
- How have the extreme weather conditions been taken into consideration in establishing long-term tailings management plans?
- What are the potential impacts of global warming on the integrity of permafrost and the tailings management plans?
- Would the tailings pond be lined? If so, would the material be resistant to scouring and annual freeze-thaw pressures?
- What mechanisms, including a possible physical barrier would be put in place to prevent wildlife from using the tailings pond area as a source of water and habitat?
- What is the expected capacity of the tailings pond?

- Would there be adequate physical barriers to prevent the contents of the tailings pond from spilling over the banks in the case of high winds or intense precipitation of extended duration?

- Would there be any barriers to prevent contaminated snow on top of the tailings from dispersing beyond the site under high wind conditions?

- What evidence is there to support the assumption that the permafrost would create an impermeable barrier to radioactive and non-radioactive contamination from the tailings and waste rock?

- What possible impacts might the presence of radioactive material in the tailings have on the permafrost beneath them?

- What levels of radioactive and non-radioactive contamination would remain in the liquid outputs, including sludge?

- How would these liquid outputs be treated and stored?

- What levels of radioactive and non-radioactive contamination would remain in the waste rock?

- Would buildings and infrastructure be contaminated after closure of the proposed mine? What plans are in place for abandonment, decontamination, removal or use of the infrastructure after mine closure?

- How long would the wastes, remain hazardous to the environment and the health of humans and wildlife?

8.0 MITIGATION AND MONITORING

Responses to this section are intended to address proposed and alternative means of mitigating potential negative impacts of the project ion the physical, biological, human, and economic environments, and to outline the proposed means of monitoring the physical, ecological and human systems to ensure that changes to these systems are identified and reported to appropriate government agencies. The Panel is interested in potential on-site and related off-site impacts. In order to enhance the understanding of environmental and social impacts from uranium mining and development in the arctic, and to assist in the evaluation of such mines in the future, the Panel expects that the proponent would place importance on developing a post-project analysis program.

8.1 Focus of Concern

Public involvement in long term monitoring of impacts and mitigation measures arose as a key issue. The possibility of public input to the development of mitigation measures was also brought forward. Long-term mitigation and monitoring of impacts associated with the tailings was of particular concern.

8.2 Spatial and Temporal Boundaries

Outline proposed mitigation and monitoring programs for the impacts identified in the EIS. The spatial and temporal boundaries for monitoring and mitigation should be the same as those delineated for potential impacts in the EIS.

8.3 Mitigation

- For all potential impacts to the environment, wildlife and humans, outline proposed mitigation plans.
    - include potential impacts to the biosphere (plants and wildlife), lithosphere, hydrosphere, atmosphere, and humans
- Give rationale for selecting the proposed plans and outline alternative mitigation options.
- In each instance, indicate who would pay for mitigation and how it would be carried out.
- Provide rationale where mitigation plans are not proposed for potential impacts.
- What approach would be taken to mitigate unanticipated impacts? Who would be responsible?

8.4 Monitoring

The remaining questions and information requests on monitoring and post-project analysis are directed to:

Urangesellschaft
Government of the Northwest Territories
Northwest Territories Water Board
Atomic Energy Control Board
Department of Energy, Mines and Resources
Department of Indian and Northern Affairs
Department of Fisheries and Oceans
Health and Welfare Canada
Environment Canada
Transport Canada
Labour Canada

- What programs are proposed to provide for effects monitoring of radiological and non-radiological contamination levels over all phases (construction to post-operation) of the proposed mine project?

- What potential environmental and human impacts would be monitored? During what phases would these impacts be monitored? How long would they be monitored for? How would they be monitored?

- What baseline data would be collected?

- Who would be responsible for the design and implementation of a monitoring program?

- Would independent experts be appointed to help with the design of the monitoring program?

- What would the roles of government agencies and the proponent be in the design and implementation of a monitoring program?

- Who would pay for various monitoring programs?

- Would ongoing independent audits of the environmental and health monitoring programs be carried out? How would they be carried out?

- What role would communities and regional organizations have in compliance and effects monitoring? Would a public monitoring committee be established? Who would be involved? How would this operate?

- Identify and refer to public monitoring programs which have been used in other areas.

- What provisions would be made to train and provide local people with independent ability to carry out compliance and effects monitoring of mine and mill effluent, airborne gases and contaminants, health effects, and food contamination?

- How would cumulative effects be monitored?

- How would "negative impacts" or failure of environmental management systems be identified? What criteria would be used to determine significant changes in environmental quality?

- When monitoring programs identify negative impacts, what would be done to mitigate them? Who would pay for mitigation?

- If technology is ever available to dispose of the wastes from the proposed site, who would be responsible for removing the waste and ensuring it is safely disposed of?

- What financial arrangements would be made by the proponent and government agencies to provide sufficient resources for- the compensation of Keewatin residents for damage to human health, wildlife and the environment identified through monitoring?

8.5 Post Project Analysis

- Outline details of the proposed post-project analysis program. What elements of the project would undergo post-project analysis?

- Who would be represented in development of the post-project analysis program?

- What roles and responsibilities would each organization have in the program?

- How would the public be involved in post-project analysis?

- Estimate the approximate costs of the program and the organizations that would bear these costs.

- What is the estimated time frame for the post-project analysis?

- Who would continuously review the project records and report to the proponent, government agencies, interested groups and the public?

- How would elements of the projects be selected to undergo post-project analysis? Would the public be involved in identifying "key issues" to addressed in the post-project analysis program?

- Would there be a clear, precise definition of hypothesis testing?

- Who would ensure that adequate and sufficient data are collected to provide an effective data base for post-project analysis?

- Would independent experts be engaged in the post-project analysis? At what stages? Who would pay for them?

- Would the public have access to all information?

- How would the information gained for the post-project analysis be made available to improve scientific knowledge and the procedural/administrative framework of future projects?

- How would the information collected be documented and stored? Who would have access to this information? What information would the public have access to?

- Would post-project analysis information be made available in English and Inuktitut?

- How would the post-project analysis review cumulative impacts?

- How would the post-project analysis be coordinated with the monitoring program?

- Would the post-project analysis be a condition of licensing or project approval?

APPENDIX 2: Fairlie: ‘Childhood cancer near nuclear power stations’

Environmental Health

BioMed Central

Commentary

Open Access

Commentary: childhood cancer near nuclear power stations

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Abstract

In 2008, the KiKK study in Germany reported a 1.6-fold increase in solid cancers and a 2.2-fold increase in leukemias among children living within 5 km of all German nuclear power stations. The study has triggered debates as to the cause(s) of these increased cancers. This article reports on the findings of the KiKK study; discusses past and more recent epidemiological studies of leukemias near nuclear installations around the world, and outlines a possible biological mechanism to explain the increased cancers. This suggests that the observed high rates of infant leukemias may be a teratogenic effect from incorporated radionuclides. Doses from environmental emissions from nuclear reactors to embryos and fetuses in pregnant women near nuclear power stations may be larger than suspected. Hematopoietic tissues appear to be considerably more radiosensitive in embryos/fetuses than in newborn babies. Recommendations for advice to local residents and for further research are made.

Introduction

Increased incidences of childhood leukemias were first reported near UK nuclear facilities in the late 1980s. Various explanations were offered for these increases; however the UK Government Committee on the Medical Aspects of Radiation in the Environment (COMARE) concluded in a series of reports [1-4] that the causes remained unknown but were unlikely to involve radiation exposures. This was mainly because the radiation exposures from these facilities were estimated to be too low, by two to three orders of magnitude, to explain the increased leukemias.

Recently, the KiKK (Kinderkrebs in der Umgebung von KernKraftwerken = Childhood Cancer in the Vicinity of Nuclear Power Plants) study [5,6] has rekindled the childhood leukemia debate. The KiKK study had been established partly as a result of an earlier study by Körblein and Hoffmann [7] which had found statistically significant increases in solid cancers (54%), and in leukemia (76%) in children aged < 5 within 5 km of 15 German NPP sites. It reported a 2.2-fold increase in leukemias and a 1.6-fold increase in solid (mainly embryonal) cancers among children living within 5 km of all German nuclear power stations. The web publication [8] of the study in December 2007 resulted in a public outcry and media debate in Germany which has received little attention elsewhere.

The KiKK case-control study commands attention for a number of reasons. The first is its large size: it examined all cancers at all 16 nuclear reactor locations in Germany between 1980 and 2003, including 1,592 under-fives with cancer and 4,735 controls, with 593 under-fives with leukemia and 1,766 controls. This means that the study is statistically strong and its findings statistically significant. Small numbers and weak statistical significance often limit the usefulness of many smaller epidemiological studies.

Second is its authority: it was commissioned in 2003 by the German Government's Bundesamt für Strahlenschutz

(BfS, the German Federal Office for Radiation Protection, approximately equivalent to the United States EPA's Office of Air and Radiation) after requests by German citizen groups. The study was carried out by epidemiology teams from the University of Mainz which could not be accused of being opposed to nuclear power.

Third is the validity of its results, as vouchsafed for by the German Government's Bundesamt für Strahlenschutz. It officially accepted that children living near nuclear power plants develop cancer and leukemia more frequently than those living further away. It stated [9]

> "The present study confirms that in Germany there is a correlation between the distance of the home from the nearest NPP [nuclear power plant] at the time of diagnosis and the risk of developing cancer (particularly leukemia) before the 5th birthday. This study is not able to state which biological risk factors could explain this relationship. Exposure to ionising radiation was neither measured nor modelled. Although previous results could be reproduced by the current study, the present status of radiobiological and epidemiological knowledge does not allow the conclusion that the ionising radiation emitted by German nuclear power stations during normal operation is the cause. This study cannot conclusively clarify whether confounders, selection or randomness play a role in the distance trend observed."

Discussion

(a) Other Studies on Childhood Leukemias near Nuclear Power Stations

It has been known at least since the late 1950s [10] that radiation exposures can result in increased leukemias and that environmental exposures to radiation are a risk factor for leukemia [11-13]. In addition, several ecological and case control studies [14-16] in the past have suggested or indicated an association between nuclear power plants and childhood leukemia among those living nearby.

In 1999, Laurier and Bard [17] examined the literature on childhood leukemias near nuclear power stations worldwide. They listed a total of 50 studies (29 ecological; seven case-control; and 14 national multi-site studies). The large majority revealed small increases in childhood leukemia near nuclear power stations although most of the ecological studies were not statistically significant. The policy implications of this study do not appear to have been widely discussed in the scientific media. Two studies [18,19] then indicated raised leukemia incidences in France and Germany, but official reports in the UK [20,21] and studies in France [22,23] concluded there was no evidence of leukemia increases near their respective nuclear power stations.

After the KiKK study was published in early 2008, Bithell et al [24] found a small increase in child leukemia within 0 to 5 km near 13 (of 14) UK nuclear power stations, and Laurier et al [25] found a small increase within 10 km of French nuclear power stations. In both studies, the numbers were small and therefore not considered statistically significant (i.e. there was a greater than 5% possibility that the observations could have occurred by chance).

These studies incorrectly concluded that there was "no suggestion" or "no evidence" of leukemia increases near UK and French nuclear reactors respectively. These conclusions are regrettable because low statistical significance only means that chance has not been excluded as an explanation, assuming no bias and no real effect. In more detail, p values -that is, the probabilities that observed effects may be due to chance - are affected by **both** the magnitude of the effect **and** the size of the study. This means the results of statistical tests must be interpreted with caution [26]. The difficulty is that the use of a cut-off for statistical significance (usually p = 5%) can lead to incorrectly accepting the null hypothesis (ie that there is no effect), through dismissing a result merely because it is not statistically significant (a type II error) [27]. This can occur in small studies such as Bithell et al and Laurier et al due to their small sample sizes rather than lack of effect [28,29]. In addition, weak studies which are not strong enough to pick up effects should not conclude there are no effects: that is, absence of evidence should not be construed to mean evidence of absence [30]. These are widespread misconceptions, unfortunately.

The conclusions in the Laurier et al [25] and Bithell et al [24] studies may mislead members of the public into thinking there are no increased leukemias near French or UK nuclear power stations when in fact the question remains open. The stronger evidence from the KiKK study suggests there may well be such increases - regardless of the country in which nuclear reactors are located.

Importantly, the KiKK findings are supported by a meta-analysis which combines the results of various studies in order to have large enough numbers to reach statistical significance. Baker and Hoel [31] assessed data from 17 research papers covering 136 nuclear sites in the UK, Canada, France, United States, Germany, Japan and Spain. In children up to 9 years old, leukemia death rates were from 5 to 24% higher, and leukemia incidence rates were 14 to 21% higher- see table 1. These findings were statistically significant and leant considerable support to the KiKK findings, but this study was not cited in the KiKK, Laurier and Bithell studies.

More recently, Dr A Körblein [32] observed the relative risk in the Bithell et al [24] data was RR=1.52 ($p>0.05$)

Table 1: Leukemia mortality risks

Age Groups	Proximity to nuclear facility	Leukemia mortality
0-9	All distances	1.05
0-9	Under 16 km	1.24
0-25	All distances	1.02
0-25	Under 16 km	1.18

Source: Baker and Hoel, 2007[31]

and in a recent re-analysis of the KiKK data [33] using an ecological study design it was RR=1.46 (p>0.05). Combining the 2 studies, the RR=1.49 which was statistically significant (p=0.026).

Recently, Laurier et al [34] reviewed epidemiological studies on childhood leukaemia in 198 nuclear sites in 10 countries, including 25 major multi-site studies in eight countries. They found that increased risks of childhood leukaemia near nuclear installations were a recurrent issue. They confirmed that clusters of childhood leukaemia cases existed locally, but were reluctant to generalise their findings.

(b) Need for Powerful Epidemiological Studies

It is a truism that we should be guided by the best available scientific evidence. For a number of reasons the KiKK study provides more reliable evidence than the more recent Bithell et al [24] and Laurier et al [25] studies. First, the KiKK study found statistically significant cancer increases. The p-values in the KiKK study were 0.0034 for all cancers and 0.0044 for leukemias (both one-tailed), i.e. well below the commonly-used 0.05 figure for statistical significance. Second, the KiKK findings were supported by a meta-analysis, as mentioned above. Third, the KiKK study is a case-control study (examining 593 under five year olds with leukemia together with 1,766 controls) which means its findings should take precedence over the Bithell and Laurier studies which were less reliable ecological studies. Finally, the KIKK study used very accurate distance measures. It estimated distances between the homes of cancer cases and the chimneys of nuclear power stations to within 25 metres, unlike the imprecise areas of the Bithell and Laurier studies. The latter studies simply cannot invalidate the findings of the more sophisticated KiKK study, as their conclusions seem to imply.

(c) KiKK Study Findings

The KiKK study showed an increased risk of cancer in children under 5 years living near all nuclear power plants in Germany. The inner 5 km zone showed an increased risk (odds ratio 1.61; lower 90% confidence limit 1.26). A categorial analysis showed a statistically significant odds ratio of 2.19 (lower 90% confidence limit: 1.51) for residential proximity within 5 km compared to residence outside this area. For all leukemias combined, the study showed a statistically significant trend for proximity to nuclear power stations with a positive regression coefficient of 1.75 [lower 90% confidence limit: 0.65]. That is, the leukemic children lived closer to nuclear power plants than randomly selected controls.

These increased risks are statistically significant and are larger than the cancer increases observed near nuclear facilities in many other countries. The data indicate that the increased risks mainly lie within 5 km of NPPs though this does not necessarily mean that there are no increased risks beyond 5 km. The most significant finding was the association between increased cancers and proximity to nuclear installations. As discussed above, many previous reports have studied increased cancer risks near nuclear facilities, but the KiKK report for the first time in Europe measured how far each cancer case was from the chimney of the nearest nuclear reactor. This allowed the study to examine the distance/risk relationship. The proximity-risk relationship was pronounced for leukemias - see table 2.

Table 2: KiKK odds ratios for leukemias in children < 5 years old

Distance from reactor - km	Mean distance - km	Odds ratio
>5	3	1.76
5 to <10	8	1.26
10 to <30	18	1.10
30 to <50	37	1.05
50 to <70	57	1.03
>70	74	1.02

Source: continuous regression model used by Kaatsch et al, 2008[5]

The odds in table 2 were calculated by the KiKK authors using a linear relationship between distance and relative risk (that is, RR~$e^{1/r}$). This is uncertain as the true relationship is unknown. For example, a number of statistical tests (the sum of squared residuals and goodness of fit) indicate that a quadratic regression model (that is, RR~ e^{1/r^2}) fits the KiKK data better [32].

The KiKK study tested the proximity-risk relationship by examining whether confounders could have had an appreciable effect on the result. Kaatsch et al stated their results "may possibly be influenced by confounders (like social class, pesticides, factors influencing immunological factors, exposure to other ionizing radiation)". However the companion study by the same team [6] stated as regards uncontrolled confounding "no risk factors of the necessary strength for this [KIKK] effect are known for childhood cancer and specifically childhood leukemia." The KiKK team actually tried to control for these confounders in a separate analysis but there was some self-selection among the controls interviewed, meaning they might not have been representative of the study population. For this reason, the results of their confounder analysis were not presented in their published reports. However the team stated that "none of them [the confounders] changed the distance parameter by more than one standard deviation". In other words, the confounders studied by the KiKK team appear to have had little effect on the KiKK findings.

The study investigated whether the cancer increases were due to population mixing - sometimes mooted as an explanation for increased cancers near nuclear power stations. Their results suggested this was not the case but this part of the study was underpowered, statistically speaking. Therefore there could have been such an effect as absence of evidence of effect does not provide evidence of absence.

The KiKK authors also removed each nuclear power station in turn from their analyses to see if the results were dependent on the findings near one nuclear power station alone, and the answer was no. (Unfortunately, the KiKK authors have refused to release the data for each of the 16 nuclear power stations for further analyses.)

(d) Association vs Causality

The question arises as to whether the association found by KiKK is causative: that is, are the increased cancers due to living near the reactors. In such situations, the authoritative Bradford Hill [35] tests are usually applied. The results of applying these nine tests to the KiKK study are listed in table 3.

Most of the Bradford Hill tests when applied to the KiKK study support the inference of causation between increased cancers and proximity to nuclear power stations. As regards the similar tests of plausibility/coherence with existing knowledge, it is the case that the estimated radiation doses from NPP releases are too low to cause the high cancer risks near German nuclear power stations, using current dose models. Many scientists have therefore concluded that the cause of the cancer increases cannot be releases from nuclear power stations. However they fail to consider that official dose and risk estimates may be incorrect as discussed by Crouch [36] and Sumner et al [37]. (This point is further discussed below.) In other words, the current "generally known facts" as stated by Bradford Hill may be incorrect, as official dose estimates from nuclear releases could be uncertain or unreliable. If this seems implausible, Bradford Hill applies Sherlock Holmes' dictum to Watson "...when you have eliminated the impossible, whatever remains, **however improbable**, must be the truth..." (emphasis in original). The overall conclusion is that proximity of residence to German nuclear power stations is the most likely explanation for the increased cancer risks.

(e) Possible Explanations for Increased Cancer Incidences

Various hypotheses have been put forward to explain cancer increases near nuclear installations including coincidence; a postulated virus from population-mixing (the Kinlen hypothesis [38]); the response to the lack of childhood immunity to infectious diseases (the Greaves

Table 3: Summary of Bradford Hill test results

	Bradford Hill Guideline	Explanation	Result
1	Strength	numbers large enough not to be chance observation	yes
2	Consistency	association observed by different persons, in different places and times	yes
3	Specificity	association limited to specific people/areas/effects	yes
4	Temporality	effects occur after exposure	yes
5	Biological gradient	association has biological gradient or dose-response relationship	yes
6	Plausibility	suspected causation fits biological knowledge of the day	no
7	Coherence	suspected causation accords with natural history and biology	no
8	Experiment/animal studies	other experimental evidence available	not available
9	Analogy	similar evidence from other studies	yes

hypothesis [39]); parental preconception irradiation (the Gardner hypothesis [40]); genetic predisposition to cancer; synergistic effects between radiation and unnamed chemicals; or combinations of these factors. Some remain little more than suggestions, others have not been supported by the KiKK study. Although some hypotheses are vigorously promoted by individuals, none commands widespread support.

Any possible explanation must be guided by the KiKK study's main finding - that the increased risks were directly linked with proximity to nuclear power plants (NPPs). Therefore it is useful to examine those aspects of the normal operation of NPPs which might result in increased exposures and risks. These include -

- direct radiation, i.e. gamma rays and neutrons, from reactor cores;
- "skyshine" radiation from reactor neutrons being reflected back to earth by N, C and O atoms;
- electro-magnetic radiation from power lines near NPPs;
- water vapour emissions from cooling towers at about half the 16 German NPPs, and
- radioactive releases to the environment.

The cancer increases could also be due to a combination of the above factors, as there may well be interactions between environmental exposures we are yet to understand. For example, synergistic effects may exist between radiation and chemicals may act to increase cancer risks [41,42]. Nevertheless, this is considered unlikely as synergistic effects would not exist in combination with radiation exposures from NPPs alone and not from other radiation exposures, egg from the Chernobyl plume in 1986, natural radiation and medical radiation. These latter exposures would differ for persons living at approximately the same place.

None of these aspects was explored by the KiKK study, but the estimated risks from most of them are considered to be small or non-existent. The major exception is nuclide releases from nuclear power stations which are examined next. It is noted that the KiKK study clearly had these releases in mind when it was set up. All distances to cancer cases were measured from the station chimneys, and the geographical areas monitored specifically included areas downwind from the stations.

(f) Radioactive Releases from Nuclear Power Stations

Radioactive releases from nuclear power stations occur by emissions to air and liquid discharges to rivers in Germany (or to the sea in other countries). Air emissions [43] are more important, as they cause most of the radiation dose to humans. The relationship between air releases and proximity to nuclear power stations is complicated by variable weather patterns. To say there is no relationship between releases from nuclear power stations and proximity to them would be incorrect. Figure 1 clearly shows the proximity/concentration relationship (note that the y-axis is logarithmic) near Canadian reactors. Of course, tritium air concentrations near German NPPs will be lower than those near Canadian reactors (which emit greater amounts of tritium) but the proximity/concentration relationship is likely to be similar.

When there is no wind, a simple diffusion relationship would exist in all directions from the NPP chimney. When winds occur then a relationship would exist but only in the predominant downwind direction. What should have been created by KiKK is a computer model to investigate the air releases/proximity relationship for each NPP in Germany. This would incorporate annual major nuclide releases, Pasquill weather categories, wind speeds, wind directions, and average them over a number of years, in order to estimate likely nuclide concentrations in air at the homes of cancer cases near all NPPs, and the resulting possible inhalation/ingestion doses.

The largest emissions from all pressurised water reactors (PWR) and boiling water reactors (BWR) nuclear power stations are, in order of magnitude

- H-3 (tritium) as radioactive water vapour
- C-14 as radioactive carbon dioxide, and
- radioactive noble gases including Kr, Ar and Xe isotopes.

These emissions result in elevated nuclide concentrations in vegetation and foodstuffs near nuclear power stations as shown in figure 2 which indicates tritium concentrations in vegetation and food moisture near Canadian nuclear power stations. This graph is log-log and indicates that (at least for distances under 20 km) the risk-proximity relationship varies approximately with $1/r^2$ as the slope of the line is about minus 2. In other words, the tritium concentration/distance relationship resembles the risk/distance relationship observed in the KiKK study. Although tritium emissions from Canadian heavy water nuclear reactors are larger than from German PWR and BWR reactors, the same pattern of raised concentrations in vegetation and food is expected to occur near German reactors.

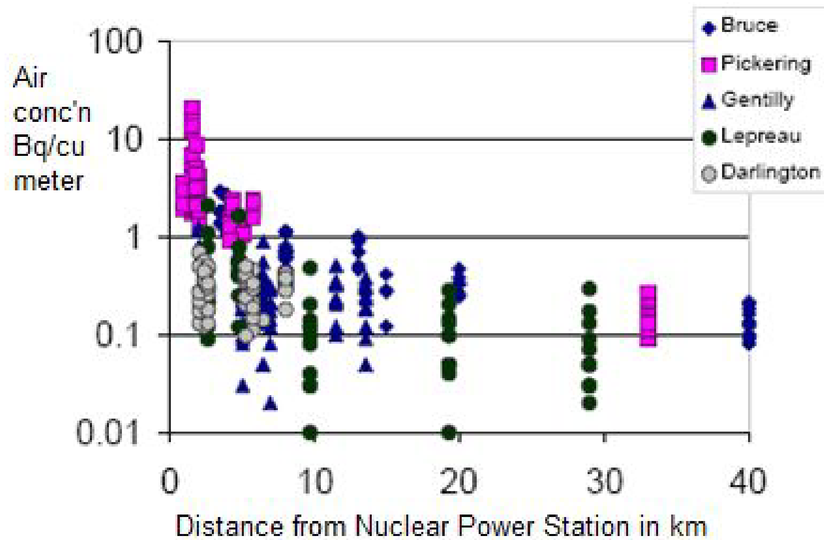

Figure 1
Annual averages of tritium concentrations in air measured at distances from nuclear power stations in Canada, 1985-1999. Abstracted from: Tritium in the Canadian Environment: Levels and Health Effects. Report RSP-0153-1 (2003). Prepared for the Canadian Nuclear Safety Commission under CNSC contract no. 87055-01-0184 by Ranasara Consultants and Richard Osborne. Data from Health Canada: Environmental Radioactivity in Canada. Radiological Monitoring Report. Ottawa, Canada: Government of Canada; 2001.

The most obvious explanation - releases from nuclear reactors - is often discounted because current official estimates of the radiation doses from reactor emissions are too low, typically by about three orders of magnitude, to result in the cancer risks observed by the KiKK study. But how reliable are these dose estimates and risk estimates? Unfortunately this question was not examined by the above German, UK and French studies, nor by the KiKK study itself.

(g) Uncertainties in Dose Estimates

Estimated radiation doses to adults near nuclear power stations are invariably very low (10^{-2} to 10^{-4} mSv per year). How these estimates are derived is not widely understood by scientists, and not at all by members of the public. In fact, the methodology is quite complicated, as they are derived using at least four computer models in sequence

- models for the generation of fission/activation products in reactor cores; these generate the emission data published by utilities for most nuclides
- environmental transport models for radionuclides, including weather models
- human metabolism models which estimate nuclide uptake, retention and excretion
- dose models which estimate radiation doses from internally retained nuclides

Each model derives a range of results log-normally distributed from which only the median value is normally used. Each of these probability distributions would be log-normal rather than normal distributions; that is, they would be skewed to the right. This means that, although the real value could be larger or smaller than the median value, in practice some high values could result.

The problem is that each model's central result is inherently uncertain (the real result lying within the shown distribution). The uncertainties from each model have to be combined to gain an idea of the overall uncertainty in the final dose estimate [44]. Further uncertainties are introduced by unconservative radiation weighting factors and tissue weighting factors in official models [45]. The cumulative uncertainty in dose estimates could be very large as recognised by the report of the UK Government's CERRIE Committee [46].

This does not mean that official dose estimates from nuclear power plant releases are always incorrect. But it does mean they contain unquantified uncertainties which could be large and which render them unreliable where evidence exists that they may be incorrect. In other words, when we try to ascertain the reasons for the wide gulf

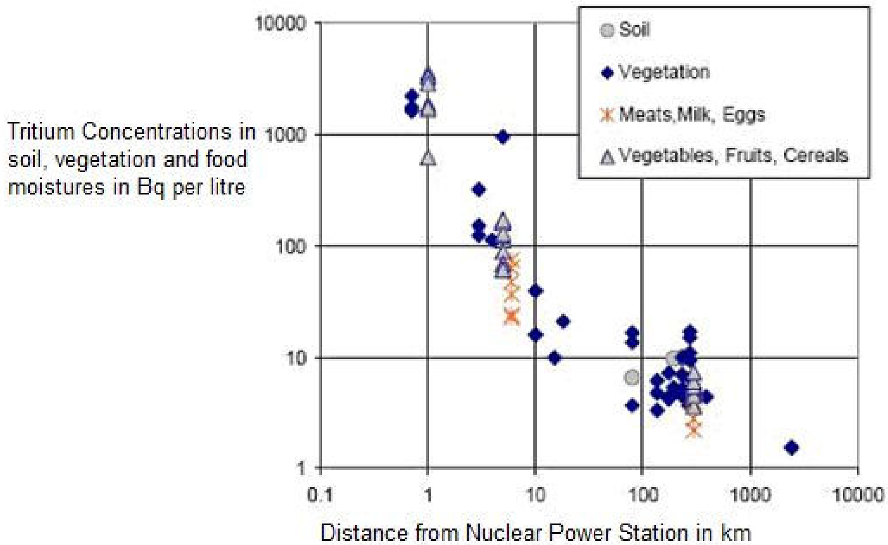

Figure 2
Tritium concentrations in vegetation/food moisture near Canadian nuclear power stations. Abstracted from: Tritium in the Canadian Environment: Levels and Health Effects. Report RSP-0153-1 (2003). Prepared for the Canadian Nuclear Safety Commission under CNSC contract no. 87055-01-0184 by Ranasara Consultants and Richard Osborne. Data from Health Canada: Environmental Radioactivity in Canada. Radiological Monitoring Report. Ottawa, Canada: Government of Canada; 2001.

between estimated risks and risks observed by KiKK, we should not dismiss radiation exposures as a possible cause just because official dose estimates are too low.

(h) Uncertainties in Risk Estimates
In addition, there are uncertainties with estimated risks as well as estimated doses. This is because a risk model has to be applied to doses to estimate the likely level of cancers, but large uncertainties could exist in this model as well. For example, current official risks are derived mainly from the Japanese survivors of the atomic bombs. However many scientists worry that these risk estimates from an instantaneous external blast of high energy neutrons and gamma rays are not really applicable to the chronic, slow, internal exposures from the low-range alpha and beta radiation from most environmental releases. Uncertainties in official risk model also derive from the application of risks from a Japanese to a European population, from its application to adults only, from its application of age and gender-averaged risks, and from the practice of arbitrarily halving risks to take account of cell studies suggesting lower risks from low doses and low dose rates. However it is difficult to quantify these uncertainties and to give a figure which may indicate how much the current leukemia risk estimate may be an underestimate.

(i) Hypothesis: In utero Exposures from Environmental Releases
The KiKK findings have prompted much debate among scientists as to the cause(s) of the increased leukemia cases near German nuclear power stations. Indeed, it is a primary task of science to attempt to explain observed phenomena which are apparently at odds with received wisdom or, in this case, with our current understanding of radiation risks. It is for this reason that the following hypothesis is suggested to explain the risks shown by the KiKK study.

It is theorised that observed high rates of infant leukemias in KiKK may be a teratogenic effect from nuclides released by nuclear reactors being incorporated in embryos and fetuses in the womb. This is suggested from the KiKK findings of increased "embryonal" cancers, that is, cancers in embryos. Spikes in releases from nuclear power stations may result in the labelling of the embryos and fetuses of pregnant women living nearby at high concentrations. These concentrations could be long-lived and could result in high doses to radiosensitive tissues and subsequent cancers. This suggestion was first made by the late Professor Edward Radford, the former Chairman of the BEIR III Committee. He mooted it 30 years ago during testimony to the Ontario Select Committee on Hydro Matters [47] which then was examining possible health effects of tritium discharges from nuclear facilities near Toronto, Canada.

Spikes in the emissions of radioactive carbon and hydrogen (as carbon dioxide and water vapour) occur at nuclear power reactors when their pressure vessels are opened (approximately once a year) to replace nuclear fuel. Figure 3 indicates quarterly ^{14}C releases from a German PWR nuclear power station in recent years. Tritium and noble gases will be released at the same time as ^{14}C. It can be seen that gaseous releases are episodic with spikes occurring about once per year.

In order to assess this hypothesis, we discuss below a number of aspects which lend support to it, including

- the nature of the emissions from nuclear power stations i.e. mostly carbon (^{14}C) and hydrogen (^{3}H)
- the bio-accumulation of ^{3}H and ^{14}C in embryos and fetuses
- the increased radiosensitivity of embryos and fetuses, and
- the increased radiosensitivity of pre-natal hematopoietic cells

(j) Major Radioactive Emissions: Carbon (^{14}C) and Hydrogen (^{3}H)

As stated above, the largest nuclide emissions from nuclear power stations are radioactive carbon (^{14}C), hydrogen (^{3}H) and some noble gases. ^{3}H and ^{14}C exist in the forms of liquid water, water vapour and carbon dioxide gas. These isotopes rapidly exchange with stable H and C; and recycle in biota. Figure 3 above indicates the relationship between tritium concentrations in food/vegetation/soil and distance from nuclear power stations. A similar relationship is expected for carbon-14.

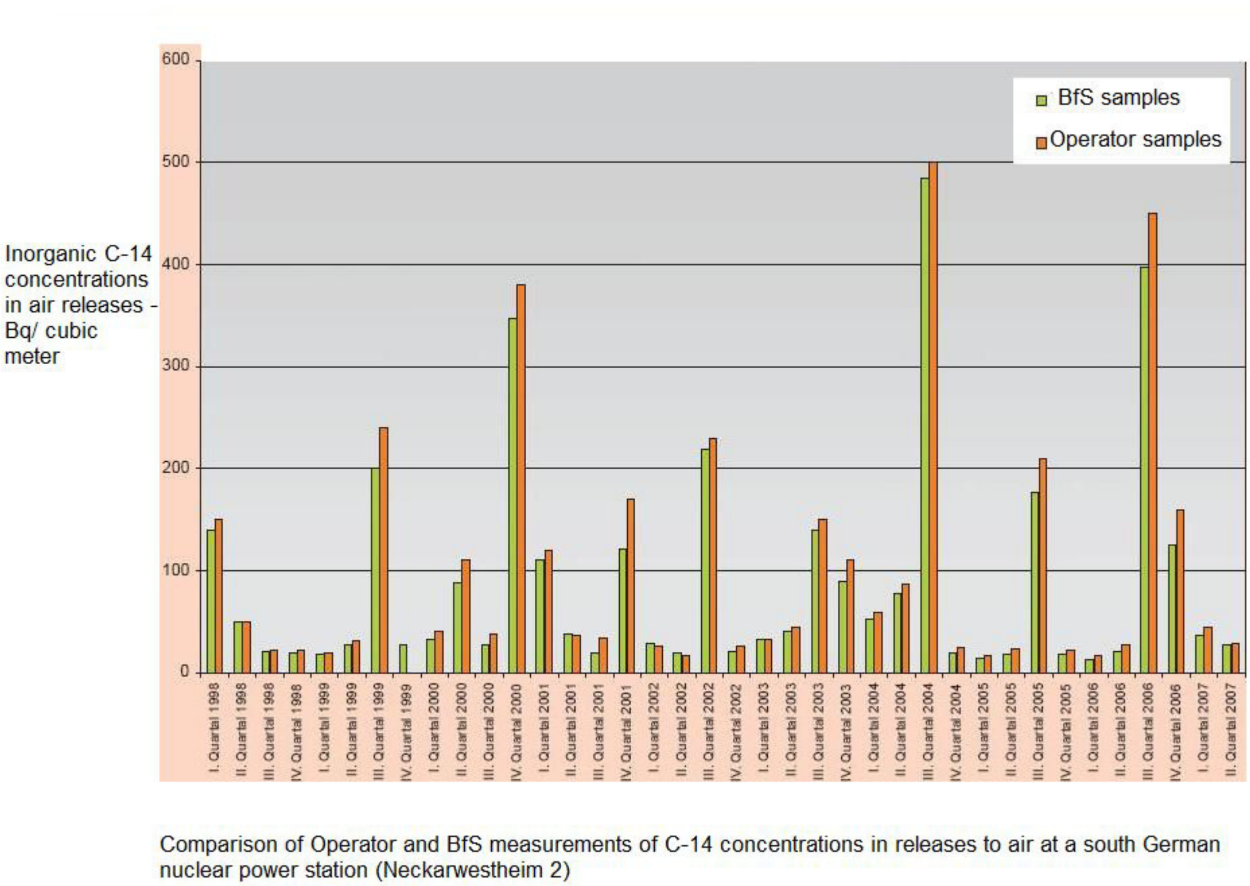

Figure 3
Quarterly ^{14}C air concentrations near the Neckarwestheim 2 nuclear power station in Germany. Abstracted from Jahresbericht (Annual Yearbook) 2007, Bundesamt für Strahlenschutz, Berlin, Germany.

Organically Bound Tritium (OBT) and Organically Bound Carbon (OBC) are formed by embryos and fetuses taking up tritium and ^{14}C atoms during new cell production. The result is that embryos and fetuses near nuclear power stations may be labelled at the levels of environmental ^{3}H and ^{14}C concentrations. The resulting radiation could lead to the formation of pre-leukemic clones in the critical period of development (organogenesis) which later may lead to full leukemia.

(k) Bio-Accumulation of ^{3}H and ^{14}C in Embryos And Fetuses

Stather et al [48] have estimated that, following tritium intakes by the mother during pregnancy, tritium concentrations in her fetus are 60% higher than in herself. As a result, the HPA now estimates [49] that doses in embryonic and fetal tissues are raised by factors of 1.5 to 2 compared to adult tissues following exposures to air releases of tritiated water vapour (HTO). Both studies showed similar increases for ^{14}C intakes.

(l) Increased Radiosensitivities of Embryos and Fetuses

The best data on the radiation risks of in utero exposures, that is, on the radiosensitivity of embryos and fetuses, are from the UK Oxford Survey of Childhood Cancer (OSCC) in the 1950s to 1980s [50]. Recently, Wakeford [51] comprehensively reviewed the OSCC and more than 30 similar studies worldwide. The latter studies confirmed the presence and size of the risks of in utero radiation initially found by Stewart. From OSCC and other data, Wakeford and Little [52] have estimated that the excess relative risk (ERR) of leukemia in children aged under 15 was 51 per Gy (95% CI: 28, 76) from abdominal exposures to X-rays.

If we apply this risk estimate to the KiKK situation, three corrections are needed. First, the leukemia risk rate for under 5 year-olds (as in KiKK) is greater than that for under 15 year-olds because the peak years for leukemia diagnoses are in children aged two to three years. This would result in the average relative risk being greater by a factor of perhaps ~1.5. Also, most (>90%) OSCC exposures were in the last trimester, and it has been estimated [53] that risks from exposures in the first trimester are perhaps five times greater than those from exposures in the last trimester.

These risks arose from external X-rays, whereas the KiKK risks are hypothesised to arise from internal exposures to radionuclides. There are few estimates of the risks arising from internal in utero exposures. However Fucic et al [54] have recently suggested that in utero risks from internal nuclides were four to five times greater than from in utero X-rays*. Summing these factors, we postulate that the relative risk (RR) of child leukemia in 0-5 year olds from internal nuclides in the first trimester near nuclear power stations would be about 2 per mGy. This suggests that human embryos and fetuses may be considerably more radiosensitive than currently acknowledged. It also suggests that background radiation of about 1 mGy per year (excluding radon doses) could be a major cause of naturally-occurring childhood leukemia: this has already been proposed [55].

If we were to apply the KiKK relative risk for childhood leukemia of 2.2, it would suggest in utero doses to embryos in pregnant women near German nuclear power stations of a few mGy or so. Although this is a low dose, it is still about 1,000 times higher than the official estimated doses of a few μGy (albeit to adults) from emissions from nuclear power stations.

(m) Increased Radiosensitivity of Pre-natal Hematopoietic Cells

Finally, we need to consider the different radiosensitivities of various embryonic tissues. Since we are primarily concerned with leukemia which is a cancer of white blood cells, our attention is focussed on the hematopoietic† system, i.e. bone marrow and lymphatic tissues. These contain many stem cells which create new cells: indeed, a large percentage of the stem cells in humans are found in hematopoietic tissues. Radiation-caused mutations to stem cells would clearly be damaging to the hematopoietic system and could result in increased malformation rates of white blood cells, i.e. in increased leukemia risks.

Bone marrow contains a high concentration of stem cells compared to other organs and it is likely to be among the most radiosensitive of embryonic/fetal tissues. This pronounced radiosensitivity has been remarked upon in the past. In 1990, after the Gardner team [56] had published their hypothesis of paternal preconception irradiation, the BMJ published various letters questioning the hypothesis. One by Morris [57] stated that, assuming mutations were the cause of the observed 10-fold increase in leukemia incidence observed by Gardner's team, it would require a 100 to 1,000-fold increase in the radiation-induced mutation rate if acting on the germ cell; a 10-fold increase if acting on lymphocytes during early extra-uterine life; but only a 1.8-fold increase if acting on lymphocytes throughout intrauterine life, i.e. >100 fold increase in embryo radiosensitivity. He added the latter seemed the most plausible mechanism even though the exposure pathways were unclear [58].

In 1992, Lord et al [59] made a similar suggestion when they stated that pre-natal hematopoietic cells could be up to 1,000 times more radiosensitive than post-natal ones. They added that different mechanisms of inducing this damage operated at different embryonic/fetal stages. More recently, the suggestion that pre-natal hematopoietic cells are highly radiosensitive was supported by Ohtaki et al [60] in their study of chromosome translocation frequencies in the white blood cells of Japanese A-bomb survivors irradiated in utero. They found that precursor lymphocytes of the fetal hematopoietic system may be highly radiosensitive, perhaps 100 times more so than post-natal lymphocytes. From this study, Wakeford [51] surmised that radiosensitive primitive cells (whose mutation may result in childhood cancers) remain active throughout pregnancy, including during the third trimester but not after birth, although it is not known at present why this is the case.

It is concluded that the increased radiosensitivity of hematopoietic cells before birth might prove to be a major factor in explaining the discrepancy between official dose estimates and the observed level of risks in the KiKK study.

(n) Increases in Embryonal Cancers

Although the increased numbers of embryonal cancers in the KiKK study were not statistically significant, this does not mean that there are no such risks (see discussion above). There are good theoretical grounds for expecting solid cancers in KiKK. For example, the OSCC study [49] found increased incidences of solid cancers as well as leukemias from in utero exposures. The numerical difference between leukemia risks and solid cancer risks could be explained by the exceptional radiosensitivity of hematopoietic tissues in utero compared to other tissues. This in turn could be explained by their higher concentrations of stem cells compared with other tissues and organs.

Conclusion

It is proposed that the observed high rates of infant leukemias in the KiKK study may be a teratogenic effect from incorporated radionuclides. Such effects, egg congenital malformations, are often recognised at birth but infant leukemia is not easily ascertained. Such babies are born pre-leukemic with full-blown leukemias only being diagnosed after birth, i.e. after their bone marrows have accumulated sufficient radioactive decays.

A possible biological mechanism to explain the KiKK observations is that emission spikes from nuclear reactors result in the radioactive labelling of embryonic and fetal tissues in pregnant women living nearby. Such concentrations, factored over two to five years both before and after birth could result in radiation exposures to the radiosensitive organs of embryos and fetuses, particularly their hematopoietic tissues. Cumulative radiation doses and risks to specific organs and tissues in embryos/fetuses from nuclide uptakes during pregnancy are not specifically considered in official publications on radiation protection.

Whatever the final explanation for the increases, the KiKK study and its implications raise many questions, including whether vulnerable people, such as pregnant women and women of child-bearing age, should be advised on possible risks of living near nuclear power stations.

It is recommended that US regulatory agencies should establish a KiKK-style epidemiological study of cancer incidences near all US nuclear power stations with precise distances being measured between cancer cases and nuclear reactors. In particular, they should establish whether a significant relationship exists between increased cancers among <5 year olds within 5 km of nuclear power stations and proximity to them. Inter alia, they should also estimate ^{14}C and ^{3}H uptakes to nearby residents from US nuclear power stations and from other sources. They should also estimate doses and risks from episodic nuclide emissions from nuclear power stations; estimate bone marrow doses to developing embryos and the subsequent risks of leukemia and solid cancers in very young children; assess the confidence intervals around their estimates and publish their results.

List of Abbreviations

BWR: boiling water reactor; CERRIE (UK): Committee Examining the Radiation Risks of Internal Emitters; CI: confidence interval; COMARE (UK): Committee on the Medical Aspects of Radiation in the Environment; ERR: excess relative risk; KiKK: Kinderkrebs in der Umgebung von Kernkraftwerken = Childhood Cancer in the Vicinity of Nuclear Power Plants; mGy: milligrays; mSv: millisieverts; NPP: nuclear power plant; OBC: organically bound carbon; OBT: organically bound tritium; OSCC (UK): Oxford Survey of Childhood Cancer; PWR: pressurised water reactor; RR: relative risk; μGy: micrograys.

Competing interests

The author declares that he has no competing interests.

Note

*the internal nuclides studied by Fucic et al were mainly ^{99m}Tc and ^{131}I.

†hematopoiesis - sometimes termed hemopoiesis - is the formation of blood cellular components.

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