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R. Samuel McLaughlin Centre For
Population Health Risk Assessment

And

PAHO/WHO COLLABORATING CENTRE IN POPULATION HEALTH RISK ASSESSMENT

Geoscience workshop report

McLaughlin Centre for Population Health Risk Assessment

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Use of Geoscience in Population Health Risk Assessment Workshop

McLaughlin Centre for Population Health Risk Assessment
University of Ottawa, Senate Room
Ottawa, Ontario, Canada
November 28, 2007

Workshop report

Preface

This summary is based on presentations and discussions during and after the one day workshop November 28, 2007 on "Use of Geoscience in Population Health Risk Assessment" and represents the collective views and key messages of speakers, panel members and workshop participants. This group included representatives from a number of federal government departments (NRCan, Health Canada, Public Health Agency of Canada, National Land and Water Information Services and Agriculture and Agri-Food Canada), provincial government (Ontario Geological Survey), U.S federal government (United States Geological Survey), Institutes (Institute of Population Health, Elizabeth Bruyère R. Institute and the Institute of the Environment), the McLaughlin Centre, six Canadian Universities (Carleton, McMaster, Victoria, Ottawa, British Columbia and Queen's) and one American university (University of California) (covering a wide variety of departments including health, geography, earth sciences, environment) and at least three companies (DMTI Spatial and A-Maps Environmental Inc., and Hudson Bay Mining and Smelting Co. Limited).

This summary represents the primary messages that the morning speakers and the panel members presented along with group discussions in the afternoon of the workshop. Post-workshop discussions through email and telephone calls were also added in response to an invitation to workshop participants (and their associates) to recommend research proposals/ideas that could be developed as a follow-up of this workshop. The summary was prepared by Stephanie Douma, Canadian Shield Research Institute, University of Ottawa and revised by McLaughlin Centre staff.

Welcome, André Lalonde, University of Ottawa

An example of early geology-health interaction opportunity missed

Dr. André Lalonde (Dean of Science at the University of Ottawa) - early days of research in mineralogy and asbestos- mineralogists knew of the structure of these minerals and at the time Dr. Lalonde (while a graduate student with supervisor Dr. Bob Martin) wondered why health professionals did not understand the implications of these minerals (with their acicular form) may cause health affects on human tissue. I feel that the early years of the asbestos files are ones that mineralogists should not be proud of` -they (mineralogists) could have helped in the identification and brought forth the evidence that these minerals might be hazardous to humans.

Workshop Objectives, Dr. Andy Rencz Natural Resources Canada (NRCan)

Are earth scientists at giving tax payers good value for their research-invested money? Opportunities for improvement

Dr. Andy Rencz (NRCan, GSC) asks "Are we as geoscientists at NRCan give good value to taxpayer in their research science allocated dollars?" I think at the Geosciences side we can produce information on the movement, origin and transport (of elements)" for implementation into policy and guidelines (part of the population health risk framework." Geosciences would not be the main source of information for Dr. Krewski's flow diagram of Population Health risk assessment data but the geosciences is one of the parts of the database. I am interested in seeing the development of short and long-term action plans to incorporate geosciences knowledge into population health research.

What is Geosience? Dr. Rod Klassen, NRCan

Risk Assessment in Population Health have we added the Earth Science Component?

- Natural sciences enhances the certainty in population health risk assessment

- Understanding of geochemical hazard through knowledge of element concentrations, speciation, chemical associations, reactivity to environment, increases certainty in risk assessment [3]

- Earth material (including geochemical hazards and geochemical nutrients) host, support and nourish the biomass at the earth's surface

- Natural distributions, abundance and potential bioaccessibility of elements can be modeled by natural scientists [1,2] (see case studies below)

- Earth materials receive, modify, store and transmit contaminants.

- Earth materials sequester, transmit, buffer and modify groundwater and soil gas.

- Earth Scientists have a role in enlightening decision makers in the geological based risk of certain earth materials to population health.[5]

- Earth Scientists have a capacity to help in proactive risk assessment. [6]

Case studies in earth science
Presented by Dr. Rod Klassen

1. Examples of environmental models on a scale of Canada-wide depicted by analyses of copper content in lake sediment linked to geochemical background variation linked to geological terrains (mafic intrusives, black shale and mafic volcanics). Low values of copper in lake sediment associated with bedrock consisting of clastic sedimentary rocks and carbonate sedimentary rocks.

2. An example of the predictive and modeling by geologists interpreting arsenic contamination was shown in the glacial dispersal train of debris from a point source (of arsenic contaminant) - (near Pitz Lake) NWT.

3. Geological knowledge of provenance, process and biological affects predicted nickel distribution in trees in an area of glacial dispersal train (ex. Near Lake Aylmer); copper and mercury smelter contamination and predicted the distribution and pattern of contamination from stack emission source; naturally occurring asbestos in Sacramento California and therefore increased mesothelioma risk in population living in the asbestos areas.

4. The specific knowledge of soils and their horizons (A horizon affected by human development) (C-horizon influenced primarily by geological factors) help to develop predictive models fluorine concentrations in areas (an example given was southern Ontario indicating some of the highest values within the Ottawa area) and mercury concentrations of great than 50 ppb in C-horizon soils in great than 25% of Ontario. “West of Thunder Bay there is an area of black shale containing high values of mercury. Black shales are soft- and therefore favourable in the use of construction material for roadbeds- potentially spreading the mercury ‘contaminant’ with the use of the black shale.

5. The capacity for geologist to help in proactive risk assessment was illustrated by the study of concentrations of elements in lithologies and land use of these lithologies. Geochemical knowledge not only of the composition of the material to be used but also the probability of mobility of the elements through knowledge of mineralogy and redox potential (Eh-pH) was illustrated for copper, nickel and magnesium concentrations in trees near Thetford Mines.

6. Risk of environmental change by acid rain was illustrated with an Acid Rain Sensitivity map of Eastern Canada (compiled through geochemical knowledge).

What is Population Health Risk Assessment?
Dr. Daniel Krewski, McLaughlin Centre, University of Ottawa

Population Risk Assessment …what does it mean?

● "Population health risk assessment is the comprehensive assessment of health risks in the general population based on genetic and biological, environmental and occupational, social and behavioural determinants of health. This forms the basis for evidence-based population health risk policy analysis, and, ultimately cost-effective population health risk management decisions."

● The McLaughlin Centre assess and manages population health risks. Existing population health risks include: diet, air pollution, infectious disease, ionizing radiation, lifestyle, pesticide residues, water pollution, and prions.

● Emerging population health risks studied at the McLaughlin Centre include: cellular telephones, biotechnology products, superbugs, child poverty, endocrine disruption chemicals, climate change, youth violence, genetically modified crops. The centre will play a role in anticipation and prevention of potential population health risks with these studies.[1,2,3]

Case studies in population health
Presented by Dr. Daniel Krewski

1. Dr. Krewski gave a specific example of a case controlled study in a Winnipeg radon study that he conducted in the 1980's looking at the potential for lung cancer risk in Canadian homes (part of a study of 18,000 homes measured for radon across Canada). Results gave average value of 150 Bq/m^3 in Winnipeg). Krewski noted that uranium (U^{238}) degrades to radium then radon. Results indicated at the time (and published in 1994 in the American Journal of Epidemiology (v. 140, pp. 310-322) was the radon levels in homes did not have an affect on the increase in incidence of lung cancer.

2. The "Beir VI" report - 1994, report released 1999, indicated that radon was responsible for 10-15% of all lung cancer deaths in the United States. What happened? Why the difference in results? As further data began to come in with combined total of seven study areas (with a total of 10,000 subjects) (including New Jersey, Winnipeg, Missouri, Iowa…) data began to show a slope of the dose response curve significantly great than zero, showing that radon gas in homes did have an affect on the lung cancer incidence . Results of this study helped legislation changes for radon safety levels (lowering from the original value of $800Bq/m^3$ to $200Bq/m^3$). Particulate size became a critical factor for interpreting risk- with particulates of 2.5 microns size the most relevant for causing an increase in lung cancer rates.

WHO International Radon Project.

3. A large scale, $440 million study in the US of 10 research projects on air pollution in urban centres is currently underway (duration of study 13 years-started in 1998) in the USA. Every year the study produces updates. Our knowledge of how particles in the air affect population health has increased significantly with this study. You can see 'hot spots' even with just 160 measurements of large cities in the U.S., you can get a good picture of the distribution of slightly elevated mortality rates in concordance with slightly elevated pollution levels. "When the results of this report (showing the significant increase in lung cancer rates with elevated radon pollution levels (comparability to environmental tobacco) the media was all over us". We were able to go down to the zip code level, residents' locations, and smaller geographical aerial units.

4. Dr. Krewski asked Mike Jerrett to talk a little about the air pollution project in Los Angeles. Dr. Jerrett noted that the variation in air pollution monitor in Los Angeles related to the location of patient. Results showed that Lung Cancer and Cardiovascular risk increased significantly (1.25 to 1.60) in areas of significant air pollution.
   See: http://www.healtheffects.org

   In the area of air pollution work at the Centre has developed air quality management recommendations, production of detailed guidelines taking into account a wide range of information. The production of a detailed guidance document is the culmination of 5 years of work. Dr. Krewski noted that Montreal and Vancouver were using the centres' recommendations for air pollution for their cities.

Geoscientific Databases: data Types, Availability and Application, Dr. Eric Grunsky, NRCan

What tools can Earth Scientists offer?

● The types of geoscience databases available for use in population health research are: geology, geophysics, geochemistry (i.e. arsenic across Canada in lake sediments, stream, glacial till and sediments), geochronology databases, remote sensing (optical, hyper spectral and radar (i.e. (K, U, Th)), eco-regional (including land cover and climate), groundwater. These databases are located provincial, territorial, municipal and federal government departments and are available in many different scales (ranging from 1:5,000 to 1: 5,000,000). It can be quite a challenge to obtain all material because of the diversity of groups housing the databases.[1]

● *Access* to Geoscience Database (federal) can be obtained at: http://gDr.nrcan.gc.ca/index.php

● The measures of geochemical abundance at the surface and near surface when evaluated in the context of regional background can be a significant measure of Population Health Risk. There is a large amount of geochemical survey data available. The geochemical variability is

dependent on sample media, underlying bedrock, ecoregion, glacial and weathering histories. Levelling (calibrating, correcting) the regional geochemical data is required.

● Caution should be used in interpreting 'raw' data from surveys before checking that 'levelling' (standardization, calibration etc.) has been done on the dataset. Dr. Grunsky also indicated that each element within the periodic table had preferred methods to use for their analyses. I would caution use of geochemical databases by non-geospecialists without consultation with geospecialists given the variables that affect resultant chemical abundances. The geospecialist will help outline what values to use within your study areas (and what affects these values

● Natural Resources Canada has a geochemical repository of geochemical data where longitude and latitudes can be used to pull up data available fore particular regions (areas). Large amounts of geochemical survey data are available from provincial/territorial and federal governments. The quality of the geochemical data is variable and is dependent on sample media, underlying bedrock, ecoregion, glacial and weathering histories. Levelling of regional geochemical data is often required.

● The measures of geochemical abundance at the surface and near surface when evaluated in the context of regional background can be a significant measure useful for population health risk studies.

Case Studies: Earth science datasets in use
Presented by Dr. Eric Grunsky

1. Examples of high arsenic values (greater than 250 ppm) in sample of lake sediments, stream sediments, glacial tills and soils (from map Dr. Grunsky showed in presentation) despite only approximately 25% coverage of Canada do indicate some areas of 'hot' values including north central shoreline of Yellowknife (on Great Slave Lake)(NWT), Yellowhead Pass Jasper Alberta, Snake River (Yukon Territories), Payne Lake Northern Quebec, Sudbury Ontario, Noranda Ontario (to name a few).

2. The datasets that Dr. Grunsky showed in his presentation are downloadable for free. He noted that the 'data for sale' approach used by the federal departments in geomapping was impeding the use of the data.

Linkages between geoscience and population health
Dr. Dave Smith, United States Geological Survey (USGS)

Earth materials, natural processes and anthropogenic disturbance

Dave Smith works with Dr. Geoffrey Plumlee (USGS) and the presentation Dr. Smith gave at the workshop is based on Geoffrey Plumlee's PowerPoint presentation.

● Examples of earth materials generated by natural processes (that could cause health effects) include volcanic ash, and gases, wildfire smoke, gases, particulates, flood sediments. Natural weathering and erosion of geological materials are producing dusts, solids and sediments.

● Earth materials generated by human disturbance of geologic materials include construction, mining and off-road driving. Anthropogenic use of geological materials include urban particulates, mine wastes, concrete, other construction materials, industrial minerals (commercial asbestos, silica vermiculate), coal dust, coal fly ash, auto exhaust, other combustion products, industrial emissions etc.

● Earth materials commonly are complex mixtures of biodurable, bioreactive and/or biosoluble particles.

Earth science and human tissue

● Air, dusts (and other atmospheric particulates) and soils can contain a variety of natural and anthropogenic toxicants and pathogenic microbes. Some are know; more are speculated, to result in adverse impacts on individuals or populations exposed above threshold levels.
● Detailed understanding of the exact causal links to disease, as well as the minimum exposure levels needed to trigger disease, are lacking for many earth materials.

● Toxicity affects of earth materials as a function of:
Exposure pathway;
Exposure intensity, duration (=dose);
Particle characteristics (particle mineralogy, shape, chemical composition, surface freshness), particle solubilities and chemical reactivities in body fluid(s) encountered along exposure pathways; chemical form of potential toxicants as they are released from the earth materials into the body fluids (i.e., oxidation state has strong influence).

● Other controls on toxicity of Earth materials include:
Absorption,
Distribution,
Metabolism,[1]
Elimination of toxicants released by the materials into the body
Personal factors (smoking, nutritional status, other environmental exposures)
Genetics (individual susceptibility)

● Multiple exposure pathways:
Inhalation, ingestion, dermal, breaks in skin, large range in body fluid compositions can be encountered, the same earth material can vary substantially in its chemical behaviour in vivo depending up the fluid encountered" Some (of many) examples shown in the PowerPoint slide of a human anatomy are: lung fluid= pH 7.4, intracellular fluids pH 7.4, stomach pH 1.5.

● Particulate size and shape matters:
Inhalation: size fraction as particles are trapped on mucus lining respiratory tract: inhaled<~10-20 microns; respired<~2-5 microns (fibers < 0.4-1.5 microns wide, 4-20 microns long); coarser particles penetrate deeper in mouth breathing. For ingestion: particles < 250 microns by hand to mouth- the coarser particles ingested as a result of geophagia."

● Earth materials commonly are complex mixtures of biodurable, bioreactive and/or biosoluble particles.

Earth science and its importance to health studies

● Interdisciplinary methods used to study the potential health effects of earth materials.

● Importance of 'historic databases' for geohealth research.

● Geochemistry can provide insights into the behaviour of earth materials for the medical researchers in vivo studies.

● Strength (as geologists) is in the ability to map the distribution of those sources (earth materials) in time and space.

● Earth science methods and technologies provide the fundamental characterization needed for public health studies of earth materials.

● Are significant and growing opportunities for collaboration between the earth and health science communities.

Case studies
Presented by Dr. Dave Smith

1. Study interests…
   arsenic, and resulting toxicity,
   asbestos, erionite and mesothelioma,
   mercury and autism (still debated)

2. Earth sciences (for understanding sources, mapping sources, characterization of source materials, in vitro leach tests using simulated body fluids. Biomedical Sciences were used for In vivo toxicity testing, in vivo toxicant uptake (in pigs in this case), epidemiology, in vitro toxicity testing assays, pathology and biomonitoring data.

3. Pyrite in coals= a factor in Coal Worker's Pneumoconiosis (CWP)? Research by Xi Hunag and others from NYU School of Medicine, Bob Finkelman (USGS an emeritus Scientist (rbf@usgs.gov). Their study correlated CWP rates with levels of bioavailable iron (BAI) in coals, using USGS Coal Quality database. The BAI correlates with

increased pyrite, decreased calcite content of the coals. Results of the evident can be found in Huang et al. (2005) *Env. Health Persp.* Vol. 113 #8 (p. 964-8) and Huang et al. (206) in Medical Mineralogy and Geochemistry and they conclude "Our studies indicate that levels of BAI in the coals may be used to predict coal's toxicity, even before large-scale mining."

4. Bioaccessibility of heavy metals from mine wastes (in particular lead poisoning in 90 year old mining town in Zambia. This community has the legacy of the most highly polluted mining site in the world. In the Kabwe's area of Zambia the vegetation and soil and waterways are heavily contaminated with the highly poisonous lead metal from the now defunct lead mine. The Kabwe lead occurs in highly bioaccessible form (making it particularly toxic to humans). The bioavailability of lead varies depending on mineral type (increased bioavailability from lead phosphates, to lead oxides to manganese oxides with the highest bioavailability occurring with lead carbonates.

5. Research on asbestos in the 1990's in Libby, Montana, California Sierra Nevada foothills. Asbestos is considered to be an evolving societal concern with potential health effects resulting from exposures to geologic (naturally-occurring) asbestos from rocks or mineral deposits. Plumlee's study of the Libby area showed: high incidences of mesothelioma, other cancers and asbestosis among vermiculite minerals and millworks, their families and the general population in Libby, Montana (population _2500). Fibrous and asbestiform amphiboles were common impurities in the vermiculite mined in Libby. Plumlee completed in vitro biosolubility studies on various asbestos types (including asbestos from Libby).

6. Naturally occurring asbestos near Sacramento where serpentinite in ultramafic bedrock material is the source of the asbestos and were expanding communities from the Sacramento area are building new housing on this 'toxic' material.

7. Natural occurring asbestos linked to cancer->Mineralogy and Morphology of Amphiboles observed in Soils and Rocks in El Dorado Hills, California. Independent USGS- assessment of geologic asbestos occurrences in the soils rocks (Meeker et al. 2006). USGS open file report 2006-1362.

8. NHANES=National Center for Health Statistics conducted by National Center for Health Statistics in the testing blood and urine in 70 communities in the U.S.A. for inorganic and organic fluids. This systematically trying to cover the whole country- it's a very long – term project with the eventual goal to compare these two wonderful data sets. This includes surface soil versus blood lead analyses (see Smith and Huyck (1999).

9. National asbestos occurrences in the U.S.- by Van Gosen, 2005, 2006 USGS Open-Files Reports 2005, 1189; 2006,-1211; Rocky Mountain Region, 2007: West Coast States, 2008. Anthopylitte asbestos exposed at a construction site near Atlanta
   National age-adjusted rates of asbestosis-related mortality by county for U.S. residents age 15 and over, 1970-1999. Reproduced from NIOSH (2006). (map included in Plumlee map of U.S.).

Use of Geoscience data in population health risk assessment
Dr. Mark Richardson, Health Canada

Federal Contaminated Sites- how contaminated are they?

● From 2003-2007 the number of federal contaminated sites has grown from 4,000 to in excess of 17,000 sites all of which need to be assessed, but not necessarily all remediated.

● First task at each of the federal contaminated sites is to estimate the background daily intake. [1,2]

● Relationship established between Health Canada and Geological Survey of Canada to ensure background geochemistry recorded (using GSC open files, provincial datasets etc. provided by the GSC).

● Estimates of daily intake by humans:

$$EDI = \{([Cair] \times IRair) + ([CH2O] \times IRH2O) + (\Sigma[Cfoodi] \times IRfoodi) + ([Csoil] \times IRsoil)\} / BW$$

[Cair]= concentration of contaminant in air
IRair= inhalation rate of air
([CH2O]= concentration of contaminant in water
IRH2O= daily rate of ingestion of water
Σ[Cfoodi]=concentration of the contaminant in all foods ingested daily
IRfood= ingestion of each of the contaminated foods daily
([Csoil]= concentration of contaminant in soils
IRsoil = ingestion of soil daily
BW= body weight

***** The information used to input into this equation is obtained from the Geological Survey of Canada

● Guidelines for background contaminant concentrations used by Health Canada is the Canadian Council of Minister of the Environment CCME Soil Quality Guidelines. Threshold elements are elemental values above background- but what is background?

● The Federal Contaminated Sites Action Plan within Health Canada- Dr. Richardson's department conducts risk assessments for all sorts of contaminants, arsenic and most of the natural elements, because they are present in mining sites.

● CCME Soil Quality Guidelines:

Threshold elements equation: Function of risk:

Threshold elements

– $SQGHH = \frac{(TDI-EDI) \times SAF \times BW}{} + BSC$

$$[(AFG \times SIR)+(AFS \times SR)+(AFL \times IRS) \times ET2] \times ET1$$

TDI= Tolerable Daily input
EDI=estimated daily input
SAF=
BW= body weight?
AFG= Average
SIR= soil intake rate
AFS= AF ground
SR=
AFL=
IRS=
ET2=
ET1=
BSC=background soils concentration

The information used to input into this equation is obtained from the Geological Survey of Canada

●"Before a site is considered contaminated, on-site concentrations of contaminants, particularly natural elements, should also be compared to data from local or regional surveys of background soil quality and groundwater quality (and surface water quality if relevant) in uncontaminated areas, if data are available. On-site contamination would be considered to be consistent with background where the maximum measured concentration of a chemical of potential concern (COPC) is less than or equal to a representative background concentration for that element/contaminant (i.e. a representative statistic, generally not the maximum)."(Health Canada, 2004)

● In order to give the Heath Canada's stamp of approval for funding a project , we require that not only does the measurement have to exceed the soil quality guideline for that element, it must exceed natural background. We don't view taxpayers to be responsible for cleaning up background.

Case studies

Presented by Dr. Mark Richardson

1. One thing that has been done in the Health department is looking at the concentration of contaminant (i.e Hg) in hair in aboriginal communities and compare the sample with what was anthropogenic (what was natural?).

2. Yellowknife (an area of high natural As contamination) and are at values ranging from 7 ppm to 1,560 ppm. That 'national' background soil concentration is considered to be 10 mg/kg (2ppm), while the CCME health-based soil quality guideline for As is 12 mg/kg (CCME: 1999) Arsenic soil values exceed the CCME 1999 levels for safety. But these are areas with naturally high levels of contaminants. Increase arsenic daily intake increases risk for skin cancer. How do you separate the risk factor in producing skin cancer from arsenic exposure from risk of skin cancer due to south-bound vacationing practices?).

Panel Discussion: "Development of a Canadian health geoscience initiative"

There were seven panelists ranging in expertise from government (USGS Surveys, Mapping and GIS; programs branch, of Natural Resources Canada -director of Environmental, Safety and Security portfolio; Health Canada, geologist from Health Canada) and universities (University of Victoria-professor in Geography expertise in population health studies , University of Ottawa -Canadian Shield Research, Earth Science Department, University of California -School of Public Health at the University of California, and Carleton University- paleoecology, and environmental).

Developing a Canadian Health Geoscience Initiative

Dr. Dave Smith (USGS, Surveys, Mapping GIS)

- "Documenting and understanding natural variability is a vexing topic in almost every environmental problem: How do we recognize and understand changes in natural systems if we don't understand the range of baseline levels?"[2] Zoback, GSA Today, December 2001"

- There are an enormous number (and exponentially increasing with time) of chemicals registered on the Chemical Abstracts Service Registry Number and Substance Count. 32,911,316 organic and inorganic substances (and increase of over 5 million within a year). http://www.cas.org/cgi-bin/regreport.pl

- A need to standardize sampling protocols so that regions can be compared to each other- with confidence in the validity in the comparison. There is a need to standardize protocols for environmental standards on an international level.[2]

- There is a need to test chemicals but the rate of growth of new chemicals and the rate of testing of chemicals are too far apart- e.g. According to the RECEP 2003 report there are 30,000 chemicals in use but only 26 of them are risked assessed with an outcome of only two regulatory decisions.

- There is a need to standardize soil cleanup values internationally

Case studies
Presented by Dr. Dave Smith

1. Tungsten: in A-horizon soils in U.S. Basic geochemical database- Water soluble Tungsten in Nevada area- Bioavailable tungsten- Fallon, NV Cancer Cluster- 16 children in N.V. Churchill Count diagnosed with acute leukemia (in an area predicted to only have < 2 diagnosed)- see 2nd National Report on Human Exposure to Environmental Chemicals based on NHANES reference population

2. Notice the differences in standard levels internationally:
   National soil clean-up standards in mg/kg (residential land use) (mg/Kg)

	As	*Pb*	*Cd*	*Ni*	*Hg*	*Zn*
Slovakia	*30*	*150*	*5*	*100*	*2*	*500*
Canada	*12*	*140*	*10*	*50*	*6.6*	*200*
Sweden	*15*	*80*	*0.4*	*35*	*1*	*350*
France	*37*	*400*	*20*	*140*	*7*	*9000*
Belgium	*110*	*700*	*6*	*470*	*15*	*1000*

Geneviève Bèchard, NRCan
Earth Science Sector, Programs Branch, Director of Environmental, Safety and Security Portfolio). Ms. Béchard's portfolio includes groundwater and reducing risks in natural environments.

● A need for a multidiscipline approach to environmental management to solve these problems.

● We need to determine what are the key areas of interest to us as a group?

● What mechanisms can we put into place so that all specialty groups (organizations) are involved in discussions.

● NRCan reports to parliament and Canadians. We will be reporting our results against very specific outcomes relating to ecosystem risk management. "This is an area that we believe is important".

● How can we prepare the next 'bridge' of scientists as cross-discipline researchers to help solve these questions.

● NRCAN will report on ecosystems and risk mechanism for human health.

Dr. Harold Foster, Professor University of Victoria- Department of Geography

"Minerals and Health"

● There are at least 14 possibly 17 minerals that are essential for human health. That means that al over the planet, the risk of being deficient in these minerals is dependant upon where you live.[1,.2]

● With time we are changing our soils (through overuse by crop growth) - and their mineral content is changing. We are probably removing roughly 17% of minerals from Canadian topsoil between 1940 and 1991.

● Selenium is important to health. [3]

● Selenium is less bioavailable as a result of acid rain.

Case studies
Presented by Dr. Harold Foster

1. Dr. Harry Warren (1920's and 1970's) was really the first Canadian who (worked in geohealth)- while doing consulting work for mining companies would 'sneak' in samples for analyses on health issues and sample composition.

2. Dr. Foster's presentation included tables of Pearson Correlation tables of between cancer mortality rates and soil levels of the elements selenium, mercury and calcium in the U.S.; between diseases of the heart and certain characteristics of soil composition (i.e. calcium content, strontium, arsenic, barium, sodium, selenium).

3. Dr. Foster's current interest is in selenium content of soils in Africa and the correlation with HIV/AIDS.

Dr. Mark Hannington, Canadian Shield Research, Earth Science Department, University of Ottawa

The Canadian Shield as a study area

● Mining and geological research is typically done in areas where people don't live.

● The Canadian Shield contains half of all of Canada, and contains a majority of the mining developments in Canada.

● The Shield contains the bulk of Canada's mineral wealth and is now on the verge of massive development.

● Currently, there are about 250 active mines within the Shield. This means there are 250 communities, the largest employer being aboriginals and therefore a good study population (relatively stable in terms of location).

● The mining sector is well ahead of most governments in responding to risk.

● This is where I think the spatial relationship of the Shield really comes into the forefront as a good area for study.

● If you are looking for places as scientists to look at massive concentrations of specific elements of concern in a health context, the Canadian Shield is a good place to look.

Dr. Michael Jerrett, Professor School of Public Health University of California, Berkeley

"Spatial Analysis in Population Health Sciences: Health Sciences: A Medical Geography Perspective"

Spatial analyses are used in population health studies:

● Able to access spatial relationship between contaminant source and distribution of increased exposure of contaminant.

● Integration of numerous data.

● Ability to use very large data sets: critical when effect sizes are small.

● Increased speed of delivery.

"**Why does GIS have so little penetration into Population Health Fields**?

● GIS field driven by natural resource, transportation, utilities planning; health is a small part of GIS.

● Public Health sector under-funded already, not eager to adopt new mandates.

● Most GIS is temporally static – health processes dynamic.

● Data cost, integration and privacy concerns.

Looking to the future:

● Promising increase in satellite and other remotely-sensed imagery.

● Google Earth is awaking the "geographical imagination" in many people.

● Real-time environmental sensors now being integrated with GIS and Geolocation technologies – many health applications.

● Benefits being seen in health field now driving demand.

● Data providers more willing to deal with data access.

● Canada has a very unique opportunity to conduct health research with their universal health policies.

● Canadian health data extraordinary.

Case Studies
Presented by Dr. Mike Jerrett

1. Hamilton Steel Mills - close to high concentration of population creating a distinct health geography.

Dr. Nancy Doubleday, Carleton University

Professor, paleoecology, environmental health, arctic contaminants) "Atlas and classification of arctic combustion particles suitable for paleoenvironmental work.

● Put public back into "public policy" There is a communication gap between policy writers (government) and population.

● Make research transparent.[1]

● We have to think about quite different orders of engagement. [2]

● We need to educate citizens and inform them.[2]

● Share the risk inherent in decision making. The shift in onus more to the public. We need to build a better informed public.[2]

● We need a paradigm shift-Reduce health expenditures by understanding population health risks. We need to shift the paradigm to include government, industry, commercial consumers, also include first nations.[3]

Case Studies
Presented by Dr. Nancy Doubleday

1. An example of increased transparency and accountability is the Canadian International Polar Year project where results of studies are posted within 6 months of completion.

2. Brian Day- Canadian Medical Association (CMA) – there has been $160 billion dollars spent by the end of this year in health expenditures. By educating the population on risks – we give a mechanism for reducing these health expenditures.

3. An example of much needed regulation…a paradigm shift…ex. Should we continue to build houses with basements in shale and clay? - no we should not.

Dr. Pat Rasmussen, Health Canada and Canadian Shield Research, Earth Science Department, University of Ottawa

" The Role of Geoscience in Environmental Health"

- Determine the source and nature of each environmental contaminant or stress[1].

- Assess exposure - how and in what form it comes into contact with people.

- Measure the effects of the contaminant.

- Apply controls when and where appropriate.

- The difficulties increase where there are multiple types of exposures (inhalation, to airborne particles).

- There are gaps in our knowledge of exposure assessment. [2]

- Focus on exposure measurement errors, the crude exposure assessments area a major weakness, they contribute a profound effect on predicted risks and public policy. Therefore improving the accuracy of exposure assessments is critical to risk assessment and to epidemiological studies.

- When quantifying rates of transfer (flux) must know temporal variability and special variability.

- It is the particle size (not the particle composition) that is what is causing problems with red blood cells (as the particles of size less than 200 microns can move into red blood cells.

Case Studies
Presented by Dr. Pat Rasmussen

1. Of concern for instance is the shale in the Thunder Bay area- this material is used for roads and buildings (mercury being spread around).

2. Also – large areas of black shale in Selwyn basin central Yukon (in situ monitoring in this area occurred in July and August 2001). Dr. Rasmussen used classification of satellite imagery- False colour composite (TM bands 3, 4 &5) to identify black shale lithology in Yukon study area. It was noted that varying rates of mercury were assigned to the area dependent on methodology for interpreting size of emitting lithology-

A. if assume entire map area is black shale (with no overburden) rate of mercury flux would be 11.2 kg of Hg per year.
B. if assume only areas not covered in overburden produce mercury flux then rate reduces to 1 mg Hg per month.

Questions from workshop participants:

Dr. Heather Jamieson- Comment to Dr. Mark Hannington-
The potential for Canadian Shield in resource development.

What about the legacy left behind from the 10,000 orphaned or abandoned mine sites when mining was in its book in the 1950's and 1960's. Rouyn-Noranda with its Cu, Zn and sulphide emissions in the 1960's. These would be good test areas- the old mining communities often population are remain stationary in areas- therefore exposures of metals through generations can be mapped.

Dr. Mark Hannington replies that mining communities tend not to move (i.e. Sudbury) – you could stop mining now and the community would not go away. This represents, from my totally ignorant approach to health sciences a good example of exposure to very high concentrations of minerals and its affects of populations over time.

Stephanie Douma-has relatives in the community around Silver Mining towns of Cobalt-New Liskeard- with health issues- probably related to mineral contaminants.

Dr. Harold Foster also mentions that China is a very good place to do geoscience-health studies as they have good records and populations is very immobile. They drink the local water.

Dr. Pat Rasmussen thinks there should be statisticians on the team of investigators.

Dr. Claire Franklin- asks Dr. Hannington how to start to move forward?

Dr. Mark Hannington- a good case study would be Alaska and Red Dog Mine Pb-Zn mine (probably largest in world) - just being environmental tested before production starts in mine- It is largely a native community? The USGS has done a lot of work in this area. It is owned by Tech-Cominco Ltd- The collection f pre-development work can (or has been done) and can now look at data to compare what was the impact of the mine (through time)- this is a unique opportunity.

Dr. Nancy Doubleday suggests that this is a good example (Red Dog Alaska) - It is important to use co-management principles and include the people in the community in the project.

Dr. Harold Foster advised that if you want to move forward with any of these projects, you have to identify companies with tremendous power. You are going to need support.

Dr. Harold Foster suggest two organizations that may be good supporters (allies)
1. International Society of Molecular Medicine
2. International Schizophrenia Association

Dr. Mike Parsons said they (in Nova Scotia) started out a study where we were doing government research. Federal government geoscientist will be restricted from informing risk assessment to the population. Dr. Parsons was not allowed to sample of private lands (this was

very restrictive) - how do we deal with this as federal researchers? If the research was for research purposes only then they were allowed to sample. Recommends if you go into a mining community you talk to the local residents. Keep the population informed. Arsenic in Nova Scotia well water 10-50 ppb.

Dr. Mike Jerrett says the land titles for the trinational data is restricted now and probably should continue to be so. It would allow for geographic co-ordinates on a person. Gives access to that person allowing I.D. of that person. Also there is the issue of stigmatization of property values. But if toxins are very great there would be more harm in not releasing the data. Privacy is an important issue but Dr. Jerrett believes it can be dealt with through institutionalization.

Stephanie Douma asks panel - "with your expertise can you recommend funding mechanisms for 1) a case study scale project 2) regional mapping/correlation project?"

Dr. Doubleday responds we are assuming some kind of 'parental role' in these discussions. Maybe now the population should become involved therefore consent and informed consent. Health and economic well being versus property values- the populations may choose their health.

Dr. Harold Foster suggests that it is better if told the population only the positive affects of studies (don't emphasize the negative).

Heather Gingerich thinks that there is a funding opportunity with the International Polar Year (but deadline 31 Dec. 2007).

Dr. Mike Parsons - Informing risk assessment to population- the federal geoscientists will be restricted. Produced a great map but someone (in government) said that can't release these finding to the public- I think that we need to revisit this as a group- I think its an issue that we can all run into.

Dr. Harold Foster suggests a system of land use credits where by people in high risk areas get credits but cannot build in their area. Areas of low risk must buy credits in order to build on their land (this fairly distributes the wealth among contaminated vs non-contaminated land owners).

Ross Kelly- Ontario Geological Survey- has done well water survey in the Temiskaming area- Arsenic levels.

Major workshop on Zn, Cu, Mn in Spring 2008- for risk assessment- Population Health.

Dr. André Lalonde MSc. Student- looking at mineralogy of asbestos.

Dr. Bob Seale (USGS) - working in Red Dog area (Alaska)?

Dr. Bob Garrett says there is a recent paper on Red Dog- in Geochemical Exploration E. Analysis).

Dr. Richard Burnett is going to link tax record to Canadian Health Survey- Spatial property spatial database- University of Victoria- Consensus will give race, income, gender, tax record will give general, marital status, income, age.

Currently there is a 5,000 people biomonitoring study- with Stats Canada- Canadian Committee Health Survey- in Vancouver and Edmonton.

May 6 and 7th, 2008- GAC/MAC- GeoHealth talks.

Talks with Dr. Bob Garrett- outlining the first years of the Metals in the Environment Research (MITE).

1st program had $2 million per year. This allowed for a series of workshops involving industry- results of workshops were the enlistment of people from GSC who could work on these subprograms.

Responses for request for proposals – research ideas developed as a consequence of the Geoscience workshop.

Dr. Pat Rasmussen (Health Canada)
Pat_Rasmussen@hc-sc.gc.ca

"House dust: toxic and on your table" in Globe and Mail Friday December 27, 2007.
By Carly Weeks.
Exposure to a variety of metals, chemicals and pesticides on a daily basis result from house dust…
Health Canada in conjunction with the Public Health Agency of Canada have embarked on a four-year national study to determine what levels of these agents occur in house dust across Canada.

Dr. Kapil Khatter- family physician and pollution policy adviser for Environmental Defence, a national advocacy group.

The study area will be in 1,040 randomly selected detached homes across 13 Canadian cities including Barrie, Ontario and Hamilton and Thunder Bay.
Results of this study will be completed by 2010. The department may consider creating guidelines as a result of findings from this study.
A study in 2000 found 50 Ottawa homes contained "significantly higher concentrations' of many elements including Pb, Hg and Cd than outdoor soil.
Pb results in homes from this study range in values from several hundred to several thousand parts per million. In comparison the Pb content of most toys is 600 parts per million.
"I think it won't be long until more studies have the ability to relate some of these toxic chemicals with a wide range of behaviour effects states Dr. Miriam Diamond (an environmental science professor at the University of Toronto and lead author on a 2005 American Chemical Society on dust and polybrominated diphenyl ethers exposure.

Dr. Walter Fraser (Head, Manitoba Land Resource Unit, Senior Land Resource Officer, Agriculture and Agri-Food Canada, Land Resource Unit)
fraserw@agr.gc.ca

Dr. Fraser (responding to forwarded email by Dr. Xiayuan Geng)

1. There are several metals in soils that affect human and animal health. Some, such as cadmium, may be harmful in high amounts, while others such as selenium may be low. Uptake may be influenced by the crop type, soil parent material, soil pH and other factors. The National Agri-Environmental Health and Reporting Program (NAHARP) has a number of different indicator, including an indicator of risk of soil contamination by trace metals.
http://www.agr.gc.ca/env.naharp-pnarsa/pdf/chapt16_e.pdf

Many of the NHARP Agri-Environmental Indicators use our AAFC Soil Landscapes of Canada maps and soil attribute data bases as input for their risk models and as the framework for their reports and national scale risk maps. Useful contacts for the heavy metals indicator are
Dr. Steve Sheppard- ecologist Pinawa Manitoba
Dr. Marsha Sheppard- Ecologist Pinawa Manitoba
Dr. Cynthia Grant- AAFC Research Station in Brandon
We've had several requests from Health Canada officials this year for interpretive soil maps showing the distribution of various heavy metals in soils in various provinces.

Other countries are also active in this area, such as the European Geosciences Union:
http://www.cosis.net/members/meetings/sessions/information/php?p_id=236&s_id=4067
The upcoming 2008 meeting of the European Geosciences Union also has a session on Iodine and Selenium in soils and health.

Excerpt from 2008 conference brochure:
EGU General Assembly 2008
Information –SSS7 Iodine and Selenium anomalies in soils and Health
Event Information
"Selenium and iodine are essential trace elements for humans. Low intakes of iodine results in a series of problems collectively described as Iodine Deficiency Disorders, the most serious effect being mental retardation where infants have been deprived of iodine during foetal development and very early childhood. Selenium is an essential component of several proteins and enzymes one of the most import being flutathione peroxidise which is an antioxidant in the body. In addition, with regard to selenium, excessive dietary intakes can result in toxicity problems. It is thus essential to understand the sources and distribution of these elements in soil, and to gain insight into the controls on their bioavailability. To this end this session solicits contributions on both field and laboratory studies on sources and pathways of selenium and iodine in the surficial environment, especially in soils and into the rest of the biosphere. In this Session all works proceeding from both private and public organizations form any of the five continents related to the above topics will be considered for oral or poster presentation."

2. Another soil-health issue is Radon. This is strongly correlated to soil parent material textures. A typical website link for this is:
http://irc.nrc-cnrc.gc.ca/pubs/cb/cbd247_e.htm
The table in this publication shows typical Radon values in homes in various Canadian Cities. Fine textured clay soils, such as those in the Red River valley of Manitoba, and the Regina plains in Saskatchewan are the reason for much higher radon values for Winnipeg and Regina. Radon Hazard maps could be generated using our 1.1M Soil Landscapes of Canada maps, if a future project were funded to do this.

3. The Terrestrial Ecological Stratification of Canada was released in 1996, and has been used as a framework for various types of reporting, including health statistics. The report and map can be obtained from the Canadian Soil Information System (CANSIS) website:
http://sis.agr.gc.ca/cansis/publications/ecostrat/intro.html

The national Ecological framework was a collaborative effort between Environment Canada and the AAFC CANSIS Soil Resource Group.

Dr. Fraser attended a meeting in London Ontario approximately 10 years ago, in which breast cancer rats were compared for different parts of Canada, using ecological units such as the Mixed Woods Plain Eco-zone in southern Ontario and Quebec.

Dr. Chang-jo Chung (Research Scientist, NRCan, GSC)
chung@nrcan.gc.ca

Two future activities related to public health and geosciences are:
1."Radon hazard potential" mapping by integrating spatial geosciences data such as airborne radiometric geophysical survey data, bedrock geology map data, surficial geological map data, soil geochemistry survey data.
2."Quantitative spatial correlation/association" between the radon potential map generated and the public health data such as lung cancer.

"I know that Health Canada is very much interested in the above two topics and is more than willing to finance the study. Dr. Chang-Jo Chung is very interested in attending a meeting with Dr. Daniel Krewski and Dr. Mark Hannington to discuss these two proposals.

Heather Gingerich M.Sc. (Field Geologist, Hudson Bay Mining and Smelting Co., Limited).
Heather.gingerich@hbms.ca

Heather considers (outside of GSC/NRCan) that the mining industry has the best geochemical datasets available and lots of available money to finance projects. She considers the key players (for engaging industry) are Mining Association of Canada (in Ottawa) and the Prospectors and Developers Association of Canada (Toronto).
Heather is a member of the International Medical Geology Association and with a strong interest in research papers being submitted to the Journal of Medical Geology.
Heather ponders the efficacy of studying elements within the periodic table (all at once or start with one or two? Research into Fluorine would be "A fluorine World Atlas would be a big hit".
Or
Should research concentrate of addressing all disease (i.e. just run the statistics from the Canadian Community Heath and National Public Health Surveys against the geochemistry datasets and see what comes up? Or, should we long at only 'high profile' pathologies like cancer and AIDS?
She gives an example of resources like the following:
http://www.businessfightsaids.org/live/home/home.php
Sample material that could be used for future studies were suggested by Heather who noted that there are bedrock cores/cuttings from all over south western Ontario- available through the head of Ontario Petroleum Institute (Joe Vanoverberg). Heather has discussed the possibility of accessing this core- and Mr. Vanoverberg was very interested.

Dr. Rod Klassen (Research Scientist, Central and Northern Canada Branch- Geological Survey of Canada, Earth Sciences Sector)
klassen@nrcan.gc.ca

Natural variability and natural sources are the primary target of interest but notes the importance of also including natural properties, their functions and capacities and their potential to mitigating risk by anthropogenic sources (like industrial contaminants). "I think there is an aspect of environmental impact that must always be considered in health risk assessment."

Dr. Harold Foster (Professor, Medical Geographer, Department of Geography, University of Victoria)
hfoster@office.geog.uvic.ca
Dr. Foster writes…
"I have been working on minerals and health for some 25 years and have published several books and probably some +100 articles and book chapters on the topic. Dr. Foster considers it important to include double blinded, clinical trials to prove mineral/health causal relationships and is currently raising money to study the link between selenium and the diffusion of HIV and between Alzheimer's disease and monomeric aluminum. A 310 patient nutritional HIV trial testing his AIDS hypothesis just completed its first year at Mengo Hospital in Uganda. The results have just been published in the Journal of Orthomolecular Medicine.

About the journal the International Medical Geology Association.
Dr. Olle Selinus (International Medical Geology Association)
Olle.selinus@gmail.com

Dr. Selinus supplied a compilation of medical geology papers and book chapters for the year 2006 that his organization had produced. These papers are part of the reference list included with this workshop summary and will give a select-only sampling of the current published literature in peer reviewed journals in published books.

Dr. Bob Garrett
Robert.Garrett@nserc.gc.ca
(Geochemist, Natural Resources Canada, Geological Survey of Canada, Ottawa- past leader of the Metal in Environment project GSC).

Some thoughts on the trace elements and human health issue.

In as much as exposure through the food pathway is multi-source due to international commerce for most of Canada's urban populations it makes it difficult to tie local communities to their geological/trace element environments. The exceptions are First Nations communities or families that still rely dominantly on local country foods. The situation with water is not so bad, though the popularity of 'bottled water' confounds things. In this respect, some of these 'bottled waters' may in fact lack essential micronutrients essential for good health. I seem to remember hearing recently (radio/TV) that there is concern over increases in dental caries due to insufficient F

intake. Air is an important vector; HC is working on that, e.g., Pat Rasmussen. I am reminded of the impact of Mn, with MME in petrol engines being a ubiquitous source, in populated areas and Mn effects on brain tissue (Donna Mergler's work).

Re elements, I guess the ones of most interest are still As, Cd, Ce, F, Hg, I, Pb & Se as they have obvious health impacts if in deficiency or excess (as appropriate, or both). Fe is terribly important, but often overlooked, but deficiency leads to anemia and so on to other problems. But other micronutrients and TEs probably have more subtle impacts, e.g., Cu, Zn, Mo & Ni. And Tl is a nasty we know remarkably little about.

At the analytical chemistry end, the whole matter of estimating bioaccessibility as a measure of true bioavailability is a key issue in determining actual exposures. So stimulants for lung and gastric fluids, and the intestinal environment are important research topics. The work of BARC here and BARGE in Europe are important in this respect.

In the Canadian context, I think far better data from market-basket surveys would be useful. By that I mean not average Canada, but the different regions, and knowing the source of the food items is essential. For example, I think potatoes are grown commercially in every Province except Newfoundland & Labrador. I am sure their trace element chemistry varies across Canada. How important is this? With improved data it should be possible to better allow for ethnic and cultural differences in diet. The objective would be to get better estimates of weekly TE intakes to try to tie those to community health statistics. That should include what we take in from fluids, tap water, milk, tea, coffee, 'pop', etc. Along that line, I think it would be very educational for people to have access to comprehensive analyses of bottled water. In that context I am more worried about TE deficiencies and the chronic effects they can have than the odd case of acute toxicity. Personally I am not a fan of bottled water, and am more concerned about the leaching of plasticizers, e.g., phthalates, biphenyl-A, etc., and carcinogenic effects they might have than some TE's that my body knows how to deal with as long as I have an appropriate diet; adequate Se and antioxidants.

As a species we have co-existed with metals and TEs for as long as we have been evolving, and our bodies have developed mechanisms to ensure homeostatsis and elimination. That is not the case with all the organic-C based compounds that have been produced in the last 50 or 60 years for use and as unwanted by-products that have been released into the environment, e.g., various endocrine disruptors. They scare me more.

Hope this is of some interest. In a nutshell, if we are to link with community health statistics we need to have the best exposure estimates possible, and from a geological perspective, we need to understand the links between the natural environment and those exposures through food (soil and water), water and the atmosphere.

PS. Guess I am a regional geochemist (GSC), who works with agronomists and food chemists (AAFC and CGC), and the biological/human health community (MITHE), and risk assessors and managers.

Dr. Chris Findlay
Corjfindlay@ripnet.com
(former Director of the Geological Survey of Canada), retired geologist.

I have no particular expertise in any of the topics discussed at the workshop but I think that the subject of radon will likely get more play in the future; in particular of course radon in basements in granitic terrenes and implications for building codes. It is a subject we have not heard much about recently (publicly) but it is lurking out there like the elephant in the room.

Dr. Scott Findlay
Chris.Findlay@uottawa.ca

(Director of the Institute of the Environment- University of Ottawa). (Stephanie Douma interviewed Dr. Findlay post-workshop).

1. Establish a research program that would look at geochemical origin (i.e. U and radon). Establish origin of elements (anthropogenic versus natural sources) ex. Mercury exposure at pulp mills versus natural sources.

2. Look at multiples stressors on human health. Cumulative risks associated with combinations of geochemical (multiple contaminants) or geochemical with applied non-natural risk factors.
Ex. Is mercury a contributing factor to diabetes?
Do pesticides link to diabetes?

3. Dr. Findlay is particularly interested in the influence/relationship between biological and geochemical interaction. i.e. bioaccessibility and routes of exposure. With increased climate warming there will be an increase in microorganisms and then increased methylation- what will be the affects on trace elements and human health?
Eg. Eco-toxicology (Danielle Fortin)

Recommendations

Increase interaction with
1. Canadian Council of Ministers of the Environment. (CCME)
Re***: Soil Quality Guidelines:***

- Review guideline Development Process
- Contact Soil Quality Guidelines Task Group
- Current Priorities of this organization include selenium.

2. Get affiliated with and work with the procedures team for the **Procedures for Guideline Development (Protocol) for the Canadian Soil Quality Guidelines** (CSoQGs).

3. Environmental Quality Guideline activities in Canada for air, water, soil, sediment and tissue residue have been integrated into one comprehensive document, the Canadian Environmental Quality Guideline. Recommend reviewing this document to determine whether methodology, background levels obtained in this document are reasonable and have geological data should be integrated with it.

4. Increase the communication links between **Health Canada** and Natural Resources Canada-GSC—part of the interaction would be educating biologists on the knowledge available through earth science.

5. Look into becoming 'expert support" (NRCan-Geological Survey of Canada) for **Health Canada** on risk assessment co-joining **Environment Canada and Fisheries and Oceans.** NRCan's knowledge of geochemistry, geology, and remediation is important and they should be part of the 'team' making decisions for healthy communities. We need better links between geology and Health Canada. We need pro-active decision making.

6. CEPTA Environmental Registry- through Environment Canada- part of the Canadian Environmental Protection Act, 1999 (CEPA 1999, section 76)- requires the ministers of the Environment and of Health to establish a **Priority Substances List (PSL)-** that identifies substances to be assessed on a priority basis to determine whether they are toxic (as defined under Section 64 of the Act) and pose a risk to the health of Canadians or to the environment.
Recommend: **GSC be part of a revised CEPA Act 2008**- which includes **Natural Resources** in the partnership with **Environmental Canada and Health Canada.**

7. Recommend that **NRCan- GSC-along with Environment and Health Canada** review the Priority Substances List 1 and 2 (PSL 1 and 2) to see if all elements that GSC is concerned about appear on the list.

8. Solicit support and guidance with the **Canadian Public Health Agency** to have **NRCan-GSC** and its resources available in a proactive way in regards to contaminated sites.

9. When dealing with the public do not use scientific terms- ex. Instead of mafic and ultramafic rocks use the term asbestos-rich rocks (on a study of asbestos distribution).

10. Increase communications of geological hazard findings to local and regional health officials (through release of information as well as educational programs). Make this mandatory.

11. Build an expert support department (involving **Health Canada, Environment Canada, Natural** resources, **Fisheries and Oceans and Public Works**) to a central place to find guidance, training and advice by inquiring departments.

12. Increase interaction of **Agriculture Canada** (and soil mapping dept.) and **Natural Resources** Canada (soil maps)- compare and contrast. See Dr. Fraser (National Agr-Environmental Health and Reporting Programme (NAHARP) has a number of different indicators, including an indicator of risk of soil contamination by trace metals.
http://www.agr.gc.ca/env.naharp-pnarsa/pdf/chapt16_.pdf
Use contacts for the heavy metals for the AAFC Soil Landscapes of Canada maps and soil attribute data bases is:
Dr. Steve Sheppard- ecologist Pinawa, Manitoba
Dr. Marsha Sheppard- Ecologist Pinawa Manitoba
Dr. Cynthia Grant- AAFC Research Station Brandon

13. Become part of team that collaborated on the **Terrestrial Ecological Stratification of Canada** (released in 1996). The report and map can be obtained from the Canadian Soil Information System (CANSIS) website. The national Ecological framework was a collaborative effort between **Environment Canada** and the **AAFC CANSIS Soil Resource Group**. Meet with Dr. Walter Fraser (Head, Manitoba Land Resource Unit, Agriculture and Agri-Food Canada).

14. Increase collaboration (submissions to) the Medical Geology Association.

15. Published papers that will appear in **PubMed database** (these can be viewed by medical professionals).

16. Establish contact with the Department of the Environment (University of Ottawa) and learn the Fuzzy-Logic Algorithm for incorporating quantitative and qualitative data from a large number of sources.

17. Establish contact with the Department of Geography- University of Ottawa (and Carleton University) to review their projects on ARCGIS and begin establishing graduate student links with Health-Population Health data and depiction of data using ARCGIS.

18. Continue links with BARC (Bioaccessability Research of Canada) and C.N.T.C. (Canadian Network of Toxicology Centres) to see if elements interested in are being looked at by BARC.
Note: Dr. Mark Richardson (from Health Canada), Dr. Pat Rasmussen (Health Canada and Canadian Shield Research), Dr. Andy Rencz was at the recent (October, 2007) "Strategic Research Planning Workshop on Bioaccessibility, Bioavailability in Contaminated Site Assessment" Oct 11-12, 2007 Mississauga, ON.

Specific case studies that would be interesting to conduct:

1. Rouyn-Noranda with its Cu, Zn and sulphide emissions in the 1960's. These would be good test areas- the old mining communities often population are remain stationary in areas- therefore exposures of metals through generations can be mapped.

2. Mineral types (lead carbonate, manganese oxide, lead oxides, lead phosphates)- look for occurrences of lead carbonates in host lithologies-Pb in these minerals are the most bioavailable and therefore toxic to humans…

3. Barium contamination in Mississippi Valley type deposits- sedimentary basins very fertile- but high in Ba contamination. Map out all the rocks in Canada with Mississippi Valley-type deposits.

4. Document well water supplied homes (from city water supplied) when defining radon-risk potential on maps (radon can enter homes in a variety of different mechanisms)- Areas of well-water will be at higher risk than those with central city water supplies.

5. Review coal compositions throughout Canada- for trace elements (in particular mercury). Make maps across Canada defining health risks of coal and associated toxic elements. Also a study of pyrite content in coals (pyrite in coal is a factor in Coal Worker's Pneumonconiosis (CWP). The amount of bioavailable iron (BAI) appears to correlate with increase pyrite content in the coal. The levels of BAI may be used to predict coal's toxicity even before large-scale mining put into production.

6. Map out mafic and ultramafic rock bodies to define likely asbestos sites (and therefore areas to avoid populating).

7. Mining communities within the Precambrian Shield (these mining communities tend not to move making ideal case studies for contaminants).

8. Look at Red Dog Lead-Zinc mine Alaska (probably will be the largest mine of its kind in the world) - There is a lot of environmental data collected pre-mine development. The area will be an excellent one for studying health concerns of the mine (and comparing with background natural contaminants (pre-mine development data).
The USGS has done a lot of work on this area. Also talk with Dr. Mark Hannington (Canadian Shield Research) who is familiar with geology of the Red Dog area.

9. Dr. Harold Foster interested in correlation between monomaric Aluminum and Alzheimer's.
Note- a paper by Perl and Maolem 2006 on Aluminum, Alzheimer's Disease and Geospatial Occurrence of Similar Disorders is published in *Medical Mineralogy and Geochemistry. Reviews in Mineralogy and Geochemistry,* Volume 64 p.115-134.

10. Thunder Bay, Ontario Black Shale Deposit- associated risk to population health.

11. Potential Role of Soil in the Transmission of Prion Disease- Epizoological and experiental evidence defines a hypothetical environmental resource for prions in soil environments. Define what these are and map out for Canada and cattle grazing (see **Schramm et al. 2006** for article on potential role of soil in the transmission of prion disease).

12. Study First Nations communities as these communities are considered better for analyses in evaluating trace element exposure through the food pathway. First Nations communities or families may rely dominantly on local country foods. Pathways are air, water (confounded by use of bottled water not locally derived water), air (Dr. Pat Rasmussen with Health Canada is looking at this) and food.

13. Consider establishing links with agronomists and food chemists (AAFC and CGC) and the biological/human community (MITHE) communities to help establish better exposure pathways of trace elements. We need to understand the links between the natural environment and those exposures through food (soil and water), water and the atmosphere.

What large scale projects can Natural Resources Canada undertake?

1. Assessing Priority Substances under the **Canadian Environmental Protection Act (CEPA)**. CEPA was established in 1988 to provide a means of identifying, evaluating, and managing toxic chemicals. "CEPA is administered jointly Health Canada and Environment Canada. The act is designed to protect human health and the environment by reducing or eliminating toxic substances from the environment, and controlling the entry of new substances into Canada that may pose a threat to health and the environment. An important part of CEPA's work is to provide the public with the results of assessments of priority substances, i.e. chemicals identified as priorities for evaluation, as well as to inform people of any health risk associated with these substances. CEPA also designs strategies to effectively control exposure to these substances."
From: **The Health and Environment Handbook for Health Professionals "Health and Environment"** Health Canada-Ontario October 1991, Prepared by Great Lakes Health Effects Program, Health Canada and Public Health Branch, Ontario Ministry of Health. Contaminant profiles are listed in Appendix 3: Fluoride, Pb, Hg, Radon, NaCl, SO2, Tritium, Al, As, asbestos (and fibrous materials), Cd, dioxins and furans, nitrites, nitrates, nitrosamines, particulate matter. **NRCan** could supply for information to the source of these 'contaminants'.

> *"The Canadian Environmental Protection Act (CEPA) authorizes the Ministers of the Environment and Health to investigate a wide variety of substances that may contaminate the environment and cause adverse effects on the environment and/or on human health. Under the Act, assessments were accomplished in 1994 for the 44 environmental contaminants (or groups thereof) on the first Priority Substances List (PSL 1)." From Health Canada publication "Health-based Tolerable Daily Intakes/Concentrations and Tumorigenic Doses/Concentrations for Priority Substances. Environmental Health Directorate Health Protection Branch Published by authority of the Ministry of Health 96-EHD-194. 15pp. Priority Substances are classified into one of 6 categories, based on the weight of evidence of carcinogenic to humans are classified as Groups I or II of the scheme. "It is assumed, for genotoxic carcinogenic effects, that there is some probability of harm to human health at any level of exposure; therefore, continuing efforts should be made to reduce exposure to compounds considered to be "carcinogenic to humans" or "probably carcinogenic to humans" (Groups I and II of the classification scheme for carcinogenicity under CEPA) to the greatest extent possible" (p. 5 of report)*
> *Tumorigenic Doses/Concentrations for Priority Substances (Carcinogenic Effects) include:*
> ***As** and its inorganic compounds (7.8 microgram/m^3 (air), 840 micrograms/litre (drinking water),**Cd, fluoride, Ni (and its compounds), Hexavalent Cr, Mineral fibres, Oxidic Ni, sulphidic nickel, soluble nickel***

2. Geological assessments into populated areas (typically mapping has been down outside of populated areas).

3. Create a set of interdisciplinary maps (Environment, Health, Population, and Aboriginal with NRCan data).

4. Canada-wide map illustrated Acid Rain Sensitivity at various scales.

5. In conjunction with Institute of Population Health supply geological data needed for within populated areas in Canada (may have to do the mapping in these areas).

6. Microbial and geochemical characterization of soils: Regional variation and effects of soil type, geological setting and agriculture practices in populated centres in Canada (similar study being done by USGS in Central Valley of California).

7. Landscape Geochemistry in National Parks look at arsenic, fluoride, mercury and molybdenite (related to hydrothermal features and the affects on animal life)- similar study being undertake by USGS _ Dr. D.B Smith- for Yellowstone National Park and Joshua Tree National Park (USGS).

8. Define Black Shales (and associated weathering relocation of material)- for toxic trace element contamination of areas habited by people or animals.

9. Health Canada very interested in a Radon Hazard Potential Map- mapping by integrating spatial geosciences data such as airborne radiometric geophysical survey data, bedrock geology map data, surficial geological map data, and soil geochemistry survey data. (Dr. Chang-Jo Chung (GSC) is interested in collaborating on this project).

10. Health Canada Quantitative spatial correlation/association between the radon potential map generated and the public health data such as lung cancer. (Dr. Chang-Jo Chung (GSC) is interested in collaborating on this project).

11. Study the bioaccessibility- estimating bioaccessibility as a measure of true bioavailability is a key issue in determining actual exposures (says Dr. Garrett). So stimulants for lung and gastric fluids, and the intestinal environment are important research topics. The work of BARC her and BARGE in Europe are important in this respect.

12. Dr. Bob Garrett (who was leader in the MITE (Minerals in the Environment) project at NRCan suggests that the element of most interest to human health issues are **As, Cd, Ce, F, Hg, I, Pb and Se** as they have obvious health impacts if in deficiency or excess (as appropriate, or both). "Fe is terribly important, but often overlooked, as deficiency in iron leads to anemia. "But other micronutrients and trace elements probably have more subtle impacts e.**g. Cu, Zn, Mo and Ni.** And TI is a nasty we know remarkably little about." Dr. Bob Garrett, Geological Survey of Canada

13. Increase the knowledge of data about market-basket surveys (a look at element contamination (natural) from growing areas. Look at different regions within Canada and assess the foods grown within the areas. Ex. Potatoes are grown commercially in every province except Newfoundland and Labrador. I am sure their trace element chemistry varies across Canada. How

important is this? With improved data it should be possible to better allow for ethnic and cultural differences in diet. The objective would be to get better estimates of weekly trace element intakes to try to tie those to community health statistics.

What data is already out there and usable for studies

1. Health Data is computerized for Canada- in a universal Health system unique in the world. Therefore the potential is great for this very useful database. There will be concerns with privacy and with chronic under funding of public health.
National Health Expenditure Trends 1975-2007 – on **Canadian Institute for Health Information (CIHI)** website.
Health Indicators 2007- Statistics Canada- **from Canadian Institute for Health Information (CIHI)** (includes regional map health profiles).

2. Rock samples (drill core and cuttings) available for southwestern Ontario- through head of Ontario Petroleum Institute (Joe Vanoverberg). Heather Gingerich has discussed the possibility of the samples use with Mr Vanoverberg (who is interested).

Possible funding opportunities

1. Mining Association of Canada

2. Public Health Agency of Canada (PHAC)

3. Mining Companies (they are well ahead of most governments in terms of assessing risk and they have put massive investment in assessing risk)
XStrata
Barrick Gold
GoldCorp
Kodiak
For complete list of suggested mining companies see *****

4. International Society of Molecular Medicine

5. International Associations with diseases that can be attributed to geological hazards.

6. Prospectors and Developers Association of Canada

7. Canadian Institute of Mining

**Its worth hiring someone to compile a list of possible financial contributors for health-earth science projects.

Barriers

1. Government research scientists are currently restricted from informing risk assessment to the public.

2. If produce maps showing non-desirable places to live, property values will drop- How does one deal with this?

Meetings

Upcoming Geology and Health Meetings:

1. European Geosciences Union 2008- have a session on Iodine and Selenium in soil and health.
http://www.cosis.net/members/meetings/sessions/informaion/pjp?_id_236&_id=4067

2. Geological Association of Canada and Mineralogical Association of Canada Meeting including Geology and Health May 2008 (Montreal).

3. Institute of Population Health- McLaughlin Centre: Health Risk Assessment of Essential Metals: Copper, Manganese, and Zinc, May 6-7, 2008.

* List of potential Mining Companies to contact for funding…

DE BEERS CANADA INC	*400-65 Overlea Blvd. East York, Ont M4H 1P1*
DIAVIK DIAMOND MINES INC	P.O. Box 2498, Suite 205, 5007-50th Avenue Yellowknife X1A 2PA
BHP Billiton Diamonds Inc	*800-1055 Dunsmuir St., 4 Bentall Centre, PO Box 49223 Vancouver, BC V7ZX 1L2*
BARRICK GOLD CORPORATION	*3700-161 BAY STREET, PO BOX 212 Toronto M5J 2S1*
BREAKWATER RESOURCES LTD.	*950 - 95 WELLINGTON STREET Toronto M5J 2N7*
CAMECO CORPORATION	*2121- 11TH STREET WEST Saskatoon S7M 1J3*
ABER DIAMONDS	*PO Box 4569 Station A, Toronto, Ontario M4W 4T9*
DENISON MINES CORP.	*Atrium on bay, 402-595 Bay St. TO M5G 2C2*
DYNATEC CORPORATION	*200-9555 YONGE STREET Richmond Hill L4C 9M5*
FNX MINING COMPANY INC.	*55 UNIVERSITY AVENUE, SUITE 700 Toronto M5J 2H7*
GOLDCORP INC.	*3400-666 BURRARD STREET Vancouver British Columbia, V6C 2X8*
HUDBAY MINERALS INC.	*1906-201 PORTAGE AVENUE Winnipeg R3B 3K6*
INMET MINING CORPORATION	*1000-330 BAY STREET Toronto M5K 1A1*
KINROSS GOLD CORPORATION	*5200-40 KING STREET WEST Toronto M5H 3Y2*
NORTH AMERICAN PALLADIUM LTD.	*2116-130 ADELAIDE STREET WEST Toronto M5H 3P5*
SHORE GOLD INC.	*300-224 4TH AVENUE SOUTH Saskatoon S7K 5M5*
TAHERA DIAMOND CORP.	*77 KING STREET WEST, PO BOX 1020 TDC Stn Toronto, Ontario M4K 1P2*
WOLFDEN RESOURCES INC.	*401-1113 JADE COURT, Thunder Bay P7B 6M7*
XSTRATA CANADA Inc. (Nickel, Copper and Zinc)	*200-181 Bay St. BCE Place T.O. M5J 2T3*
CVRD-INCO	*1500-145 King St. W Toronto M5H 4B7*
TECK COMINCO LIMITED	*600-200 Burrard St. Vancouver, BC V6C 3L9*
ALEXIS MINERALS CORPORATION	*815 - 65 QUEEN STREET WEST, P.O. BOX 75 Toronto M5H 2M5*
AQUILINE RESOURCES INC	3680-130 KING STREET WEST, PO BOX 99 Toronto On M5X 1B1
BAFFINLAND IRON MINES CORPORATION	*1016-120 ADELAIDE STREET WEST Toronto M5H 1T1*
CLAUDE RESOURCES INC.	*200-224 4TH AVENUE SOUTH Sasktoon S7K 5M5*
CLINE MINING CORPORATION	*530 LASALLE BOULEVARD Sudbury P3A 1W9*
CROWFLIGHT MINERALS INC.	*815-65 Queen St. W. PO Box 67 Toronto, On, M5H 2M5*
DIAGEM INC.	*2930-630 RENE-LEVESQUE BLVD WEST Montreal H3B 1S6*
DIANOR RESOURCES INC.	*649 3RD AVENUE, 2ND FLOOR Val D'Or, Quebec J9P 1S7*
FIRST NICKEL INC.	*206-120 FRONT STREET E Toronto M5A 4L9*
FORTUNE MINERALS LIMITED	*1902 - 140 FULLARTON London N6A 5P2*
FREEWEST RESOURCES CANADA INC.	*1155 UNIVERSITY STREET, SUITE 1308 Montreal H3B 3A7*
IBERIAN MINERALS CORP.	*360 BAY STREET, SUITE 500 Toronto M5H 2V6*
LAKE SHORE GOLD CORP.	*1650-701 WEST GEORGIA STREET Vancouver B.C. V9TY 1C6*
MEGA URANIUM LTD.	*2810-130 KING STREET WEST Toronto M5X 1A9*
NORTHERN MINING EXPLORATIONS LTD.	*1010 DE LA GAUCHETIERE STREET WEST, SUITE M-110 Montreal*
NORTHERN STAR MINING CORP.	*153A, PERREAULT AVENUE Val D'Or H9P 2H1*
PATRICIA MINING CORP.	*Suite 1300 8 King Street East, toront, ON M5C 1B5*
QUEENSTON MINING INC.	*1116-111 RICHMOND STREET WEST Toronto M5H 2G4*
RICHMONT MINES INC.	*2130-1 PLACE-VILLE-MARIE Montreal H3B 2C6*
SABINA SILVER CORPORATION	*646 CLEARWATER CRESCENT London N5X 4J7*
SAN GOLD CORPORATION	*LOT 1, BLOCK 12 Bissett Manitoba ROE 0J0*
SOUTHERNERA DIAMONDS INC.	*401 BAY STREET, SUITE 2700 M5H 2Y4*

Reference list:
Selection of interesting papers, books on geology and health

New Journals with interesting articles:
International Journal of Health Geographics
Health and Place
And many other GIS journals including articles featuring health.
PubMed citations for GIS and health by year- 3 articles in 1994 to over 70 articles in 2004.

References suggested by Pat Rasmussen
Good references are: 1992 Moeller, Dade Environmental Health, Harvard University, Press Cambridge, USA.
Factors that Affect Oral Bioavailability of Metals
(Ruby, M. et al. 1999), Advances in Evaluating the Oral Bioavailability of Inorganics.