



Stream F: Risk Assessment and Risk Management (Ecological and Human Health)

Environmental Site Investigation and Human Health and Ecological Risk Assessment of Legacy DDT Contamination at Prince Albert National Park, Saskatchewan

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In the summer of 2008, the Environmental Sciences Group (ESG) conducted Phase I and II environmental site assessments (ESAs) at Prince Albert National Park (PANP), Saskatchewan. These were conducted for the Parks Canada Agency (PCA) and focused on assessing the degree of dichloro-diphenyl-trichloroethane (DDT) contamination in the park. ESG's goal was to understand the impact of past activities at the park, specifically those activities related to the application of DDT in different locations inside the townsite and surrounding areas.

DDT was used in PANP over a 30-year period to control mosquitoes in areas frequented by park residents and visitors, starting in 1948 and ending in the mid-1970s. Spraying activity focused on, but was not limited to, the residential, commercial and recreational areas in the town site of Waskesiu. Most studies regarding DDT contamination have focused on agricultural settings at which widespread contamination exists. PANP provides a case study in which there are many localized areas of DDT contamination within a residential setting.

The 2008 site assessment included a review of previous environmental reports and site records, a data gap analysis and the review of historic aerial photographs to assess the impact of development on DDT environmental fate and transport in the park. Unfortunately, no records were available regarding past use of DDT or the decommissioning of the former maintenance compound in which DDT was prepared and stored; therefore interviews with current and former PCA staff members involved with DDT spraying were crucial to identifying areas of potential concern.

ESG developed a sampling strategy that accounted for the large geographic area of PANP, site access restrictions and changes in site characteristics related to development and changes in land use that have occurred since spraying ended 30 years ago. Soil and sediment samples (n=500) were collected from each area of potential concern and were assessed using the appropriate Canadian Council of Ministers of the Environment (CCME) environmental quality guidelines. DDT concentrations ranged from below the analytical method detection limit (<0.001 ppm) in both media to more than 80 and 180 times the environmental quality guideline in soil (0.7 ppm) and sediment (8.51 ppb), respectively.

ESG performed a human health and ecological risk assessment to determine site-specific remediation criteria for PANP. Additional biota samples were collected to provide measured data of DDT loading in receptors. This process was conducted with the co-operation of local stakeholders, including the PANP science liaison committee and the Waskesiu Community Council. It is anticipated that this project will lead to the creation of a remedial action plan that addresses the concerns of local stakeholders while meeting PCA's environmental obligations. In addition, it will be used as a template to assess the environmental impact of DDT use at other national parks that share a similar history.

Soil Vapour Assessment

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An environmental assessment generally involves the investigation of environmental media such as soil, sediment and water (i.e., surface water and groundwater). However, recently the Ministry of Environment (MOE) in British Columbia (BC) included vapour as a regulated medium. Vapours from semi-volatile and volatile compounds can migrate into ambient air (i.e., indoor and outdoor) from underlying contaminated groundwater and/or soil. These vapours may affect the health of human and ecological receptors.

Although, vapours have only been regulated in BC as of January 2009, we have annually assessed vapours as a part of investigation, remediation, and risk assessment at four remote northern sites along the Alaska Highway in BC and the Yukon since 2006.

The soil vapour investigations conducted at these sites considered 1) vapour source in soil and groundwater; 2) receptors likely to be exposed (i.e., onsite worker, residents, visitors); and, 3) route of exposure (i.e., pathways).

Based on the vapour source, receptors and pathway, the following were considered in developing a program:

- Potential contaminants of concern (i.e., contaminants identified in soil and groundwater);
- Sample locations (i.e., access, source(s), expected pathways, etc);
- Sampling method (i.e., media, time);
- Soil conditions (i.e., soil type, texture);
- Influential factors (i.e., meteorology, seasonality); and,
- QA/QC (leak tests, duplicates).

Challenges of the soil vapour assessment work we've completed include site remoteness, access, cold weather (–35 degrees Celsius), transportation issues, and consultation with site users. Variability that likely arises from a variety of causes reinforces the need for a reasonably large temporal data set to allow robust interpretation.

Bioaccessibility in Human Health Risk Assessment: Method Development and Applications

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In the process of performing human health risk assessments, it has been shown that the assumption that all of a contaminant in a soil matrix poses risk is not always accurate. Specifically, not all of the contaminant is bioavailable, especially when ingestion – the predominant exposure path for contaminants in soils – is considered. In this context, the definition of a bioavailable contaminant is the fraction that reaches the bloodstream and organs and causes toxic effects; another useful term is the bioaccessible fraction, which is the portion that is dissolved in the gastrointestinal environment and is available for absorption. Bioaccessibility can be measured in a laboratory environment mimicking the human gastrointestinal system, and methods incorporate one or more phases, representing the mouth, stomach, intestine or colon. The research consortium Bioaccessibility Research Canada (BARC) was formed to advance knowledge about bioavailability and bioaccessibility in risk assessment, and has been involved with Health Canada in method-development studies. Testing of a soil standard reference material using 16 different methods in 14 laboratories revealed that while the range of bioaccessibility results was quite large, reproducibility within and between laboratories was close to normal laboratory uncertainty. The design of additional studies to compare bioaccessibility method results with bioavailability results (derived from animal testing) is under way and the design and logistical considerations will be presented, along with other BARC updates. The application of selected bioaccessibility methods to soils from contaminated sites will be demonstrated. An example is a Kingston brownfield site, at which bioaccessibility results confirmed the finding from the inter-laboratory experiment that lower pH is a determining factor in extracting higher proportions of the contaminants. Bioaccessibility method variables, including liquid-to-solid ratio and particle size, were studied using the brownfield soils, and the applicability of results to human health risk assessment was determined. The choice of method for bioaccessibility measurements and the variability inherent in the resulting choice is often considered to be a compromising factor in using bioaccessibility in risk assessment. Therefore, studying these method variables and

their effect on risk assessment outcomes is crucial to improving acceptance of using bioaccessibility as a tool in risk assessment.

A Risk-Based Ranking Methodology for Prioritizing Abandoned Mine Sites in B.C.

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The Crown Land Restoration Branch (CLRB) of the British Columbia Ministry of Agriculture and Lands is responsible for managing thousands of historic and abandoned mine sites on provincial lands (referred to as Crown Contaminated Sites). The extent of potential contamination and associated risks is largely unknown for most of these sites. The CLRB sought a system for prioritizing investigation and management efforts among the sites. We developed a Risk Ranking Methodology (RRM) to meet this objective. The RRM uses a risk-based site assessment approach to gather key information about the sites. The information for each site is analyzed and summarized according to a number of attributes aimed at characterizing potential health and ecological risks. The summary information (more than 25 attributes) is then used in a workshop setting to evaluate relative rankings among sites, and also to identify subsequent management actions for each site. Ranking was based on discussion and consensus, which is feasible when the number of sites to be ranked at one time is 50 or fewer. In the first two years of application, regulators and workshop participants have had a high level of confidence in the process and the outputs.

A Case Study of Canadian Coast Guard Lightstations

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From 1999-2004 the Canadian Coast Guard undertook a major capital project to rebuild the network of staffed lightstations in coastal British Columbia. Early in this project Phase II ESAs were commissioned and identified environmental contamination at all 27 lightstations. This presentation will describe the practical, risk-based and cost effective approach developed by the Canadian Coast Guard to assessing and developing management plans for the contamination within the time and budget constraints of the major capital project. A panel of expert risk assessors was struck to guide the development and implementation of an innovative risk-based assessment strategy that took advantage of the common risk issues, operational histories, receptors and biophysical features among the sites. Management, regulators and stakeholders were consulted early and often. As a result of this innovative and collaborative process, Phase III ESAs and full risk assessments were not necessary at all 27 sites for the development of effective remediation and risk management plans. The lightstations were the first projects approved for risk management under FCSAP. The annual costs of risk management at the lightstations is approximately one hundred and twenty-five thousand dollars. The cost estimates for remediation range from thirty to sixty million dollars.

Risk Assessment and Risk Management at Fisheries and Oceans Canada Major Facilities in the Pacific Region

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Fisheries and Oceans Canada (DFO) is the custodian of approximately 8,200 properties nationally, many of which have contaminated sites aspects. Of these properties, DFO identified eight major facilities and bases in the Pacific Region. A team of consultants was retained to develop and implement a five-year overall program that supports the implementation of consistent risk management plans to deal with contaminated sites issues at these facilities. Key features of this process include: 1) applying a unified risk assessment/risk management strategy to provide consistency between sites; 2) seeking input from federal agencies to ensure that implementation addresses key concerns; 3) using a standardized, defensible site characterization and risk assessment approach across the eight major facilities; 4) undertaking the investigation of soil and groundwater conditions following standard methodology; 5) forming a conceptual model of contamination sources and their migration potential; 6) interpreting the results in terms of the conceptual model and making recommendations in terms of the need for remediation or risk assessment/management; 7) conducting preliminary risk assessments for human health, aquatic habitat and

terrestrial wildlife where appropriate; and, 8) developing risk management options which may include a combination of removal, in-situ treatment, or in-situ management based on risk assessment.

Risk Assessment When Background Exposures Exceed Toxicological Limits

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The development of Canadian soil quality guidelines for non-carcinogens includes subtracting background exposure, as represented by the Estimated Daily Intake (EDI), from the tolerable daily intake (TDI) to calculate a “residual tolerable daily intake” which is used to represent allowable exposure from a contaminated site. Similarly, site-specific risk assessments often consider both background exposure and exposure from the site; when the sum of these exposures exceeds the TDI then further action is normally considered warranted.

For several substances, the EDI is greater than the TDI, meaning that background exposures are predicted to result in a hazard quotient greater than unity even without consideration of site exposures. Soil quality guidelines cannot be calculated under these circumstances, since there is no residual tolerable daily intake. Therefore, addressing these substances at federal contaminated sites poses unique challenges.

In order to address the difficulties in conducting site-specific risk assessments or developing soil quality guidelines for substances with an EDI greater than the TDI, several different approaches were examined, including deterministic and probabilistic evaluations of the effects of increasing soil concentrations on total exposures. It was found that for many of these substances, particularly many metals, exposure from soil is a relatively minor contributor to the total exposure, and significant increases in soil concentrations may not have a noticeable effect on the total exposure. Specific examples are presented, and implications for risk assessment and guideline development are discussed.

Human Health Risk Assessment of Country Foods from Victoria Harbour

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In order to assess potential human health risks associated with consumption of aquatic life, a human health risk assessment (HHRA) was completed for Victoria Harbour. The methods used to assess human health risks were based on risk assessment procedures commonly used by regulatory agencies such as Health Canada, World Health Organization and the US Food and Drug Administration. Exposures to chemicals were estimated based on a variety of assumptions relating to how persons may use the harbour. Dietary exposures were estimated using values represented by mean and maximum concentrations of the contaminants in the various media sampled and analysed. The toxicological literature was then reviewed to identify exposure rates that have been determined to be acceptable or “safe” (or more specifically, exposure rates without unacceptable risks of adverse effects to humans). Toxicological reference values were obtained from recognized health agencies that included Health Canada’s Chemical Health Hazard Assessment Division as a primary source of information. For the purpose of this risk assessment of country foods, risks were deemed to be acceptable if Hazard Quotient values were less than 1 or Incremental Lifetime Cancer Risk estimates were less than 1×10^{-5} .

The results of the HHRA indicated that there is little likelihood of unacceptable risks under current conditions. The harbour is currently under a Fisheries and Oceans Canada ordered sanitary closure for bivalve harvesting, commercial closure for crab fishing and a recreational consumption advisory for crab hepatopancreas. Interviews with persons knowledgeable about harvesting habits confirmed that the advisories and closures seem to be well known and largely followed. With this in mind, it currently appears that the only foods that certain persons are likely to be commonly consuming are crab muscle and fish. These food groups contain relatively low concentrations of chemicals (at least for chemicals that may be associated with the seabed) and, consequently, no unacceptable risks were predicted for persons consuming these foods at a rates ranging from once per week to once per month. It is noted that potentially unacceptable risks were predicted from consumption patterns for certain foods (i.e., once per week consumption of crab hepatopancreas, bentnose clams and sea lettuce); however, these foods are not known to be commonly consumed from the harbour. Consequently, the current environment state of the harbour does not appear to be posing unacceptable risks to persons consuming foods collected from this area.

Overall, although the harbour contains sediments with elevated chemical concentrations, it does not appear to pose unacceptable health risks from country foods. Although there is no reason to suspect that environmental conditions will worsen with time, the risk assessment recommended continued monitoring of the environmental conditions and usage of the harbour. If conditions change, it is recommended that revised results should be disseminated in a timely manner to the general public and various environmental agencies.

**Risk Assessment and Site Closure Strategies for Phytoremediation Plots on Persistent Organic
Pollutant-Contaminated Brownfield Sites**

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It has now been repeatedly demonstrated that certain plants, in particular those in the subspecies *Cucurbita pepo* ssp *pepo*, have the ability to take up and store significant concentrations of persistent organic pollutants (POPs) in their shoots. Further work has investigated the effects of soil amendments and growing conditions on POP uptake by plants, and the mechanisms of POP uptake by plants. These studies have resulted in some significant successes in POPs phytoextraction. For instance, the soil concentration of POPs has been observed to decrease significantly after two or three plantings and accumulations of POPs concentrations in parts of the plant shoot have been observed that are greater than or equal to that of the soil. Given these successes, it is important to now consider some of the more practical aspects of phytoextraction that need to be understood before this technology can be successfully implemented at the commercial scale.

The goal of phytoextraction is to reduce the mass of contaminated solids for transport and treatment offsite. In order for this to occur, the final phytoextraction-generated plant material must have a higher contaminant concentration than the original contaminated soil. This potential can be assessed using the shoot bioaccumulation factor (BAF). If the harvested shoot material consistently achieves contaminant concentrations greater than the original soil contaminant concentration (i.e., shoot BAF>1) disposal of contaminated vegetation directly will be more economical than disposal of the contaminated soil. Moreover, composting of phytoextraction-generated plant waste reduces the mass of the contaminated plant matter, thereby increasing the contaminant concentration and further decreasing transportation and treatment costs. Our preliminary studies suggest that composting of PCB-contaminated soil may also result in the degradation and/or dechlorination of individual PCB congeners.

Since PCB phytoextraction takes place in situ, another important practical issue that must be accounted for is the effects of the phytoextraction process on the surrounding natural environment. Since the root exudates of some *C. pepo* plants have been shown to increase the aqueous solubility of certain POPs, it is possible that growth of these plants in POPs-contaminated soil could increase POPs bioavailability to non-target organisms. Our current studies at two field sites in Ontario are looking at the impact of phytoextraction activities on PCB bioavailability to native soil invertebrates.

Finally, successful phytoextraction is unlikely to completely remove all of the target contaminant from the soil. In metals phytoextraction projects, applications of various stabilizers (limestone, etc.) have been applied to decrease the bioavailability of the remaining soil metals as part of a 'finishing step' after the phytoextraction on site is complete. We are developing a similar strategy for POPs-contaminated soil. In a greenhouse study, we observed that the addition of granulated activated carbon (GAC) to contaminated soils virtually eliminated the bioavailability of DDT to *C. pepo*. This suggests that GAC might be applied to soil as part of a comprehensive site closure strategy following sufficient rounds of POPs phytoextraction.

In this paper, our recent research findings on the above practical aspects of phytoextraction will be presented.

***In situ* treatment of Ammoniacal Nitrogen-Contaminated Water and Denitrification at a Former Landfill Site**

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In developing and remediating contaminated sites, some cities confront problems related to landfill sites dating back to periods prior to the 1980s. These former landfill sites were in operation and accepted household waste and

sometimes industrial waste. As these sites age, they release contamination into the groundwater. The generation of ammoniacal nitrogen, a compound harmful to aquatic life, is a frequent problem.

One of the technologies under development for in-situ treatment of ammoniacal nitrogen in leach water is to convert the landfill site into a bio-reactor. This technique is designed to promote biological activity that speeds up the biodegradation of putrescible materials and causes nitrification of the ammoniacal nitrogen and thus denitrification of the nitrates. Ammoniacal nitrogen is transformed into gaseous nitrogen when the reaction is complete. The in-situ treatment trial performed in 2008 at a major site in Montreal involved pumping underground water from an extraction well, circulating some of the water through a biofilter acclimatized to seed the underground water, oxygenate the water and then return it to the in-situ treatment area through an injection well. A 40% decrease in ammoniacal nitrogen levels was observed over the 8-week testing period. Underground water quality in the in-situ treatment area was then monitored. Based on the findings from this site, the most beneficial approach to eliminating ammoniacal nitrogen could be to use an ex-situ biological system combined with in-situ treatment through nitrification and denitrification.

Contrasts in LNAPL Risk Factors for Different Petroleum Products

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Petroleum products released to the subsurface are a potential source of contamination to groundwater and may also cause vapour impacts in buildings. Any petroleum product is a complex mixture of chemicals reflecting aspects of the crude oil from which it was made and the refining process used to bring it to market. Most petroleum fuels are light non-aqueous phase liquids (LNAPL, a.k.a., oil, hydrocarbon, etc.), meaning their density is less than water and there is only a limited propensity for mixing with and dissolution into water. Although oil, water, and vapour exist as separate phases in the subsurface, there is partitioning between the phases resulting in potential contaminant impacts in all phases. Different types of petroleum products will have unique physical/chemical properties that affect the distribution and partitioning of the various phases (i.e., dissolved phase, vapour, LNAPL), which has a direct relationship to the associated risk to environment and human health.

In general, lighter and more refined products like gasoline have a much greater propensity to cause environmental harm than heavier products like diesel and heating oils. This is a reflection of both physical and chemical differences between fuels. All other things being equal, gasoline is thousands of times more potentially dangerous in the environment than diesel or other heavier fuels. Despite that, common industry practice tends to treat all “free product” spills in the same manner, often with a leaning to recover that free product to the degree practicable. This can lead to the non-beneficial expenditure of limited resources that would be better spent on higher risk priorities.

This paper explores the specific chemical and physical differences between different petroleum products to contrast their comparative risks to the environment and provides a basis for an enhanced LNAPL site management strategy based on these concepts. As a result, the authors believe that industry cleanup and investigation activities should be modified to account for these real and demonstrable differences in the risk characteristics of these different oils and fuels. It is also important to recognize that a release of any type of petroleum product to the environment can pose real and substantial risks in certain settings. Comprehensive consideration of physical, chemical, transport, and receptor conditions are necessary to make safe and protective decisions to protect water resources and the environment.

External Expert Review and Land-Use Planning as Strategies to Re-Focus Risk Management and Remedial Planning at a Ten Year Old Site: A Case History

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The paper describes a strategy to re-focus remedial and risk management work at a First Nations’ site bordering a major river in B.C. This strategy was jointly developed with the First Nations to address concerns associated with proposed remedial work at the five-hectare site estimated to cost approximately \$2 million. This is in addition to approximately \$2 million already incurred in initial clean-up, ESA and risk assessment costs. This strategy involved an external expert review that provided fresh perspectives on both on and off-site risks. The review also facilitated

the communication of such risks and the decision to develop an “environmental” land-use plan as a tool to help focus future remedial and risk management work at this site.