APPENDIX S

IERP REVIEW

Review of the Flin Flon and Creighton Human Health Risk Assessment

Volume I

Report of the Independent Expert Review Panel (IERP) meeting
June 23-24, 2009
Winnipeg, Manitoba

Review Organized by:
Toxicology Excellence for Risk Assessment
(http://www.tera.org/peer/)

Final Report
September 14, 2009
Amended June 8, 2010

June 8, 2010

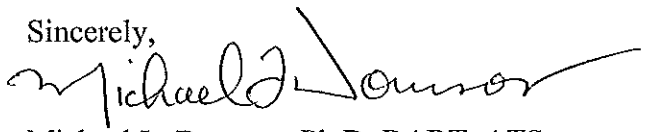
To the Residents of Flin Flon and Surrounding Areas:

On behalf of the Independent Expert Review Panel (IERP), **I am pleased to release this final report of the IERP for the Flin Flon Human Health Risk Assessment (HHRA).** Colleagues and I have reviewed Intrinsik authors' responses to the IERP comments and the revised HHRA. The authors were responsive to the panel's concerns and recommendations and revised the HHRA accordingly.

Specifically, the IERP found that the HHRA followed commonly accepted human health risk assessment methods and that overall the input data and assumptions were valid and appropriate. The IERP offered numerous suggestions for improvement to the HHRA, most of which the authors accepted. While a few differences of scientific opinion remain between the IERP and the authors of the HHRA, these differences do not impact the conclusions of the HHRA or the protection of public health in Flin Flon and surrounding areas. The HHRA and results were found to be scientifically-sound and appropriately health protective. The HHRA has been revised to address the IERP recommendations and be responsive to the IERP issues and concerns.

My best wishes to your continuing efforts to protect your community's health.

Sincerely,



Michael L. Dourson, Ph.D, DABT, ATS
Chair, IERP

NOTE

This report was prepared by scientists of Toxicology Excellence for Risk Assessment (*TERA*) and reviewed by the panel members. The members of the panel served as individuals, representing their own personal scientific opinions. They did not represent their companies, agencies, funding organizations, or other entities with which they are associated. Their opinions should not be construed to represent the opinions of their employers or those with whom they are affiliated.

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Executive Summary

An independent expert review panel (IERP) of scientists met June 23-24, 2009 to conduct an independent review of the draft human health risk assessment (HHRA) for Flin Flon, Manitoba, and Creighton, Saskatchewan. The draft HHRA was prepared by Intrinsik Environmental Sciences Inc. to address the potential human health risks associated with exposure to smelter-related metals in soils and other environmental media (such as air, water, dust, local foods, and fish) in the Flin Flon and Creighton area. A Technical Advisory Committee with representatives from national and provincial agencies provided technical guidance to Intrinsik on the draft document and attended the IERP meeting. Hudson Bay Mining and Smelting Co., Limited (HBMS) provided funding for the HHRA and the IERP.

The panel included eight well-respected scientists with relevant expertise. The panel carefully reviewed the draft HHRA and supporting documents prior to the meeting. At the meeting, the Intrinsik authors presented information on the data, analyses, and conclusions and the panel asked questions to better understand the authors' approach and results. The panel then discussed the data, assessment, and key questions and scientific issues to evaluate the quality and completeness of the risk assessment. The IERP report summarizes the panel's discussions, conclusions, and recommendations. This executive summary is intended to provide a brief overview of the IERP report for a non-technical audience.

Environmental Sampling and Laboratory Testing

Panelists thought that the supplemental sampling to measure the concentrations of the metals in soil, indoor dust, air, water, fish, and local foods was very comprehensive. Individual panel members suggested gathering some additional data that would strengthen the assessment including: more sampling in non-impacted areas for background metal concentrations to cross reference with the Flin Flon and Creighton sampling data and mineralogical analysis of mine tailings to better characterize the source of contamination; The panel also suggested that the authors return to locations where higher boron concentrations were found in soils and do additional analysis of samples using two analytical methods to confirm the accuracy of the concentrations measured.

The panel members suggested that the authors explain better how they decided which metals to address in the HHRA. The IERP agreed with the decision to include arsenic, lead, mercury, nickel, cadmium, and copper, but were not convinced that selenium should have been included.

Laboratory testing was conducted on sample soils to provide information to help determine how much of the metals would be absorbed by humans from ingesting contaminated soil. The percentage absorbed is important to determining how toxic the metals could be to humans. The panel thought that the absorption percentages used in the HHRA for cadmium, copper, mercury, lead, and selenium were appropriate. For arsenic in soils, not all of the panel agreed with the percentage used, and after some discussion the panel suggested the authors consider the panelists' individual suggestions and use their best scientific judgment to decide what to use for arsenic.

Exposure Assessment

The panel discussed the ways that people living in the Flin Flon area might come in contact with the metals of concern (for example, eating home grown foods, playing in contaminated soil, drinking water, breathing air) and the exposure characteristics of the populations (for example, breathing rates, blueberry consumption). The panel agreed that most of the population characteristics and exposure values used in the HHRA were appropriate. Some panel members suggested that the HHRA should also evaluate whether nursing infants may be exposed to the chemicals or if outdoor recreational activities might expose people to contaminated lake sediments. Panel members questioned whether the average amount of food consumed was a realistic estimate, particularly the amount that was assumed for toddlers.

The IERP discussed that there may be other sources of pollution (other than the mining and smelting operations) that are contributing to the levels of copper and lead found in drinking water. The IERP discussed if there was a contamination source within the water distribution system or at the household tap to explain the measured concentrations, which are significantly higher than the maximum copper and lead concentrations in the waters that are the source of local drinking water. The IERP also suggested some testing of homes for lead-based paint and water pipes for lead and copper. The IERP also found the indoor dust concentrations of lead unusual, in that they are higher than outdoor soil concentrations; and the IERP thought that there may be other sources of contamination for these metals. The IERP suggested investigating other sources of contamination, perhaps contaminated dust remains in seldom used parts of home (for example attics) from high smelter emissions in the past, and that this contaminated dust is contributing to current concentrations in living areas. The panel thought the discussion of exposure to lead from consumer products was helpful to understand the total picture and suggested that potential consumer product exposure for other metals be included.

The IERP discussed the concentrations in air, soil, indoor dust, water, local foods, and fish that were used in the HHRA and whether they were appropriate and scientifically sound. The panel discussed whether the use of the 95% upper confidence limit on the mean (95% UCLM) was conservative enough for estimating people's exposure to chemicals in the soil. Other options would have been to use the average (or mean) or the highest concentration measured. Some panel members thought that these upper confidence limits of the mean may not represent the level to which a child living on a property with high soil concentrations could be exposed. However, other panelists pointed out that because the toxicity for most of the metals of concern (with the exception perhaps of lead and methyl mercury) is based on long-term exposure over a lifetime, the 95% UCLM for soil is the appropriate value to use. Panel members did not all agree on which statistic to recommend and noted that preference for the 95% UCLM or maximum value varies among countries and agencies.

Hazard Assessment

The IERP agreed with the authors that most of these metals are well-studied compounds with excellent toxicological assessment documents available that can be reliably used for the HHRA. However, the panel noted that sufficient scientific disagreement exists with regard to oral arsenic

carcinogenicity that the HHRA should provide more discussion of recent arsenic toxicity evaluations and the scientific issues surrounding arsenic carcinogenicity. The panel thought that the authors should present the range of risk assessment values for arsenic rather than rely on a single value.

HHRA Results and Risk Characterization

The panel members generally agreed that overall the HHRA followed the commonly accepted human health risk assessment methods. Overall, the panel agreed that the input data and assumptions used in the assessment were valid and appropriate, they raised a number of issues and questions and made some recommendations for revisions.

The panel noted that estimating risk from short-term exposures to the chemicals is problematic, as is identifying human medical conditions or adverse effects from short-term exposures. The panel also noted that the only relevant short-term exposures to consider are from air. In contrast, lifetime exposure to contaminated soil, water and food should be assumed when calculating risk in a screening assessment. The IERP recommended that the HHRA not estimate risk for short-term exposures to metals in the air, but clearly explain that if short-term exposures are below the long-term risk benchmarks, then people will be protected from the effects of short-term exposures.

The HHRA calculated non-cancer hazard quotients (HQs) for five different age groupings, and found that the highest HQs were for the toddler group. Panel members questioned the appropriateness of the toddler results, and thought that the larger HQ for toddlers only reflects that this age group drinks more water on a per kilogram body weight basis than the other age groups. They also cautioned that the toddler's few years of exposure are being compared to toxicity values meant to be protective for a lifetime of exposure. For most of the chemicals of concern, particularly arsenic and cadmium, these toddler hazard quotients are not appropriate because the toxicity values are based on studies with whole life human exposures. For arsenic, the panel noted that there is no indication that children are more sensitive to arsenic than adults on a body weight basis, therefore calculating risk for different age groups for arsenic is not appropriate. An author agreed that the arsenic risk assessment results alone do not provide a realistic assessment and suggested that a urinary arsenic study in the population can provide additional information to better characterize risk. Panel members noted that other toxicity reference values (e.g., lead) are based on effects from shorter exposures and calculating HQs for smaller age categories may be appropriate for lead.

The panel suggested that the authors consider whether a particular local lake is a "favorite" and therefore give more weight to concentrations of chemicals from this preferred lake, rather than averaging all local lakes. The IERP also questioned whether the evaluating an outdoor worker exposure is necessary when the HHRA assumes indoor and outdoor air concentrations are the same, so workers inside or outside would have the same exposure. The panel suggested that the HHRA include a discussion of potential recreational exposure to contaminated sediments (for example accidentally ingesting sediment while swimming and playing near shore) because it is a common pathway considered in HHRAs. However, the panel did not think such a discussion would affect the quantitative results. The panel also suggested that the authors present the number of properties that have concentrations exceeding the level of concern for at least one of the COCs, to provide an indication of the magnitude of concern.

The panel discussed whether the U.S. EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model was appropriate to use for a community risk assessment. The panel recommended that the HHRA rely upon the risk characterization based upon exposure concentrations using the same Canadian and site-specific assumptions as the other metals. They suggested the IEUBK model be used to support the other results and that the details on the model be moved to an appendix. Some panel members questioned why preliminary remediation goals (PRGs) for soil were calculated, regardless of whether a chemical exceeded a safe level, or whether soil was a significant contribution to exposure. Typically, PRGs are not calculated unless it is determined there is a problem. Other panelists agreed with the authors that the PRGs are useful to help identify the metals or exposure to focus efforts.

HHRA Recommendations

The draft HHRA recommended a comprehensive biomonitoring program, including urinary arsenic, blood lead, and urinary inorganic mercury, to evaluate environmental contaminant exposure to children in Flin Flon and Creighton. The panel discussed the HHRA conclusions and recommendations and the support for the recommendations.

For arsenic biomonitoring, some panel members thought the recommendation was appropriate, while others voiced concerns. Panelists thought it would be difficult to distinguish between background levels to which all Canadians are exposed and local sources of arsenic exposures. The authors indicated that they do not expect to find elevated arsenic levels in the community, but hope that the biomonitoring results will allow them to compare people in the community exposed to different soil concentrations to see if soil is the driver of exposure. The panel cautioned that the authors must be careful interpreting the arsenic hazard quotients for toddlers because the toddler's few years of exposure is inappropriately being compared to chronic toxicity values that are based on lifetime human exposures, which already account for exposure to the infant, toddler and in the mother's womb. Some panelists thought that employee biomonitoring data should be evaluated before community biomonitoring is considered, and were concerned that the number of people in the community participating in the biomonitoring study may not be large enough to be able to determine that blood and urinary measurements are from local soil and air exposures. Half the panel agreed with the authors' recommendation for an arsenic biomonitoring program, while the other half either did not agree, or had significant reservations about such a program.

The draft HHRA recommended a blood lead survey be conducted for a sample population up to age 7. One panelist did not think the testing was justified based on the risk assessment and the relative contribution from the HBMS facility. The other panel members supported this recommendation for lead testing, although most of the supporters had some reservations and offered cautionary advice. One reviewer thought that the risk assessment did not support the recommendation, but agreed that a blood lead survey would be helpful to alleviate uncertainties in people's minds. Some thought that if the authors step away from using the IEUBK model, their conclusions may be somewhat different, with hazard screening resulting in identification of fewer problem properties. One panelist thought that a blood lead survey is a good idea for any community with an aged housing stock, near a source of lead emissions, and with some properties with high soil concentrations. Having these data will assist future risk assessment

efforts (particularly if the Health Canada toxicity benchmark for lead is reduced) and can provide data for measuring effectiveness of cleanup efforts. A panelist suggested the authors consider testing for lead up to age 16 to include older children who may have more opportunity for exposure. Panelists cautioned that the limitations and study design should be carefully explained to the community and there should be a plan for how to respond to any elevated levels found, including if the source is lead based paint.

The majority of the panel did not agree with the recommendation for a biomonitoring program for inorganic mercury, noting that it appears that duration of exposure is a factor involved for inorganic mercury's toxicity and that the hazard quotient for inorganic mercury averaged only 2. The panel agreed with the recommendation to consider a fish advisory for methyl mercury and suggested ongoing monitoring of methyl mercury in fish.

Final Panel Conclusions

The panel members generally agreed that overall the HHRA followed the commonly accepted human health risk assessment methods. Overall, the panel agreed that the input data and assumptions used in the assessment were valid and appropriate, except for those identified during discussion. The panel agreed that in general, the HHRA was presented clearly and completely, and that it was a very comprehensive effort. Panel members recognized the challenges in conducting such a comprehensive assessment and thought that the panel's suggestions and recommendations could be incorporated fairly readily into a revised HHRA.

Technical Executive Summary

An independent expert review panel (IERP) of scientists met June 23-24, 2009 to conduct an independent review of a draft human health risk assessment (HHRA) for Flin Flon, Manitoba, and Creighton, Saskatchewan. The draft HHRA was prepared by Intrinsik Environmental Sciences Inc. to address the potential human health risks associated with exposure to smelter-related metals in soils and other environmental media in the Flin Flon and Creighton area. A Technical Advisory Committee with representatives from national and provincial agencies provided technical guidance to Intrinsik and attended the IERP meeting. Hudson Bay Mining and Smelting Co., Limited (HBMS) provided funding for the HHRA and the IERP review. The panel included eight well-respected scientists with expertise in multi-pathway risk assessment; environmental fate; toxicology and epidemiology; biomonitoring studies; exposure assessment; bioaccessibility of metals from soils; sampling and analysis for metals; derivation of clean up levels; and, uncertainty and sensitivity analyses. The panel carefully reviewed the draft HHRA prior to the meeting. At the meeting, the Intrinsik authors presented information on the data, analyses, and conclusions and the panel asked them many questions to better understand the authors' approach and results. The panel discussed the data, assessment, and key questions and scientific issues to evaluate the quality and completeness of the risk assessment. This report summarizes the panel discussions and conclusions.

Problem Formulation and Sampling

Panelists indicated that the supplemental sampling effort was very comprehensive. Individual panel members suggested some additional data and analysis to increase confidence in the assessment including: more sampling in un-impacted areas for background levels; analysis and speciation of tailings to characterize the source of contamination; and testing of homes for lead-based paint and lead and copper from water pipes. The panel also suggested that the authors return to locations where high boron concentrations were found and do split samples with the two analytical techniques to confirm the concentrations and determine whether boron should be a chemical of concern (COC).

The panel members discussed the selection of COCs and recommended that objective screening criteria be defined and applied systematically, and that the screening process be made more transparent in the assessment document. Several panel members questioned the inclusion of selenium as a COC because of the few samples where selenium exceeded the criterion for inclusion.

The conceptual model, scenarios, and receptor characteristics used for the exposure assessment were discussed. Some suggested further consideration of a nursing infant scenario and recreational exposure to sediments. The panel agreed that most of the receptor characteristics and values were appropriate. Panel members suggested other sources for the food consumption values that might be more realistic (particularly for the toddler).

In Vitro Bioaccessibility Testing

In vitro bioaccessibility testing was conducted to provide information for the soil ingestion pathway and relative absorption factors (RAFs) were calculated. The panel agreed with the

RAFs selected for four of the COCs (cadmium, copper, mercury and selenium), and further discussed the bioaccessibility testing results for lead and arsenic. For lead, panel members agreed that the *in vitro* results are reliable, and the RAF of 58% was appropriate. The panel discussed whether the RAF of 34% for arsenic was appropriate to use when the *in vitro* bioaccessibility method for arsenic has not been fully validated with an *in vivo* model. One panel member supported use of 34% as reasonable for this community assessment, based on the fairly good, but not perfect, correlation seen between *in vivo* and *in vitro* results, and the mineralogy data on house dust. Another reviewer questioned whether evidence is available to be confident that the community soils are more like those with the good correlations than those with poor correlations. The panel did not reach consensus on this, but recommended that the authors consider the suggestions, examine the data closely, and calculate an estimate for the soil levels of concern.

The panel also discussed the relationship between bioaccessibility and soil concentrations, noting that results may differ depending on the soil concentration, and therefore the soil concentrations used for the *in vitro* assays should be representative of the community soils. A panel member suggested that regression analysis could be used to evaluate the relationship between soil concentration and bioaccessibility. The panel discussed that the arsenic bioaccessibility results do not look reliable at lower soil concentrations and several panelists suggested dropping results from those arsenic samples below 50 ppm and recalculating the 95% upper confidence limit on the mean (95% UCLM) for arsenic bioaccessibility. The panel suggested the authors analyze whether the variance at low concentrations introduces bias in estimating the 95% UCLM .

Exposure Assessment

Exposure point concentrations (EPCs) were derived from the available exposure data and additional modeling for lead in children was done with the Integrated Exposure Uptake Biokinetic (IEUBK) model. EPCs under the residential scenario were derived for all media including outdoor soil, indoor dust, ambient air, drinking water, garden vegetables, local fish, wild game, and snow. Exposure estimates were derived for receptors in each of the five age classes for the residential exposure scenarios for each of the five communities of interest (COI).

Other potential sources for the contamination were discussed. Panel members questioned the EPCs for copper and lead in drinking water and wondered if there was a source within the distribution system or at the tap to explain these values, which are significantly higher than the maximum surface water concentrations. The indoor dust levels of lead are unusual in that they are higher than soil levels; potential other sources could be lead-based paint, high levels of emissions in the past; or attics serving as reservoirs of continuing contamination for the homes.

The panel also discussed the inclusion of non-smelter sources of exposure, such as consumer products, in calculating the exposure point concentrations. The authors accounted for consumer product exposure for lead quantitatively and the panel recommended that the consumer product pathway should be discussed qualitatively for the other five COCs.

The panel discussed whether the use of the 95% UCLM was sufficiently conservative for the soil EPCs. These upper confidence limits of the mean may not account for the child living on a property with high soil concentrations. Panelists pointed out that because the toxicity for most of

the COCs (with the exception perhaps of lead and methyl mercury) is based on long-term exposure over a lifetime, the 95% UCLM for soil is appropriate. Panel members did not reach agreement on which statistic to recommend and noted that preference for mean or maximum value varies among countries and agencies.

The assessment compared local results to national soil and water background levels for the COCs. Several reviewers questioned whether the national background levels are representative of background for a mining area.

Hazard Assessment

The authors explained that the COCs are well-studied compounds with excellent toxicological assessment documents available, but noted issues with use of the arsenic cancer risk value and the lead and copper TRVs. The panel discussed the problems with the acute TRVs and the arsenic oral carcinogenicity assessment and their use in the HHRA. The panel recommended that the authors address acute risks qualitatively (but not quantitatively) and clearly explain that the chronic values are protective of acute exposures. The panel noted that there is sufficient controversy with regard to oral arsenic carcinogenicity that the assessment should discuss more recent arsenic assessments, additional data, and the issues surrounding arsenic. The panel thought that the authors should qualitatively discuss the range of risk assessment values for arsenic.

Results and Risk Characterization

The HHRA found that there were some elevated concentrations of arsenic and mercury in the West Flin Flon area with soil identified as a significant pathway with respect to arsenic and inorganic mercury. Fish and some other foods drive the methyl mercury risk. The assessment evaluated lead exposures using a deterministic approach and the IEUBK model, but the authors noted that measurement of blood lead levels would be a definitive measurement of exposure.

Acute exposures apply only to the air pathways in this study and estimating acute exposures and risks is problematic. The panel recommended the authors reconsider the available acute TRVs and consider addressing acute risks qualitatively, but not quantitatively. The panel recommended the authors carefully describe acute exposures and risks so that members of the public do not respond inappropriately to the perceived magnitude of the risk.

The HHRA calculated non cancer hazard quotients (HQs) for five age groups, and the highest HQs were for the toddler group. Panel members questioned the appropriateness of using the toddler because this age group drinks more water per kilogram body weight than the other age groups and this is the cause for the larger HQ. Panel members noted that the arsenic TRV is based on populations exposed over an entire lifetime, including children and *in utero* exposures, and there is no indication that children are more sensitive to arsenic than adults on a body weight basis, therefore use of age groups for arsenic is not appropriate. Other TRVs (e.g., lead) are based on effects from shorter exposures and breakdown by the smaller age categories may be more appropriate. An author agreed that the arsenic risk assessment results alone do not provide a realistic assessment and suggested that a urinary arsenic study can provide additional information to better characterize risk.

The panel recommended that the authors recalculate the risk estimates for cadmium. They also noted that the statement regarding the cancer risk for cadmium being elevated should be evaluated closely, as the estimated risk is no greater than that for arsenic.

The panel identified a number of additional concerns with the chronic endpoints. For the residential scenario, the assessment added risks from different routes and then compared the sum to an oral TRV. Some panel members questioned this, while others agreed with the approach. The panel recommended that the authors calculate separate oral and inhalation HQs when toxicity values are available. These HQs should then be added together and presented with the authors' original approach.

After examining the results, panel members made a number of other recommendations. They suggested that the authors consider a "favorite lake" scenario or some use of a weighted average based on the data to reflect local fish consumption patterns; use a composite receptor for arsenic given the carcinogenicity endpoint; use a mean exposure value for the outdoor worker and reconsider whether the outdoor worker scenario is even necessary if one assumes indoor and outdoor concentrations are equivalent; address sediment exposure (e.g., oral exposure while swimming and playing near shore) qualitatively because it is a common pathway considered, although they did not think it would materially affect the quantitative results; and provide an indication of the magnitude of concern by communicating the number of properties that exceed a target level for at least one of the COCs.

The panel also discussed a number of issues with use of the IEUBK lead model, in particular that the model is meant to be applied to a homogenous exposure scenario, which is not the case here. A reviewer noted the variability in bioaccessibility of the lead samples, which leads this reviewer to think there are different sources of lead. The reviewer thought that the IEUBK model will indicate the problem is soil, when it is likely the lead is from house paint. The reviewer suggested looking for consistency in bioaccessibility by source or area and noted that mineralogical analysis will help understand which bioaccessibility estimates to apply to which soil concentrations. The panel agreed that the HHRA should use the hazard indices derived from the deterministic model for lead risk, noting that the deterministic approach used the same Canadian and site specific assumptions as the other COCs. However, they also suggested the authors use the IEUBK model to support the spreadsheet model results, harmonizing the parameters between the two as much as possible.

Panel members questioned why preliminary remediation goals (PRGs) and provisional trigger concentrations (PTCs) were calculated regardless of whether a COC exceeded the decision criteria or whether soil was a significant contribution to exposure. Some questioned why market basket foods and dental amalgams were included in intake calculations. In particular panel members questioned a PRG for selenium, where the soil accounted for just 2% of intake. Other panelists thought the PRGs are useful to identify which media and compounds to focus efforts.

Recommendations

The draft assessment recommended a comprehensive biomonitoring program to evaluate environmental contaminant exposure to children in Flin Flon and Creighton. Surveys of urinary arsenic, blood lead, and urinary inorganic mercury levels in a sample population were

recommended to help refine and validate the HHRA's exposure estimates. The assessment did not recommend further action for cadmium, noting that the smelter is closing in the next year and with its closing, the air concentrations will reduce dramatically. For methyl mercury, the authors recommended more evaluation to determine the best action for reducing exposures (including consideration of a fish consumption advisory), but noted that biomonitoring would not assist in decision making.

The authors noted that for lead, both the IEUBK and deterministic models predicted average lead related exposures to be within acceptable levels. However, because a significant number of residential properties in West Flin Flon have concentrations in outdoor soil greater than the residential PTC, and Health Canada is expected to lower the benchmark for lead, the authors recommended a blood lead survey focused on sampling children up to age 7 to reduce uncertainty in the exposure assessment.

The panel discussed the HHRA conclusions and recommendations. Panelists thought it would be difficult to distinguish between background levels and sources for arsenic and the authors indicated that they do not expect to find elevated arsenic levels in the community, but hope that the biomonitoring results will allow them to compare people in the community exposed to different soil concentrations to see if soil is the driver of exposure. Some panel members thought the recommendation for arsenic biomonitoring was appropriate, while others raised a number of concerns. The panel cautioned that the authors must be careful interpreting the arsenic hazard quotients for toddlers because the toddler's few years of exposure is inappropriately being compared to chronic toxicity values that are based on lifetime human exposures, which already include infants and *in utero* exposures. Additional panel concerns included that employee biomonitoring data should be evaluated before community biomonitoring is considered, the statistical power of a community biomonitoring study may not be sufficient to attribute an incremental exposure to soil and air exposures, and with the smelter closing postponing biomonitoring because current emissions are more relevant to exposure than soil concentrations. Half the panel agreed with the authors' recommendation for an arsenic biomonitoring program, while the other half either did not or had significant reservations about such a program.

The HHRA recommended a blood lead survey be conducted for a sample population up to age 7. All but one panel member supported this recommendation, although most of the supporters had some reservations and offered caveats. One reviewer thought that the risk assessment did not support the recommendation, but agreed that it would be helpful to alleviate uncertainties in people's minds. Some thought that if the authors step away from using the IEUBK model, their conclusions may be somewhat different, with hazard screening resulting in identification of fewer problem properties. One panelist thought that a blood lead survey is a good idea for any community with an aged housing stock, near a source of lead emissions, and with some properties with high soil concentrations. Having these data will assist future risk assessment efforts (particularly if the TRV for lead is reduced) and can provide data for measuring effectiveness of cleanup efforts. A panelist suggested the authors consider testing for lead up to age 16 to include older children who may have more opportunity for exposure. Panelists cautioned that the limitations and study design should be carefully explained to the community and there should be a plan for how to respond to any elevated levels found, including if the source is lead based paint. One panelist did not think the testing was justified based on the risk

assessment and the relative contribution from the HBMS facility. The panelist thought it would have been better to do such a survey prior to the HHRA and incorporate the results.

The majority of the panel did not agree with the recommendation for a biomonitoring program for inorganic mercury, noting that it appears that duration of exposure is a factor involved for inorganic mercury's toxicity. The TRV is based on a chronic study and an exposure slightly greater than the TRV for the toddler (HQ of 2), does not support biomonitoring. The panel agreed with the recommendation to consider a fish advisory for methyl mercury and suggested ongoing monitoring of methyl mercury in fish.

The panel members generally agreed that overall the assessment followed the commonly accepted human health risk assessment methods. Overall, the panel agreed that the input data and assumptions used in the assessment were valid and appropriate, except for those identified during discussion. The panel agreed that in general, the HHRA was presented clearly and completely, and that it was a very comprehensive effort. Panel members recognized the challenges in conducting such a comprehensive assessment and thought that their suggestions and recommendations could be incorporated fairly readily.

1. Participants

Authors/Presenters

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[1] Affiliations listed for identification purposes only. Panel members served as individuals on this panel, representing their own personal scientific opinions. They did not represent their companies, agencies, funding organizations, or other entities with which they are associated. Their opinions should not be construed to represent the opinions of their employers or those with whom they are affiliated.

2. Overview of the Independent Expert Review Panel (IERP) Process

This meeting of an independent expert review panel (IERP) was organized by Toxicology Excellence for Risk Assessment (*TERA)*. *TERA* is an independent non-profit organization with a mission to protect public health through the best use of toxicity and exposure information in the development of human health risk assessments. *TERA* convened this panel to review the draft human health risk assessment (HHRA) of Flin Flon, Manitoba, and Creighton, Saskatchewan. The draft HHRA was prepared by Intrinsik Environmental Sciences Inc. to address the potential human health risks associated with exposure to smelter-related metals in soils and other environmental media in the Flin Flon and Creighton area. A Technical Advisory Committee (TAC) with representatives from national and provincial agencies provided technical guidance to Intrinsik. TAC members attended the IERP meeting. Hudson Bay Mining and Smelting Co., Limited (HBMS) provided funding for the HHRA and the IERP review.

The IERP included eight scientists with expertise in the key disciplines to review the assessment. Each panelist is a well-respected scientist in his or her field. Collectively, the panel has expertise in multi-pathway risk assessment; environmental fate, human toxicology and epidemiology; biomonitoring studies; exposure assessment and pathways modeling; bioavailability and bioaccessibility of metals from soils; sampling and analysis for metals in diverse media; evaluating human health hazards of soils and dust; derivation of Soil Trigger Concentrations (STC) and soil preliminary remediation goals (PRG); and uncertainty and sensitivity analyses. Panel members were very familiar with Canadian and United States (US) guidance and methodologies for multimedia risk assessments. Each panel member disclosed information pertinent to evaluating potential conflicts of interest and biases related to the HHRA and its sponsor. *TERA* carefully evaluated this information when selecting panel members. *TERA* was solely responsible for the selection of the panel members. Short biographical sketches and disclosure statements for panel members are provided in Appendix A.

The panel was sent the HHRA and review materials approximately six weeks prior to the meeting to ensure adequate time to carefully review the document and prepare for the meeting discussions. *TERA* developed a "charge to peer reviewers" document that outlined the key questions and scientific issues to evaluate the quality and completeness of the risk assessment. A copy of the charge is found in Appendix B, along with other meeting materials.

Members of the TAC were invited to observe the panel meeting process. The TAC members were provided some opportunities to ask questions of the panel. A list of attendees is found in Appendix B.

TERA prepared this meeting report. The report summarizes the authors' presentations, the panel discussions, the authors' comments during the discussions, and questions from the TAC attendees. The meeting report is a summary, not a transcript. Opinions and recommendations of the panel members are noted (although panelists are not identified by name). Panel members have reviewed the draft report, and their comments and corrections have been incorporated into this report.

3. Panel Introductions, Conflict of Interest, and Meeting Process

The meeting opened with a welcome by Ms. Jacqueline Patterson of *TERA*. She described the background and purpose of the peer consultation and the agenda for the meeting. Ms. Patterson noted that copies of panel members' biographical sketches and conflict of interest and bias statements were provided to all attendees (see Appendix A). The panel members then introduced themselves and noted whether they had additions or changes in their statements. None of the panel members had any substantive changes to their statements.

Dr. Dourson, the panel chair, then described how the meeting would be conducted. He explained that discussions would be organized around the charge questions and would follow the order in the agenda (see Appendix B). He noted that all panelists would have the opportunity to state their own positions on the charge items and panel members are encouraged to question one another to make sure that all the panel members and the authors understand the scientific basis for the panelist's opinion. The panel will seek agreement, but if agreement is not reached, areas where panelists' disagree will be noted. Authors will make brief presentations and answer clarifying questions from the panel members. The authors will also be permitted to ask clarifying questions of the panelists so that they fully understand what is being suggested or said.

4. Background

4.1 Presentation by Mr. Alan Hair, Hudson Bay Mining and Smelting Co., Limited (HBMS)

Mr. Alan Hair of HudBay Mineral Inc. presented background information on the Flin Flon/Creighton HHRA including maps of the area, pictures of the smelter, and a history of the smelter. Slides of his presentation are found in Appendix C. Mr. Hair noted that by 1993 major process upgrades for the zinc plant significantly reduced emissions. The copper smelter, however, uses standard technology and is slated to close in 2010. He explained that ore and materials from outside the area have been trucked in for processing on site, along with material from the Flin Flon mines. The mill tailings are currently stored directly next to the complex and Mr. Hair noted a large dust storm in 2002 spread contaminants from the mill tailings area throughout the community.

4.1.1 Clarifying Questions

Panel members asked a number of questions about the tailings impoundment and measures in place to control run-off and migration off-site. Mr. Hair explained that Flin Flon Lake was drained to store the tailings and it all drains to the lake bottom; therefore there is just one point of effluent discharge, and no issues with contamination of local waters. Tailings have been managed with sand and slag cover and soil cement to eliminate tailings migration from the management area. Major changes were implemented after the dust storm in 2002. Mr. Hair also noted that smelter slag has been widely used throughout the area. The slag passes all the leachate tests, and metals are locked up fairly well and levels are low. In response to a question about availability of a wind rose, Mr. Sigal (an author) explained that there is a wind rose in the CD of references provided to the reviewers.

In response to panel questions, Mr. Hair explained that the communities started as unplanned settlements directly adjacent to the HBMS mining and metallurgical complex when operations commenced in 1927. Flin Flon was not incorporated until 1933. In the uptown area next to the operations, part of West Flin Flon in the study, housing was built from the 1930s onwards with constant redevelopment. Farther out from the operations, in the area referred to as East Flin Flon, there would have been some original housing dating from the 1930s and 1940s, but the main expansion occurred after World War II, with subdivisions being progressively developed from the 1950s through to the 1990s. The town of Creighton was first incorporated in 1952, and most housing would also have been developed after World War II.

5. Problem Formulation and Sampling

5.1 Presentation by Mr. Adam Safruk, Intrinsik

Mr. Adam Safruk, one of the HHRA authors from Intrinsik, presented information on the problem formulation used in this risk assessment. Slides of his presentation are found in Appendix C. He described the site characterization and the communities of interest (COIs) and noted numerous studies have indicated elevated levels of metals in the area soils. It was noted that the predicted wind direction was towards the southeast. A residential soil sampling study was initiated in fall 2007 by Jacques Whitford (2008). A chemical of concern (COC) list that included 6 COCs was identified based on the comparison of concentrations in soil and health risk guidelines, as well as consideration of regional background concentrations. The authors identified human receptors as infant, toddler, child, adolescent, and adult. Exposure pathways included oral, inhalation, and dermal pathways from soil, dust, home garden vegetables, blueberries, fish, wild game, surface water, drinking water, and snow. Scenarios included residential (children and adults) and outdoor commercial workers, the latter at the request of the TAC. The worker scenario is meant to assess exposure to an outdoor worker in the area who does not also live in the area. The authors derived PRGs and provisional trigger concentrations (PTCs) to assess on a property-by-property basis because they thought it was not realistic to assume that most receptors will move randomly throughout the community.

5.1.2 Clarifying Questions

Panel members had no clarifying questions on the presentation itself, but asked a number of questions on information in the HHRA and in particular sought to understand some of the monitoring data presented. In response to their questions, Mr. Safruk reported that there are air monitoring data back to the 1990s, but that for the HHRA the 2007-2008 data were used. Chapter 4 of the HHRA includes a table of the timeline for the air data covering the last few years, but Mr. Safruk noted that the data prior to 2002 were not relied upon because technologies have greatly improved since then. The authors revised this table to include a longer time frame and provided the revised table to the panel later in the day (see Appendix D).

The authors did not know the reason for the substantial decrease in lead, copper, and zinc concentrations associated with particulate matter air sampling from 2002 to 2006, but thought that the data reflected normal variability in weather, wind and feed materials. They did not know why there was an apparent increase in copper and lead concentrations in drinking water from 2002 through 2006 collected as part of the ongoing HBMS monthly sampling program (as reported in Table 2-4). Mr. Safruk noted that the annual concentrations reported in Table 2-4

represent mean values of samples from multiple locations. This prompted panelists to question whether these values represent water in the distribution system, or the tap, or a mix of the two, and pointed out that if the source is not consistent between years, or treatment changed, this might explain the variations in the data. The authors noted that the historic data were used to identify additional sampling needs, and the subsequent sampling was of tap water. The authors stated that they would check to see if the surveys included questions about lead pipes. However, only one of the fifty tap water samples exceeded lead guidelines in the Jacques Whitford (2008) survey. Thus, the authors do not think that lead from pipes is a problem in these communities.

In response to other panel questions, Mr. Safruk noted that he was not aware of the area being naturally high in radioactive materials or radon; and that there are no fish advisories for Ross Lake, because there are no fish present due to poor water quality and sewage.

Panel members questioned the authors on what criteria were used for selection of COCs. Mr. Sigal stated that they used a criterion of 1% of samples exceeding the screening level.

Mr. Sigal clarified that the data for yard soils, indoor dust, and tap water were all from self selected volunteers. A panel member suggested that Tables 3-3 and 3-4 list local background concentrations, particularly for arsenic and cadmium. The screening criteria used for arsenic and cadmium are below background levels found in some parts of the world.

A panel member sought explanation for why arsenic concentrations were an order of magnitude higher for Ross Lake than Schist Lake, and why lead concentrations in sediment differ. The panelist asked if the Stantec (2008) data were included and explained that these questions relate to background and stack emissions and which lake to use for calculating risk from fish consumption. Mr. Safruk indicated he would have to look into this. The reviewer was also concerned that fish concentrations of arsenic from Schist Lake were lower than other lakes, and questioned the representativeness of Schist Lake for the greater community. Mr. Safruk responded that the reason for the fish survey was to have a consistent source of fish data to make comparisons among the lakes; it is difficult to do a comparison among all the studies due to the uncertainties in the historic data.

Panelists had a number of questions regarding the fish data. Mr. Safruk agreed that the percentage of surveyed residents who consumed the filet portion of fish was inconsistently reported and that they would have to go back to the original data to determine what is meant by the term "majority." He did note that the proportion of fish eaters eating non-muscle was less than 5% and stated that the fish sampling data only included the filet. Panel members noted that metals accumulate in gills, bones, and organs, and this could be a concern if the whole fish with bones are eaten. A panel member was concerned that the authors better distinguish what is rare and what is common for the local area. Mr. Safruk also explained that the local food survey did not ask respondents whether they were First Nations or non-First Nations people. He noted that First Nations' reserves are far from the Flin Flon and Creighton area, but there are some First Nations people living in the local area.

The panel sought clarification on how the exposure point concentrations for COCs in fish presented in Table 4-10 were calculated and whether consumption was species specific. Mr.

Safruk explained that they pooled the fish data over all lakes and used the 95% upper confidence limit on the mean (95% UCLM) for the exposure point concentration (EPC), unless the 95% UCLM for walleye exceeded the value. This is because the surveys show that many local people consume walleye exclusively. Table 4-8 shows the concentrations for each fish species. A panelist asked if the authors conducted a sensitivity analysis for how often the higher concentration fish are eaten. The authors indicated they had not. The panel suggested the authors more clearly explain how they derived these EPCs in the text.

Mr. Safruk also clarified that the mushroom data represent annual consumption and that there is a very short mushroom season.

Panel members also sought clarification on scenarios and pathways. Mr. Safruk reported that they considered the nursing infant scenario but could not find a validated approach for these COCs and that this is mentioned in the uncertainties section. A panelist asked whether the authors considered swallowing of airborne dust. Mr. Safruk responded that in their past work they found that swallowing of particles was much less than direct ingestion. Another panelist thought that the swallowed portion of inhaled particles would be accounted for in the toxicity factors as they are generally based on occupational studies and those workers would have swallowed and inhaled. In addition, Figure 3-2, the conceptual site model needs an arrow from surface water to the receptor to represent ingestion of water while swimming. In response to panel questions, Mr. Safruk also noted that they could add an assessment of ingestion of suspended or deposited sediments, but would have to determine whether surface water samples were filtered or unfiltered.

5.3 Panel Discussion

The panel members discussed Charge Questions 1-5, which covered issues on the problem formulation and supplemental sampling.

5.3.1 Charge Question 1

> **Charge Question 1: Comment on the adequacy of the data gap analysis and supplemental sampling. Were the appropriate types of data collected and analyses performed that are necessary to assess the extent of contamination? Did they adequately characterize the distribution and concentration of COCs in each of the media of interest?** [[1] For example - Were the appropriate major data gaps identified and have the relevant media been tested or estimated? Is there an adequate description of the sampling methodologies and did they follow a standard method? Were the methods appropriate for the communities? Do the study reports include a description of quality assurance and quality control measures for each study?

Panelists indicated that the overall sampling effort was very comprehensive and examined a multitude of media pathways. Individual panel members had some additional questions and comments. One panelist pointed out a few areas where additional sampling and analysis would be helpful to increase confidence in the assessment. The soil screening levels are close to background levels and it might be helpful to do more sampling in un-impacted areas; in particular, the Cranberry Portage area used for background levels. Since the tailings impoundment is a source of contamination in the recent past, it would be useful to analyze and speciate the tailings to characterize the source of contamination and determine what is from the

facility. In addition, given the age of much of the housing stock, it would be helpful to test more homes for lead-based paint and lead from water pipes.

Another panel member questioned the representativeness of the yard soil and dust measurements and suggested that the potential for selection bias should be addressed to help determine representativeness. The panelist asked whether data are available to quantify or to determine spatial variability and also noted that normally with self-identified subjects, one sees more participation from less impacted communities. An author explained that the Jacques Whitford (2008) study was not 100% volunteer participants. A predetermined number of houses were identified for each community and if they did not generate sufficient volunteers, the study workers went door-to-door to recruit participants. As a last resort they sampled vacant lots.

Addition of more information about the nature of the data, including sample size and variability was recommended for the tables in Chapter 2. Some tables provide more of the needed information than others, and it would be helpful to the reader if the authors provide sufficient data in all tables.

The analytical techniques used for the boron samples (hot water soluble boron and total acid digestion techniques) were discussed and the implications addressed. Panel members asked which technique was used to analyze the different samples, and which technique was the protocol for the screening levels to which the sampling concentrations were compared. One panel member noted that the Canadian Council of Ministers of the Environment (CCME) guideline is 2 micrograms per gram (µg/g) based on the hot water soluble boron technique, but the guideline is based on ecological effects. The reviewer did not know what protocol the US Environmental Protection Agency (EPA) Region 9 value used, but noted that the EPA value does not account for intake from plants and livestock and that boron accumulates in plants, so this is an important potential pathway for humans. He noted that they divided the EPA screening values by 5 to allocate just 20% of the reference dose (RfD) to soil.

An author explained that the Jacques Whitford (2008) study used the hot water technique, but he was not sure what the Manitoba study (Manitoba Conservation 2007) used. A reviewer questioned whether boron should be included as a COC and indicated that local background concentrations should also be examined to help make this determination. An author explained that they do not have measured concentrations that are comparable to the soil guidelines and a panelist suggested they could use a standard conversion between the hot water soluble concentrations and the total acid digestion concentrations. The reviewer explained that the relationship between hot water soluble and acid digestible boron analyses is that the acid digestion method can give results about five times greater than the hot water method and that the conversion is a function of soil texture. The panel suggested that the authors return to locations where high boron concentrations were found and do some split samples with the two techniques to confirm the ratio between results. This work would be helpful to have greater confidence that boron is not a COC.

5.3.2 Charge Question 2

Charge Question 2: Were the appropriate Chemicals of Concern (COC) selected for the communities?

The panel members discussed the screening criteria and recommended that the authors be more transparent in describing the screening of the sampling data to identify the chemicals of concern. The authors had explained that they used a cut-off of 1% of samples above the soil screening guidelines and noted that it was easier to include more COCs (selenium in particular) at this stage than have to add them later. One panel member thought the 1% seemed somewhat arbitrary and would have thought that persistence and toxicity should be considered, along with the distribution of the concentrations. Many reviewers found the rationales for individual COC selection less than transparent and identified seeming inconsistencies between COCs. For example, several reviewers were not convinced that selenium should be a COC, even if it is a component of the smelter emissions, noting that there were only 13 samples out of 1362 above the guideline. One of these reviewers suggested the authors include a table of background concentrations for selenium as had been done for other metals and was concerned that including selenium dilutes emphasis on other more important COCs. Another reviewer noted that 16% of the samples for manganese exceeded the soil criterion, but because there was no correlation with any known or suspected elements of smelter emissions and the concentrations were less than the local background, manganese was not selected as a COC. A third reviewer agreed with the decision not to include aluminum and zinc, but thought the decisions should be based on human health criteria. The panel recommended that objective screening criteria be explicitly stated and applied systematically and that the screening process be made more transparent in the assessment document.

A panel member asked whether the soil concentrations used for the screening were yard-by-yard measurements, a single point, or a composite of samples. An author explained that the concentrations used for the screening represent concentrations for individual samples which are a composite of multiple cores. Multiple samples from individual properties were included in the screening process. To derive EPCs for the HHRA, individual samples from a single property were averaged to represent a single property concentration.

5.3.3 Charge Question 3

Charge Question 3: Does the conceptual model adequately demonstrate the potential human receptors and the related exposure pathways? Do the selected exposure scenarios sufficiently cover the situations, behaviors, and conditions under which receptors are likely to be exposed?

The panel discussed the conceptual model, scenarios, and receptor characteristics used for the HHRA. A panel member asked for clarification on the commercial worker scenario. An author explained that the commercial worker was assumed to spend 50 hours /week working out of doors in the study area and to not live in the area (i.e., no exposure at home). A reviewer questioned whether seasonal differences should be considered when estimating the proportion of

time outdoors by different receptors. An author noted that because the indoor and outdoor air concentrations were assumed to be the same, allocating time to indoors and outdoors is not needed for air exposures. In addition, the authors had originally used a 45/55 split for soil and dust ingestion, based on the US EPA Integrated Exposure Uptake Biokinetic Model (IEUBK) default, but the TAC requested they assume 100% exposure to soil in the summer and 100% exposure to dust in the winter.

Food estimates were also discussed. A reviewer questioned the reasonableness of estimates of food consumption, particularly for the toddler, noting that the local and market basket foods added up to over three pounds of food per day, which seems unreasonable. There is little difference between child and adult consumption rates and alternate sources of data should be considered to generate more realistic estimates, particularly since the toddler is the receptor of interest and market basket foods are such a high proportion of intake. Using these unreasonably high consumption rates will overestimate risk. An author explained that they used the mean values from Richardson (1997), a commonly used reference for food consumption in Canada which is based on Nutrition Canada food consumption survey results (3 day self reported recall). The mean values were used in the HHRA.

Panel members suggested several other sources for food consumption data, particularly for the toddler. One noted that more recent Canadian fish consumption data are found in a methyl mercury report by Health Canada (2007). The Exposure Factors Handbook (EFH) of the US EPA was suggested by several panelists who noted that this reference uses recent USDA food survey data and so is based on US data, but it might be useful for comparison with the Canadian data. Another panel member thought that the EFH data may be broken down by region of the US and if so, a northern region might be most appropriate to compare with Canada. The inorganic fraction of arsenic in seafood is addressed in a paper by Schoof and Yaeger (2007) and includes more recent studies on arsenic. Another panel member asked whether the Schoof and Yaeger (2007) ratio of inorganic-to-organic arsenic would apply to a range of exposure levels. The first panelist noted that some of the studies used by Schoof and Yaeger (2007) were from contaminated mining/smelting sites. An author indicated that a fish sampling is planned for this summer and additional analysis could be done.

A panel member suggested the authors further consider a nursing infant exposure pathway and scenario for the HHRA and discuss the issue in the uncertainty section. The panelist thought there might be an appropriate approach for this pathway for methyl mercury. Another panel member suggested that the authors be careful in their use of qualitative terms to make sure they are appropriate and internally consistent. For example, on Page 2-40, 500 milliliters (ml) of blueberries is referred to as a small amount, but this is equivalent to about 2 cups, which does not seem small.

An author provided clarification on the wild game consumption estimates, indicating that they used an 8 ounce (oz) serving size based on the serving size for fish recommended by provincial and national agencies. Eight ounce serving size was used for wild game meat, and local fish. Up to 20% (32 grams (g)) of total meat consumed (market basket and wild game) was assumed to be wild game (percentage varied by age group) and it was also assumed that all age groups (excluding infants) ate wild game. A panel member thought that this sufficiently captures the

upper bound of exposure, but less so for the average, and suggested explaining this in the text. Another reviewer suggested that if local foods do not have different concentrations than market basket foods, then this breakdown is not necessary, and the breakdown does cause problems for use of the IEUBK model where one would be double counting. An author agreed that this would result in double counting in the IEUBK model runs, but that they wanted the community to see the wild game results. He indicated that they could compare market basket and local concentrations. A panel member suggested this be explained in the text or a footnote to it.

5.3.4 Charge Question 4

Charge Question 4*: In vitro* bioaccessibility testing was conducted to provide information for the soil ingestion pathway. Were the approach and results valid? Are the recommended relative absorption factors (RAFs) appropriately calculated?

The panel members agreed with the relative absorption factors selected for the COCs and discussed the use of bioaccessibility testing results for lead and arsenic. The panel agreed that the results for lead are reliable, but several questioned the use of results from arsenic bioaccessibility testing.

A reviewer noted that *in vitro* bioaccessibility method for lead was optimized and validated against *in vivo* animal bioavailability studies. In the US, EPA accepts the use of the *in vitro* bioaccessibility method for lead, by itself, to determine the bioavailability factor to apply to lead in soil. Therefore, this panel member can accept the *in vitro* bioaccessibility results for lead from the Flin Flon study with no reservations.

A reviewer questioned whether the RAF for arsenic (34%) is appropriate, when the bioaccessibility assay has not been validated with an *in vivo* model. Another reviewer explained that bioaccessibility for arsenic ranged from 5-60% in the *in vivo* animal models and therefore defaulting to 100% is clearly overly conservative. This reviewer thought that while there is some uncertainty using an unvalidated method, the weight of evidence leans toward 34%. The reviewer explained that the method has not been optimized and validated for arsenic, but it is thought to be pretty close and noted that in a regression analysis comparing over 35 *in vitro* and *in vivo* arsenic results from juvenile swine and monkeys they find a correlation coefficient of 0.8 for all but 7 samples. The reviewer noted that US EPA's Region 8 uses arsenic test results, but they back them up with speciation of the samples. This reviewer would not accept the *in vitro* bioaccessibility results *per se* without also looking at the mineralogy of the samples tested. While there was no mineralogical analysis of the soil samples at Flin Flon, in Sub-appendix H of the HHRA, a mineralogical analysis was conducted for a number of indoor dust samples. For the samples which appeared to be associated with smelter contamination, the arsenic was primarily associated with arsenopyrite and iron oxy hydroxides. These mineral forms are relatively insoluble and have been shown to have low bioavailability in *in vivo* swine and monkey studies. Based on the *in vitro* bioaccessibility results, the fairly good, but not perfect, correlation seen between *in vivo* and *in vitro* results, and the mineralogy this reviewer concluded that the use of a 34% bioavailability factor for arsenic in soil is reasonable for this site. Another reviewer provided a number of additional studies on comparison *in vitro* and *in vivo* results that the authors might find helpful (see list in Appendix E). The first reviewer questioned what evidence

is available to say that the community soil is not like the seven problem soils found in the bioaccessibility testing, and suggested some language to express this potential concern.

The panel discussed the relationship between bioaccessibility and soil concentrations. A reviewer suggested identifying the soil concentrations that were used in the bioaccessibility tests because one can get different results based on soil concentration, and the concentrations used should be representative of the site. Another panelist commented that for lead, bioaccessibility is higher at low concentrations, and asked if the same situation would apply to other metals. Other reviewers said they have seen the concentration differences at some sites and thought that it reflects source differences and geochemical speciation. This precludes one from generalizing from low and high concentrations. They also thought that the variability around detection limits for low concentrations might also give higher results. The reviewer asked if it is possible one might exclude taking action on a relatively low concentration property because the bioaccessibility factor was too low because it was based on a higher concentration test result. The other reviewers thought that if samples are representative of the variation in site concentrations, one can have confidence in the results. The authors confirmed that they looked at the range of concentrations and the bioaccessibility testing did represent the concentrations in the area. Panel members suggested the authors present soil concentrations and size fractions with the results and noted that Health Canada has some guidance on how to demonstrate independence of size fraction and bioaccessibility estimates.

One reviewer questioned the validity of the comparison of results from the different size fractions and solute:solid ratios in the bioaccessibility summary table (Table 2-16). The reviewer thought the authors were confounding the influence of the two variables by changing them both, and it is not clear which is changing the results. Another reviewer interpreted the table to show that Methods 1 and 2 indicate particle size does not make a difference and Methods 2 and 3 show that the solute ratio makes a large difference. An author explained that they did not intend to use eight different methods, but followed Health Canada guidance for different particle sizes and solute ratios. They tried to do a range finding study to see if one method was most reliable and then just run one method with 50 samples. The reviewers thought that this should be better explained in the report. The text needs to better describe the rationales for the method selections.

A reviewer asked other panel members which solute ratio they thought was more representative of the human digestive system. A reviewer thought that the 100:1 is much more representative, but that humans are highly variable. When soil first enters the system, it is thought that most of the contaminants will desorb from the soil in the first hour. The problem with the larger ratio is a detection problem and that the ability to detect small amounts in solution controls how finely one can detect the contaminant and accurately estimate bioaccessibility.

The panel agreed with use of the 100% bioaccessibility for the COCs other than lead and arsenic. The panel recommended that the authors move much of the bioaccessibility discussion to an appendix and focus the report text on the lead and arsenic testing and results used.

Later in the meeting, the authors provided a handout on relative absorption factors to assist the panel members in their review (see Appendix D). The panel discussed this new information. One panel member said that there does not appear to be a consistent pattern between soil

concentration and bioaccessibility and for most of the compounds there is a reasonable distribution of soil concentrations. This panelist suggested doing regression analysis to determine if there is a relationship between concentration and bioaccessibility. In response to panelist questions, an author said he thought they eliminated the non-detects, and a panel member agreed that would be the best approach rather than using half the detection limit. Another panel member entered the lead data into a spreadsheet and found there was no relationship between lead concentration and bioaccessibility; the arithmetic bioaccessibility mean was 0.69 compared to the 95% UCLM.

A panel member asked the authors about the quality control and assurance on the bioaccessibility testing and whether the data were evaluated to see if they met the data quality objectives (DQO). The panel member asked if detection limits and recovery percentages were specified prior to the work and pointed out that this needs to be discussed in the report. An author explained that they did not independently assess this, but deferred to the laboratory which said they met the DQOs.

The panel discussed that the arsenic bioaccessibility results do not look reliable at lower concentrations and discussed approaches to address this. Two panelists suggested dropping results from all the samples for arsenic that are below 50 parts per million (ppm) and recalculating the 95% UCLM for arsenic bioaccessibility. They explained that the results from the assay are highly variable and therefore uncertain at concentrations that are close to the detection limit; small differences are significant because the denominator is so small. These panelists suggested 50 ppm would be a good cut-off based on their personal experience that the method is very sensitive to perturbations at low concentrations. Another panel member pointed out that to use the 50 ppm cut-off, the authors should determine if the laboratory they used has the same detection limits as the laboratories with which these panel members have worked. If the laboratory used here has a lower detection limit, then a lower concentration should be considered. Several panelists did not entirely agree with discarding the lower concentration data and suggested the authors look at the data closely to see what the scatter is and analyze the data to see whether the variance at low concentrations introduces bias in estimating the 95% UCLM. Another thought that the scatter in bioaccessibility results at low soil concentrations will introduce bias in calculating the magnitude of variation in the bioaccessibility at the high end (i.e., 95% UCLM); uncertainty in the estimate at low concentrations will drive the 95% UCLM bioaccessibility higher. The panelist also pointed out that accuracy in the bioaccessibility estimate is most desirable at higher concentrations near where a cleanup level might be set, not at lower concentrations near background, which are less of a health concern. The panel did not reach consensus on this, but recommended that the authors consider the suggestions, examine the data closely, and calculate an estimate for the soil levels of concern.

For lead, the authors calculated a RAF of 58%. Panel members agreed that this was an appropriate RAF noting that the method is reliable. They discussed whether the lead concentrations below 50 ppm should be discarded in a fashion similar to arsenic. A panelist thought this was not likely an issue for lead as the lead concentrations were generally higher than arsenic concentrations, but that the authors should ask the laboratory for their level of confidence in the lead results. The panel concluded that the 58% RAF for lead was appropriate and suggested that the authors might consider plotting on a map the variation of bioaccessibility for

different areas of the communities, which may reflect manmade distribution of tailings used as fill.

5.3.5 Charge Question 5

Charge Question 5: Are there any concerns or limitations of these studies that affect the usefulness of the data in the HHRA? Do you have any further concerns or comments regarding the problem formulation or supplemental sampling?

Many panel members questioned whether the assessment assumed soil is the problem source for lead, and did not adequately address other potential sources, including potential contributions from lead based paint and lead pipes. The indoor dust levels of lead are unusual in that they are higher than soil levels, which would indicate that there must be some other source. An author clarified that they did dust wipes in homes and found no elevated lead levels, which gave them some indication that lead paint is not a problem. They could collect more data on paint in the future if necessary.

The author also noted that they do not have data on lead in pipes, but would look at the Jacques Whitford (2008) report to see if they included a question on lead in pipes. [The authors reported after the meeting that the Jacques Whitford (2008) report does not include information on lead in pipes of sampled homes]. There are also some data from residential taps in the HBMS data. A reviewer indicated that the raw data will be important for PRG calculations; if there is a water pathway driving exposure and it is related to pipes, this will affect risk management decisions.

A reviewer asked why the Jacques Whitford (2008) residential soil sampling was not combined with the Manitoba (2007) data to make larger data set. The authors clarified that the Manitoba (2007) study did not sample residential properties; it was limited to public areas, some of which (e.g., ditches and behind gas stations) were not representative of places people would generally be exposed to soils. The authors felt that they should use the residential data alone.

The reviewer questioned why different sieve sizes were used and thought they should be consistent between dust and soil. The authors explained that the soil was sieved the same between the Manitoba (2007) and the Jacques Whitford (2008) studies. They followed ASTM International protocols which recommend a smaller sieve size for dust than soil. In the bioaccessibility studies, the soil was sieved as per the individual method's protocols, and Health Canada requested use of different sieve sizes.

A reviewer asked about the dust sampling. An author clarified that the samples were collected with a special vacuum from carpeted areas away from the entrance and traffic (e.g., sitting areas) and virtually every home had carpet or area rugs. Houses ranged from old to new and spanned the economic range of the community. A reviewer questioned the use of 100% relative absorption for lead in house dust and noted that the IEUBK model default is 30%. An author clarified that the TAC asked them to use 100%.

The panel briefly discussed the study objectives of the HHRA as they are described in Chapter 1 of the HHRA report. One panel member expressed concern that the HHRA reads as if the

objective was to justify biomonitoring specifically. An author clarified that the HHRA was not done to set up a biomonitoring program, but from the start there were people asking for biomonitoring and it was in the authors' minds to use the HHRA results to help scope a biomonitoring program. From the authors' perspective, biomonitoring data may help characterize bioaccessibility and bioavailability uncertainties.

Other panel members agreed that the objectives were not clear; in particular they were concerned with Objective 2 – development of a risk management plan. One noted that this is a screening risk assessment without probabilistic and uncertainty analyses and so this HHRA could not determine specific properties to clean up. Mr. Sigal confirmed that they have not developed a risk management plan at this stage. An observer from Manitoba Conservation noted that they had found soils with levels of metals above the CCME guidelines. The goal of the HHRA is to determine whether metals in soils posed undue risk to humans in the long term, recognizing other exposures in the community, and to better define what the risks are. CCME screening levels are very conservative and the HHRA is the second step; the second objective is not addressed yet. An author and a Manitoba provincial representative explained that the plan is for the HHRA to be released in conjunction with any biomonitoring studies that may be done, and that risk management will be addressed at the same time (target early 2010).

6. Exposure Assessment

6.1 Author Presentation

Mr. Adam Safruk presented information on the exposure assessment portion of the risk assessment. Slides of his presentation are found in Appendix C. The exposure assessment included selection of exposure point concentrations (EPCs) from the available exposure data, and additional IEUBK modeling for lead in children. Under the commercial worker scenario, maximum concentrations were used for the soil EPCs, which reduced the need to derive PRGs for commercial land use. If there is no risk with exposure to the maximum concentration, then there would be no need to derive commercial PRGs. EPCs under the residential scenario were derived for all media including outdoor soil, indoor dust, ambient air, drinking water, garden vegetables, local fish, wild game, and snow. Exposure estimates were derived for receptors in each of the five age classes for the residential exposure scenarios for each of the five communities of interest (COI). The IEUBK model predicted blood lead concentrations for children that reflected the distribution of soil lead in the region.

6.1.1 Clarifying Questions

Mr. Safruk answered a number of clarifying questions regarding the exposure assessment. He clarified that indoor dust values were predicted using regression equations, based upon statistically significant relationship between outdoor soil and indoor dust. For lead there were no statistical significant relationships, and so they used the 95% upper confidence limit on the mean (95% UCLM) from the results of the indoor dust study for the communities of East Flin Flon, Channing, and Creighton. For the community of West Flin Flon, the multiple source analysis (MSA) methodology recommended within the IEUBK model accurately predicted indoor dust concentrations based on concentrations measured in outdoor soil and air. Therefore, the MSA methodology was used to predict indoor dust concentrations within West Flin Flon homes to allow for the coordinated adjustment of indoor dust concentrations when deriving soil PTCs.

A panelist asked whether the authors thought that assumption that indoor air concentrations would be the same as the outdoor concentrations was conservative (health protective), noting that some think that indoor air concentrations may be greater than outdoor, particularly for volatiles (e.g., mercury is volatile). The panelist noted that this is an area of uncertainty. Mr. Safruk responded that the TAC recommended they estimate indoor concentrations to be equivalent to outdoor.

One panel member noted that Shaw (1981) measured higher concentrations of lead at Lewis Lake, but this was not included in the UCLM values and asked why. An author said it was not included because it was older data and since 1981 there have been mitigation efforts that reduced emissions (emissions were reduced to 10% of previous levels since 1991). The panelist suggested returning to the Shaw sampling sites to determine if concentrations have been reduced from previous measurements. The same panelist also questioned the adjustment factor for inorganic to organic arsenic and wondered if contamination of the gardens is from aerial deposition, in which case the plant may not be transforming inorganic arsenic to organic arsenic. Mr. Safruk agreed it would be helpful to go back and determine the source of contamination in the study used to derive the inorganic arsenic adjustment factor.

A panel member questioned the use of the Student t-test rather than a parametric value for the fish data. The authors indicated that they would check this as it may be a software mistake and they generally choose what the statistical software recommends. They also recognized that reference to the inhalation of fine particulates in indoor air by the outdoor commercial worker is a typographical error in the title of equation 9.0 in Chapter 4 and should refer to the inhalation of fine particulates in outdoor air.

Mr. Sigal also reported on the snowfall data, noting that sampling was conducted in a typical year, and the protocol they used was the same as that used by Manitoba Conservation to estimate a concentration for the season. He recognized that deposition varies and so they had more samples taken and stated that the snow consumption assumption (one snowball per day) was his best professional judgment.

Panel members had a number of clarifying questions regarding the mercury exposure estimate. A panel member asked how the authors determined the organic fraction of mercury in air. Mr. Safruk replied that the fractions of organic mercury in drinking water and air were based on recommendations from the CCME, which he believes are measured mercury data, and that CCME says it is methyl mercury in the air, but he will confirm. He also said that the fraction was also applied to background exposures.

Mr. Safruk further clarified that current measurements of COCs in outdoor ambient air collected from the Provincial Building were used to derive EPCs for the community of West Flin Flon. However, since the air monitors on the Provincial Building currently only measure COC content associated with total suspended particulates (TSP), concentrations associated with the PM_{10} component were approximated using the ratio for historic paired data for TSP and PM_{10} concentrations within samples collected at the Provincial Building. These ratios were applied to

current TSP data from the Provincial Building to derive EPCs for PM_{10} concentrations in West Flin Flon ambient air.

Mr. Safruk clarified that Table 4-5 includes data for drinking water from two studies which explains why some of the values are less than the one study's detection limit.

A panel member pointed out that a standard fish size was used, but that fish of different sizes and age will have different concentrations of mercury. Another panel member questioned dental amalgams assigned to toddlers, as generally baby teeth are not filled, and recommended reconsidering this. The estimate of the amount of blueberries consumed per day per child (4 g/day) was considered excessive by a panel member, but Mr. Safruk explained that this value was based on US EPA's Exposure Factors Handbook for those with berries in home gardens and noted that blueberries are widely available in the area and free for picking.

Panel members questioned the exposure point concentrations of copper and lead in drinking water and wondered if there was a source within the distribution system or at the tap to explain these values which are significantly higher than the maximum surface water concentrations. The authors were unable to get Manitoba or Saskatchewan background levels and noted that the Jacques Whitford (2008) study was flushed samples; they will check with HBMS regarding their water samples.

6.2 Panel Discussion

The panel discussed Charge Questions 6-12 on the Exposure Assessment.

6.2.1 Charge Question 6

Charge Question 6. The authors evaluated the sampling data, and calculated the exposure point concentrations (EPCs) for ambient air, indoor air, drinking water, garden produce, fish, indoor dust, wild game, blueberries, surface water, and snow. Are the selected exposure point concentrations appropriate for the risk assessment?

The panel discussed whether the use of the 95% UCLM was sufficiently conservative for the soil concentrations because of the assumption that people, particularly toddlers will not move randomly throughout the community, and the mean may not account for the child living on a property with high soil concentrations. For air and water concentrations the authors used the 95% UCLM as these are media in which contaminants would widely distribute. The authors compare values at individual properties to this 95% UCLM to determine how many properties exceed that number.

A panel member noted that if the authors want to estimate exposure then back calculations (e.g., PRGs) will determine the prevalence of exposure, but not the magnitude of exposure. Another noted that a forward risk calculation would probably identify an unacceptable risk at some properties, but these are population level statistics, and are not meant to be applied to individuals.

One panelist supported use of the 95% UCLM for soil (for all but lead, and maybe methyl mercury) because the toxicity is based on long-term exposure and people do not stay in one place but move around the community. The panelist explained that there are decades of biomonitoring

of arsenic and lead at multiple sites that show no relationship between levels in blood and yard soil. The exposure is coming from the larger community, and not the personal yard. For lead, children are the age group of interest and they are less mobile. If there are areas closer to the smelter with higher concentrations, one could divide these into subareas with higher concentrations. Others agreed when one averages all areas, this may be stretching the boundaries for the younger people, and so subareas may be helpful. However, another reviewer thought that some toxicity reference values are based on shorter periods of exposure that correspond with limited movement from individual properties. A reviewer noted that the Bunker Hill (Von Lindern et al., 2003) and Rochester studies (US EPA, 2007) have shown statistically significant correlations between blood lead and concentrations in neighborhood soils. But another reviewer thought that the Bunker Hill situation is unusual in that the average blood lead level was very high (70 micrograms per deciliter (µg/dL)), there had been lots of uncontrolled air emissions and a recently operating smelter in the community, there was high deposition on soil and high lead concentrations in soil, and there was old housing with lead paint and many years of accumulated emissions. Soil concentrations near the smelter site were also very high and the housing stock was also older and in poorer condition closer to the smelter. These factors tend to produce stronger apparent correlations between blood lead and soil lead. In addition, lead is often confounded by paint and consumer products, especially for soil samples taken from near foundations where lead paint can be found. Several studies in the literature that report correlations between blood lead and soil actually are between blood lead and soil near the foundation of the house which is highly influenced by eroding paint (e.g., Succop et al., 1998; Lanphear et al., 1998, 2002). Correlations are much weaker between blood lead level and average yard soil. For arsenic, until one reaches about 300 ppm of arsenic in soil, there is no correlation because these exposures are within the dietary noise (i.e., background inorganic arsenic exposure from diet). Another reviewer pointed out that studies of twins living in the same homes do not have the same blood lead levels, presumably because personal behaviors are more important determinants of exposure and uptake than simply residential lead contaminant concentrations.

Reviewers thought identification of the maximum concentrations would be helpful as well as seeing the distribution of hazard within a community by identifying how many properties exceed a certain concentration and the magnitude of the exceedence. Breaking up areas with higher levels into subareas may be useful. Some panel members questioned whether this level of work would be worth the effort and particularly for lead, biomonitoring seems most appropriate. Others thought it worth considering to aid risk managers in determining where to sample next.

An author clarified that he thinks they have accomplished what the panel is discussing in that they derived PRGs independent of soils concentration and then looked at how many properties exceeded the PRG. It would be reasonable to sample other houses in close proximity to those that had concentrations in excess of the PRG, but they did not make this recommendation, since they would like to see biomonitoring results first. They thought it best to use the 95% UCLM for forward calculations and back calculate on a property-by-property basis using US EPA methods. They clarified, however, that their conclusions are not based on EPCs, but on the percentage of properties that exceed the PRGs. Showing a distribution will not change the results as the PRGs are independent of soil concentration. A panel member noted that it would affect the prediction of risk if one used subareas. An author was not sure they have sufficient delineation to do

smaller subareas. An observer commented that the areas studied are very small in terms of geography and population, probably equivalent to a few blocks of a major city, and therefore equivalent to neighborhoods already. A panel member disagreed with the use of the back calculation (i.e., PRG) approach, noting that the purpose of the risk assessment is to determine if you have a risk and if so then decide what to do to manage it. If there is no risk in an area, then there is no need to develop PRGs or PTCs. If the authors do not think the four COIs are the appropriate exposure areas, they should revise them and redo the forward risk calculations.

A panel member pointed out that since the authors used mean values for some exposure parameters; the PRG is protective of the mean, not the 95% UCLM. Some exposure parameters, for example breathing rate, food consumption, water consumption are means. If one did the same back calculation based on 95th percentiles of these parameters, then the PRG would be lower, and one would be protecting 95% of the population. The panel member suggested using the 95% upper confidence limit on the mean for the parameters where they used mean values. The reviewer pointed out that the risk assessment is not necessarily conservative if they use means for some values. After some additional discussion, the panel recommended that the authors list beside each exposure factor, the statistic used (e.g., 95% of the distribution, 95% UCLM, mean value, or combination) so that it is clear to the reader what the number represents.

The panel did not reach resolution on which statistic to use. Panel members pointed out that selection of the mean or a maximum value varies among countries and agencies. In Ontario they prefer central tendency and a reasonable upper bound. In like fashion, soil concentrations at US EPA Superfund sites are based on the 95% UCLM for the central tendency and a high-end exposure estimate. The panel agreed that the concept of estimating an average concentration for an area is important. Panel members agreed that choosing the area to average must consider the receptors and their exposure patterns. For example, for lead, exposure is on a specific property basis; in contrast, the community average concentration does not have much meaning.

The panel discussed whether the 95th percentile of soil concentrations should be used to assess risk to the person who is on a high concentration property. Several panel members pointed out that on a single property one generally finds variable concentrations and so it would be most appropriate to use an average concentration term, given people move around the property and do not remain in just one place. Several panel members discouraged more sampling, pointing out that sampling yard by yard would not be practical given the relatively low concentrations found in the sampling. Rather, the panel suggested that the authors calculate the percentage of properties that exceed the PRGs and indicate the magnitude of the exceedence, to put the concentrations in perspective. In addition, the authors could show the hazard quotients in a frequency distribution and avoid identifying individual properties.

The panel was comfortable with using the 95% UCLM for a conservative central tendency for soil concentration. One panel member cautioned that if the authors choose to use the 95th percentile of an exposure value, they have to carefully explain this to the residents so that they understand the results; otherwise people may think everyone is in danger, when this is not the case.

6.2.2 Charge Question 7

> **Charge Question 7. Which size fraction of particulate matter and its associated metal constituents should be used to best estimate the risk associated with the ambient air exposure pathway? (Section 4.1.1.2)** ***Footnote*****:** Recently, the US EPA revised its National Ambient Air Quality Standard (NAAQS) for lead and discusses use of TSP (see in particular page 66988, Federal Register, Vol. 73, NO. 219, November 12, 2008, http://www.epa.gov/fedrgstr/EPA-AIR/2008/November/Day-12/a25654.pdf

In response to this charge question, a reviewer noted that it is best to try to match the particle sizes used with the data that were used to derive the toxicity criteria. However, this is difficult for these metals and most of the toxicity criteria are based on data from workers in refineries and smelters. These workers were exposed to a mixture of fumes and small and large particulates. For air exposures, there is no consistent guidance, although using fine particulates is conservative. This reviewer agreed with the authors' use of particulate matter less than 10 um in diameter (PM_{10}) in the assessment. Another panel member noted that in the US EPA lead NAAQS expert review, there was much discussion on this issue with some panel members arguing strongly for smaller sizes (i.e., $PM_{2.5}$ or PM_1), but for practical reasons the EPA decided to use PM_{10} because PM_{10} samplers are what is currently employed in EPA's ambient air sampling programs. The fraction of PM_{10} to total arsenic was 0.8, meaning not much is missed by using the PM_{10} fraction. A panel member referred to Figure I-22 in Appendix I and asked whether based on emissions from the facility, would one expect particle size fractions to be the same? Based on physical properties of the COCs, they may be different. Copper has a nice distribution of particle size but other metals do not, which makes the reviewer wonder if there are additional sources (besides the smelter) for the other constituents where there is a less uniform particle distribution. The reviewer asked whether any particle geochemists had looked at this and an author said no.

6.2.3 Charge Question 8

> **Charge Question 8. Were the best available data used to calculate appropriate background exposure values?**

Several reviewers questioned whether the national background levels are representative of the local area, since this is a mining area it may be very different from what was used for national background. Are the geology and soil type of the background areas similar to the Flin Flon area? Sampling protocols for the national soil studies and local studies could also be different. Similarly, the arsenic water concentration is quite low compared to the national water providers, but higher than Ontario. The reviewer asked if there is a better measure of background of drinking water in an area away from the smelter. An author said they were unable to get provincial background values. Another reviewer thought that background levels on fish might be a data gap that could be filled.

A reviewer again noted that for arsenic, copper, and zinc, recent data 2005 and/or 2006 (Tables 2-5 and 2-12 of the HHRA) show that the concentrations were higher in the finished drinking water than the raw water, which indicates the potential of contamination by these metals from other sources. Another reviewer noted that the drinking water data seem to suggest that the

water distribution systems may contain lead and copper. For example, lead and copper concentrations from the Creighton Distribution System are <0.1 and 3 µg/L, respectively (Table 2-5). Yet the exposure point concentration terms for lead and copper in Creighton are 3.1 and 124 µg/L, respectively. If this holds true for the other COIs, it appears that a source of these inorganics (i.e., plumbing) has not been discussed in this report. Another reviewer thought it appropriate to discuss and calculate the contribution from other sources to provide perspective, and the authors should be careful about attributing chemicals in the drinking water to the municipal water source and be sure there is evidence that the source has contaminated the drinking water supplies. The panel cautioned the authors to not send mixed messages that a risk manager will find hard to interpret.

A panel member asked the authors to clarify why potential non-smelter exposures were included in the HHRA. An author explained that the federal guidance dictates that if background is not accounted for, then one apportions 20% of the safe dose to the soil medium. By calculating all exposure sources, the authors can determine a data-based apportionment from soil, rather than defaulting to 20%. A panel member pointed out that the HHRA does not consider consumer products (one of the five exposure media) and therefore, the HHRA should only use 80% of the RfD. The authors clarified that for the lead PRG the assessment allocated 20% of the residual RfD (*i.e.*, RfD minus market basket exposure) for consumer products. However, for arsenic, because it is a carcinogen and a linear dose response assessment is presumed, the apportionment is not relevant. This reviewer thought that consumer products should be accounted for with the other COCs, while other reviewers thought that the consumer product pathway would not be that relevant for the others. However, all panelists agreed that the consumer product pathway should be discussed qualitatively for the other five COCs.

6.2.4 Charge Question 9

Charge Question 9. Are the selected receptor characteristics and values the most appropriate for use in this assessment? Were the assumptions and exposure input parameters appropriate and were the intake rates calculated correctly?

The panel agreed that most of the receptor characteristics and values were appropriate with the exception of some values discussed under Charge Question 3. Reviewers suggested improvements or revisions to the text. They recommended that the authors standardize the exposure equations; many are missing exposure duration or frequency components and some (e.g., indoor/outdoor air apportionment) are not needed. Concentration units should be used for the inhalation equations to be consistent with the toxicity values (US EPA Superfund guidance provides newer equations). Several reviewers commented on terminology, noting that labeling of parameters as RME (reasonable maximum exposure) was not accurate as the RME describes the individual who receives the highest amount of exposure that can be reasonably anticipated, not the individual parameters themselves. The equations and parameters used to develop an RME risk estimate combine both high-end and central tendency inputs. They suggested adding a column to the tables to indicate what each parameter represents (e.g., percentile of the distribution).

A reviewer expressed concern about the fairly high concentrations of lead measured in indoor dust, noting that blood lead and arsenic levels are more correlated with indoor dust than outdoor soil and that most people spend the largest time indoors. The dust was analyzed by four laboratories with differing results. The reviewer speculated that lead-based paint might be contributing and/or high levels of emissions in the past. The reviewer asked if it is possible that attics are serving as reservoirs of contamination for the homes, a situation that has been seen in a former smelter site in Montana.

The panel recommended that the authors add receptor characteristics and assumptions for the receptors to the relevant tables, as well as a column to indicate the type of parameter estimate for each.

6.2.5 Charge Question 10

Charge Question 10.The exposure assessment predicts the rate of exposure using site-specific data and conservative assumptions. Are the exposure estimates correctly calculated?

Two panel members independently spot checked the exposure calculations and found no problems with the equations or calculations. One panelist noted that some of the assumptions are conservative while others may not be as conservative. Another reviewer pointed out that the purpose of a risk assessment is not to provide a conservative estimate, rather to provide an accurate characterization of the exposure distribution, including the average and upper-end exposures. It is the risk manager's purview to decide what is conservative. The panel reiterated its recommendation to explicitly identify what each parameter represents within this distribution (particularly for Tables 3-7 to 3-11).

6.2.6 Charge Question 11

Charge Question 11. Was the US EPA Integrated Exposure Uptake Biokinetic Model (IEUBK) model for lead used appropriately in the HHRA?

Please see discussion under Charge Question 18.

6.2.7 Charge Question 12

Charge Question 12. Do you have any further concerns or comments regarding the exposure assessment?

The panel members had a number of remaining questions or suggestions on the exposure assessment. In response to a question an author said that the 99% UCLM was used for arsenic in above ground vegetables, rather than the 95% UCLM which was used for other COCs, based on the recommended value for the upper bound estimate of mean from the statistical software.

Several panel members provided editorial comments and suggestions.

- The authors should check the number of significant figures used throughout the document, for example the fraction of inorganic arsenic was reported to one figure and the organic arsenic fraction to two.
- Small errors in the text are distracting and reduce confidence in the assessment. For example, the number of samples for the West Flin Flon area is reported as 77 in some places and 76 in others. Table 5-15 lists different concentrations than reported in the text.
- Indicate in the text whether the household water data were first draw or flushed samples.
- Yost et al. (2004) corrects values for grapes and watermelon used by Schoof et al. (1999).
- Sieved soil samples are more indicative of what gets on children's hands. 100% is too conservative. Look at data for another estimate that can be derived.
- Including the non-detected samples in the averaging of bioaccessibility results is not reliable. One panel member suggested removing the bioaccessibility results from samples with low arsenic concentrations before calculating the average bioaccessibility of arsenic in soil.

7. Hazard Assessment

7.1 Author Presentation

Mr. Elliot Sigal, another of the Intrinsik HHRA authors, presented information regarding the selection of toxicity reference values (TRVs) for the COCs from those derived by various government and international agencies. Slides of his presentation are found in Appendix C. He noted that the COCs are well-studied compounds that have excellent toxicological assessment documents available, therefore it was not necessary for Intrinsik to review the literature data base on these compounds. They selected TRVs for acute (1-hour and 24-hour exposures) and chronic (lifetime) durations for cancer and non-cancer endpoints. Mr. Sigal noted that the chronic values selected are well-accepted for use by the risk assessment community; however, the acute values are less established. Mr. Sigal reviewed the selection of the TRVs for arsenic, cadmium, copper, lead, mercury, and selenium, noting some of the strengths and weaknesses for each. He noted that for arsenic the oral slope factor is based on Taiwanese data sets and that the use of this value results in background risk calculations in Canada often exceeding acceptable risk levels. For lead, he noted that Health Canada is currently revising its TRV and the new value is expected to be lower than the current provisional Tolerable Daily Intake (p-TDI) of 3.6 µg/kg-day. Because Health Canada has not released a revised value, they used the current value in this assessment. He noted that one reason to recommend biomonitoring for lead is to then have local data to compare to the new value when it is released. Mr. Sigal also described the bioaccessibility studies conducted by Dr. Ken Reimer at Royal Military College/Queens University. The author noted that Dr. Reimer is a well-regarded expert in the field and his methods are similar to Dr. John Drexler, another leader in the field.

7.1 Clarifying Questions

None.

7.2 Discussion

The panel discussed charge questions 13-15 on the hazard assessment.

7.2.1 Charge Question 13

Charge Question 13. Were the most appropriate exposure limits or toxicological criteria selected for each of the COCs, and are the rationales for the selections defensible?

The panel discussed the selected chronic and acute TRVs. The panel members had concerns with the selection of the acute toxicity values. They recognized that some of the regulatory agencies that set these values (e.g., Ontario MOE) are combining risk assessment and management objectives. Some of these acute values are lower than chronic values. This is counterintuitive, and it is sometimes difficult to determine the scientific rationale for the value. One panel member thought that the regulatory agencies are force fitting the chronic methods to acute situations and thought that it is more appropriate for these acute values to protect for endpoints such as allergic response, irritation and poisoning; such as the approach used in occupational settings.

A panelist pointed out that when the public reads the document and sees the inconsistencies between acute and chronic values, their confidence in the assessment and credibility of the process will be diminished. Another noted that if the focus of the document is on long-term protection, then a chronic assessment is most important. Others agreed and questioned the need for acute values. After some additional discussion, the panel agreed that the acute values are problematic and recommended that the authors use their best professional judgment whether such values were even needed. If they are needed, the authors should clearly present the reasoning for their choices. If no appropriate acute values are available, or determined not to be needed, then the authors should explain this and provide a qualitative discussion. The authors indicated that the TAC was interested in the acute assessment and that Manitoba relies on some of the Ontario numbers. The authors will have to discuss these issues with the TAC. Panel members also suggested the authors look for inconsistencies between acute and chronic values and also between oral and inhalation values for the same COC. The authors should explain that the chronic values are protective of acute exposures.

The panel discussed the oral carcinogenicity estimates for arsenic, noting that there is sufficient controversy with regard to arsenic carcinogenicity that the assessment should address some of the additional data and issues surrounding arsenic. For example, there are other cohorts with positive associations, such as those in Argentina and northern Chile despite sufficient nutrition unlike in SE Taiwan. However, other data from SE Taiwan, China, West Bengal, and Bangladesh have been evaluated and it has been shown that poor nutrition and certain nutrients or factors do affect the potency of arsenic. There are also low-level drinking water studies in the US and other countries (e.g., Finland, Argentina) with populations with good nutrition (Mink et al., 2007) and meta analyses of groups of studies showing no relationship between arsenical cancers (i.e., bladder) and arsenic, that should be considered. Several agencies and organizations

(e.g., Health Canada Biostatistics Units, US EPA, US NRC) have published more recent arsenic assessments than the US EPA IRIS (1998) used in the HHRA. The panel recommended that the other assessments and their differences should be presented.

A panelist pointed out that the selected TRV for copper is lower than the RDA for copper (IOM, 2003), which is based on an upper limit of the safe dose. The authors should look into this TRV further.

Panel members discussed whether the assessment might present a range of arsenic risk values based on different selections. Some thought that using a range of values is leading to probabilistic assessment and the methods are not good enough. The panel thought that the authors should qualitatively discuss the range of risk values for arsenic.

7.2.2 Charge Question 14

Charge Question 14. Was the approach used to account for bioavailability and bioaccessibility of the COCs in the various media appropriate and are the results incorporated into the HHRA appropriately?

See discussion under Charge Question 4.

7.2.3 Charge Question 15

Charge Question 15. Do you have any further concerns or comments regarding the hazard assessment?

Individual panel members suggested several editorial revisions or clarifications:

- The Ontario intake of concern for lead should be mentioned in the text. The value of 1.85 µg/kg-day is a population-based value.
- The definition of incremental lifetime cancer risk needs to be rewritten to make it clear that it refers to a population risk and not a prediction of risk for an individual. The upper bound lifetime cancer risk is an upper bound risk estimate. The true risk is likely to be lower and could even be zero. Health Canada's TD_{05}, however, is not an upper bound, but is a linear extrapolation from the TD_{05} representing the best estimate. If one divides the TD_{05} by 5000, the result is a dose with a best estimate risk of 1 in 100,000.
- The discussion on interactions between COCs could be put into a table. Most of the interaction data are on high doses where people would be expected to see effects, but what is really of interest for this assessment is interactions at low concentrations below the "safe" level, resulting in risk to those exposed. Panel members suggested using ATSDR toxicological profiles and the *Handbook of Metals Toxicology* (2007). Several other metals are elevated or present in site soils that might interact with the COCs, e.g., zinc antagonizes the absorption and effects of several metals such as cadmium.
- A panel member suggested mentioning limited sunlight and Vitamin D deficiency as a potential special consideration.
- For arsenic, a correction for early life exposure is not needed as arsenic is not mutagenic and the data are from full generation exposures.

- The community blood intervention level for Saskatchewan and Manitoba is not an absolute 10 µg/dL.
- There is a statement in the document regarding lead indicating that the assessment is conservative in respect to adverse health effects, but elsewhere the authors acknowledge the potential for effects at lower levels of lead.

8. Results, Risk Characterization, Uncertainties

8.1 Author Presentation

Mr. Elliot Sigal presented on the assessment results, risk characterization, and uncertainties. Slides of his presentation are found in Appendix C. For acute inhalation risk estimates he noted that some elevated risks reflect the use of TRVs that may not be reliable. He noted that the frequency of 24-hour exceedences in most cases is quite low. The TAC had requested that snow consumption be considered and the hazard quotients for acute snow exposure in toddlers were estimated based on consumption of one snowball per day. He noted a number of issues: the hazard quotients for acute soil exposure for toddlers have a number of uncertainties, the copper TRV is highly suspect, and there were some fairly elevated concentrations of arsenic and mercury in the West Flin Flon area. The pathway specific hazard quotients for toddlers with other COCs showed soil as a significant pathway with respect to arsenic. Inorganic mercury risk is driven by soil, and methyl mercury is driven by fish and some other foods. While the assessment evaluated lead exposures using a deterministic approach and the IEUBK model, Mr. Sigal noted that measurement of blood lead levels would be a definitive measurement and therefore they recommend biomonitoring for lead. While the contribution of air pathways to total arsenic exposure was significant, the authors stayed away from recommendations related to air because the focus of this study in on soils. In addition, it was recently announced that the smelter will close next year, which will cause emissions to drop dramatically. A sensitivity analysis was used to identify exposure variables that may be driving the risk values and to demonstrate the impact of variable selection on the risk assessment process. Mr. Sigal noted that Chapter 7 discusses many of the uncertainties and they will continue to add to that discussion.

8.1.1 Clarifying Questions

A panelist asked whether the authors looked at all parameters for the sensitivity analysis and wondered if there are other parameters not evaluated that could potentially influence the results more than others. Mr. Sigal indicated that they only looked at key exposure parameters, many of which were identified through community and technical advisory committee activities. They did not do a sensitivity analysis with the toxicology values.

8.2 Panel Discussion

The panel members discussed Charge Questions 16-22 on the risk characterization.

8.2.1 Charge Question 16

Charge Question 16.Was the approach used to estimate Concentration Ratios (CRs) and Hazard Quotients (HQs) for acute inhalation and ingestion risk, respectively, consistent with accepted risk assessment methods, and were the values calculated correctly?

The panel again discussed the problems quantifying acute risks – the lack of defensible acute TRVs and large uncertainties in the results led them to recommend that the authors characterize acute risks qualitatively, but not quantitatively (see also discussion under Charge Question 15). They indicated that this is appropriate for a screening assessment because the TRVs and hazard quotients (HQs) are not bright lines and should not be interpreted as such. Panelists voiced concerns that the acute results presented in the draft may be interpreted inappropriately causing people to be concerned when they should not. Panelists noted that if the authors do not have one-hour sampling data then they should not calculate one-hour hazard quotients. The characterization of chronic risk will protect for acute exposures. One panelist agreed with the others, but cautioned that if there are TRVs based on *in utero* developmental toxicity endpoints these should be explored and communicated carefully.

A panelist noted that most of the pathways (i.e., soil, drinking water, food) are chronic exposure situations, with the exception of the pica child behavior and so acute values are not important. But, the panelist pointed out that air is a relevant acute pathway, as there may be short term excursions. The assessment should focus the acute discussion on the air pathway. The panel asked HBMS if there are any warning systems for the community. A representative from HBMS noted that there are no methods for testing metals emissions in real time. A Level 1 and Level 2 warning system for sulfur dioxide emissions is used by the company and community, which would probably minimize metals exposures that track with sulfur dioxide stack emissions.

In summary, the panel agreed that estimating acute exposures is very problematic, as is identifying medical conditions or adverse effects from acute exposures. Acute exposure concerns apply only to the air pathways. Current air excursions are addressed through sulfur dioxide monitors and warnings. The assessment should characterize acute risks qualitatively. They cautioned the authors to be careful in characterizing acute hazards and risks so that the public does not misinterpret the true risk and take actions that are inappropriate to the magnitude of the risk.

8.2.2 Charge Question 17

Charge Question 17. Was the approach used to calculate the HQs and Incremental Lifetime Cancer Risks (ILCRs) for residential, outdoor workers, and recreational scenarios consistent with accepted risk assessment methods, and were these calculated correctly?

The panel members discussed several general issues with how the HQs and incremental lifetime cancer risks (ILCRs) were calculated. A panel member addressed the inclusion of other sources

in the risk calculations, noting that it is Canadian policy to do so, but other governments such as the US approach this differently. In the US Superfund program, they are looking at exposure from the source alone and therefore when a risk is given it reflects the additional risk above background. For example, a cancer risk of 1 in 10,000 indicates that the population risk of cancer from the source may be as high as 1 case in 10,000 exposed above the background cancer risk(1 in 2 for men and 1 in 3 for women). An author clarified that they followed the regulatory guidelines of Health Canada and the CCME and did not add risk from the background sources for cancer, but do include all the background sources in the noncancer calculations.

The panel again expressed concern with quantitative estimates of risk for acute exposures (see discussion above). They briefly discussed issues regarding interpretation of the hazard quotient with one panelist pointing out that one needs to look at the TRV behind the HQ to interpret the HQ and potential values around or exceeding 1. This panel member also suggested the authors review their use of significant figures for the HQs, pointing out that in Table 5-4 for example; a HQ of 1.2 for arsenic should be 1, as only one significant figure is appropriate.

A panelist suggested the authors consider some way to assess risk from fish consumption for specific lakes. The issue is that some lakes have elevated concentrations and if these are favorite lakes for some people, exposure may be higher than the average for all the lakes. The panelist suggested a "favorite lake" scenario or some use of a weighted average based on data collected. Another panelist suggested evaluating the impact of a fish advisory on the overall risk to determine if a fish advisory would be an appropriate risk management consideration. An author clarified that the risk assessment back-calculated the concentration of mercury in local fish that would result in an HQ of 1 using the assumed consumption rates and additional sources of exposure. This concentration (0.19 ppm) was lower than the provincial (Manitoba and Saskatchewan) and federal (Health Canada) guideline of 0.5 ppm, likely as a result of the higher local fish consumption rate assumed in the risk assessment. The risk assessment provided a comparison of the 0.5 ppm guideline to the 95% UCLM mercury concentrations for each fish species and for fish in each individual lake. A panel member pointed out that there is no pattern of elevated methyl mercury levels in fish with distance from the source.

A panel member questioned why the authors did not use a composite receptor for arsenic given its carcinogenicity. Others agreed the composite receptor would be appropriate and the panel recommended its use for arsenic.

The panel discussed the outdoor worker scenario and questioned use of the maximum value for exposure point concentrations for the outdoor worker, noting that the resulting cancer risk for arsenic does not look right as it indicates the worker has a risk when the public who lives in the community does not. A panelist suggesting that a mean exposure value would be more appropriate because the worker would be expected to move around the community and not stay in one location. An author noted that the cancer slope factor for arsenic is problematic because it indicates a cancer risk at the normal Canadian background levels. The author agreed that a mean value would be more appropriate. Another panelist questioned if the outdoor scenario is necessary in that if indoor and outdoor air concentrations are assumed equivalent, and the general public is not at risk, then anyone working outdoors and not living in the community would be protected as well.

The HHRA calculated non cancer hazard quotients for arsenic and cadmium for five age groups, and the results showed that toddlers have the highest risk. Panel members questioned the appropriateness of this – the toddler drinks more water per kilogram body weight than the other groups and this is the basis for the larger HQ. The authors should look closely at the data and endpoints that the TRVs are based upon to determine if smaller age categories are appropriate. For example, the arsenic TRV is based on populations exposed over an entire lifetime, including children and *in utero* exposures; much longer than the few toddler years would be needed to elicit effects from arsenic. There is no indication that children would be more sensitive to arsenic than adults on a body weight basis, therefore use of age groups for arsenic is not appropriate. However, for methyl mercury and lead, the TRVs are based on effects from shorter exposures and breakdown by age category may be more appropriate, although the methyl mercury TRV is based on an adult female intake per body weight and associated fetal exposure. A panelist explained that risk assessors try to keep the exposure metric equivalent to the toxicity metric. To look at chronic exposure greater than 7 years, one compares these exposures to chronic risk values. For exposures less than 7 years, one would use a subchronic value. The panelist noted that ATSDR has developed a shorter term arsenic value and the panelist will provide this to the authors. An author agreed that the arsenic results alone do not provide a realistic assessment and that was why they presented multiple lines of evidence for consideration. The authors think that a urinary arsenic study can provide additional information to better characterize risk.

Panel members recognized the sediment data are limited and will not materially affect the quantitative results, but recommended that sediment exposure (e.g., oral exposure while swimming and playing near shore) be addressed qualitatively because it is a common pathway considered.

A panel member sought clarification on why the CCME soil criteria used for screening are lower than the TRVs used for calculating risk and how this would be explained to a member of the public. An author explained that the CCME criteria are intentionally developed to be very conservative to protect all situations and people across Canada and are used to trigger further study. Site specific information is used for the risk assessment to reflect the site situation and populations.

Panel members recommended that the authors consider providing an indication of the magnitude of concern by communicating the number of properties that exceed a target level for at least one of the COCs. They should avoid double counting properties.

8.2.3 Charge Question 18

Charge Question 18. To assess lead exposure, the authors used the HHRA exposure model as well as the US EPA IEUBK model. Comment on the analysis and scientific defensibility of the results.

The panel members discussed the problems with presenting two different approaches (deterministic model and IEUBK model) for characterizing the risk from lead exposure. Panel

members noted that both are good tools, but the results cannot be compared quantitatively (apples and oranges comparison). The deterministic approach compares modeled lead intake to a tolerable lead intake (lead intake is the denominator in the hazard quotient). The IEUBK models a blood lead concentration and this output is compared to some benchmark of acceptable blood lead concentration (blood lead concentration is the denominator in the IEUBK approach). The authors of the report argued that the tolerable lead intake used in the deterministic approach (3.6 µg/kg-day) was equivalent to the benchmark of acceptable blood lead concentration used in the IEUBK approach (10 µg/dL). However, the report does not provide any evidence to support this assumption. From first principles, a lead intake of 3.6 µg/kg-day could produce a wide variety of blood lead concentrations because the relationship between intake and blood lead is dependent on the bioavailability of the source of lead.

Panel members raised issues with use of the IEUBK model; in particular one noted that the model is meant to be applied to a homogenous exposure scenario. The authors took the UCLM of a variable exposure scenario and used it as an input; the distribution that comes out of the IEUBK is meant to reflect individual behaviors and physiology, not variability in the population's exposures. The exposure concentrations from the Manitoba soils study and the Jacques Whitford (2008) study are not homogenous; the coefficient of variance is about 0.8.

The panel discussed comparing results of the deterministic model with the IEUBK outputs. Several panel members suggested ways that might make the two results more comparable. One panel member suggested that using the same parameter values would make the comparison of results a little better, but there is still the issue of bioavailability to contend with. Another panel member noted that even with the same assumptions, the two models use different toxicity benchmarks. A third agreed and noted that the two models are fundamentally different in that that the deterministic approach uses conservative estimates and the IEUBK model uses central tendency estimates and then using an assumed geometric standard deviation, calculates the 95th percentile blood lead level, which is then compared to 10 µg/dL. The authors stated that they did not intend to compare the two approaches and added that the deterministic approach used Canadian parameter values, while the IEUBK model uses US values.

One panel member thought that using the IEUBK model results in inappropriate comparisons between the two methods. This reviewer noted that the US CDC does not recommend that their lowest blood lead intervention level (10 µg/dL) be used as a toxicity reference value for setting allowable concentrations of lead in the environment (Brown and Rhoads, 2008; Brown and Meehan, 2004; CDC, 1991). The blood lead intervention levels are derived to guide secondary prevention (after exposure has already occurred), not establish acceptable levels for primary prevention (defining acceptable levels of exposure). This reviewer did not think the model adds to the HHRA or should be used, stating that the IEUBK model is most appropriately used for interventions, not for prevention activities, which should be based on the TRVs. Another agreed saying the deterministic model reflects the concept of a community blood level and the two should be kept in separate contexts. A third panelist thought that there is uncertainty with all models, but the results of the two models are within the same range. Other panel members agreed that the two results generally support each other, but were concerned about making an explicit or quantitative comparison. A panelist pointed out that if the authors do not use the IEUBK model they will be subject to criticism from those who know it is an available tool which

is used widely. The authors agreed that they would be considered remiss if they did not use the IEUBK model but they understand and agree with the panel's concerns and comments. They clarified that they used the IEUBK defaults for the most part, but used some site specific parameters as they were justified.

One panel member noted that there is a large difference in the contribution from different media in the IEUBK and deterministic approaches for market basket foods. IEUBK says 80% of lead from soil, while the spreadsheet model says 50%, and it looks like diet is the difference. An author pointed the panel to the brief discussion above Table 5-24 and stated that the IEUBK model uses a higher soil ingestion rate than the deterministic approach, and for market basket the IEUBK model uses updated recommended values by EPA, which are significantly lower than the spreadsheet model using Canadian data (Dabeka 1993, 1995, 2003). The authors considered using IEUBK market basket food values, but sufficient details were not available.

The panel was comfortable with the lead hazard indices from the deterministic modeling and noted that the authors used the same Canadian and site specific assumptions as the other COCs. The panel recommended that the authors mention the IEUBK model and results very briefly in the text, but move all the details to an appendix where they can explain how the results of the IEUBK model support those of the HHRA. The primary reasons for moving the IEUBK to the appendix is the homogeneity issue and that the two models are not directly comparable. Moving the details to an appendix will also improve the readability of the chapter. The authors should attempt to harmonize the input parameters so that the results are even more comparable. The final paragraph in section 5.2.4 recommending blood lead monitoring should be retained (except for comparison to 10 µg/dL, see below). A panel member noted that it is useful to compare different models, but they need to use the same exposure inputs, and thought that if the authors used the same inputs as the spreadsheet model, the IEUBK results will be lower. An author noted that one difficulty is that the spreadsheet model does not have parameter values for all the different age groups evaluated within the IEUBK model.

A panel member questioned the accuracy of calling 10 µg/dL the Canadian community blood lead intervention level, noting that the appropriate guidance is CEOH (1994). That guidance does not identify 10 µg/dL as a standalone value, but recommends community intervention be considered when the mean blood lead levels of a sample from the community exceeds a reference mean plus three standard deviations from the reference mean, or when the percentage of children in a community with values above 10 µg/dL is double that seen in the general population.

Another panel member asked the authors how they calculated the TDI and equated it to the 10 µg/dL blood lead level. An author indicated that the TDI was based on studies of formula fed infants, breast milk, and infant food and that 58% absorption factor is used. The panel member thought this absorption factor seemed high given that the absolute gastrointestinal absorption of soluble lead in water is 50%.

A panel member suggested that when calculating the contribution of lead exposure from each medium that soil and dust contributions be separated. This reviewer also cautioned presenting absolute values and predictions from the model and that it is more appropriate to use the results

in a relative comparison of two scenarios. Several reviewers suggested rewording some of the conclusions in section 5.2.5, in particular the inappropriately predictive statements regarding the percentage of properties containing levels of lead that may have adverse effects on young children.

A reviewer noted the variability in bioaccessibility of the samples, which leads this reviewer to think there are different sources of lead. The reviewer suggested looking for consistency in bioaccessibility by source or area and noted that mineralogical analysis will help understand which bioaccessibility estimates to apply to which soil concentrations. Plotting these as contour lines on a map would be helpful. This reviewer also thought that the risk at most sites is not from soil, but from the house (e.g., paint). The information on the relationship between concentrations of lead in soil and blood lead levels from different North American populations and sites (Table 5-27) does not convey a straight story. In the well-controlled studies, the relationship of soil to blood lead is not very strong. The reviewer thought that the IEUBK model will indicate the problem is soil, when it is likely the lead is from house paint. Another reviewer suggested adding two more studies – the Rochester cohort (US EPA, 2007) and Succop (1998), and provided these references to the authors. The first panelist clarified that Succop found correlations of blood lead with perimeter soil, which is influenced by eroding house paint but not yard soil.

An author asked if the panel members thought they should adjust inhalation rates for the IEUBK model to put on scale with body weights, a parameter which cannot be changed in the model. A panelist suggested scaling for body weight as appropriate, and to leave the other parameters that cannot be changed. Another noted that the soil pathway is 85% of the risk and so uncertainty in inhalation will not matter much.

In summary, the panel agreed that the HHRA should use the hazard indices derived from the deterministic model for lead risk. However, they also suggested the authors use the IEUBK model to support the spreadsheet model results, harmonizing the parameters between the two as much as possible. The authors should move the detailed discussion of the IEUBK to an appendix.

8.2.4 Charge Question 19

Charge Question 19. Soil Preliminary Remediation Goals (PRGs) and Provisional Trigger Concentrations (PTCs) were derived in Chapter 5 for the COCs. Was the approach consistent with accepted risk assessment methods and were the values calculated correctly?

A panel member again reiterated that inclusion of market basket foods and dental amalgams has to be clearly communicated to the risk managers, noting that in the US PRGs are derived for contaminants when risk decision criteria are exceeded (i.e., an unacceptable risk occurs). In this assessment, PRGs and PTCs were derived regardless of whether the risk assessment results were above or below decision criteria. This approach seems to be counterproductive and begs the question of why the risk assessment was even done. A particularly egregious example is that of selenium. All calculated non-cancer risks were below a hazard index of 1.0. The market basket

dietary intake accounted for 73% of that risk, whereas soil accounted for only 2%. Yet a PRG was developed for selenium. Cadmium and copper were also below non-cancer decision criteria with market basket dietary intakes accounting for the majority of the estimated risk. Yet PRGs were developed for these inorganics. In the case of copper this could result in unnecessary and expensive soil cleanups, while completely ignoring what appears to be a significant contribution of copper from the water distribution systems in homes.

Another reviewer noted that the market basket foods are not an adjustable factor and therefore PRGs should not be derived for this pathway. That leaves just air and soil because if one predicts a risk from a pathway, then one needs to look at where something can be done to reduce exposure. Unfortunately, only 10% of properties were sampled for soils and nothing is know about the other 90%. Another reviewer suggested the author set the air levels to background to calculate a PRG because the smelter will be shut down.

A panelist questioned why the authors calculated PRGs for compounds where soils are small contributors to exposure. Another panelist thought the PRGs are useful to identify which media and compounds to focus efforts to reduce exposure and prioritize use of resources.

8.2.5 Charge Question 20

> **Charge Question 20. Chapter 6 identifies and evaluates other risk issues relevant to the HHRA. Are the analyses and conclusions for these issues scientifically sound? Have the issues been appropriately considered in the overall HHRA and recommendations? Have potentially sensitive populations been adequately addressed?**

Several panelists thought that the discussions in Chapter 6 were very good. Panel members had specific comments on several items.

- A panel member suggested that the discussion of mixtures found on page 6-14 would benefit from inclusion of some newer publications from the US EPA and referred the authors to www.epa/ncea for these publications (publications listed in Appendix E).
- In Section 6.8 and discussions of lead body burden, panelists questioned statements that lead is partitioned to bone. The panel members pointed out that lead in bones is a dynamic process, with ossification and de-ossification over time. Panelists also noted that cadmium accumulates in the kidney, another organ that accumulates metals over a lifetime.
- A panelist sought clarification from the authors whether they applied age-dependent uncertainty factors to increase the cancer dose response assessment slopes. An author indicated they did not and will clarify this in the text.
- Referring to the body burden discussion in Section 6.8.1, a panel member noted that there are *in vitro* studies that suggest that methylated daughter products of arsenic may be more toxic than the inorganic form. Another panel member noted that ingested methylated arsenical compounds have been determined by the US EPA's Science Advisory Board to be threshold carcinogens, and that more extensive methylation capacity results in more

efficient excretion and less *in vivo* exposure to inorganic arsenic and certain more toxic metabolic intermediates (e.g., trivalent monomethyl forms).

- Under the discussion of arsenic uptake, distribution, storage, and elimination, a panel member questioned how one could have inhalation exposure to arsenobetaine as it is a non-toxic, water-based compound that is excreted unchanged from the body. An author indicated they would check on this.
- A panelist clarified that the discussion at the bottom of page 6-5 regarding the NAS (1993) recommendations on a child protective uncertainty factor. Discussions related to children's exposure and risk, for example, as found on page 63, should include some additional publications for a more balanced presentation. On the bottom of page 6-5, the NRC statement that EPA uses an uncertainty factor when developmental toxicity data are available is not correct; rather EPA uses a database uncertainty factor when such data are missing. Several publications were suggested and are listed in Appendix E.

8.2.6 Charge Question 21

Charge Question 21. Are there additional issues or concerns that the authors should have addressed regarding the hazard assessment, the selection of exposure limits and the appropriate use of the values in the risk assessment? Do you have additional comments regarding aspects of the risk characterization and results?

Several panel members asked about the biomonitoring study plans. An author explained that the biomonitoring is on a parallel process as the HHRA due to timing issues. They would like to conduct biomonitoring in the fall of this year and a team of experienced medical practitioners and others experienced with biomonitoring studies is working on this. The biomonitoring plan is being peer reviewed separately from the HHRA. The TAC plan is to release the HHRA and the biomonitoring results at the same time, so that the individual evaluations are independent.

Other panel members discussed the community health assessment with Dr. James Irvine, an observer from Saskatchewan Ministry of Health during a break and asked him if there were key disease endpoints missing from the community assessment. Dr. Irvine told them that the assessment could not address skin cancer due to differences in nomenclature between the two provinces. Dr. Irvine explained to the panel that community assessment combined data from the two provinces. It was meant to be an overall approach to a community health assessment to compare demographics, non-medical health determinants, cancer incidence, and the common causes of death for Flin Flon and Creighton with their corresponding health regions and provinces but it was not specifically related to the COCs. Unfortunately, they could not get accurate data for skin cancer. He also explained that the health endpoints were not standardized for economic status, although they did compare non-medical health determinant statistics (including economic indicators) for Flin Flon and Creighton with the comparison groups. They compared the Creighton – Flin Flon data to the general population of Manitoba and Saskatchewan in addition to NOR-MAN and Mamawetan Churchill River Health Regions to provide a more comparable socioeconomic status. An author noted that Flin Flon has a relatively high standard of living, about three times the Canadian average. A panel member commented that when the report indicates that the health status of Flin Flon is better than the province, the results were not corrected for socioeconomic differences and one would expect Flin Flon with a

higher standard of living to have a better health status than the province. The panel recommended that the authors more fully discuss the community assessment and the strengths and weaknesses of the study and conclusions, particularly that the most likely cancer from arsenic exposure would be skin cancer and the community assessment did not evaluate skin cancer.

8.2.7 Charge Question 22

> **Charge Question 22. Chapter 7 presents uncertainty and sensitivity analyses. Were all the significant sources of uncertainty identified and characterized? Were quantitative uncertainty and sensitivity analyses done correctly? Are the conclusions regarding the significance and impact of the uncertainties on the resulting assessment correct?**

A panel member noted that normally with a sensitivity analysis, one changes each parameter by a certain amount (e.g., 5%). But since linear regression was used, all the parameters will be the same. In this assessment, the authors evaluated different choices and so it is hard to understand the true sensitivity in the model when you vary the parameter values. An author did not entirely agree and thought that changing a soil ingestion rate by two times does not necessarily change the other parameters by the same amount. A panelist noted that the authors had not done a sensitivity analyses on the changing soil concentrations as a function of the various slope factors for arsenic. He encouraged them to do so. Another panelist suggested adding a qualitative discussion about potential exposure from breast milk for each of the COC and whether breast milk would be a pathway of concern for any of the COC. The panelist suggested a number of papers on concentration of constituents in breast milk and blood, and thought that breast milk exposure will be important for methyl mercury, less so for lead (see Appendix E for list of recommended papers). Another panel member noted that the arsenic TRV is based on a population with exposure to drinking water throughout all life stages and therefore breast milk exposure would have been included. Exposures to arsenic in soil and dust for the Flin Flon population for pregnant and nursing women would be considerably lower than for children compared to in a population exposed by drinking water. Thus, the Flin Flon population would not receive much exposure *in utero* or through breast milk as the population that forms the basis for the arsenic TRV. Information on fish consumption for the child receptor is mentioned in Chapter 7, but was not described in earlier chapters and should.

9. Conclusions and Recommendations

9.1 Author Presentation

Mr. Elliot Sigal presented the conclusions of the risk assessment for each of the COC, along with the authors' recommendations. Slides of his presentation are found in Appendix C. He noted that the utility of the findings of the community health status assessment are fairly limited, given the small population size. For arsenic, one needs to look at more than just the results and consider the overall weight-of-evidence. The authors recommend a urinary arsenic study, focusing on homes in West Flin Flon and Creighton, where a significant number of homes in the residential sampling program had concentrations in excess of the PTC. They recommended

comparison with a control community or control values found in the literature, as the literature has enough control information to rely upon.

The authors did not recommend further action for cadmium; they reported that the predicted cancer risk for cadmium from the ambient air was elevated, but noted that the smelter is closing in the next year and with its closing, the air concentrations (and corresponding risks) will reduce dramatically.

For lead, both the IEUBK and HHRA models predicted average lead related exposures to be within acceptable levels. However, because a significant number of residential properties in West Flin Flon have concentrations in outdoor soil greater than the residential PTC, and Health Canada is expected to lower the benchmark for lead, they recommended a blood lead survey focused on children up to seven years to reduce uncertainty in the exposure assessment.

A significant number of residential soils in West Flin Flon exceeded acceptable levels for inorganic mercury for the toddler receptor and the authors recommended biomonitoring as an option to more accurately assess exposure. However for methyl mercury the authors noted that the primary route of exposure is from fish and they originally considered biomonitoring, but noted that this would require venous blood draws which would complicate sampling. The authors recommended more work to determine the best action for reducing methyl mercury exposures, but noted that biomonitoring would not assist in decision making.

Mr. Sigal concluded that they recommend a comprehensive biomonitoring program to evaluate environmental contaminant exposure to children in Flin Flon and Creighton. Urinary arsenic, blood lead, and urinary inorganic mercury studies are recommended to start in the fall of 2009. Assessing biomarkers of exposure will help refine and validate the HHRA's exposure estimates

9.1.1 Clarifying Questions

A panelist asked why the authors recommended biomonitoring for inorganic mercury and arsenic up to age 16, but only to age 7 for lead. Mr. Sigal said that they wanted a large enough population size, but before individuals may start working in the facility and potentially have occupational exposure. The panelist noted that given the levels of arsenic in the market basket it would be difficult to distinguish between background and source. The author agreed but thought that they will not likely find elevated arsenic levels in the community. They hope to be able to compare people in the community exposed to different soil concentrations to see if soil is the driver of exposure, but may have difficulty recruiting enough children and expect issues related to speciation and creatinine correction will complicate this goal. The panel member recommended a paper by Dana Barr (Barr, 2005) of the CDC regarding the pitfalls of using creatinine for correction of urinary biomonitoring data.

A panelist suggested the authors consider testing for lead up to age 16. In other studies it is found that boys who are not under continual adult supervision have the highest levels of lead and so older children should be included. The panelist asked how exposure will be confirmed. The author explained that they would use the results of biomonitoring, and look at population trends, and levels in urine and blood to determine if elevated exposures are occurring and if they are at levels of concern. The panelist noted that they are then using biomonitoring results for risk

assessment and asked what criteria will be used to compare with the findings, noting there are guidelines for lead, but not arsenic. The author noted that the biomonitoring study principals are developing the criteria.

Another panelist asked whether the referent population for blood lead levels for children under six has been identified as there are few studies on young children and recent data are needed. The author indicated they will use other Canadian studies. Panelists also questioned the basis of the statement in slide 8 that children under 7 are more sensitive to neurological effects of lead. They noted that children of different ages with the same blood lead levels are not more or less susceptible, but children under 7, for an equivalent amount of lead in the environment, will have higher exposure. The younger child will be exposed and take up more than an older child; however an older child with an elevated blood lead level is a concern.

9.2 Panel Discussion

The panel reviewed the recommendations and conclusions of the assessment and discussed charge questions 23-29.

9.2.1 Charge Questions 23 and 24

Charge Question 23. Are the conclusions for each COC valid and are they supported by the data and the risk assessment? What is the likelihood that actual health risks have been over or under estimated? Are the potential human health hazards of the COCs adequately addressed?

Charge Question 24. The authors discuss biomonitoring and make recommendations regarding arsenic, lead and mercury. Are these recommendations appropriate and adequately supported?

The panel reviewed the conclusions and recommendations as presented in Chapter 8. Below is a summary of the panel's recommendations.

- *Acute Endpoints (8.1.1)*

The panel reiterated their recommendation that the authors carefully consider the available acute toxicity reference values and consider addressing acute risks qualitatively, but not quantitatively.

- *Chronic Endpoints – Residential Scenario (8.1.2)*

Mr. Safruk clarified how the authors added risks from multiple routes. He explained that for systemic toxicity endpoints they added inhalation, dermal, and oral daily intakes (mg/kg-day) and then compared the total intake with the oral TRV. In addition, they compared the inhalation intake alone with the inhalation TRV. For arsenic carcinogenicity, the oral and dermal intakes were added and risk calculated with the oral slope factor. For inhalation they calculated risk with the inhalation unit risk. The inhalation and oral/dermal risks were then added for a total carcinogenic risk. For lead, a separate inhalation risk was not calculated. Exposure *via* inhalation was added to the oral and dermal exposures for comparison to the oral TRV.

A panel member disagreed with the approach for the systemic toxicity endpoints and recommended that the authors keep the intake metric consistent with the toxicity metric (for inhalation - $\mu g/m^3$). The inhalation and oral hazard quotients can then be added for a hazard index. This reviewer thought that the authors' approach was not correct in that they did not take into account absorption and distribution, and when there are systemic toxicity values for both routes, they should not convert the inhalation intake to a dose. Another panelist agreed with the authors' approach for assessing endpoints that are portal of entry effects in addition to systemic endpoints where doses from multiple routes were added by the authors and compared against a TRV for a systemic endpoint for one route. The panelist explained that one is concerned with the dose to the target tissue and the separate HQs (for portal of entry effects as well as systemic effects from multiple routes of exposure) is defensible. The approach taken by the authors is defensible and allows for assessing portal of entry affects against a portal of entry TRV as well as adding exposure from multiple portals of entry for evaluating risk based on a systemic endpoint. However, this reviewer thought that it the approach would be limited in terms of adding HQs for different endpoints based on toxicokinetic considerations. Another reviewer agreed and thought that the oral and inhalation results should be added together for systemic toxicity endpoints because what gets absorbed and distributed systemically is then available. A fourth panel member agreed that systemic dose is what is important and that one needs to account for relative bioavailability by pathway.

Panel members also sought clarification on how the authors adjusted dermal concentrations to calculate intake noting that it should be based on gastrointestinal bioavailability from the oral toxicity study. An author indicated that they used relative dermal absorption factors provided by Health Canada (2006). The panel members suggested explaining this in the text and providing the reference for the Health Canada values. One panelist noted that the 3% dermal absorption for arsenic that the authors used is based on a study by Wester et al. (1993) that had some design issues and used soluble arsenic freshly added to soil rather than arsenic in soil from a site. Lowney et al. (2007) repeated the study with a breathable patch and aged soils. They found that they could not detect any dermal absorption of arsenic.

The panel recommended that in addition to what the authors have presented, they should calculate separate oral and inhalation HQs when toxicity values are available. These HQs should then be added together and presented with the authors' original approach. The alternative HI should be discussed with the results in Chapter 8 (e.g., Table 8-4).

The panel also cautioned that one must be careful interpreting the hazard quotients for toddlers. The toddler's few years of exposure is being compared to chronic toxicity values and for most of the COCs these hazard quotients are not appropriate because the toxicity values are based on lifetime exposure. For example, the arsenic and cadmium TRVs are calculated from studies with whole life human exposures.

- *Chronic Endpoints – Outdoor Commercial/Industrial Workers (8.1.3)*

The panel recommended the authors use the 95% UCLM rather than the maximum value.

- *Chronic Endpoints – Recreational Scenario (8.1.4)*

The panel recommended the authors qualitatively address the potential for exposure through sediments.

- *Summary of Discussion of Chronic Residential Results (8.2)*

  - Arsenic

The panel discussed the recommendation for arsenic biomonitoring of a sample population of children up to 16 years of age. Some thought the recommendation appropriate, based on results of the HHRA. Others expressed concerns with the recommendation. One panelist did not think biomonitoring would be justified because the results of the HHRA were not elevated much above background and the panelist did not think that biomonitoring would show anything above background levels. Another expressed concern that the bulk of intake is from market basket foods and the panelist was not convinced that one would be able to distinguish site sources from food. A third thought that if the biomonitoring finds that levels are not above background, this would be a useful finding and one could conclude that exposure levels in the COIs are similar to other populations in Canada. This panel member thought that communicating risk on arsenic has always been difficult and if they do not do a urinary arsenic study, what other measures can they take? Others cautioned that the TAC must think about risk communication and identify beforehand what health screening benchmarks to use and what message to communicate about higher values and whether they will give individual their results.

An author clarified that the biomonitoring protocol is being developed. They have health benchmarks selected and plan to give individuals their results and follow up with the individuals. They will use community-wide results to feed into the risk assessment.

Several panel members cautioned the authors to be careful with using non-cancer endpoints for arsenic, particularly for toddlers. Cancer is driving the recommendation and the cancer toxicity value is based on populations with lifelong exposure. A panel member asked why the authors recommend testing only those under 16. An author explained that those over 16 may be working at the site and have additional occupational exposures. Several asked what levels are seen in the workers and suggested that the employee biomonitoring data be analyzed as a first step.

Panel members discussed what to use for a reference population. One thought that having a reference population was not always necessary. If the effect of soil concentrations is the question, then the authors could look at biomarker levels of children within the community exposed to different soil concentrations to see if a relationship exists. Another panel member suggested the authors use a nearby referent population; otherwise community members will see the study as deficient. Another suggestion was to use the population being testing for internal reference and the question is whether the individual's soil and biomonitoring results are correlated.

One thought that at best, biomonitoring could be useful to reassure people that their results are within expected ranges and the ranges of other communities. Biomonitoring may assist with risk

communication with the public, but the panelist did not think it would provide useful data to fine tune the risk assessment.

Several panel members questioned the value of biomonitoring at the present time if the smelter is closing next year and emissions will be reduced. Current emissions are more relevant than soil concentrations for contributions to exposure and the biomonitoring should be done after shut down. They cautioned that it would be unfortunate if the biomonitoring triggered soil cleanup, if the soil is not the source of exposure, and encouraged that the TAC plan for home visits by medical professionals and identification of sources before any remedial actions are taken. Another panelist, however, pointed out that biomonitoring at this point would provide a reference point for the future.

The authors noted that when they tried to determine which properties would benefit from biomonitoring they did not use the 95% UCLM values, rather they looked at the number of properties exceeding a back calculated value. A panelist again cautioned that they used values from oral exposures to toddlers and those risk statements need to include caveats as explained earlier.

The chair asked if the panel could definitively recommend biomonitoring if all the concerns they raised were addressed. Half the panel recommended that biomonitoring for arsenic be done. One of these suggested using a local population as reference and split properties below and above a trigger concentration to see if there is a difference between them. Others thought biomonitoring could provide the community with assurances regarding risk. One of these panelists did not think that the HHRA findings support biomonitoring, but thought it could be useful if people want it; however, the program would need to include surveys on activities and diets to help determine the sources of exposure and the relative contribution of non-site exposure.

The other half of the panel did not recommend biomonitoring for arsenic, or had significant reservations about such. One panelist did not see a medical or scientific rationale at this point that suggests the need for biomonitoring to assure the safety of the population, but noted that the HHRA has yet to be revised based on the panel's comments. The panelist was also concerned that by collecting this information on individuals, there is a responsibility to deal with the information and work with the individuals. Two panelists suggested first looking at employee biomonitoring data before community biomonitoring. One expressed concern about the power of a community biomonitoring study, the *a priori* sample size, and the variance. The panelist questioned how they would be able to attribute an incremental exposure to soil and air. This panelist's experience is that biomonitoring is hard on the communities being studied, and thought this should be considered carefully in making a decision. One panelist stated that based on the HHRA and the relative contribution of arsenic from the site sources, the panelist did not think biomonitoring was justified. This panelist would have conducted biomonitoring before the HHRA but thought that if they do it now and do it very well it can be useful to the risk assessment; however, if it is not done well, it could do more harm than good.

- Lead

The authors recommended a blood lead survey up to age 7. All but one panel member supported this recommendation, although most of the supporters had some reservations and offered caveats. One panelist noted that if the authors step away from the IEUBK model in the text, their conclusions may be somewhat different, with hazard screening resulting in fewer problem properties. Another panelist thought that blood lead survey is a good idea for any community with an aged housing stock, near a source of lead emissions, and with some properties with high soil concentrations. Blood lead can help identify the need for intervention sooner rather than later. Another thought that the recommendation is supportable, but that the community should be involved in the design, and the limitations and study design should be carefully explained to the community members. Another also cautioned that those conducting the blood lead testing will have to be very savvy with risk communication and what they tell people about risk.

One panel member supported biomonitoring for lead, particularly because the TRV for lead is expected to be reduced and when that happens, it may call into question the validity of this HHRA's conclusions. Having blood lead measurements will provide information to help assess risk with the expected lower value. This panelist also thought that soil is a large contributor to lead exposure and the biomonitoring data will provide information for measuring effectiveness of clean up.

A reviewer was of the opinion that the risk assessment did not support the recommendation, but agreed that it would be helpful to alleviate uncertainties in people's minds. The panelist recommended they plan in advance how to respond to elevated levels and if the source is lead based paint, they should have a plan to address it. Another panel member agreed with biomonitoring because the panelist could see no other feasible way to integrate uncertainty of individuals into the assessment.

One panelist did not think the testing was justified based on the risk assessment and the relative contribution from the site. The panelist thought it would have been better to do the testing prior to the HHRA and incorporate the results. The panelist thought that if the TAC goes forward with biomonitoring and it is done very well, it can be useful, but if it is not done well, it could do more harm than good.

The panel discussed a panelist's recommendation that pre-pregnant women be included because the prenatal influence of lead is very important. Occupational guidelines recommend considering blood lead levels prior to pregnancy. This panelist recommended using 10 µg/dL as an action guide for pre-pregnant women, and suggested seeking to reduce exposure if they were near that level. The panelist did not think bone lead measurements would be needed. Another panelist did not recommend initially including the elderly or pre-pregnant women because children will have the highest exposures. If there is a problem in children, then they can expand to other sub-populations. Other panel members cautioned that one would have to be very careful communicating risk to pregnant women.

- Cadmium

The panel noted that with the previous discussions, the authors need to recalculate and revise the text for cadmium. They noted that the statement regarding the ILCR being elevated should be

checked closely, as the risk is no greater than that for arsenic. The authors need to be careful to be consistent with these types of qualitative judgments and statements between COCs. They also noted that the reference to future smelter emissions should be revised.

- Methyl Mercury

An author clarified that they have revised this section and no longer recommend biomonitoring for methyl mercury. The authors did recommend that a fish consumption advisory be considered, particularly for sensitive populations, to reduce exposures to methyl mercury. One panelist thought that the levels were just marginally different from market foods and was not sure a fish advisory would do any good. The panel agreed with the recommendation to consider a fish advisory for methyl mercury and suggested ongoing monitoring of methyl mercury in fish.

- Inorganic Mercury

The panel discussed the authors' recommendation for biomonitoring for inorganic mercury. They discussed that the TRV for inorganic mercury is based on a NTP chronic rat study with renal effects (tubular necrosis). A 14-day study in rats has a no effect level at the same critical dose and so it appears that duration of exposure is a factor involved for inorganic mercury's toxicity. A panel member pointed out that the only receptor with a hazard quotient over 1 was the toddler and asked who they would suggest for biomonitoring. Another panelist asked what would be used for the trigger level and pointed out that the hazard quotient for inorganic mercury averaged only 2. Panelists objected to biomonitoring for inorganic mercury because the TRV is based on a chronic study, whereas the HQ for toddlers is 2, and there is a large uncertainty factor associated with the TRV; therefore, exposures slightly greater than the TRV may not be associated with any appreciable risk of adverse effects. Another reviewer noted that the HHRA authors used 100% bioavailability in their calculations and in this panelist's opinion, 50% would be more appropriate.

All but one panel member thought that the data did not demonstrate a need for biomonitoring given the concerns discussed above. The one panel member who disagreed thought that if arsenic biomonitoring in urine was being conducted, they might as well include urinary mercury; they can both readily be done at the same time.

- Selenium

Panel members questioned selenium's inclusion as a COC, no one on the panel disagreed with the HHRA conclusion that there are no risks from selenium in the COIs.

9.2.2 Charge Question 25

Charge Question 25. Have the key objectives of the HHRA been addressed by this assessment? (Section 1.3)

<u>Objective 1:</u> To assess risks to human receptors residing in Flin Flon, Manitoba and Creighton, Saskatchewan as a result of exposure to metals in soil and other environmental media impacted by the activities of the HBMS complex. The HHRA will estimate the contribution from individual exposure pathways and environmental media to assist in the development of risk management objectives; and,

<u>Objective 2:</u> Develop risk management objectives and/or mitigation plans if unacceptable risk levels are identified in the HHRA. These risk management plans will be based on scientific approaches in consultation with the Technical Advisory Committee and the community.

The panel discussed the objectives earlier under Charge Question 5. For the most part, they thought the HHRA had met Objective 1, but pointed out difficulties posed by some of the wording. One panel member noted that Objective 1 (as written in Section 1.3 of the HHRA) is to assess risks to human receptors as a result of exposure to metals in soil and other environmental media impacted by the activities of the HBMS complex. Inclusion of the market basket dietary intake into the risk estimates is not consistent with this objective and makes sound risk decision making more difficult. Another countered that this type of approach is valuable because it provides a picture of total exposure from all sources for the people of the community.

The panel recognized that Objective 2 was not intended to be met by the HHRA document that they were charged with reviewing. However, one noted that if they intend to meet Objective 2, they will have to identify what is an acceptable risk for each COC.

9.2.3 Charge Question 26

Charge Question 26. Was the approach used for this community assessment consistent with commonly accepted methods and procedures by government agencies (such as Environment Canada, Health Canada, the Canadian Council of Ministers of the Environment, and the US EPA)?

The panel members generally agreed that overall the assessment followed the commonly accepted methods. However, there are some instances where the commonly accepted methods differ from one another or with the current scientific literature.

9.2.4 Charge Question 27

Charge Question 27. Overall, were the input data and assumptions valid and appropriate for the Flin Flon and Creighton communities?

Overall the panel agreed that the input data and assumptions were valid and appropriate, except for those that were discussed at the meeting.

9.2.5 Charge Question 28

Charge Question 28. Is the Human Health Risk Assessment presented clearly and completely?

The panel agreed that in general, the HHRA was presented clearly and completely, and that it was a very comprehensive effort. One panelist thought the authors did a good job organizing the document and the panelist was able to quickly find everything. Panel members recognized the challenges in conducting such a comprehensive assessment and thought that their suggestions and recommendations could be incorporated fairly readily.

9.2.6 Charge Question 29

Charge Question 29. Are there additional important issues that should have been addressed?

None.

10. Post Meeting Review of Revised HHRA

In late December 2009, Intrinsik forwarded to *TERA* a copy of the revised HHRA and a 39-page "Response to IERP Comments on the Human Health Risk Assessment". In their response, Intrinsik authors identified each of the IERP recommendations and explained how they revised the HHRA to be responsive. *TERA* forwarded the Intrinsik response document to the IERP committee. The IERP agreed that *TERA* and Dr. Dourson, as Chair of the IERP, should review the revised HHRA and Intrinsik responses for consistency with the IERP recommendations and consult with IERP members as needed to make these determinations. Dr. Michael Dourson and scientific staff of *TERA* carefully reviewed the HHRA authors' responses to the IERP recommendations. *TERA* staff checked the HHRA text to verify the revisions and their completeness. Dr. Dourson also read the revised HHRA to determine the authors' overall responsiveness to the IERP recommendations.

Several of the Intrinsik responses to IERP recommendations were initially not clear to Dr. Dourson and the *TERA* staff and clarifying questions on these items were sent to Dr. Sigal, who provided responses. In addition, *TERA* reviewed the IERP report and identified several additional panel member recommendations that were not clearly addressed in the Intrinsik response document and forwarded this list to Dr. Sigal. Intrinsik staff provided written responses to each of the clarifying questions and the list of additional items. These email exchanges are documented in Appendix T of the final HHRA.

Overall, the *TERA* review found that the Intrinsik authors had revised the document appropriately to be consistent with the IERP recommendations. There were a few issues or recommendations for which the Intrinsik authors did not fully accept the IERP recommendations. Dr. Dourson and *TERA* reviewed Intrinsik's explanations carefully and for several of these consulted with relevant IERP members to determine whether the Intrinsik positions and explanations were acceptable. In particular, panel members were consulted on issues related to the IEUBK model and Health Canada and CCME guidance on selection of TRVs to match exposure duration. While a few differences of scientific opinion remain between the IERP and the authors of the HHRA, these differences do not impact the conclusions of the HHRA or the protection of public health in Flin Flon and surrounding areas. The HHRA and results were found to be scientifically-sound and appropriately health protective. The HHRA has been revised to address the IERP recommendations and be responsive to the IERP issues and concerns.

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Independent Expert Review Panel (IERP)
Human Health Risk Assessment for
Flin Flon, Manitoba and Creighton, Saskatchewan

Volume II

June 23-24, 2009
Winnipeg, CA

Peer Consultation Organized by:
Toxicology Excellence for Risk Assessment
(http://www.tera.org/peer/)

August 28, 2009

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Appendix A

Independent Expert Review Panel (IERP)
Human Health Risk Assessment for Flin Flon, Manitoba and Creighton, Saskatchewan

June 23-24, 2009

Panel Biographical Sketches and Conflict of Interest

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Conflict of Interest

An essential part of an independent expert review is the identification of conflicts of interest and biases that would disqualify a candidate, as well as identification and disclosure of situations which may appear to be a conflict or bias. *TERA* was selected by the TAC to independently organize and conduct this expert panel review and is solely responsible for the selection of the panel. Prior to selecting *TERA* to conduct this expert review, the TAC reviewed the proposals which included information regarding *TERA* past and current work necessary to evaluate *TERA* independence. *TERA* has experience in risk assessment and toxicity of a number of the chemicals of concern and this work has been done for a variety of public and private sponsors, but none of it is or was directly related to the Flin Flon and Creighton HHRA. *TERA* has not participated in the development or preparation of the human health assessment that is the subject of this meeting. *TERA* is not contracted to do any other work for HMBS and has no financial stake in the outcome of this review. As outlined in the contract between *TERA* and HBMS, *TERA* has independently selected the panel and organized this review. HBMS has had no influence on the selection of the IERP panel or implementation of the process.

The purpose for evaluating conflict of interest is to ensure that the public and others can have confidence that the peer reviewers do not have financial or other interests that would interfere with their ability to carry out their duties objectively. *TERA* asked each promising candidate to report on his or her financial and other relationships with HBMS and Intrinsik. In addition, *TERA* asked candidates to identify relationships with members of the TAC, so that we could insure that the panel members have not been indirectly involved with the HHRA through work for the TAC organizations.

The evaluation of real and perceived bias or conflict of interest is an important consideration in panel selection. *TERA* follows the U.S. National Academy of Sciences (NAS) guidance on selection of panel members to create panels that have a balance of scientific viewpoints on the issues to be discussed. As a result, the expert panels have a broad and diverse range of knowledge, experience, and perspective, including diversity of scientific expertise and affiliation. Panel members serve as *individuals*, representing their own personal scientific opinions. They do not serve as representatives of their companies, agencies, funding organizations, or other entities with which they are associated. Their opinions should not be construed to represent the opinions of their employers or those with whom they are affiliated.

Prior to selection, the candidates completed a questionnaire, which *TERA* used to determine whether their activities, financial holdings, or affiliations could pose a real or perceived conflict of interest or bias. The completed questionnaires were reviewed by *TERA* staff and discussed further with panel candidates as needed. (See www.tera.org/peer/COI.html for *TERA* conflict of interest and bias policy and procedures for panelist selection.)

TERA has determined that the selected IERP member have no conflicts of interest and are able to objectively participate in this peer consultation. None of the panel members has a financial or other interest that would interfere with his or her abilities to objectively participate on the panel.

None of the panel members is employed by HBMS or Intrinsik. Nor do the panel members have any financial interests in HBMS or the outcome of the review or assessment. None of the panel members was involved in the preparation of the human health risk assessment.

This panel of experts collectively has extensive experience in the key areas necessary to review the Flin Flon Human Health Risk Assessment, including multi-pathway risk assessment; environmental fate, toxicology and epidemiology; biomonitoring studies; exposure assessment and pathways modeling; bioavailability and bioaccessibility of metals from soils; sampling and analysis for metals in relevant media; evaluating human health hazards of soils and dust; derivation of Soil Trigger Concentrations (STC) and soil preliminary remediation goals (PRG); and uncertainty and sensitivity analyses. Panel members are very familiar with Canadian and U.S. guidance and methodologies for multimedia risk assessments including Health Canada Contaminated Sites Program, U.S. EPA Superfund Program, and Ontario Ministry of the Environment guidelines for contaminated sites.

A brief biographical sketch of each panel member is provided below. To promote transparency, a short statement describing situations which might appear to present a conflict of interest or bias are included, as appropriate.

Biographical Sketches of Panel Members

Ronald Brecher, Ph.D., C.Chem., QPRA, DABT
GlobalTox and University of Waterloo

Dr. Ronald Brecher is a Principal at GlobalTox International Consultants Inc. in Guelph, Ontario and an Adjunct Professor at the University of Waterloo. He earned his Ph.D. in Medicinal Biochemistry from the University of Sussex and a B.Sc. (Hon.) in Biochemistry from Carleton University. Dr. Brecher has over 20 years of experience as a senior consultant in toxicology, with an emphasis on assessing and communicating human health impacts of chemicals found in the environment and consumer products. His technical duties include assessment of human health impacts of toxic chemical exposures; design and implementation of full scale hazard, exposure and risk assessments for toxic chemicals in the workplace, drinking water, air and other environmental media; computer modelling of exposure; and, risk assessment, characterization and communication in public forums. He has served on governmental expert committees in both Canada and the U.S. and provides expert peer review of risk assessments prepared by others. Dr. Brecher has been actively involved in a scientific communications role in a number of high-profile risk assessment projects in high-concern, low-trust situations for clients including Department of Defence, Noranda Ltd., Health Canada, and local and provincial agencies. Dr. Brecher, in partnership with Frontline Corporate Communications has developed and conducted risk communication training for various groups. Dr. Brecher has served on several expert panels, including the American Council on Science and Health Blue Ribbon Panel on the Use of Phthalates in Medical Devices and Toys (2000), Health Canada's Expert Advisory Panel on Diethylhexyl Phthalate in Medical Devices (2001), and Ontario's Inter-ministry Expert Advisory Committee on N-Nitrosodimethylamine in Drinking Water (1990). In 2004, he was appointed to Ontario's Advisory Council on Drinking Water Quality and Testing Standards.

Dr. Brecher was selected for the panel for his expertise in risk communication, multimedia and site assessments, toxicology, bioavailability/bioaccessibility, sampling and analysis of metals in various media, evaluation of human health hazards from soils and dust, calculation of soil clean up goals, uncertainty and sensitivity analysis, and familiarity with Canadian and U.S. risk assessment methods that are used in this HHRA.

Disclosure: Dr. Brecher works for GlobalTox International Consultants, Inc, which has consulted with the document authors (Intrinsik) on past and current projects. Dr. Brecher has assisted Intrinsik on similar projects that evaluated historic metal impacts in soil, including serving as an independent scientific advisor for the Sudbury Soils Study. None of GlobalTox's work has involved Flin Flon/Creighton or HBMS. This relationship is being disclosed to promote transparency. *TERA* has determined that the relationship with Intrinsik is not a source of bias or conflict of interest because it does not involve the subject risk assessment and is a very small portion of GlobalTox total sales. The relationship should not impair Dr. Brecher's scientific objectivity as a panel member.

Michael L. Dourson, Ph.D., DABT, FATS
Toxicology Excellence for Risk Assessment (TERA)

Dr. Michael Dourson is the President of Toxicology Excellence for Risk Assessment (*TERA*), a nonprofit corporation dedicated to the best use of toxicity data in risk assessment. Before founding *TERA* in 1995, Dr. Dourson held leadership roles in the U.S. Environmental Protection Agency as chair of EPA's Reference Dose (RfD) Work Group, as a charter member of the EPA's Risk Assessment Forum and as chief of the group that helped create the Integrated Risk Information System (IRIS). Dr. Dourson received his Ph.D. in Toxicology from the University of Cincinnati. Dr. Dourson has served on or chaired numerous expert panels, including peer review panels for EPA IRIS assessments, EPA's Risk Assessment Forum, *TERA* International Toxicity Estimates for Risk (*ITER*) independent peer reviews and consultations, FDA's Science Board Subcommittee on Toxicology, the NSF International's Health Advisory Board, and SOT's harmonization of cancer and non-cancer risk assessment. Dr. Dourson has organized numerous symposia on a variety of topics, including: risk communication; chromium; information resources for toxicology and environmental health; risk assessment of essential trace elements; risk characterization; EPA's IRIS; uncertainty in risk assessment techniques; statistical and dose response models in risk assessment; benchmark dose methodology; basics of risk assessment; improvements in quantitative noncancer risk assessment; and neurotoxicity risk assessment. Dr. Dourson is a Diplomate of the American Board of Toxicology and a Fellow of the Academy of Toxicological Sciences. In 2003, Dr. Dourson was awarded the Arnold J. Lehman award for major contributions that improve the scientific basis of risk assessment by the Society of Toxicology (SOT). He has been elected to multiple officer positions in the American Board of Toxicology, SOT, and the Society for Risk Analysis. He is also a media resource specialist in risk assessment for the SOT, member of the editorial board of three journals, and vice chair of the NSF International Health Advisory Board. Dr. Dourson has chaired dozens of expert panels reviewing risk assessments, including the Sudbury Soils Study human health and ecological risk assessment IERPs.

Dr. Dourson was selected for this panel for his expertise in dose-response assessment, metals toxicology, multimedia risk assessment, and familiarity with various agency risk assessment methodologies. In addition, Dr. Dourson has extensive experience effectively chairing panels of expert scientists in review of risk assessments.

Disclosure: Dr. Dourson is the President of *TERA*, which is under contract with HBMS to independently organize and conduct this peer review. See discussion above.

Susan Griffin, Ph.D., DABT
U.S. Environmental Protection Agency

Dr. Susan Griffin has a doctorate in Veterinary Pharmacology and Toxicology and a B.S. in genetics from the University of California at Davis. She is board certified by the American Board of Toxicology. She has worked for the U.S. Environmental Protection Agency for over 20 years in the Toxic Substances Control Act (TSCA), Resource Conservation and Recovery Act (RCRA) and Superfund programs. She is currently the Senior Toxicologist in EPA's Region 8 Superfund program where she has extensive experience in assessing exposure and risk from mining and smelting sites in the Western U.S.. She has been responsible for the preparation of several hundred human health baseline risk assessments, including the design and collection of site-specific environmental and biological data to more accurately characterize risk. She has also been involved in the design and conduct of bioavailability studies in juvenile swine to determine the bioavailability of lead and arsenic from soil contaminated by mining and smelting activities. Currently she is working on a collaborative research project to develop and validate a faster and less expensive *in vitro* benchtop method for assessing the bioavailability of arsenic from soil. Dr. Griffin has also worked with the U.S. Agency for International Development in Romania to instruct environmental agencies and citizen groups in assessing lead exposures and risks from smelters. In 2000, she was asked to consult with the Chilean Ministry of Mines on arsenic exposures and health effects at the Chuquicamata Mine. In addition, she is actively involved in writing and developing national Superfund guidance documents, such as the Probabilistic Risk Assessment Guidance for Superfund, the Superfund Guidance for Inhalation Risk Assessment, the Guidance Manual for the Integrated Exposure Biokinetic Uptake Model. She also reviews chemical toxicity values for EPA's Integrated Risk Information System (IRIS) database as an IRIS consensus reviewer. Dr. Griffin served as an expert on the Sudbury Soils Study human health risk assessment IERP.

Dr. Griffin was selected for this panel for her extensive experience in multimedia and site assessments (particularly of mining and smelting sites), toxicology of metals, bioavailability, sampling and analysis of metals in various media, evaluation of human health hazards from soils and dust, calculation of soil clean up goals and extensive knowledge of the U.S. EPA risk assessment methods that are used in this HHRA.

Disclosure: None. Dr. Griffin is participating in this review on her own time and outside of her duties with her employer, the U.S. Environmental Protection Agency.

Sean Hays, M.S.
Summit Toxicology

Mr. Sean Hays is the President and founder of Summit Toxicology, a toxicology and risk assessment consulting firm. Mr. Hays received his B.S. in Biomedical Engineering from Texas A&M University in, a M.S. in Physiology from the University of Vermont, and a M.S. in Chemical Engineering from Colorado State University. Mr. Hays specializes in conducting exposure assessments, developing pharmacokinetic and physiologically based pharmacokinetic (PBPK) models, deriving acceptable exposure limits, and in developing methods for interpreting biomonitoring data in a health risk context. Mr. Hays has developed PBPK models for a wide range of chemicals and metals, including volatile organic solvents, lead, dioxin, chromium, benzo[a]pyrene, and glycol ethers. He has specialized in developing models for pregnancy and the developing child. He has experience in performing pharmacokinetic modeling of lead in humans and in using the US EPA IEUBK model to assess potential health risks for a wide range of potential exposure scenarios and to set site-specific clean-up goals for numerous lead impacted properties, to model the potential for elevated blood lead levels among children exposed to elevated levels of lead in school drinking water supplies, and for modeling the likely changes in blood lead levels among astronauts who experience rapid and substantial bone loss while on extended space travel. Mr. Hays has performed detailed analyses to evaluate the scientific differences between the various lead pharmacokinetic models and to evaluate in which risk assessment scenarios each lead model is scientifically valid for predicting changes in blood lead levels. Mr. Hays has served on numerous advisory panels including the All Ages Lead Model Review Panel (U.S. EPA Scientific Advisory Board [SAB)]); the panel Clean Air Scientific Advisory Committee (CASAC) review of the U.S. EPA National Ambient Air Quality Standard (NAAQS) for Lead; and the peer review panel for U.S. EPA's Acrylamide Assessment. He has served as the President of the Biological Modeling Section of the Society of Toxicology.

Mr. Hays was selected for the IERP for his expertise in multi-pathway risk assessment, toxicology and epidemiology, exposure assessment, lead pharmacokinetics, biomonitoring equivalents, and uncertainty and sensitivity analysis.

*Disclosure**:*** None**.**

Norm Healey, B.Sc., DABT
Azimuth Group

Mr. Norm Healey is with the Azimuth Consulting Group in Sidney, British Columbia. He has more than 10 years experience as a risk assessor and toxicologist, both as a practitioner and as a regulator. Most recently, the focus of his work has been on various human health projects including the development of Canadian Soil Quality Guidelines, derivation of toxicological reference values, and development of Health Canada risk assessment policy and guidance documents. Mr. Healey has a B.Sc. in Environmental Science from Royal Roads University. Prior to joining Azimuth in 2009, he was a risk assessment and toxicology specialist with Health Canada and an environmental officer with the Canadian Coast Guard. Mr. Healey has directed or peer reviewed several multi-media human health risk assessments of lead. He was the principal author of Health Canada's 2008 draft toxicological evaluation of lead and in 2008 directed an evaluation and international panel review of the O'Flaherty and US EPA IEUBK models of lead exposure, uptake and toxicokinetics. Mr. Healey is currently a co-investigator of an epidemiological study to assess chronic lead exposure among Canadians by measuring lead in whole blood, serum and bone. He was also a scientific advisor to the Canadian House Dust Study, where he derived the schedule of lead values in house dust that would require the researchers to warn participants of potential lead exposure risks from dust in their homes. Mr. Healey has authored or co-authored over 15 papers or conference presentations on risk assessment and health effects of lead and has been an invited speaker on the topic at international scientific conferences. He represented Health Canada at the World Health Organization's Working Group on Lead and Children's Health and chaired Health Canada's Vapour Intrusion Working Group.

Mr. Healey was selected for the panel for his expertise in multimedia and site assessments; toxicology of metals (particularly lead); bioavailability/bioaccessibility; sampling and analysis of metals in water, soil, and dust; evaluation of human health hazards from soils and dust; calculation of soil clean up goals; and, extensive knowledge of Health Canada contaminated sites risk assessment methods.

Disclosure: None.

Anthony L. Knafla, M.SC., DABT
Equilibrium Environmental Inc.

Mr. Knafla is the President of Equilibrium Environmental Inc., in Calgary, Alberta. He has worked as a toxicologist and risk assessor in Canada for 16 years. He is a Diplomate of the American Board of Toxicology, obtained a B.Sc. in biochemistry from the University of Calgary and a M.Sc. in Medical Sciences (Toxicology) from the Faculty of Medicine. Mr. Knafla has developed toxicological profiles and methods for deriving soil quality guidelines that have been applied at provincial and federal levels for substances including lead, arsenic, perfluorooctanoic acid, PAHs, mercury, salts, and hydrocarbons. He has developed state of the science reports for application under the Canadian Environmental Protection Act. Mr. Knafla has also been responsible for scientific advisory roles in public hearings and consultation to the Alberta Energy and Utilities Board, Alberta Environment, the Canadian Council for Ministers of the Environment, Environment Canada, and Health Canada.

Mr. Knafla was selected for the panel for his expertise in multi-pathway human health risk assessments; biochemical sciences, toxicology of arsenic, lead, cadmium, selenium and mercury; biomonitoring studies; fate and transport models, sampling and analysis of metals in air, soil, and dust; evaluation of human health hazards from soils and dust; calculation of soil clean up goals; uncertainty and sensitivity analysis; and extensive knowledge of Health Canada contaminated sites risk assessment methods.

Disclosure: Mr. Knafla was an employee of Cantox (now Intrinsik) from 1992-1996 but has no current financial relationship with Intrinsik. This information is being shared to promote transparency. *TERA* has determined that Mr. Knafla's previous employment by Cantox is not a conflict of interest because it was over ten years ago and should not impair Mr. Knafla's scientific objectivity as a panel member.

Rebecca L. Tominack, M.D., FAACT, FACMT
Missouri Regional Poison Center and Saint Louis University School of Medicine

Dr. Rebecca Tominack is a medical toxicologist and serves as the Assistant Medical Director of the Missouri Regional Poison Center. She is also an Adjunct Professor of Medicine, Division of Toxicology, Department of Pediatrics and Clinical Assistant Professor of Pediatrics, Division of Toxicology, of the Saint Louis University School of Medicine. Dr. Tominack earned her M.D. from the University of Maryland, School of Medicine, and a B.S. in Pharmacy from the University of Maryland, School of Pharmacy. She received postdoctoral training in Internal Medicine, Virology, and Clinical Pharmacology and Toxicology. Previous positions include Program Director, Occupational Medicine Residency, Saint Louis University School of Medicine (concurrent with Poison Center directorship; residency program closed by SLU) and Director, Health Promotion and Work-family Balance and Medical Toxicology for the Monsanto Company. Dr. Tominack is experienced in evaluating and treating humans exposed to metals including mercury and lead. She teaches courses on human toxicology, risk assessment, and environmental toxicology in the Saint Louis University School of Public Health and toxicology at the Medical School. Dr. Tominack is board certified in Internal Medicine and in Medical Toxicology. She is a Fellow of the American Academy of Clinical Toxicology and a Fellow of the American College of Medical Toxicology. She serves on the editorial Board of the Journal of Toxicology Clinical Toxicology. Dr. Tominack has consulted to U.S. federal and state government agencies, as well as the International Program of Chemical Safety of the World Health Organization. She has served on expert committees on medical management for chemical exposures, assessments of lead contamination, and global pesticide poisoning.

Dr. Tominack was selected for the panel for her expertise in medical toxicology, pediatrics, public health issues, toxicology and epidemiology, and biomonitoring.

Disclosure: None

Joyce S. Tsuji, Ph.D., DABT, FATS
Exponent

Dr. Joyce Tsuji is a Principal in Exponent's Health Sciences practice in Bellevue, Washington. Dr. Tsuji received a B.S. in biological sciences from Stanford University with honors and distinction, Phi Beta Kappa, and a Ph.D. focused in physiology and ecology from the Department of Zoology, University of Washington. She is a Diplomate of the American Board of Toxicology, a Fellow of the Academy of Toxicological Sciences, and has over 20 years of experience in toxicology and risk assessment on projects in the United States, Canada, South America, Africa, Australia, and Asia for industry, as well as for the U.S. EPA, the U.S. Department of Justice, the Australian EPA, and state and local municipalities and agencies. Particular areas of interest include exposure assessment and toxicology of a variety of chemicals including those from industrial releases and in consumer products and nanomaterials. Dr. Tsuji has specialized experience with mining and smelting sites and the toxicology, bioavailability, and exposure to metals such as arsenic, lead, cadmium, mercury, manganese, chromium, and zinc. She has conducted and reviewed human health and ecological risk assessments of mining and smelting sites, and has designed and directed exposure studies involving health education, environmental sampling, and biomonitoring of populations potentially exposed to metals in soil, water, and the food chain. Dr. Tsuji has served on expert committees for the National Research Council, including serving as a peer reviewer for the report on the Coeur d'Alene Basin mining site and risk assessment. She has also served on committees for the U.S. EPA, U.S. Army, and the State of Washington (including the Area Wide Soil Contamination group of experts convened by the State of Washington to evaluate arsenic and lead in soil). Dr. Tsuji served as an expert on the Sudbury Soils Study IERP for the human health and ecological risk assessments. Dr. Tsuji has served as an expert witness on several legal cases involving metals and mines and has published a number of papers on risk assessment issues, including arsenic and lead in soils and mercury in air.

Dr. Tsuji was selected for the panel because of her expertise in toxicology of metals, bioavailability/bioaccessibility, biomonitoring studies, environmental fate, multimedia risk assessment (particularly of mining and smelting sites), sampling and analysis of metals in various media, evaluation of human health hazards from soils and dusts, calculation of soil clean up goals, and familiarity with U.S. EPA and Ontario MOE risk assessment methods.

Disclosure: Dr. Tsuji and her employer Exponent have conducted risk assessments and developed community exposure intervention and monitoring programs on behalf of mining companies, government agencies, and other private clients. None of this work has been for HBMS, or any project related to this HHRA. Other professionals at Exponent have been involved in the past in litigation cases with multiple defendants (e.g., 30+) in which HBMS was a defendant. This case did not involve a mining or smelting site, Exponent was not hired by HBMS and Dr. Tsuji was not involved in this project. These activities are being disclosed to promote transparency. *TERA* has determined that these situations are not a conflict of interest because they do not involve the Flin Flon/Creighton risk assessment, and Dr. Tsuji was not involved in the legal case that involved HBMS. *TERA* also concluded that these activities will not impair Dr. Tsuji's scientific objectivity as a panel member.

Appendix B

Independent Expert Review Panel (IERP)
Human Health Risk Assessment for Flin Flon, Manitoba and Creighton, Saskatchewan

June 23-24, 2009

Overview of HBMS Peer Consultation Process, List of Attendees, Agenda, and Presenter Biographical Sketches

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Overview of the HBMS Peer Consultation Process

Background

This meeting of an independent expert review panel (IERP) has been organized by Toxicology Excellence for Risk Assessment (*TERA).* *TERA* is an independent non-profit organization with a mission to protect public health through the best use of toxicity and exposure information in the development of human health risk assessments. *TERA* has organized and conducted peer review and consultation meetings for private and public sponsors since 1996 (see www.tera.org/peer for information about the program and reports from meetings).

TERA has convened this panel to review the draft human health risk assessment (HHRA) of Flin Flon, Manitoba, and Creighton, Saskatchewan. The draft HHRA was prepared by Intrinsik Environmental Sciences Inc. to address the potential human health risks associated with exposure to smelter-related metals in soils and other environmental media in the Flin Flon and Creighton area. A Technical Advisory Committee (TAC) with representatives from national and provincial agencies is providing technical guidance to Intrinsik. The TAC is made up of members from HBMS, Manitoba Conservation; Manitoba Health; Manitoba Science, Technology, Energy and Mines (STEM); Manitoba Water Stewardship; Saskatchewan Environment; Saskatchewan Health; and, Health Canada. Hudson Bay Mining and Smelting (HBMS) provided funding for the HHRA and the IERP review.

This meeting is not open to the general public and the assessment results are not yet final; therefore, the panel and observers are asked to keep the assessment and panel discussions confidential and not discuss them with others, including the media.

Independent Expert Review Panel

The independent peer review panel includes eight scientists who have expertise in the key disciplines and areas of concern. Each panelist is a well-respected scientist in his or her field. Collectively, the panel has expertise in multi-pathway risk assessment; environmental fate, human toxicology and epidemiology; biomonitoring studies; exposure assessment and pathways modeling; bioavailability and bioaccessibility of metals from soils; sampling and analysis for metals in diverse media; evaluating human health hazards of soils and dust; derivation of Soil Trigger Concentrations (STC) and soil preliminary remediation goals (PRG); and uncertainty and sensitivity analyses. Panel members are very familiar with Canadian and U.S. guidance and methodologies for multimedia risk assessments including Health Canada Contaminated Sites Program, U.S. EPA Superfund Program, and Ontario Ministry of the Environment guidelines for contaminated sites. *TERA* was solely responsible for the selection of the panel members.

Each panel member has disclosed information pertinent to evaluating potential conflicts of interest and biases related to the HHRA and its sponsor. *TERA* carefully evaluated this

information when selecting panel members. Short biographical sketches and disclosure statements for panel members are provided (see page 8).

Review Package and Charge to Peer Reviewers

The panel was sent the HHRA and review materials approximately six weeks prior to the meeting to ensure adequate time to carefully review the document and prepare for the meeting discussions. *TERA* developed a "charge to peer reviewers" document that outlines the key questions and scientific issues that need to be discussed by the panel in order to evaluate the quality and completeness of the risk assessment. Panel members provided preliminary comments several weeks prior to the meeting for the authors to consider in preparation for the meeting. As these comments were preliminary and panelists may change their opinion upon further review and discussion, they will not be distributed further or made part of the official meeting record.

Meeting Procedures

The meeting has been organized to make the best use of the time available to hear and discuss the opinions of the panelists regarding the charge questions and the human health risk assessment. The meeting will begin with brief panel introductions and a discussion of conflict of interest and bias issues. The discussion will then address the four broad areas of the assessment: problem formulation and sampling, exposure assessment, hazard assessment, and risk characterization. To start each discussion section, the authors of the assessment document will make a short presentation. These presentations will highlight the salient points and focus on important issues. There will be a brief period for panel member clarifying questions and then the panel will discuss the relevant charge questions.

Observers

Members of the Technical Advisory Committee have been invited to observe the panel meeting process. As the purpose of the IERP meeting is to have the expert panel discuss the assessment and reach conclusions on the science and the quality, the discussions will be limited to the panel members. To insure the panel's independence, observers are asked to refrain from initiating discussions about the assessment or related issues with the panel members. Please see the observer handout in your folder.

Meeting Report

TERA will draft a meeting report that briefly summarizes the panel's discussions and recommendations. The meeting report will serve as a record of the peer review and will assist the authors in making revisions to the assessment. The report will be reviewed by the panel members for accuracy before it is finalized.

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List of Attendees

Panel Members

Dr. Ronald W. Brecher
GlobalTox International Consultants

Dr. Michael Dourson
Toxicology Excellence for Risk Assessment (*TERA*)

Dr. Susan Griffin
U.S. Environmental Protection Agency

Mr. Sean M. Hays
Summit Toxicology

Mr. Norm Healey
Azimuth Consulting Group Inc.

Mr. Anthony L. Knafla
Equilibrium Environmental Inc.

Dr. Rebecca Tominack
Missouri Regional Poison Center

Dr. Joyce Tsuji
Exponent

Observers

Dave Bezak
Manitoba Conservation

George Bihun
Saskatchewan Ministry of Environment

Ian Cooper
Hudson Bay Mining and Smelting

Dr. Lawrence Elliott
Manitoba Health and Healthy Living

Alan Hair
Hudson Bay Mining and Smelting

Ines Hiraoka
Manitoba Conservation

Dr. James Irvine
Saskatchewan Ministry of Health

Kevin Jacobs
Manitoba Water Stewardship

Geoff Jones
Manitoba Conservation

Dean Kasur
Manitoba Conservation

Tom Lindsey
Community Advisory Committee Observer

Sheldon McLeod
TAC Facilitator

Jacqueline Patterson
Toxicology Excellence for Risk Assessment (*TERA*)

Doina Priscu
Manitoba Science, Technology, Energy and Mines

Shala Ricklefs
Saskatchewan Ministry of Health

Dr. Susan Roberecki
Manitoba Health and Healthy Living

Adam Safruk
Intrinsik

Elliot Sigal
Intrinsik

Lindsey Smith
Health Canada

Alison Willis
Toxicology Excellence for Risk Assessment (*TERA*)

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Agenda

Fort Garry Hotel, Winnipeg, Manitoba

Tuesday, June 23, 2009

8:00 **Registration**

8:30 **Meeting Convenes**[1]
Welcome, Ms. Jacqueline Patterson, *TERA*
Panel Introductions and Conflict of Interest/Bias Disclosures, Panel
Meeting Process and Ground Rules, Dr. Michael Dourson, Chair

9:00 **Background**
Mr. Alan Hair, Hudson Bay Mining and Smelting

Clarifying Questions from the Panel

9:15 **Problem Formulation and Sampling**
Mr. Adam Safruk, Intrinsik

Clarifying Questions from the Panel
Discussion (Charge Questions 1-5)

11:00 **Exposure Assessment**
Mr. Adam Safruk, Intrinsik

Clarifying Questions from the Panel
Discussion (Charge Questions 6-12)

12:00` **Lunch**

1:00 **Complete Exposure Discussion**

3:00 **Hazard Assessment**
Mr. Elliot Sigal, Intrinsik

Clarifying Questions from the Panel
Discussion (Charge Questions 13-15)

5:30 **Meeting Adjourns for the Day**

7:00 **Panel Dinner**

[1] The Chair will call a break mid-morning and mid-afternoon.

Agenda

Fort Garry Hotel, Winnipeg, Manitoba

Wednesday, June 24, 2009

8:00 **Meeting Re-convenes**

Results, Risk Characterization, Uncertainties
Mr. Elliot Sigal, Intrinsik

Clarifying Questions from the Panel
Discussion (Charge Questions 16-22)

12:00` **Lunch**

1:00 **Complete Risk Characterization Discussion**

2:00 **Conclusions and Recommendations**
Mr. Elliot Sigal, Intrinsik

Clarifying Questions from the Panel
Discussion (Charge Questions 23-29)

4:00 **Meeting Adjourns**

Biographical Sketches of Presenters

Elliot A. Sigal
Executive Vice President, Intrinsik Environmental

Mr. Elliot Sigal is the Executive Vice President of Intrinsik Environmental Sciences, Inc. (formerly Cantox Environmental Inc). Mr. Sigal graduated with an Honours B.Sc. in Toxicology from the University of Toronto in 1988. Since joining Intrinsik (Cantox) in 1989, he has gained over 20 years of experience in human health and ecological risk assessment, and toxicology. Mr. Sigal is responsible for supervising over 15 employees in our Mississauga office, as well as managing both small (a few thousand dollars) and large projects (over a million dollars).

Mr. Sigal has extensive experience in all aspects of toxicology and risk assessment with specific expertise in computer exposure modeling for human and ecological receptors. He has been responsible for leading risk assessment teams in determination of potential for exposure of and risk to receptors associated with complex contaminated sites, military base closures, underground storage tanks, incinerator emissions, landfill sites and industrial processes. Mr. Sigal has been involved in the use of toxicological principles to facilitate the risk assessment process, such as the development of a health-based method for the evaluation of total petroleum hydrocarbons (TPH), and provision of a benchmark comparison of remediation alternatives, in order to determine economically feasible and scientifically sound solutions to risk management problems. Mr. Sigal was also integrally involved in development and implementation of deterministic (point estimate) and probabilistic (stochastic) exposure and hazard assessment modeling techniques.

Mr. Sigal has conducted interpretive reviews of toxicology and mechanistic databases for a variety of chemicals including metals (arsenic, lead, nickel), chlorinated organics (vinyl chloride, PCBs, dioxins and furans), volatile organic compounds (benzene, toluene), combustion gases (NO_X, SO_X), and PAHs (, benzo[a]pyrene). Mr. Sigal has conducted peer reviews on many risk assessments in jurisdictions across Canada and the U.S., and has conducted reviews of risk assessments on behalf of the Ontario Ministry of the Environment.

Adam Safruk
Environmental Scientist, Intrinsik Environmental

Mr. Adam Safruk is an Environmental Scientist with Intrinsik Environmental Sciences, Inc. (formerly Cantox Environmental Inc). Mr. Safruk completed his MES in Toxicology and Risk Assessment at York University/ University of Toronto in 2003, and his Honours B.Sc. in Fish and Wildlife Biology from the University of Guelph in 1999. His academic training has provided him with experience in environmental toxicology, fugacity modelling, aquatic toxicology, risk assessment, risk management, and environmental law/public policy.

Mr. Safruk specializes in human and ecological exposure modelling and has conducted deterministic and probabilistic risk assessments for projects in Canada and Egypt. He is also involved in fate and transport modelling, risk characterization, development of risk management criteria, and report preparation. His work at Intrinsik Environmental Sciences Inc. has also focused on the fate and toxicity of chemicals in the aquatic environment as they impact both human and ecological receptors. Mr. Safruk has also prepared sections of a sediment sampling guidance document for Ontario Ministry of the Environment.

Mr. Safruk has worked on numerous projects including evaluation of impacts of on-site contamination to aquatic receptors in an urban stream, human and ecological exposure modelling, risk characterization and risk management for chlorinated organics, PAHs, PCBs and metals in soil, groundwater and surface water, and fate and transport modelling, human and ecological exposure modelling, and risk characterization for PCBs and Petroleum Hydrocarbons in soil. Mr. Safruk has conducted critical reviews of scientific literature for expert advice to Health Canada on the human health toxicology of Trichloroethylene and Perchlorate, along with various other literature reviews.

Appendix C

Independent Expert Review Panel (IERP)
Human Health Risk Assessment for Flin Flon, Manitoba and Creighton, Saskatchewan

June 23-24, 2009

Presenter Slides

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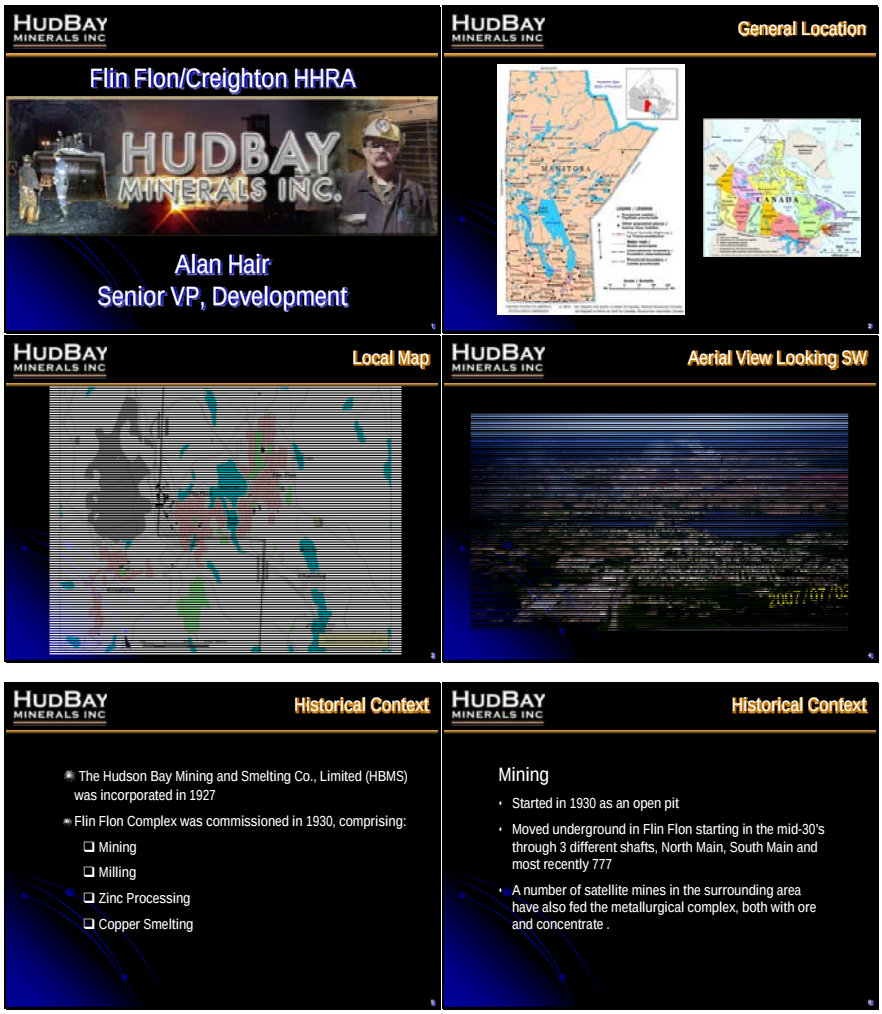
Presenter Slides

Presentation 1 - Mr. Alan Hair



HUDBAY MINERALS INC

Historical Context

Milling

- Conventional Ore Concentrator
- Crushing/Grinding/Flotation
- Produces both copper and zinc concentrates for downstream treatment on site
- Waste tailings stream stored in tailings management area adjacent to complex

HUDBAY MINERALS INC

Historical Context

Zinc Plant

- Started in 1930 as conventional Roast/Leach/Electrowin
- Significant process upgrades over the years

Copper Smelter

- Started in 1930 as roaster, reverberatory furnace and Pierce-Smith converter operation
- Flowsheet fundamentally unchanged
- Scheduled to cease operation by July 2010

HUDBAY MINERALS INC

Emissions

- Original metallurgical plants had only rudimentary gas cleaning equipment
- Emissions in the early years have been estimated to be an order of magnitude greater than today.
- Plant emissions were through two separate stacks:
  - 150' stack for zinc roaster emissions
  - 250' stack for copper roaster, reverb and converters

HUDBAY MINERALS INC

1930's Complex Looking North

HUDBAY MINERALS INC

1950's Complex Looking West

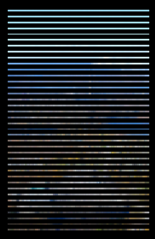
HUDBAY MINERALS INC

Emission Step Changes

- Process changes to Smelter in the 1950's saw improvements to pollution abatement with the commissioning of a large Dracco Baghouse.
- Next significant change was in the early 1970's with the commissioning of a new 825' high stack.
- In 1993 the new zinc pressure leach facility was brought into operation effectively eliminating atmospheric emissions from the zinc plant.

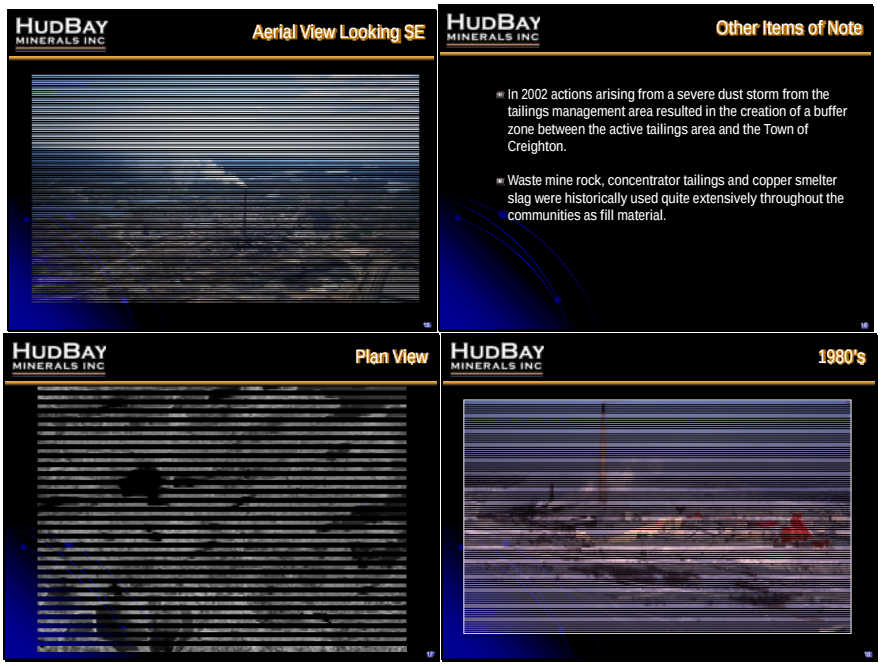
HUDBAY MINERALS INC

825' Stack

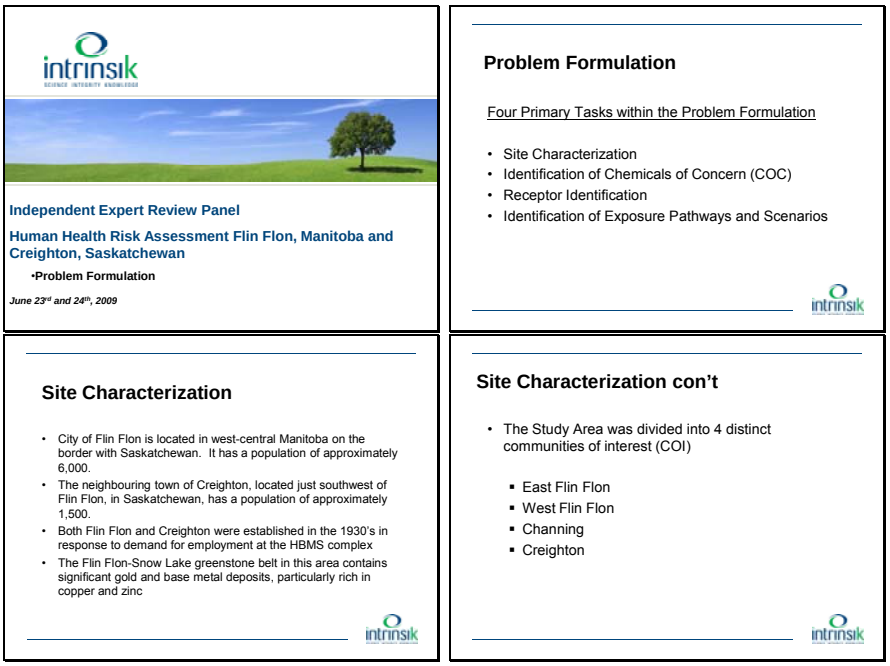


HUDBAY MINERALS INC

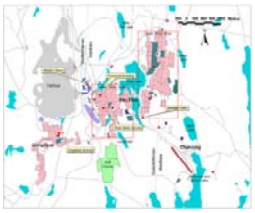
Aerial View Looking NE



Presentation 2 - Mr. Adam Safruk



Communities of Interest



Site Characterization con't

- Numerous studies over the past 20 years have indicated the presence of elevated levels of metals in soils surrounding the HBMS complex
- A strong positive inter-correlation has been noted by several sources indicating that these metals share a common point of origin
- Manitoba Conservation has completed 4 significant soil-related studies:
  - Soil and blueberry study in 2000
  - Forest soil study with sampling in 1998,1999 and 2003
  - Home garden produce study in 2002
  - Surface soil study in 2006

Site Characterization con't

- Manitoba Conservation surface soil study (2006)
  - 93 sites in Flin Flon; 13 sites in Creighton (each site had 3 samples)
  - Samples were collected from the top 2.5 cm and were a composite of 20 cores
  - Publicly accessible lands such as parks, schoolyards, boulevards, vacant lots, undeveloped areas, etc.
  - Results indicated that concentrations of 12 chemicals were elevated relative to a reference site
  - Six chemicals exceeded health-based Federal guidelines
    - Arsenic, cadmium, copper, lead, mercury, and selenium
  - Initiated the start of the HHRA

Site Characterization con't

- The literature review and data gap analysis identified the need for additional data collection which was completed in 2008
  - Residential soil
  - Drinking water
  - Supplementary air
  - Indoor dust
  - Bioaccessibility (outdoor soil)
  - Fish, surface water, sediment
  - Blueberries
  - Snow
  - Local food consumption survey

Site Characterization con't

- An initial step of the HHRA was the completion of a residential soil sampling study in fall 2007 completed by Jacques Whitford
  - 107 samples in West Flin Flon; 141 samples in East Flin Flon; 68 in Creighton; 18 in Channing
  - Samples were a composite of a minimum of 10 cores
  - Samples were collected from homes on a volunteer basis

Identification of Chemicals of Concern (COC)

- Identified based on concentrations in soil
- Current air monitoring completed by Manitoba Conservation evaluates risks associated with direct emissions
- COC identification process included:
  - Comparison of maximum concentrations to human health-based soil guidelines
  - Consideration of the percentage of samples in excess of guideline
  - Consideration of regional background concentrations
  - Known association with smelter emissions
- Selection of maximum soil concentrations considered data from the Manitoba Conservation Study (2007) and the Residential Soil Study (2008)

Identification of COC con't

- Initial comparison indicated the maximum concentration of 11 elements exceeded the selected guideline
- Three of these elements (chromium, thallium, and zinc) exceeded the guideline in less than 1% of samples
  - Therefore, not considered to be elevated across the Study Area
- Two of these elements (manganese and iron) are not correlated with smelter-related metals and are not in excess of regional background levels
  - Therefore, presence of elevated levels in soil are not related to HBMS complex
- Identified COC are: Arsenic, Cadmium, Copper, Lead, Mercury, and Selenium (consistent with those identified in the Manitoba Conservation Study)

Receptor Identification

- To assess risks for non-carcinogenic endpoints, receptors within 5 age categories as recommended by Health Canada were considered:
  - Infant (0 to 6 months)
  - Toddler (7 months to 4 years)
  - Child (5 to 11 years)
  - Adolescent or teen (12 to 19 years)
  - Adult (20 to 80 years)
- To assess risks for carcinogenic endpoints, a lifetime composite receptor was considered

Identification of Exposure Pathways and Scenarios

Inhalation exposure pathways

- Direct inhalation of COC in outdoor air
- Direct inhalation of COC in indoor air

Dermal exposure pathways

- Dermal contact with COC in outdoor soil
- Dermal contact with COC in indoor dust
- Dermal contact with COC in surface water

Identification of Exposure Pathways and Scenarios con't

Oral exposure pathways

- Ingestion of COC in outdoor soil
- Ingestion of COC in indoor dust
- Ingestion of COC *via* consumption of home garden vegetables
- Ingestion of COC *via* consumption of local wild blueberries
- Ingestion of COC *via* consumption of local fish and wild game
- Ingestion of COC *via* incidental surface water ingestion while swimming
- Ingestion of COC present in typical market basket items (*i.e.*, groceries)
- Ingestion of COC in drinking water derived from Flin Flon and Creighton area water resources
- Ingestion of COC in snow

Identification of Exposure Pathways and Scenarios con't

- Residential
- Typical Background Residential
- Outdoor Commercial Worker
- Additional Recreational Pathways

Identification of Exposure Pathways and Scenarios con't

Residential Scenario

- Receptors of all age categories
- Four communities of interest
- Community-based exposure pathways (*e.g.*, soil, dust, air, local foods)
- Market basket exposure
- Any additional sources of exposure (*e.g.*, mercury in dental amalgam)

Identification of Exposure Pathways and Scenarios con't

Typical Background Residential Scenario

- Included to allow for comparison of site-related risks to background risk levels
- Receptors of all age categories
- Exposure from typical background concentrations of COC in environmental media
- Market basket exposure
- Any additional sources of exposure (*e.g.*, mercury in dental amalgam)

Identification of Exposure Pathways and Scenarios con't

Outdoor Commercial Worker

- Members of the TAC requested that outdoor workers be included in the HHRA
- Adults only (10 hrs/day, 5 days/week, 48 weeks/year)
- Exposure to COC in environmental media while working outdoors (*i.e.*, soil, air, drinking water)
- Market basket exposure
- Reflective of a receptor that works but does not live in the study area

Identification of Exposure Pathways and Scenarios con't

Additional Recreational Pathways

- Exposure to COC in surface water while swimming *via* incidental ingestion and dermal contact
- Acute exposure to COC *via* ingestion of snow (as requested by members of the TAC)

Derivation of PRGs and PTCs

- Under the residential scenario, risk calculations were derived using community-based exposure point concentrations
- Unrealistic to assume that receptors will move randomly throughout the community
- Derived Preliminary Remediation Goals (PRGs) or Provisional Trigger Concentrations (PTCs) for residential soils
- PRGs and PTCs can then be used to determine on a property-by-property basis, which properties contain concentrations that have the potential to cause unacceptable risks

Presentation 3 - Mr. Adam Safruk

intrinsik

Independent Expert Review Panel

Human Health Risk Assessment Flin Flon, Manitoba and Creighton, Saskatchewan

•Exposure Assessment

June 23rd and 24th, 2009

Exposure Assessment

- Derivation of Exposure Point Concentrations (EPCs)
- Multi-media exposure estimates
- Spreadsheet-based deterministic calculations
- Additional assessment using IEUBK model for lead

Derivation of EPCs

- EPCs represent the upper 95% confidence interval on the arithmetic mean of the data set (95% UCLM) calculated using ProUCL software
- ProUCL tests the data set for normality, lognormality, and gamma distributions using parametric and non-parametric methods to calculate a conservative and stable 95% UCLM
- All data that were less than the method detection limit (MDL) were conservatively assumed to be present at the MDL value
- For some environmental media, EPCs are community-specific (*i.e.*, outdoor soil, indoor dust, air, and drinking water)

Derivation of EPCs con't

Outdoor Soil

- For the residential exposure scenario, EPCs are based on the results of the residential soil study completed by Jacques Whitford
- Data was divided into each of the 4 communities of interest
- Samples from the 0 to 5 cm profile
- Commercial scenario used maximum concentration from the Manitoba Conservation and Jacques Whitford soils study
- Use of maximum concentrations reduced the need to derive PRGs for commercial land use

Derivation of EPCs con't

Indoor Dust

- Residential indoor dust sampling program provided measured concentrations of COC in indoor dust at 15 locations in West Flin Flon, 14 locations in East Flin Flon, 8 locations in Creighton, and 1 location in Channing
- Regression equations were derived to relate indoor dust concentrations to outdoor soil concentrations based on co-located samples
- Statistically significant relationship between indoor dust and outdoor soil was found for arsenic, cadmium, copper, mercury, and selenium
- Regression equations and outdoor soil EPCs were used to derive indoor dust EPCs for these COC
- Measured indoor dust data was used to derive EPC for lead

Derivation of EPCs con't

Ambient Air

- Based on data collected from air monitors within different communities
- Data from a one-year period during 2007-2008
- Concentrations of COC associated with the PM10 component
- Assumed indoor air was equal to outdoor air

Derivation of EPCs con't

Drinking Water

- Drinking water for Flin Flon and Creighton are taken from separate surface water sources
- EPCs were derived for Flin Flon communities and Creighton based on data from an ongoing monitoring program completed by HBMS and a supplementary study by Jacques Whitford (2008)
- Samples were collected from post-treatment locations including residents and schools

Derivation of EPCs con't

Home Garden Vegetables

- EPCs are based on the study completed by Manitoba Conservation (2002)
- Included 5 different vegetables from 9 locations in Flin Flon
- Concentrations were from washed samples only
- Grouped into "root vegetable" and "other vegetable" categories to correspond with recommended ingestion rates recommended for Canadian populations
- Assumed residents in each of the 4 COI would consume home garden vegetables with the same COC concentrations

Derivation of EPCs con't

Local Fish

- Sampling plan was developed based on the results of a local food survey
- Stantec and Manitoba Conservation collected samples in 2008 from over 160 fish collected from 11 separate lakes
- Selection of EPCs was guided based on the most commonly consumed fish species reported within the local survey
- Although a small portion of the population may consume organs, EPCs were based on muscle samples only

Derivation of EPCs con't

Wild Game

- Measured data was not available, therefore, concentrations in tissue were predicted for two large mammals (*i.e.*, moose and deer) and two upland birds (*i.e.*, grouse and mallard)
- Conservatively assumed all wild game foraged within 15 km of the HBMS complex
- Used COC concentrations measured in forest soils, surface water, sediments, and vegetation

Derivation of EPCs con't

Other Media

- EPCs for wild blueberries were based on measured samples collected from 13 locations at varying distances and direction from the smelter complex in August 2008
- EPCs for surface water were the maximum concentration measured in 12 lakes sampled in summer 2008
- EPCs for snow were based on the results of a sampling program completed in March 2008 from 12 locations in Flin Flon and Creighton

Derivation of EPCs con't

Typical Background and Market Basket

- Based on concentrations in environmental media from areas not influenced by a direct source of emissions
- Used data from as close to the study area as possible when available
- Concentrations in market basket food items were taken from databases from Canadian sources

Exposure Estimates

- Point-estimate exposures were predicted for receptors for each of the 5 age classes as well as the lifetime composite
- Exposures were predicted on a per body weight basis (µg/kg/day)
- The contribution to internal dose *via* the inhalation route was combined with oral and dermal exposure to produce a total exposure for comparison to the RfD or cancer slope factor
- For COC where the inhalation exposure limit is based on effects on the respiratory tissues, the air EPC was used to represent exposure for an inhalation-related exposure and risk

Exposure Estimates con't

Ingestion of Outdoor Soil and Indoor Dust

- Based on recommendations from the TAC and Health Canada, it was assumed that during summer (8 months), 100% of the daily soil/dust ingested was outdoor soil, and during winter (4 months), 100% was indoor dust
- Based on recommendations from the TAC and Health Canada, only the results of the single-phase bioaccessibility analysis for arsenic and lead in outdoor soil were utilized in the HHRA
- Assumed 100% oral bioavailability for cadmium, copper, mercury, and selenium in outdoor soil, and all COC in indoor dust

Exposure Estimates con't

Consumption of Local Foods

- Based on the results of the local food survey, respondents generally indicated that receptors of all age categories consume wild blueberries, local fish, and local wild game throughout the year
- Consumption rates assumed for wild blueberries were elevated but not considered to be unrealistic based on survey response and the abundance of local blueberries
- Consumption rates for local fish and wild game were based on the frequency of consumption reported by survey respondents and a typical adult serving size of 8 oz (adjusted by body weight for younger receptors)

IEUBK Model for Lead in Children

- Computer simulation model derived by the U.S. EPA to predict childhood lead exposure and retention
- Has the ability to quantify the relationship between environmental lead concentrations in different media (*e.g.*, soil, water, air and food) to blood lead levels in children of different ages (0 to 84 months)
- Estimates of a likely distribution of blood lead concentrations are centered on the geometric mean concentration and can be used to calculate the probability that blood lead concentrations in children will exceed an acceptable level
- Standard tool for assessing lead in risk assessments

IEUBK Model for Lead in Children con't

- As recommended by the U.S. EPA, peer-reviewed exposure parameters and risk characterization assumptions set as default values within the IEUBK model were maintained unless scientifically defensible site-specific values were available
- This allowed for the prediction of blood lead concentrations that were reflective of the unique characteristics of the distribution of lead throughout the Flin Flon-Creighton area, while still relying on the widely accepted approaches used within the IEUBK model

IEUBK Model for Lead in Children con't

- Site-specific parameters used within the IEUBK model were:
  - Concentrations in outdoor soil, indoor dust, drinking water, and outdoor air
  - Site-specific bioavailability in outdoor soil
  - Contribution of local foods to total dietary intake (added to the recommended dietary intake from market basket foods)
- All other default receptor characteristics, bioavailabilities, and exposure assumptions were maintained despite discrepancies with values used in the spreadsheet-based exposure assessment

Presentation 4 - Mr. Elliot Sigal

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Independent Expert Review Panel

Human Health Risk Assessment Flin Flon, Manitoba and Creighton, Saskatchewan

- **Hazard Assessment**

June 23rd and 24th, 2009

Development of Toxicity Reference Values (TRVs)

- TRVs were obtained from regulatory agencies including the Health Canada, U.S. EPA, U.S. Agency for Toxic Substances and Disease Registry (ATSDR), California Environmental Protection Agency Office of Environmental Health Hazard Assessment (Cal EPA OEHHA), the Ontario Ministry of the Environment (MOE), U.S. Centers for Disease Control (CDC), the European Union (EU), and the World Health Organization (WHO)
- A detailed toxicological assessment was conducted for each COC, involving identification of mechanism of action and relevant toxic endpoints, and determination of receptor- and route-specific toxicological criteria

TRVs (continued)

- Toxicological profiles based primarily on secondary information sources, such as ATSDR toxicological profiles and other detailed regulatory agency reviews, and supplemented with recent relevant scientific literature
- TRVs selected for acute (1-hour and 24-hour) and chronic (lifetime) duration exposures
- Cancer and non-cancer endpoints selected as appropriate
- Chronic TRVs well established and accepted for use in Risk Assessment; acute TRVs less established

Arsenic

- Comprehensive toxicity profiles for arsenic have been established by the following regulatory agencies: U.S. EPA (1984); U.S. EPA IRIS (1993; 1998); Cal EPA (1999; 2000); WHO (2000); RIVM (2001); ATSDR (2007); and, Health Canada (2004a,b; 2006; 2008).

Chronic-Cancer (Non-threshold) Effects					
Oral	0.0015 (µg/kg-day)$^{-1}$	SFo	skin cancer	Tseng et al., 1968; Tseng, 1977	EPA, 1998
Inhalation	0.0043 (µg/m^3)$^{-1}$ 0.015 (µg/kg-day)$^{-1}$	IUR* SFi	lung cancer	Higgins et al, 1982; Enterline and Marsh, 1982; Brown and , 1983a,b; Lee-Feldstein, 1983	EPA, 1998
Chronic-Non-cancer (Threshold) Effects					
Oral	0.3 µg/kg-day	RfD	hyperpigmentation, keratosis, and possible vascular complications	Tseng et al., 1968; Tseng, 1977	EPA, 1993

Arsenic Slope Factors

- Oral slope factor based on Tiawanese data sets
- Many problems with this data set and the slope factor derived from this data
  - Exposure to arsenic impacted drinking water
  - Nutritional status of exposed population poor compared to NA population
  - Concomitant exposure (food preparation, locally grown foods)
- US EPA update on-going
- Complicates assessment since background risk often exceed acceptable risk level

Cadmium

- Cadmium has been reviewed by Health Canada (1986; 2004a; 2008); JECFA (1989); WHO (1990; 1992; 2000; 2005); U.S. EPA IRIS (1992; 1994); ATSDR (1999); Cal EPA (2000, 2005a,b); European Commission (2000); RIVM (2001); and, MOE (2006, 2008).

Chronic-Cancer (Non-threshold) Effects					
Inhalation	0.0038 (µg/m^3)$^{-1}$	Unit Risk	Detection of lung tumours	Takenaka et al., 1983; Oldiges et al., 1984	Health , 2004a; Health , 2008
Chronic-Non-cancer (Threshold) Effects					
Oral	1 µg/kg/day	pTDI	Renal tubular dysfunction	WHO 2001; 2004 based upon Friberg et al., 1971	Health , 2008

Copper

- Copper has been reviewed by Health Canada (1990; 1992; 2004a,b; 2008); U.S. EPA IRIS (1991); Cal EPA (1999); IOM (2000); RIVM (2001); ATSDR (2004); and, MOE (2008).

Chronic-Non-cancer (Threshold) Effects					
Oral	90 (0-6 mo) 90 (7 mo-4 yrs) 100 (5-11yrs) 100 (12-19 yrs) 100 (20+) µg/kg-day	UL	Hepatoxicity, gastrointestinal effects	Pratt et al., 1985; O'Donohue, et al., 1993	Health , 2008
Inhalation	1.0 µg/m^3	TCA	Respiratory and immunological effects	Not Provided	RIVM, 2001

Lead

- Comprehensive toxicity profiles for lead have been established by the following regulatory agencies: JECFA (1987); MOE (1994; 2006; 2007; 2008); WHO (1995; 2000); CCME (1999); RIVM (2001); Cal EPA (2001; 2005a,b); ATSDR (2007) and U.S. EPA (2007a,b; 2008)

Chronic-Non-cancer (Threshold) Effects					
Oral	3.6 µg/kg/day	pTDI	Behavioural effects and learning disabilities in children	Based upon the pTWI derived by: Ziegler et al., 1978 ; Ryu et al., 1983; JECFA, 1987	Health , 2004a; 2008
Inhalation (3 month averaging time)	0.15 ug/m3	AAQC	Protective of children and other at-risk populations	--	EPA, 2008

The Lead TRV and Blood Lead Level

- The current community intervention level for lead is 10 µg/dL
- There is a large volume of literature which suggests that health effects in children and adults occur at concentrations lower than this level (*e.g.*, Lanphear *et al.* 2005; Shih *et al.*, 2006; Bellinger, 2008)
- The 10 µg/dL value is currently under review by Health Canada, and it is anticipated that Health Canada will reduce the intervention level in the near future
- The Toxicity Reference Value will also likely be lowered in the near future
- While it is anticipated that the level will be lowered, it not possible to confirm what the final accepted intervention level/TRV will be at this time

Mercury

- Comprehensive toxicity profiles for mercury have been previously published by JECFA (1972); WHO (1978; 1990; 1991; 2000; 2004), Health Canada (1979; 2007a,b; 2008); U.S. EPA IRIS (1995a,b; 2001); ATSDR (1999); Cal EPA (1999); CCME (1999); OEHHA (1999); RIVM (2001); and, U.S. EPA (2001).

Mercury TRVs

ELEMENTAL MERCURY					
Chronic-Non-cancer (Threshold) Effects					
Inhalation	0.06 (µg/m³)	TC (provisional) (mercury vapour)	Neurobehavioral effects	Ngim *et al.*, 1992	Health , 2008
INORGANIC MERCURY					
Chronic-Non-cancer (Threshold) Effects					
Oral	0.3 (µg/kg-day)	(inorganic, ionic)	Kidney effects	Druet *et al.*, 1978; Bernaudin *et al.*, 1981; Andres, 1984	Health , 2004a, 2008
Inhalation	1.0 (µg/m³)	Annual average guideline (inorganic vapour)	Objective tremor, renal tubular effects and non-specific symptoms	WHO, 1991; Cardenas *et al.*, 1993	WHO, 2000
METHYL MERCURY					
Chronic-Non-cancer (Threshold) Effects					
Oral	0.47 (µg/kg-day) (general adult population) and 0.20 (µg/kg-day) (women of childbearing age, children (<12 yrs)	pTDI	Neurotoxicity and neurodevelopmental toxicity	Grandjean *et al.*, 1997; Feeley and Lo, 1998	Health , 2007a, 2008

Selenium

- Selenium has been reviewed by U.S. EPA IRIS (1991); Health Canada (1992; 2008); IOM (2000); Cal EPA (2001); ATSDR (2003); and, MOE (2005; 2008).

Chronic-Non-cancer (Threshold) Effects					
Oral	<6mo: 5.5; 7mo-4yrs: 6.2; 5-11yrs: 8.3; 12-19yrs: 6.2, 20+(70.7kg): 5.7 g/kg/day	UL	Selenosis	Shearer and Hadjimarkos, 1975; Yang and Zhou, 1994	Health , 2008
Inhalation	20 µg/m³		Clinical selenosis	Yang *et al.*, 1989a	Cal EPA, 2001

Bioaccessibility Study

- Soil samples collected as part of the Residential Soil Study were utilized for the bioaccessibility study.
- The study was conducted by Dr. Ken Reimer at Royal Military College/Queens University
- An *in vitro* physiologically based extraction test (PBET) methodology was utilized
- *in vitro* extraction consisted of a two-phase protocol (*i.e.*, simulating both gastric and intestinal phases of absorption) designed to simulate a human receptor
- Protocol developed and vetted through technical committee
- Range finding studies were conducted to consider factors such as particle size and dilution ratio
- ONLY gastric phase results for lead and arsenic were utilized in the risk assessment

Presentation 5 - Mr. Elliot Sigal

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Independent Expert Review Panel

Human Health Risk Assessment Flin Flon, Manitoba and Creighton, Saskatchewan

•Results, Risk Characterization, Uncertainties

June 23rd and 24th, 2009

HHRA Considerations

- Six chemicals of concern (COC) (arsenic, cadmium, copper, lead, mercury, and selenium);
- Four communities of interest (COI) (East Flin Flon, West Flin Flon, Creighton, and Channing) as well as a Typical Background scenario;
- Five receptor age classes (*i.e.*, infant, toddler, child, teen and adult) and a composite lifetime receptor;
- Receptor characteristics characterized by upper bound or *Reasonable Maximum Exposure* (RME) estimates;
- Inhalation, oral and dermal exposure pathways;
- Short-term (acute) and long-term (chronic) residential exposure scenarios, and long-term outdoor worker scenario; and,
- A large database of site-specific media concentrations characterized by RME concentrations represented by the 95% upper confidence limit on the mean (95% UCLM).

HHRA Scenarios

- Acute inhalation (1 hour and 24 hour durations);
- Acute oral (short-term soil and snow exposure events);
- Residential chronic multiple pathways (*i.e.*, inhalation, oral and dermal exposures); and,
- Commercial/industrial (outdoor worker) chronic multiple pathways (*i.e.*, inhalation, oral and dermal exposures).

Acute Inhalation Risk Estimates

COC	Exposure Duration	Air Concentration (µg/m³)	TRV (µg/m³)	CR_{acute}
West Flin Flon				
Arsenic	1 hr	0.74	0.19	**3.9**
	24 hrs	0.74	0.3	**2.5**
Cadmium	24 hrs	0.66	0.25	**2.6**
Copper	1 hr	4.2	100	0.043
	24 hrs	4.2	50	0.085
Lead	24 hrs	2.4	0.5	**4.8**
Mercury (inorganic) (inorganic)	1 hr	0.056[b]	1.8	0.031
	24 hrs	0.056[b]	2.0	0.028
Selenium	24 hrs	0.27[b]	10	0.027

Frequency of 24 hour Exceedances

COI	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium
West Flin Flon	9 of 210	6 of 210	0 of 210	26 of 210	ND	ND
Flon and Channing	0 of 57	1 of 57	0 of 57	0 of 57	0 of 57	0 of 57
Creighton	0 of 59	0 of 59	0 of 59	0 of 59	0 of 59	0 of 59

Hazard Quotients for Acute Soil Exposure for Toddlers

COC	Max Soil Concentration (µg/g)	Estimated Exposure (µg/kg-day)	TRV (µg/kg-day) (oral exposure limit)	HQ
West Flin Flon				
Arsenic	237	5.8	5.0	**1.2**
Cadmium	71	1.7	4.1	0.42
Copper	7,810	190	10	**19**
Lead	820	20	NA	NA
Mercury	971	24	7.0 (inorganic)	**3.4**
Selenium	286	6.9	NA	NA

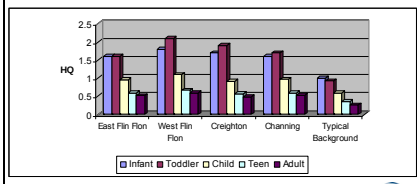
Hazard Quotients for Acute Snow Exposure for Toddlers

COC	Snow Concentration (µg/L)		Estimated Exposure (µg/kg-day)		TRV (µg/kg-day) (oral exposure limit)	HQ_{acute}	
	MAX	95% UCLM	MAX	95% UCLM		MAX	95% UCLM
Arsenic	147	96	0.15	0.10	5	0.03	0.02
Cadmium	183	113	0.18	0.11	4.1	0.05	0.03
Copper	4940	3000	5.0	3.0	10	0.50	0.30
Lead	732	483	0.74	0.49	3.6	0.21	0.14
Mercury	1.8	1	0.0018	0.0010	7	0.0003	0.0001
Selenium	2.8	2	0.0028	0.0020	6.2	0.0005	0.0003

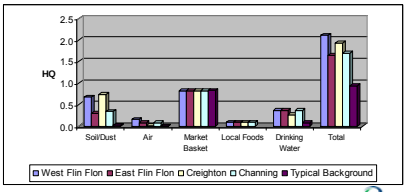
Summary of Assessment Results for Non-Cancer Endpoints (Toddler)

COC	West Flin Flon	East Flin Flon	Creighton	Channing	Typical Background
Arsenic	**1.6**	**2.1**	**1.9**	**1.7**	0.93
Cadmium	0.81	0.88	0.79	0.81	0.58
Copper	0.84	0.93	0.68	0.83	0.58
Lead	0.51	0.64	0.51	0.51	0.21
Inorganic mercury	0.44	**1.9**	0.46	0.41	0.31
Methyl mercury	**1.8**	**1.9**	**1.8**	**1.8**	0.42
Selenium	0.90	0.92	0.90	0.90	0.70

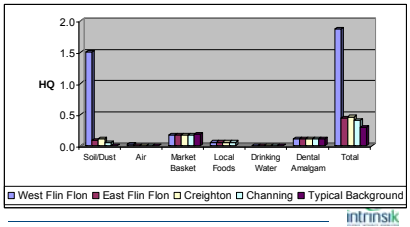
Predicted Hazard Quotients as a Result of Exposure to Arsenic



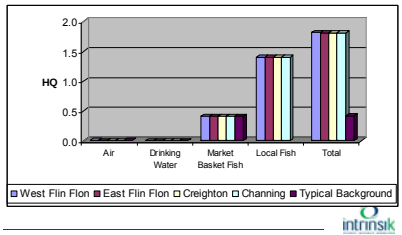
Pathway-Specific Hazard Quotients for Toddlers as a Result of Exposure to Arsenic



Pathway-Specific Hazard Quotients for a Toddler as a Result of Exposure to Inorganic Mercury



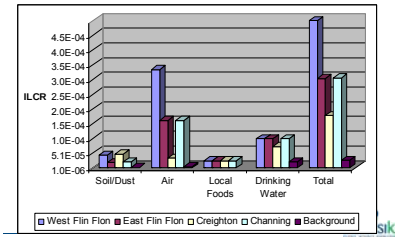
Pathway-Specific Hazard Quotients for a Toddler as a Result of Exposure to Methyl Mercury



Summary of Assessment Results for Carcinogenic Endpoints (Lifetime Receptor)

COC	*West Flin Flon*	*East Flin Flon*	*Creighton*	*Channing*
Arsenic	**3.0E-04**	**5.0E-04**	**1.8E-04**	**3.1E-04**
Cadmium	**2.5E-04**	**6.9E-04**	**4.5E-05**	**2.5E-04**

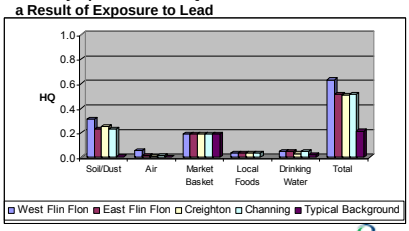
ILCRs for a Lifetime Composite - Arsenic



Lead

- The assessment of lead exposure was completed using the excel-based HHRA exposure model used for all COC as well as the U.S. EPA IEUBK model
- Blood lead monitoring data is the most effective indication of recent exposure levels to lead from all sources
- Since blood lead data for the Flin Flon area was not available, the IEUBK model was used as an additional tool as it is widely acknowledged as a very effective method of assessing risks to young children from exposure to lead

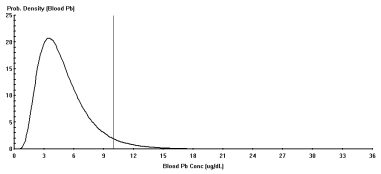
Pathway-Specific Hazard Quotients for a Toddler as a Result of Exposure to Lead



Blood Lead Concentrations Predicted by the IEUBK Model (µg/dL)

Age Categories (years)	Flon	Flon	Creighton	Channing	Typical Background
0 to 1	4.8	4.1	4.1	4.1	0.8
1 to 2	5.6	4.8	4.7	4.8	0.7
2 to 3	5.2	4.4	4.4	4.4	0.6
3 to 4	5.0	4.3	4.2	4.3	0.6
4 to 5	4.2	3.6	3.5	3.6	0.5
5 to 6	3.6	3.1	3.0	3.1	0.5
6 to 7	3.2	2.8	2.7	2.8	0.5
Geometric Mean	4.5	3.8	3.8	3.8	0.66
95th Percentile BLL	9.7	8.2	8.2	8.2	1.4
Probability of exceeding a BLL of 5 µg/dL	41%	29%	28%	29%	0%
Probability of exceeding a BLL of 10 µg/dL	4.4%	2.1%	1.9%	2.1%	0%

Probability Density of Blood Lead Concentrations (µg/dL) in West Flin Flon Children Relative to a Blood Lead Level of 10 µg/dL



Provisional Trigger Concentrations (PTCs) and Soil Risk Management Levels (SRML) for Lead (µg/g)

IEUBK Model Derived PTC	HHRA Model Derived PTC	EPA SRML	
		Play area	Bare soil Remainder
370 (protective of a 5% probability of exceeding a BLL of 10 µg/dL)	**570** (protective of a blood lead level of 10 µg/dL)	400	1,200

Sensitivity Analysis for the Assessment of Risks to a West Flin Flon Toddler Exposed to Lead as Assessed Using the HHRA Model

Variable	Value Used in HHRA	Adjusted Value	% Change in Risk Level
Indoor Air Concentration	100% of Measured Outdoor Air Concentration	30% of Measured Outdoor Air Concentration	5.5% decrease in total HQ
Outdoor Air Concentration	0.34 µg/m³	0.17 µg/m³ (50% reduction)	4.2% decrease in total HQ
Local Fish Consumption Rate	1.5 local fish meals per week	3 local fish meals per week	0.79% increase in total HQ
Local Wild Game Consumption Rate	1 local wild game meal per week	2 local wild game meals per week	0.31% increase in total HQ
Soil Ingestion Rate	80 mg/day for toddler	100 mg/day for toddler	12% increase in total HQ
Bioaccessibility in Soil	58% (single-phase analysis)	12% (two-phase analysis)	24% decrease in total HQ
Bioaccessibility in Soil	58% (single-phase analysis)	100%	22% increase in total HQ

Presentation 6 - Mr. Elliot Sigal

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Independent Expert Review Panel

Human Health Risk Assessment Flin Flon, Manitoba and Creighton, Saskatchewan

- **Conclusions and Recommendations**

June 23rd and 24th, 2009

Community Health

- The Community Health Status Assessment of Flin Flon and Creighton, completed by public health officials from Manitoba Health and Healthy Living and the Saskatchewan Ministry of Health found that the overall health status of the Flin Flon area population is as good if not better than the provincial averages for most of the indicators studied.

Arsenic

- Both non-cancer and cancer numerical risk estimates for arsenic exceeded standard acceptable benchmarks for both oral/dermal and inhalation exposures
  - Market basket foods were the main contributor to non-cancer arsenic-related risks
  - For carcinogenic risks, the inhalation of ambient air was the most significant source of risk
  - The consumption of drinking water and exposure to soil/dust also contributed significantly to both cancer and non-cancer risk estimates

Arsenic Weight of Evidence

- The most powerful and persuasive piece of evidence in other weight-of-evidence evaluations was the urinary arsenic study results
- These provide a comparison urinary arsenic levels of an impacted community with those of a control community
- It is recommended that a Urinary Arsenic study be undertaken for the Flin Flon area, focusing on homes in West Flin Flon and Creighton in which a significant number of homes included within the residential soil sampling program contained concentrations of arsenic in excess of the PTC

Cadmium

- Oral/dermal and non-cancer inhalation exposures were within acceptable levels
- Concentrations of cadmium in ambient air may have the potential to result in an unacceptable increase in the risk of developing lung cancer
- ILCR for Cadmium are quite elevated and consideration should be given to future reductions in smelter-related emissions, which would have a direct and immediate effect on reducing inhalation-related exposure and risks

Copper

- The estimated HQ values associated with copper exposures were less than 1.0 under all exposure and receptor scenarios
- Overall, the health risks to Flin Flon-area residents associated with exposure to copper are within risk levels deemed to be acceptable by Health Canada and the CCME
- Risk management measure or soil remediation are not considered to be necessary to prevent or reduce human health risks associated with exposure to copper in residential soils

Lead

- Both the HHRA model and the IEUBK model predicted average lead related exposure within acceptable levels
- A significant number of residential properties in West Flin Flon, as well as a few in East Flin Flon and Creighton, contain concentrations of lead in outdoor soil that are above the residential PTC protective of a 5% probability of exceeding a BLL of 10 µg/dL
- The health benchmarks for lead (10 µg/dL and 3.6 ug/kg/day) are currently under review by regulatory agencies such as Health Canada, and it is anticipated that these benchmarks will be reduced in the near future

Lead Follow-up

- Since a significant percentage of homes in the Flin Flon area contain soil concentrations in excess of those predicted to be protective of a 5% probability of exceeding a BLL of 10 µg/dL, the completion of a blood lead survey would be an appropriate method of reducing uncertainty in the exposure assessment and provide a more accurate measure of the levels occurring in young children in these communities
- The blood lead survey should primarily focus on children up to the age of 7 years as they are the most sensitive to the impaired neurobehavioral development associated with elevated BLLs

Mercury-Inorganic

- With the exception of toddlers in West Flin Flon, all exposures were below the acceptable levels indicating that adverse effects associated with elevated exposure to inorganic mercury are not anticipated
- Exposure of the toddler to inorganic mercury, and subsequent risk levels, are dominated by contributions from soil
- Biomonitoring would be an appropriate option to more accurately assess inorganic mercury exposure to individuals in West Flin Flon
- For long-term, low level exposures to inorganic mercury, measurement through urine samples is the preferred medium

Mercury-Methyl

- Exposure to methyl mercury was assumed to occur *via* the consumption of fish from market basket foods, consumption of local fish, consumption of drinking water, and inhalation of ambient air
- the primary route of exposure for all receptors other than the infant was the consumption of local fish
- Based on the assessment results, it is recommended that fish consumption advisories be considered, particularly for sensitive receptors

Selenium

- The estimated HQ values associated with selenium exposures were less than 1.0 under all exposure and receptor scenarios
- Overall, the health risks to Flin Flon-area residents associated with exposure to selenium are expected to be similar to those observed in other parts of Canada and are within risk levels deemed to be acceptable by Health Canada and the CCME.

Number of Properties with Concentrations of Arsenic in Outdoor Soil in Excess of the PTC of 80 µg/g

	Flon	*Flon*	*Creighton*	*Channing*	*Total*
# of Properties Sampled	77	66	30	10	183
# of Properties >80 µg/g	26 (34%)	0	10 (33%)	0	36 (20%)

Number of Properties with Concentrations of Cadmium in Outdoor Soil in Excess of the Residential Soil PRG of 58 µg/g

	Flon	*Flon*	*Creighton*	*Channing*	*Total*
# of Properties Sampled	77	66	30	10	183
# of Properties >80 µg/g	2 (2.6%)	0	0	0	2 (1.1%)

Number of Properties with Concentrations of Lead in Outdoor Soil that Exceed a Residential PTC of 370 µg/g

	Flon	*Flon*	*Creighton*	*Channing*	*Total*
# of Properties Sampled	77	66	30	10	183
# of Properties >375 µg/g	31 (40%)	2 (3%)	4 (13%)	0	37 (20%)

Number of Properties with Concentrations of Copper in Outdoor Soil in Excess of the Residential Soil PRG of 5,000 µg/g

	West Flin Flon	East Flin Flon	Creighton	Channing	Total
# of Properties Sampled	77	66	30	10	183
# of Properties >5,500 µg/g	5 (6.5%)	0	0	0	5 (2.7%)

Number of Properties with Concentrations of Mercury in Outdoor Soil in Excess of the Residential PTC of 56 µg/g

	West Flin Flon	East Flin Flon	Creighton	Channing	Total
# of Properties Sampled	77	66	30	10	183
# of Properties >46 µg/g	44 (57%)	0	0	0	44 (24%)

Number of Properties with Concentrations of Selenium in Outdoor Soil in Excess of the Residential PRG of 170 µg/g

	West Flin Flon	East Flin Flon	Creighton	Channing	Total
# of Properties Sampled	77	66	30	10	183
# of Properties >400 µg/g	1 (1.3%)	0	0	0	1 (0.55%)

Recommendations

- The HHRA provides a recommendation for a comprehensive biomonitoring program to evaluate environmental contaminant exposure in children (under 16) in Flin Flon, Manitoba and Creighton, Saskatchewan
- The study will examine urinary arsenic; blood lead; and, urinary inorganic mercury levels.
- A study of this nature is recommended for the fall of 2009, with results likely available in early 2010.

Objectives

- Broadly, the assessment of biomarkers of exposure will help refine and validate the HHRA's exposure estimates of COCs associated with elevated levels of risk.
  - What is the current level of internal exposure to arsenic, lead, and inorganic mercury in the child population residing in or about the contaminated areas of Flin Flon?
  - Do Flin Flon Area child residents have higher arsenic, lead, and/or inorganic mercury levels than residents living in other parts of Canada?
  - Based upon the current scientific literature, what are the health risks from the levels of arsenic and inorganic mercury in urine and lead in blood found in children in the Flin Flon Area?
  - What personal factors are associated with the level of measured internal exposure of children in Flin Flon Area (e.g., place of residence, place of work, level of COC in soil, age, gender, diet, personal habits, etc.)?

Appendix D

Independent Expert Review Panel (IERP)
Human Health Risk Assessment for Flin Flon, Manitoba and Creighton, Saskatchewan

June 23-24, 2009

Additional Handouts

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ESG Bioaccessibility Report ASD2008c

Site: Flin Flon
Analyst: Jessica Harris, Kim House (ESG)
Extraction Date: July 25 2008
Analysis Date: August 12, 22 2008
Report Date: September 03 2008
Method: PBET method, liquid to solid ratio 100:1 and <250 µm soil particle size

Results

Sample Name	Bioaccessible Hg (mg/kg)	Total Hg (mg/kg)	% Bioaccessible Hg (%)	Bioaccessible As (mg/kg)	Total As (mg/kg)	% Bioaccessible As (%)	Bioaccessible Cd (mg/kg)	Total Cd (mg/kg)	% Bioaccessible Cd (%)	Bioaccessible Cu (mg/kg)	Total Cu (mg/kg)	% Bioaccessible Cu (%)
PHASE 1												
FF410 P1	0.037	3.4	1.1	4.4	36	12	8.9	14	62	266	630	47
FF4088 P1*	0.028	4.0	0.70	<5.0	14	<36	7.4	9.3	80	112	284	39
CS111F P1	0.038	4.8	0.78	6.4	36	18	6.9	13	54	209	720	29
FF408F P1	0.019	4.8	0.40	<5.0	17	<29	7.8	15	50	84	540	17
FF221F P1	0.040	5.0	0.80	4.9	10	48	4.9	4.0	124	182	335	54
FF404F P1	0.036	5.5	0.66	<5.0	17	<29	14	21	68	108	660	16
FF313F P1	0.031	6.1	0.52	4.3	17	25	11	11	103	211	630	34
FF3128 P1	0.020	6.6	0.30	<5.0	14	<36	20	19	104	404	989	41
PHASE 2												
FF410 P2	0.19	3.4	5.4	7.1	36	20	6.1	14	43	206	630	33
FF4088 P2*	0.052	4.0	1.3	<5.0	14	<36	5.1	9.3	55	110	284	41
CS111F P2	0.25	4.8	5.3	11	36	31	5.1	13	40	194	720	25
FF408F P2	0.038	4.8	0.79	<5.0	17	<29	5.0	15	33	110	540	20
FF221F P2	0.21	5.0	4.2	7.2	10	70	2.9	4.0	73	171	335	51
FF404F P2	0.046	5.5	0.83	5.1	17	30	4.0	21	20	119	660	18
FF313F P2	0.059	6.1	1.0	5.4	17	32	5.9	11	53	185	630	30
FF3128 P2	0.078	6.6	1.2	<5.0	14	<36	8.0	19	42	288	989	29

Sample Name	Bioaccessible Pb (mg/kg)	Total Pb (mg/kg)	% Bioaccessible Pb (%)	Bioaccessible Se (mg/kg)	Total Se (mg/kg)	% Bioaccessible Se (%)	Bioaccessible Zn (mg/kg)	Total Zn (mg/kg)	% Bioaccessible Zn (%)
PHASE 1									
FF410 P1	100	183	55	<10	3.0	RND	1355	3350	40
FF4088 P1*	73	95	81	<10	1.9	RND	905	1210	59
CS111F P1	84	154	49	<10	4.2	RND	349	478	51
FF408F P1	87	193	45	<10	3.1	RND	1304	3000	44
FF221F P1	31	49	75	<10	1.8	RND	331	464	68
FF404F P1	53	136	39	<10	3.0	RND	725	1190	61
FF313F P1	196	111	177	<10	3.6	RND	2228	3350	67
FF3128 P1	118	164	72	<10	3.6	RND	1367	1640	83
PHASE 2									
FF410 P2	11	183	6.1	<10	3.0	RND	544	3350	16
FF4088 P2*	24	95	27	<10	1.9	RND	450	1210	31
CS111F P2	15	154	10	<10	4.2	RND	96	478	20
FF408F P2	16	193	8.8	<10	3.1	RND	620	3000	21
FF221F P2	4.8	49	11	<10	1.8	RND	127	464	28
FF404F P2	5.1	136	3.7	<10	3.0	RND	116	1190	10
FF313F P2	22	111	19	<10	3.6	RND	576	3350	17
FF3128 P2	16	164	9.8	<10	3.6	RND	405	1640	25

* average of duplicate pair
RND = total initial concentration is less than the detection limit of bioaccessible fraction, therefore % bioaccessibility cannot be calculated

ESG Bioaccessibility Report A8000095

Site: Flin Flon
Analyst: Jessica Harris, Kim House (ESG)
Extraction Date: July 23 2008
Analysis Date: August 12, 22 2008
Report Date: August 26 2008
Method: PBET method, liquid to solid ratio 100:1 and <250 µm soil particle size

Results

Sample Name	Bioaccessible Hg (mg/kg)	Total Hg (mg/kg)	% Bioaccessible Hg (%)	Bioaccessible As (mg/kg)	Total As (mg/kg)	% Bioaccessible As (%)	Bioaccessible Cd (mg/kg)	Total Cd (mg/kg)	% Bioaccessible Cd (%)	Bioaccessible Cu (mg/kg)	Total Cu (mg/kg)	% Bioaccessible Cu (%)
PHASE 1												
FF402F P1	0.024	0.31	7.8	<5.0	8.9	<56	2.0	2.9	70	51	118	43
FF408G P1*	0.0081	0.46	1.8	<5.0	7.8	<66	2.0	2.3	87	21	95	22
FF402G P1	0.013	0.55	2.4	6.5	16	42	5.0	5.3	96	59	195	30
CR112G P1	0.036	0.60	6.1	5.1	19	27	5.1	3.8	132	47	141	33
FF304B P1	0.011	1.2	0.94	<5.0	13	<38	7.2	7.9	91	141	369	38
FF407B P1	0.0094	1.2	0.77	<5.0	12	<40	3.1	3.9	78	69	165	42
FF402B P1	0.014	2.4	0.60	5.1	25	20	12	13	96	189	468	39
CR114F P1	0.030	2.6	1.2	5.6	34	16	23	28	84	199	1290	16
PHASE 2												
FF402F P2	0.018	0.31	5.7	<5.0	8.9	<56	<2.0	2.9	<69	46	118	41
FF408G P2*	0.013	0.46	2.9	7.1	7.8	93	<2.0	2.3	<87	86	95	89
FF402G P2	0.020	0.55	3.7	7.4	16	48	2.1	5.3	40	71	195	37
CR112G P2	0.065	0.60	11	6.5	19	35	<2.0	3.8	<53	55	141	39
FF304B P2	0.068	1.2	5.6	<5.0	13	<38	2.0	7.9	25	124	369	32
FF407B P2	0.061	1.2	5.0	<5.0	12	<40	2.1	3.9	54	70	165	43
FF402B P2	0.15	2.4	4.1	7.9	25	31	6.4	13	50	155	468	33
CR114F P2	0.076	2.6	2.9	6.1	34	18	6.1	28	22	194	1290	15

Sample Name	Bioaccessible Pb (mg/kg)	Total Pb (mg/kg)	% Bioaccessible Pb (%)	Bioaccessible Se (mg/kg)	Total Se (mg/kg)	% Bioaccessible Se (%)	Bioaccessible Zn (mg/kg)	Total Zn (mg/kg)	% Bioaccessible Zn (%)
PHASE 1									
FF402F P1	48	56	85	<10	0.3	BND	245	515	48
FF408G P1*	21	31	68	<10	0.7	BND	233	436	53
FF402G P1	61	107	57	<10	1.1	BND	698	1030	68
CR112G P1	1048	1490	70	<10	5.8	BND	348	350	99
FF304B P1	51	56	92	<10	1.4	BND	371	567	65
FF407B P1	63	74	85	<10	0.8	BND	309	655	47
FF402B P1	122	226	54	<10	2.3	BND	2073	2960	70
CR114F P1	77	200	38	<10	5.6	BND	1219	1270	96
PHASE 2									
FF402F P2	7.3	56	13	<10	0.3	BND	89	515	19
FF408G P2*	23	31	72	<10	0.7	BND	<100	436	<23
FF402G P2	6.4	107	6.0	<10	1.1	BND	264	1030	26
CR112G P2	101	1490	6.8	<10	5.8	BND	<100	350	<29
FF304B P2	5.9	56	11	<10	1.4	BND	<100	567	<18
FF407B P2	9.5	74	13	<10	0.8	BND	112	655	17
FF402B P2	20	226	8.9	<10	2.3	BND	844	2960	29
CR114F P2	7.1	200	3.6	<10	5.6	BND	173	1270	14

*average of duplicate pair reported
BND = total initial concentration is less than the detection limit of bioaccessible fraction, therefore % bioaccessibility cannot be calculated

ESG Bioaccessibility Report: ASD09004

Site: Flin Flon
Analyst: Jessica Harris, Kim House (ESG)
Extraction Date: July 28 2008
Analysis Date: August 18, Sept 02, 2008
Report Date: September 03 2008 AMENDED REPORT
Method: PBET method <250 µm soil particle size 100:1

Results

Sample Name	Bioaccessible Hg (mg·kg)	Total Hg (mg·kg)	% Bioaccessible Hg (%)	Bioaccessible As (mg·kg)	Total As (mg·kg)	% Bioaccessible As (%)	Bioaccessible Cd (mg·kg)	Total Cd (mg·kg)	% Bioaccessible Cd (%)	Bioaccessible Cu (mg·kg)	Total Cu (mg·kg)	% Bioaccessible Cu (%)
PHASE 1												
CS104F P1	<0.2	38.6	<0.5	27	314	8.6	16	20.5	78	546	1270	43
FF201F P1	<0.2	45	<0.4	<5.0	18.9	<26	5.8	7.22	81	232	640	36
FF206B P1	<0.2	100	<0.2	23	49.2	46	20	21	97	893	1610	54
FF210B P1	<0.2	101	<0.2	19	88.5	21	20	26.8	76	905	2120	43
FF225B P1 *	<0.2	90.0	<0.2	28	77.9	36	21	24	89	752	1830	41
FF236F P1	<0.2	127	<0.2	27	104	26	49	57.9	85	1614	3770	43
FF256F P1	<0.2	42	<0.5	27	139	19	28	35.1	73	936	2310	41
FF276F P1	<0.2	71	<0.3	15	138	12	15	25.4	64	895	2920	30
PHASE 2												
CS104F P2	1.8	38.6	4.7	46	314	15	3.9	20.5	19	482	1270	38
FF201F P2	0.71	45	1.6	<5.0	18.9	<26	2.9	7.22	41	186	640	29
FF206B P2	4.2	100	4.2	24	49.2	48	11	21	52	845	1810	46
FF210B P2	3.9	101	3.8	35	88.5	40	15	26.8	59	700	2120	33
FF225B P2 *	3.0	90	3.2	26	77.9	34	14	24	57	704	1830	38
FF236F P2	3.1	127	2.4	28	104	27	23	57.9	40	1135	3770	30
FF256F P2	1.3	42	3.0	29	139	21	15	35.1	41	893	2310	38
FF276F P2	3.0	71	4.2	23	138	17	11	25.4	42	767	2920	26

Sample Name	Bioaccessible Pb (mg·kg)	Total Pb (mg·kg)	% Bioaccessible Pb (%)	Bioaccessible Se (mg·kg)	Total Se (mg·kg)	% Bioaccessible Se (%)	Bioaccessible Zn (mg·kg)	Total Zn (mg·kg)	% Bioaccessible Zn (%)
PHASE 1									
CS104F P1	101	394	26	<10	20.4	<49	743	1690	44
FF201F P1	47	81.5	57	<10	10.2	<98	995	1280	78
FF206B P1	135	209	65	<10	32.4	<31	3256	4410	74
FF210B P1	266	420	63	<10	26.5	<38	2491	4260	58
FF225B P1 *	211	274	77	<10	28.4	<35	3053	4520	68
FF236F P1	467	638	64	<10	43.3	<23	6035	8790	69
FF256F P1	259	478	56	<10	30.5	<33	2977	7210	56
FF276F P1	219	481	47	<10	25.2	<40	2328	5675	41
PHASE 2									
CS104F P2	31	394	7.9	<10	20.4	<49	180	1690	9.5
FF201F P2	4.9	81.5	6.0	<10	10.2	<98	315	1280	25
FF206B P2	18	209	8.5	<10	32.4	<31	1478	4410	34
FF210B P2	31	420	7.5	<10	26.5	<38	1560	4260	40
FF225B P2 *	39	274	13	<10	28.4	<35	1215	4520	27
FF236F P2	41	638	6.4	<10	43.3	<23	2226	8790	25
FF256F P2	22	478	4.6	<10	30.5	<33	1739	7210	24
FF276F P2	28	481	6.1	<10	25.2	<40	1194	5675	21

* Average of the duplicate is reported

ESG Bioaccessibility Report ASCBRSs

Site: Flin Flon
Analyst: Jessica Harris, Kim House (ESG)
Extraction Date: July 30 2008
Analysis Date: August 14 -15, Sept 02, 2008
Report Date: September 03 2008 **AMENDED REPORT**
Method: PBET method <250 µm soil particle size 100:1

Results

Sample Name	Bioaccessible Hg (mg/kg)	Total Hg (mg/kg)	% Bioaccessible Hg (%)	Bioaccessible As (mg/kg)	Total As (mg/kg)	% Bioaccessible As (%)	Bioaccessible Cd (mg/kg)	Total Cd (mg/kg)	% Bioaccessible Cd (%)	Bioaccessible Cu (mg/kg)	Total Cu (mg/kg)	% Bioaccessible Cu (%)
PHASE 1												
CS108F P1	<0.2	30.5	<0.66	12	97.3	13	14	20.1	68	560	1200	47
CS125F P1	<0.2	20.7	<0.97	19	153	13	26	31.8	83	844	1800	36
CS126F P1	<0.2	19.8	<1.0	29	220	13	6.8	12.2	56	835	1330	48
FP232F P1	0.74	25	3.0	13	33.9	37	14	12.2	111	840	1290	65
FP254F P1	<0.2	22	<0.91	48	140	34	32	46.7	68	954	2190	44
FP341F P1	<0.2	32	<0.63	7.3	34.2	21	24	30.5	80	622	1770	35
FP343F P1 *	<0.2	21.4	<0.93	16	49.7	33	23	30.4	77	739	1640	45
FP344F P1	<0.2	17.9	<1.1	6.2	29	21	25	30.9	81	905	1950	46
PHASE 2												
CS108F P2	0.98	30.5	3.1	14	97.3	14	8.1	20.1	40	328	1200	27
CS125F P2	0.50	20.7	2.4	26	153	17	12	31.8	37	391	1800	22
CS126F P2	1.8	19.8	9.0	50	220	23	3.1	12.2	26	432	1330	33
FP232F P2	0.74	25	3.0	14	33.9	41	7.2	12.2	59	510	1290	40
FP254F P2	0.76	22	3.5	68	140	48	21	46.7	45	679	2190	31
FP341F P2	0.26	32	0.82	9.5	34.2	28	12	30.5	38	449	1770	25
FP343F P2 *	0.32	21.4	1.5	17	49.7	35	14	30.4	45	474	1640	29
FP344F P2	<0.2	17.9	<1.1	7.1	29	24	12	30.9	39	501	1950	26

Sample Name	Bioaccessible Pb (mg/kg)	Total Pb (mg/kg)	% Bioaccessible Pb (%)	Bioaccessible Se (mg/kg)	Total Se (mg/kg)	% Bioaccessible Se (%)	Bioaccessible Zn (mg/kg)	Total Zn (mg/kg)	% Bioaccessible Zn (%)
PHASE 1									
CS108F P1	165	287	57	<10	13	<77	1514	2812	54
CS125F P1	219	456	48	<10	15	<67	2123	4660	45
CS126F P1	201	392	51	<10	16.3	<61	389	1800	24
FP232F P1	112	121	93	<10	7.6	BND	1301	1520	87
FP254F P1	558	820	68	<10	18.1	<55	5983	9010	61
FP341F P1	302	357	56	<10	11.6	<86	4491	5650	79
FP343F P1 *	350	552	63	<10	10.4	<96	6355	8245	77
FP344F P1	275	380	72	<10	11	<91	3532	5400	65
PHASE 2									
CS108F P2	39	287	13	<10	13	<77	729	2812	26
CS125F P2	25	456	5.6	<10	15	<67	987	4660	21
CS126F P2	32	392	8.3	<10	16.3	<61	130	1800	8.2
FP232F P2	19	121	15	<10	7.6	BND	584	1520	38
FP254F P2	67	820	8.1	<10	18.1	<55	2274	9010	24
FP341F P2	39	357	8.3	<10	11.6	<86	1346	5650	24
FP343F P2 *	56	552	10	<10	10.4	<96	2868	8245	32
FP344F P2	21	380	5.6	<10	11	<91	1200	5400	22

* Average of the duplicate is reported
BND = total initial concentration is less than the detection limit of bioaccessable fraction, therefore % bioaccessibility cannot be calculated

[illegible] Bioaccessibility Report: A[illegible]

Site: Flin Flon
Analyst: Jessica Harris, Kim House (ERG)
Extraction Date: July 31 2008
Analysis Date: August 21, September 03 2008
Report Date: September 03 2008
Method: PBET method <250 µm soil particle size 100:1

Results

Sample Name	Bioaccessible Hg (mg/kg)	Total Hg (mg/kg)	% Bioaccessible Hg (%)	Bioaccessible As (mg/kg)	Total As (mg/kg)	% Bioaccessible As (%)	Bioaccessible Cd (mg/kg)	Total Cd (mg/kg)	% Bioaccessible Cd (%)	Bioaccessible Cu (mg/kg)	Total Cu (mg/kg)	% Bioaccessible Cu (%)
PHASE 1												
DB1048-P1	<0.2	8.9	<2.2	35	265	13	21	22	96	668	1380	48
DB1038-P1	<0.2	10.5	<1.9	8.5	60.4	14	18	20	91	434	960	45
PFSDP-P1	<0.2	7.4	<2.7	<5.0	17.4	<29	22	21	105	560	1100	51
PFSDB-P1*	<0.2	7.2	<2.8	<5.0	18	<28	13	15	88	408	1320	40
PFSDP-P1	<0.2	10.2	<2.0	<5.0	20	<25	27	27	97	547	1360	40
PFSDP-P1	<0.2	9.60	<2.0	8.5	37	24	17	20	85	501	970	52
PFADP-P1	<0.2	7	<2.9	8.9	31	22	16	21	76	355	700	36
PHASE 2												
DB1048-P2	0.19	8.9	2.2	39	265	14	6.8	22	31	514	1380	37
DB1038-P2	<0.2	10.5	<1.9	17	60.4	27	8.3	20	42	376	960	39
PFSDP-P2	<0.2	7.4	<2.7	<5.0	17.4	<29	6.6	21	32	368	1100	33
PFSDB-P2*	0.21	7.2	2.9	<5.0	18	<28	3.7	15	25	292	1320	29
PFSDP-P2	<0.2	10.2	<2.0	<5.0	20	<25	9.1	27	33	360	1360	29
PFSDP-P2	<0.2	9.60	<2.0	5.9	37	22	6.9	20	35	395	970	40
PFADP-P2	<0.2	7	<2.9	8.1	31.4	26	7.8	21	37	344	700	35

Sample Name	Bioaccessible Pb (mg/kg)	Total Pb (mg/kg)	% Bioaccessible Pb (%)	Bioaccessible Se (mg/kg)	Total Se (mg/kg)	% Bioaccessible Se (%)	Bioaccessible Zn (mg/kg)	Total Zn (mg/kg)	% Bioaccessible Zn (%)
PHASE 1									
DB1048-P1	153	365	42	<10	15	<67	1290	1400	98
DB1038-P1	165	249	66	<10	5.5	#ND	550	707	78
PFSDP-P1	389	304	128	<10	5.1	#ND	3535	4160	85
PFSDB-P1*	307	221	94	<10	8.0	#ND	2521	3760	66
PFSDP-P1	250	275	91	<10	8.8	#ND	4473	5460	81
PFSDP-P1	263	269	103	<10	8.3	#ND	2208	3260	67
PFADP-P1	203	266	76	<10	4.0	#ND	3258	5660	58
PHASE 2									
DB1048-P2	19	365	5.1	<10	15	<67	186	1400	10
DB1038-P2	31	249	13	<10	5.5	#ND	127	707	25
PFSDP-P2	17	304	5.6	<10	5.1	#ND	569	4160	14
PFSDB-P2*	17	221	7.7	<10	8.0	#ND	371	3760	9.8
PFSDP-P2	17	275	6.2	<10	8.8	#ND	1025	5460	19
PFSDP-P2	31	269	11	<10	8.3	#ND	502	3260	15
PFADP-P2	18	266	6.8	<10	4.0	#ND	1214	5660	21

*Average of duplicate pair
#ND = total initial concentration is less than the detection limit of bioaccessible fraction, therefore % bioaccessibility cannot be calculated

ESG Bioaccessibility Report ASD0808a

Site: Flin Flon
Analyst: Jessica Harris, Kim House (ESG)
Extraction Date: July 21 2008
Analysis Date: August 14 -15 2008
Report Date: August 21 2008
Method: PBET method <250 µm soil particle size 100:1

Results

Sample Name	Bioaccessible Hg (mg/kg)	Total Hg (mg/kg)	% Bioaccessible Hg (%)	Bioaccessible As (mg/kg)	Total As (mg/kg)	% Bioaccessible As (%)	Bioaccessible Cd (mg/kg)	Total Cd (mg/kg)	% Bioaccessible Cd (%)	Bioaccessible Cu (mg/kg)	Total Cu (mg/kg)	% Bioaccessible Cu (%)
PHASE 1												
FF202F P1	0.634	168	0.38	16.1	51	30	22.7	26	86	1221	3290	37
FF206F P1	<0.2	184	<0.11	16.3	42	39	15.4	16	99	914	1690	49
FF206B P1*	<0.2	132	<0.15	33.5	97	34	17.8	20	90	1084	1790	61
FF229F P1	<0.2	300	<0.06	21.2	67	32	28.0	31	84	788	2630	31
FF231F P1	0.366	535	0.068	76.2	124	61	67.5	51	132	2222	3970	56
FF235B P1	<0.2	370	<0.05	85.9	189	51	38.3	50	77	1605	3650	42
FF271F P1	0.191	330	0.058	22.2	99	22	46.3	50	93	2623	5530	48
FF277F P1	<0.2	183	<0.11	127	222	57	30.8	37	84	1456	2940	50
PHASE 2												
FF202F P2	3.80	168	2.1	14.2	51	28	11.2	26	42	868	3290	26
FF206F P2	4.98	184	2.7	14.7	41.7	36	8.80	16	56	915	1690	33
FF206B P2*	6.11	132	4.6	31.9	97.3	33	18.2	20	92	777	1790	43
FF229F P2	4.59	300	1.5	19.7	67	29	10.0	31	32	444	2630	18
FF231F P2	8.93	535	1.7	82.9	124	61	23.8	51	46	1893	3970	43
FF235B P2	2.85	370	0.77	90.3	189	36	18.4	50	33	1338	3650	35
FF271F P2	7.58	330	2.3	22.9	98.9	23	22.4	50	45	1856	5530	30
FF277F P2	5.44	183	3.0	110	222	50	12.0	37	33	1022	2940	35

Sample Name	Bioaccessible Pb (mg/kg)	Total Pb (mg/kg)	% Bioaccessible Pb (%)	Bioaccessible Se (mg/kg)	Total Se (mg/kg)	% Bioaccessible Se (%)	Bioaccessible Zn (mg/kg)	Total Zn (mg/kg)	% Bioaccessible Zn (%)
PHASE 1									
FF202F P1	238	335	71	<10	42	<24	2395	4010	60
FF206F P1	153	199	77	<10	41	<24	2260	3270	69
FF206B P1*	223	281	80	<10	54	<19	3189	4350	73
FF229F P1	142	353	40	<10	76	<13	2699	4550	59
FF231F P1	481	599	80	<10	124	<8.1	13503	14900	91
FF235B P1	635	746	85	<10	98	<10	10114	14900	68
FF271F P1	468	726	64	<10	95	<11	5270	9220	57
FF277F P1	494	640	77	<10	66	<15	8610	14200	61
PHASE 2									
FF202F P2	33	335	10	<10	42	<24	952	4010	24
FF206F P2	22	199	11	<10	41	<24	1079	3270	33
FF206B P2*	36	281	13	<10	54	<19	1429	4350	33
FF229F P2	18	353	5.0	<10	76	<13	794	4550	17
FF231F P2	130	599	22	<10	124	<8.1	4855	14900	33
FF235B P2	95	746	13	<10	98	<10	2711	14900	18
FF271F P2	53	726	7.2	<10	95	<11	2184	9220	23
FF277F P2	107	640	17	<10	66	<15	3371	14200	24

* Average of the duplicate is reported

Appendix E

Independent Expert Review Panel (IERP)

Human Health Risk Assessment for Flin Flon, Manitoba and Creighton, Saskatchewan

June 23-24, 2009

List of Additional Studies

Björnberg KA, Vahter M, Berglund B, Niklasson B, Blennow M, and Sandborgh-Englund G. 2005. Transport of Methylmercury and Inorganic Mercury to the Fetus and Breast-Fed Infant. Environ Health Perspect 113:1381–1385.

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