Climate Change and Human Health Risk Assessment

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Introduction

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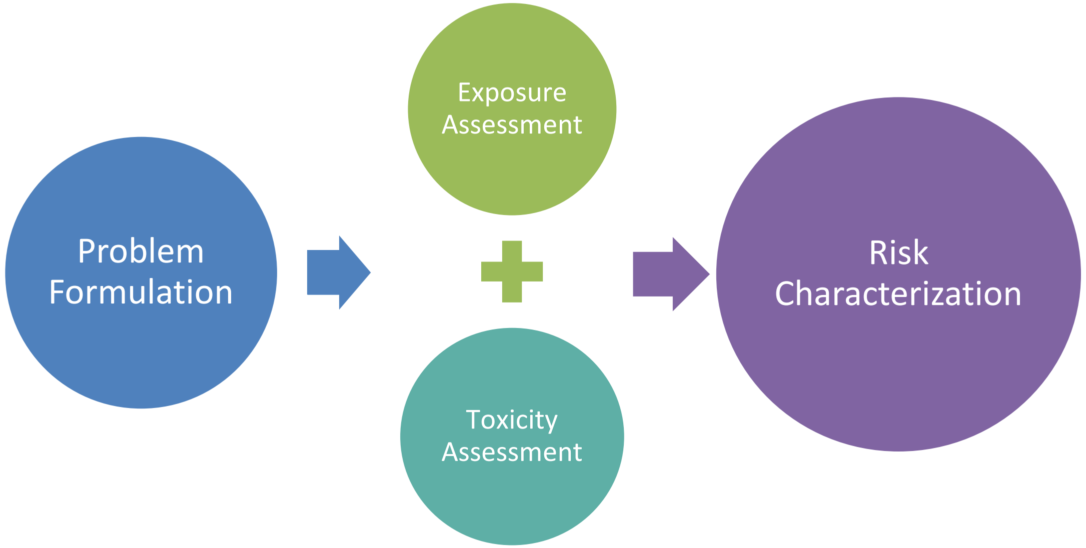
Human Health Risk Assessment (HHRA)

- Systematic process to look at potential effects to people due to the presence of contaminants
- Typical framework:



Rationale

- Human health risk assessment (HHRA) supports effective risk management and decision making
- Climate change can influence a range of environmental and physiological variables that can potentially affect the exposure and effects of chemicals
- Need a review of how to incorporate the potential impacts of climate change on HHRA

Objective

To conduct a state-of-the-science review to document the state of knowledge on how climate change may influence human health risk assessments

- To identify climate change associated events and environmental processes on the components of HHRA
  - Effects of climate change on the sources, fate, transport, exposure, and toxicity of chemicals of potential concern
  - Impact the characteristics of the receptors

Literature Review Approach

- State of knowledge review
  - Scoping Review
  - Additional papers from targeted searches and in house libraries
- Developed search term
- Databases: PubMed, Web of Science, and Scopus

	Scoping review	Targeted search	Expert input	Total
Hazard Identification / Exposure Assessment	83	-	19	102
Toxicity Assessment	3	24	21	48
Risk Characterization	1	-	20	21
Total	87	24	60	**171**

Problem Formulation

- COPC
  - Categories and Selected Examples:
    - Metal/Metalloids: As, Cd, Pb, Hg
    - Organics: PHCs

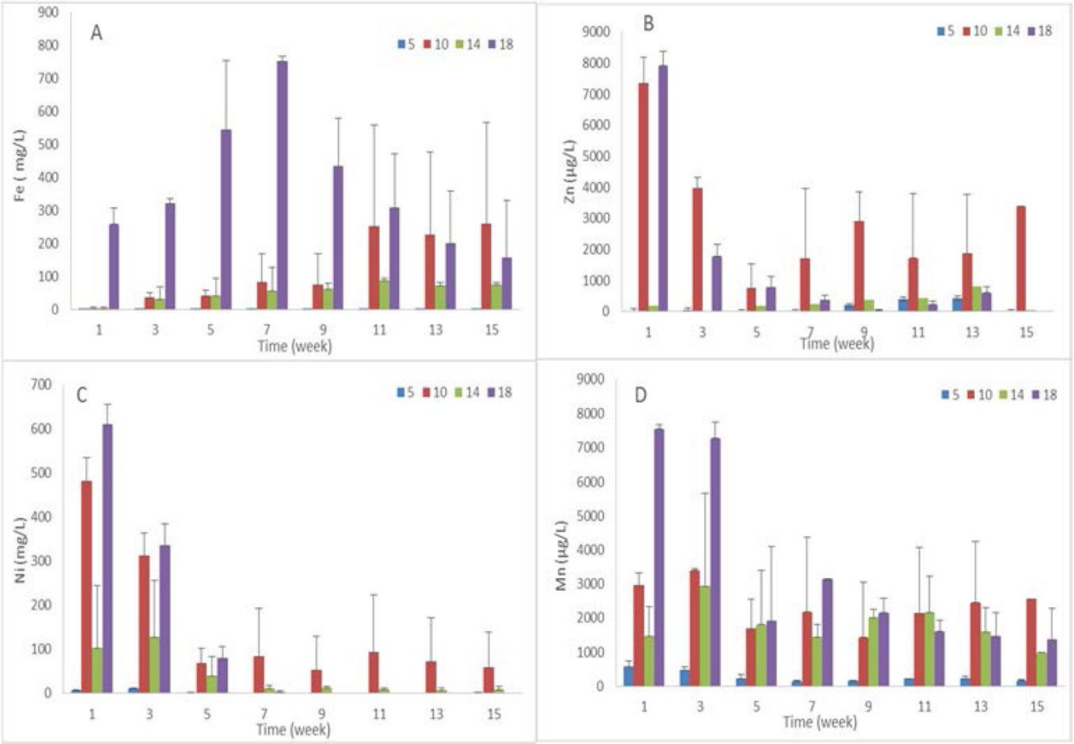
- Receptor and Pathway Identification
  - All life-stages
  - Examine whether land use changes (e.g. shift to groundwater as a source of drinking water)

Problem Formulation

- Source Identification
  - Ice melt releases contaminants accumulated in the media
  - Permafrost thaw
  - Change in precipitation:
    - Flooding and erosion – movement of COPC
    - Leaching
  - Forest fires
  - Droughts
    - Wind-generated dust
    - Soil/groundwater interactions

Source – Leaching from Tailings

- Column leaching test example:
  - Fu, S. and J. Lu, 2018. *Column leaching heavy metal from tailings following simulated climate change in the arctic area of Norway.* WIT Transactions on Ecology and the Environment, Vol 228, Water pollution XIV
    - Column test for tailings, 20 mm/week water for 15 weeks at four temperatures: 4°C, 10°C, 14°C, 18°C
    - Fe, Ni, Mn, Zn
    - Temperature had a significant impact on leaching
      - pH, salinity and TDS



Exposure Assessment

- Receptor characteristics
  - Heat – affects time indoor/outdoor
  - Food availability / food security
    - Availability (and access) of traditional foods
    - Food production

- Exposure variables
  - Example, dry periods can result in longer periods of soil re-suspension (Pb-blood levels)

Exposure Assessment

- FNFNES Study in Saskatchewan:
  - Chan, L. O. Receveur, M. Batal, T. Sadik, H. Schwartz, A. Ing, K. Fediuk and C. Tikhonov, 2018. *First Nations Food, Nutrition and Environment Study (FNFNES): Results from Saskatchewan (2015).* Ottawa: University of Ottawa.

Figure 34. Percent of First Nations adults in Saskatchewan that noticed any significant climate change in their traditional territory in the last 10 years (n=1042)

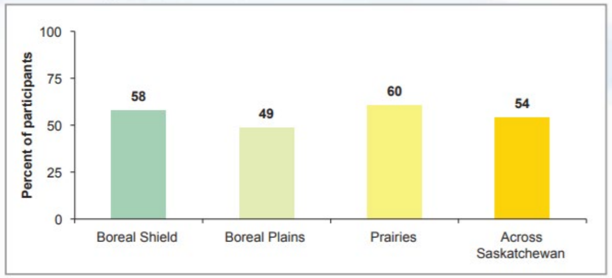
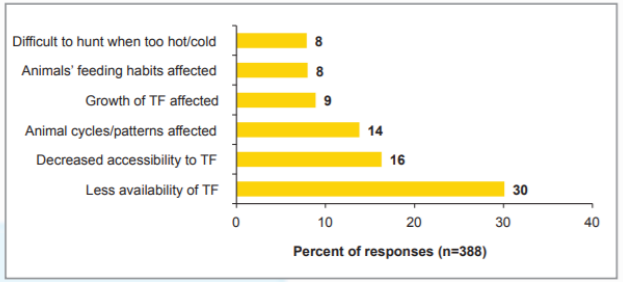


Figure 35. How climate change has affected traditional food availability among First Nations in Saskatchewan



*TF=traditional food

- Prince Albert Grand Council Elders' Forum on Climate Change:
  - Ermine, W., R. Nilson, D. Sauchyn, E. Sauve, R.Y. Smith, 2019. *Isi Askiwan-The state of the land: Prince Albert Grand Council Elders' Forum on Climate Change.* Final Research Project Report to the Prairie Adaptation Research Collaborative
- Traditional Knowledge can provide valuable insight
- Elders expressed concerns on water, wildlife (imbalance – changes in behaviour and new species), plants (due to heat and drought)
- Link between changes in natural world and social environments

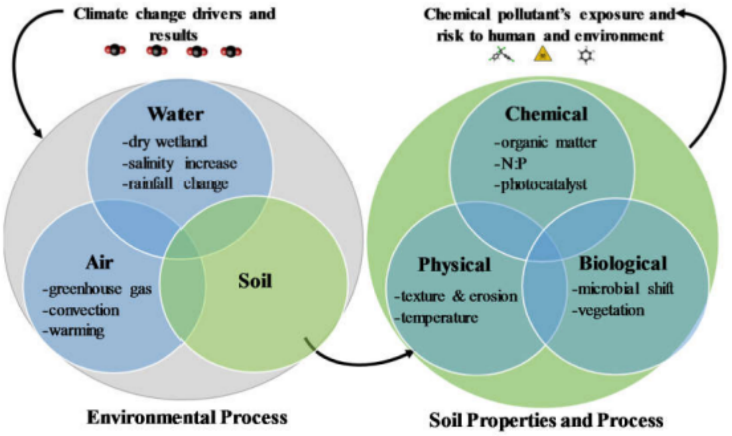
Exposure Assessment – Exposure Point Concentration (EPC)

- Abiotic environment
  - Increase degradation
  - Mobility of COPC in soil
    - Changes to organic carbon, pH, redox
  - Mobility of COPC in water
    - Increases in DOM
    - pH, redox (Fe)

  - Environmental modelling

Exposure Assessment – EPC (Soil)

- Climate change can affect soil properties:
  - Biswas, B., F. Qi, J.K. Biswas, A. Wijayawardena, M.A.I. Khan, and R. Naidu. 2018. *The fate of chemical pollutants with soil properties and processes in the climate change paradigm—a review.* Soil Systems 2(3). MDPI AG:1–20.

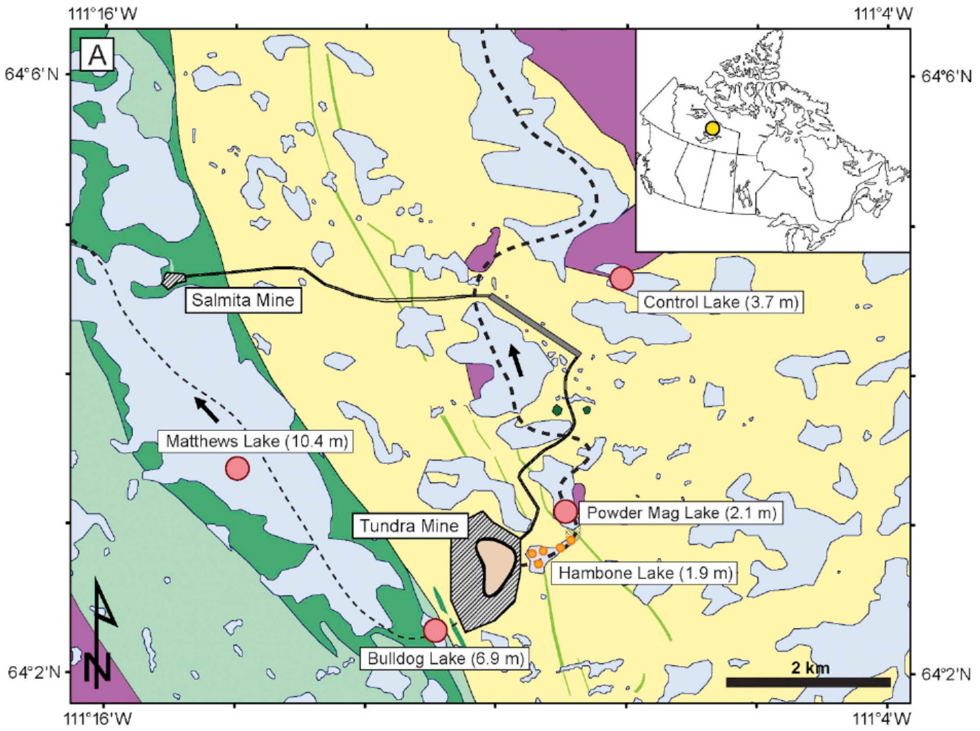


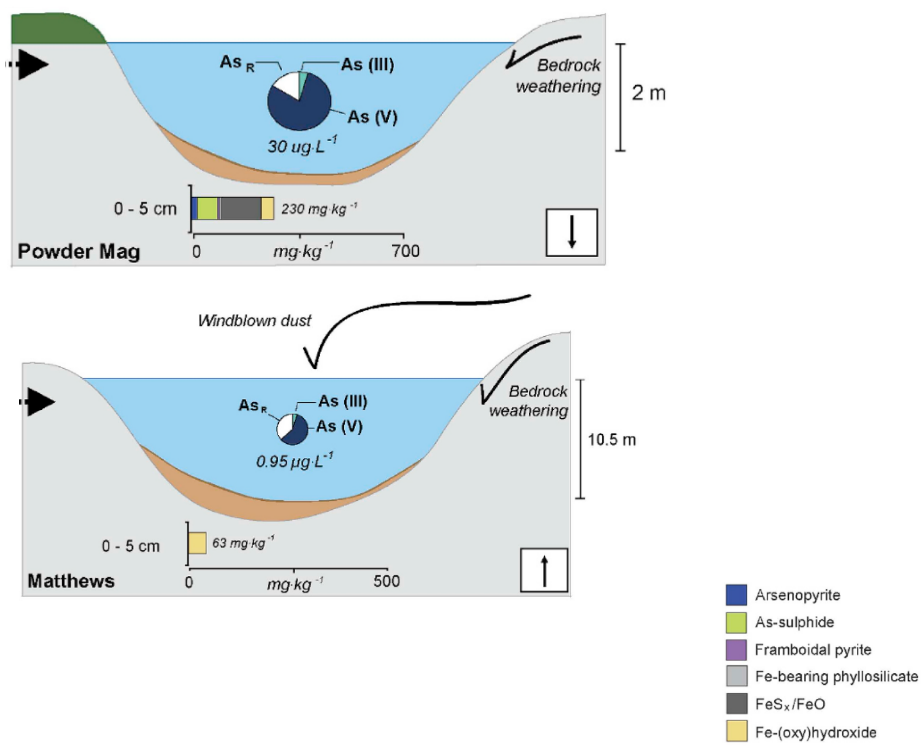
Scheme 1. The impact of climate change drivers on the soil dynamics, resulting in further risk to the exposure of chemical pollutants. The left circle indicates that climate changes and any factors responsible for climate changes influence soil properties and processes directly and via the atmosphere and hydrosphere. On the other hand, the right circle represents the physical, chemical, and biological processes involved in that soil system and the effects of these on the contaminants' fate and exposure.

Properties and Processes	Potential Impact of Climate Changes	Generalized Toxicological Results
pH	Warming: pH can drop due to formation of sulfate and rhizosphere acidification; pH can raise due to presence of calcite, dolomite or dissolution/weathering of gypsum and aluminosilicates Inundation: pH can raise (if pyrite is formed in the initially during inundation; pH can drop when flood recedes or water level drops due to dissolution of pyrite. Atmospheric deposition: N coupling with acid species increase soil acidity	Soil acidification could increase desorption of heavy metal(loid)s from their mineral-bound complex or favor re-mobilization
Temperature	Global warming: Increase of soil temperature; Degradation of SOC increases/more labile fractions to microorganisms; microbial feedback to temperature might be positive	More bioavailability of chemical pollutants; Biodegradation of organic pollutants might increase; Dissolution of metals from its substrate
SOC	Warming: Degradation of SOC increases/both persistent and labile fractions are vulnerable Erosion: Loss of SOC from soil	More bioavailability of chemical pollutants Mobility of chemical pollutants
Moisture/rainfall	Water repellence: Growth of microorganism decreases; less vegetation Inundation: Anoxic environment in soil Extreme rainfall pattern: Soil inundation, surface runoff and salt imbalance in soil	Longer residence of pollutants Redox controls the mobility of chemical pollutants; mineral's dissolution can release toxic metals, such arsenic
N and P	Deposition of atmospheric N and load of P from land-use practice: Increase of N and P in soils; acidification of soil	(Im)mobilization of metals (e.g., Cd) in P-supplemented soils; nutrient pollution and surface runoff
Clay minerals	Erosion: Loss of surface soils Warming: Increase of soil temperature Intensity of light: Light penetration in soil is high	Clay-organic matter disintegration might release heavy metals; loss of clay could reduce microbial function in rhizosphere; partial photodegradation could result in a more toxic metabolite of organic pollutants and thus increased bioavailability of them
Other minerals (e.g., oxides)	Extreme rainfall pattern: Inundation of soils affects redox of soils Temperature: Increase of soil temperature	Redox controls the mobility of chemical pollutants; mineral's dissolution can release toxic metals, such as arsenic
Microorganisms, enzyme and plants	Warming: Microbial activity may increase but community structure changes GHG in soil: Community structure changes	Biodegradation of organic pollutants may be increased but the contaminant-specific microbial functions could be affected; plant uptake of metal(loid)s is affected due to climatic influence in rhizosphere

Exposure Assessment – EPC (Water)

- Environmental changes depend on chemistry and are complicated:
  - Miller, C.B., M.B. Parsons, H.E. Jamieson, G.T. Swindles, N.A. Nasser, and J.M. Galloway. 2019. *Lake-specific controls on the long-term stability of mining-related, legacy arsenic contamination and geochemical baselines in a changing northern environment, Tundra Mine, Northwest Territories, Canada.* Appl. Geochem, 109.



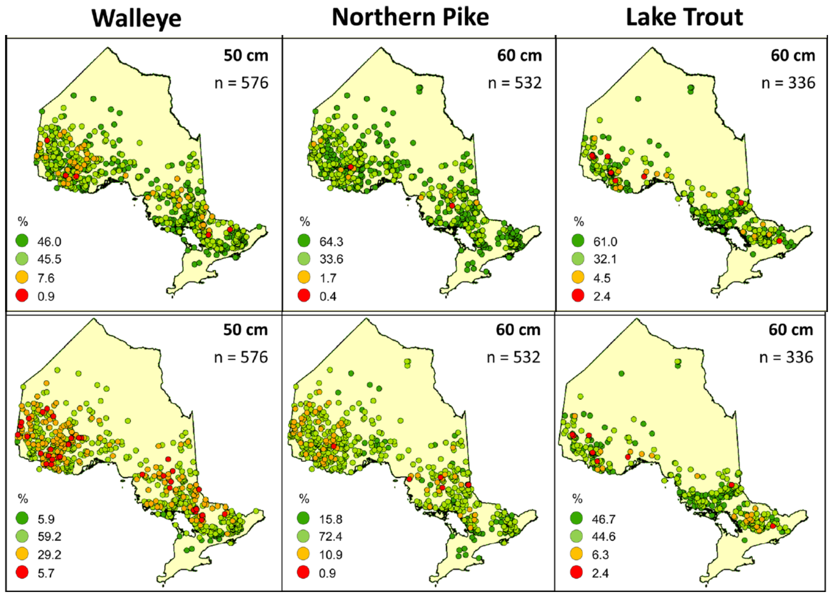


Exposure Assessment – EPC

- Biota
  - Aquatic biota (fish)
    - Increase methylation of Hg
    - Increase uptake
  - Plants
    - Altered bioavailability of metals
  - Environmental modelling: effects on bioaccumulation

Exposure Assessment – EPC

- Mercury in fish
  - Gandhi, N., S.P. Bhavsar, R.W.K. Tang, and G.B. Arhonditsis. 2015. *Projecting fish mercury levels in the province of Ontario, Canada and the implications for fish and human health.* Environmental Science and Technology 49. pp 14494-14502



2000-2012

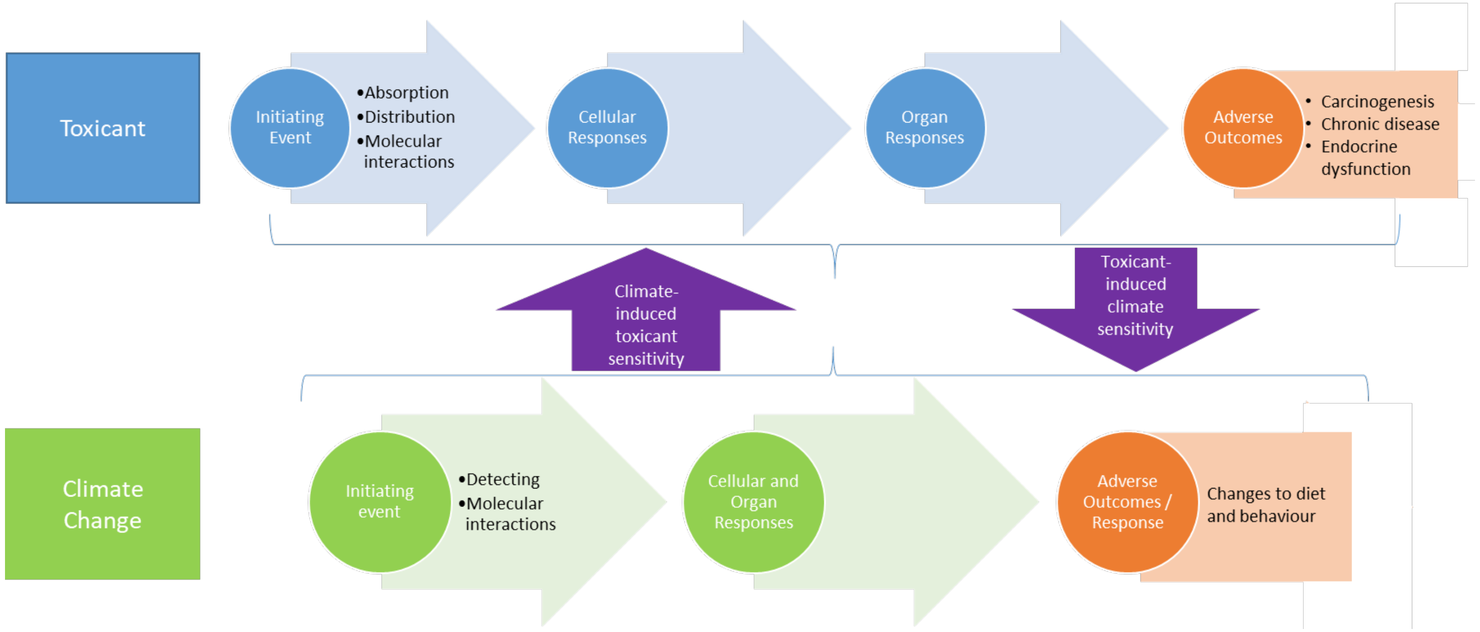
2050

  - Chen, M.M., L. Lopez, S.P. Bhavsar, and S. Sharma. 2018. *What's hot about mercury? Examining the influence of climate on mercury levels in Ontario top predator fishes.* Environmental Research 162(April). pp 63–73

- Hg in fish decreased during 1970-1992 due to emission controls, have been increasing in recent period
- Multiple linear regression for 2 native cool water and 2 warm water fish
- Local weather important for smallmouth bass and walleye
- Large-scale climate important for walleye and largemouth bass

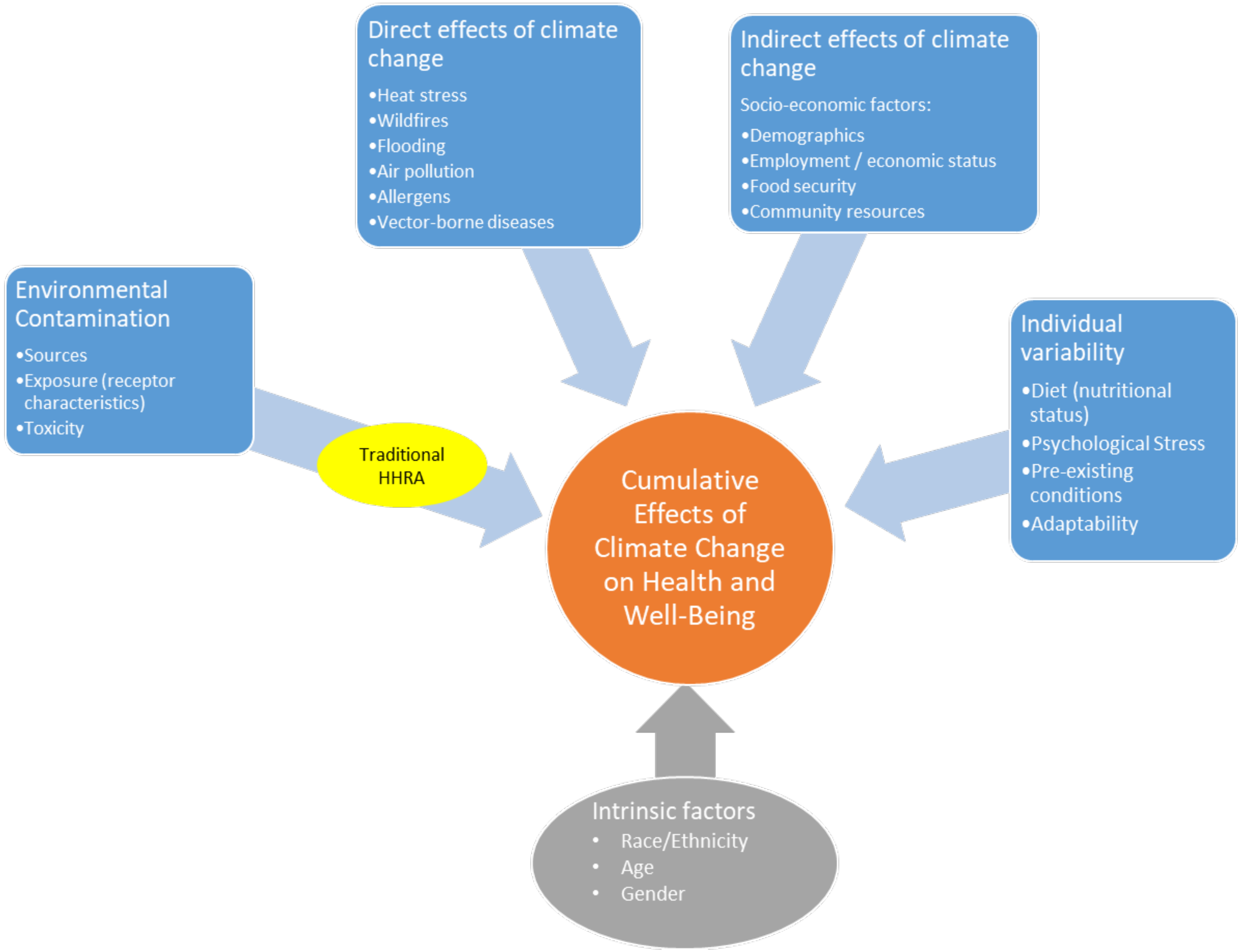
Toxicity Assessment

- Limited information on climate change effects on toxicity
  - Ventilatory intake of airborne toxicants is predicted to increase
  - Cutaneous absorption of organic chemicals enhanced under heat stress
  - In general, in vivo toxicity is exacerbated with rising body temperature
- Combined effects of chemical exposure and climate change



Risk Characterization

- Cumulative risk
- Food and water security
- Risk perception
- Management of contaminated material



Summary

- Effects of climate change on HHRA are complex and can influence every component of an HHRA
  - Inter-related
  - Site-specific
- Climate change will likely lead to more variable COPC concentrations in the environment
- Examination of the effects of climate change can be conducted within an HHRA
  - Important modelling parameters: temperature (air, soil), precipitation, soil moisture, Kd, bioaccumulation

Knowledge Gaps

- Climate change events and processes are complex and understanding is still developing
- Develop (and validate) models for all chemicals
- Effect of climate change on the dose-response is not known
- Interactions or combined effects
- Methodology to integrate the direct and indirect effects of climate change in the HHRA

Thank-you

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