Summary

What is mercury/methylmercury and what are its properties and potential harmful effects on the arctic.

Mercury (Hg) is a toxic heavy metal that changes into various chemical forms through geochemical processes. It is an element that occurs naturally in the environment but with industrialization, humans have altered its cycle by adding more mercury in the water, air, and soil. The gaseous form of mercury is quite stable allowing it to be transported from industrialized countries who combust a lot of fossil fuels such as China, the USA and, India. As a result, the mercury is transported by prevailing winds into the arctic.

Methylmercury (MeHg) is a form of mercury that is especially toxic to humans because it can easily absorb within the human body. Methylmercury is a result of the biogeochemical abiotic processes that occur within the air, snow, sediment, and water. It is harmful to humans because it bio-accumulates in the food web which is a cause of alarm to Inuit. Traditional country foods can consist of animals that are high on the trophic levels (such as polar bear, whales, and seals) which could expose Inuit to higher levels of Methylmercury.

Climate change is of special concern in terms of methylmercury for a number of reasons. The first is that with increasing temperatures, the melting permafrost, and increased precipitation probably will increase the amount of Hg and dissolved organic matter into watersheds which will facilitate methylation that occurs in sediments. The resulting MeHg will be transported through rivers into the marine ecosystem where it will enter the marine food web. As well, there will be a longer periods of ice-free seasons and permafrost melt which will prolong the season in which methylation can occur. Climate change can also affect the diet of animals within the arctic food web. This dietary shift will expose animals to different foods resulting in changes of their MeHg concentrations. Lastly, climate change is projected to increase the productivity of marine ecosystems which would allow lower trophic organisms (plankton) to absorb more MeHg than usual which could lead to higher bio-accumulation in the higher trophic levels (polar bears).

Chetelat, J. et al. (n.d.). Sources, Processes and Pathways. In *CACAR III Hg*.

BOX 2.3 Some recent observations of a changing environment in the Canadian Arctic*

Air Temperature: Mean annual air temperatures increased by 0.8–2.2°C from 1948 to 2005 in different Arctic regions, with the greatest warming occurring in the western Arctic (Yukon and Mackenzie District). Trends were strongest in the winter and spring when, for example, the average winter temperature in the Yukon warmed by 4.5°C.

Precipitation: Total annual precipitation increased 16–25% from 1948 to 2005 in more northerly Arctic tundra and mountain regions, primarily in Nunavut. Trends were strongest in fall, winter, and spring. The western Arctic had small, insignificant increases (2–5%) during the same time period.

Glacier Cover: Glaciers in the Canadian Arctic have retreated during the 20th Century. In the Arctic Archipelago, the rate of ice loss was 25 $km^3 y^{-1}$ for the period of 1995 to 2000. Greater release of fresh water has occurred from glacier melting in the Yukon.

Snow Cover: The duration of annual snow cover has decreased by about 20 days in both the eastern and western Canadian Arctic since 1950.

Lake and River Ice: Freeze-up and break-up dates for lake and river ice are shifting towards a longer open-water season. Historical records from 1856 to 1995 indicate an earlier break-up by 6.5 days per century and a later freeze-up by 5.8 days per century for lakes and rivers in the Northern Hemisphere (Magnuson et al. 2000). Limited observations are available for the Canadian Arctic, but they are consistent with these trends. The Mackenzie River showed a later freeze-up by 6.1 days from the late 19th to the late 20th Century (Magnuson et al. 2000).

Sea Ice: The extent of sea ice in the Arctic Ocean during late summer decreased by 11% per decade between 1979 and 2009 (NSIDC 2009).

Permafrost: The active layer of permafrost warmed and deepened in recent decades, with considerable variation among regions. Shallow permafrost temperatures in the High Arctic increased by 0.3–0.5°C per decade near the end of the 20th Century, while those in the western Arctic increased from 0–1°C.

* Unless otherwise referenced, information was summarized from the Federal Government report *From Impacts to Adaptation: Canada in a Changing Climate 2007* (Lemmen et al. 2008).

Assessments/Calls for future research/Referring from known knowledge/Recommendations

AMAP, 2009. AMAP Assessment 2009: Human Health in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv+254 pp. *Possible impact of climate change on Contaminants in the arctic.* Pg. 11-1

As the title suggests, it must be stressed that this publication is making possible predictions by looking at the knowledge of climate change and how methylmercury would affect the environment. The publication mentions how warming air temperatures at lower latitudes will increase the volatilization of mercury and facilitate air transport into the Arctic. The implications of climate change can increase precipitation which can easily scavenge airborne mercury. It is here that the mercury can undergo methylation and enters the trophic web at the same time solar radiation and rising temperatures are increasing productivity. It is known that methylation increases as the temperature increases. After the process of methylation, the methylmercury can be transported into runoff and into distant marine ecosystems and make its way into food webs.

Chatelat, J., et al. (2014, June 14). Special issue on Mercury in Canada's North: Summery and recommendations for future research. *Science of the Total Environment,* 261. Retrieved from www.elsevier.com/locate/scitotenv.

In this summary and recommendation, different aspects of mercury in the north are addressed and also explain which areas should be researched. In the section titled Biogeochemical Cycling of Mercury, it outlines how production of MeHg occurs in the water column of the Arctic Ocean and is an important site for the methylation of mercury. Arctic marine waters are also a substantial source of gaseous mercury to the atmosphere during the ice free season. It goes on to explain that further research is needed to better understand the biogeochemical processes and mechanistic understanding of mercury fluxes between air and various surfaces and its entry into the food web. In the section titled Climate Change, it explains that environmental change is altering the cycling and bioaccumulation of mercury in the food web structure. Climate warming may also help to mobilize mercury leading to an increase in concentration in fish and other biota (such as seen in the increased exposure of fish in the Mackenzie River). Changes in the food web due to climate change may also be affecting the bioaccumulation of mercury through dietary shifts and changes. However, more research is needed to help better understand these connections between climate change and the mercury cycle to better understand this phenomenon.

Gamberg, M., et al. (2014, May 24). Mercury in the Canadian Arctic Terrestrial Environment. *Science of the Total Environment*.

The purpose of this particular paper is to assess the state of science on Hg in terrestrial environments of the Canadian Arctic. In terms of MeHg, it goes on to say that concentrations of MeHg measured in the Arctic sea water and emission estimates based on flux measurements suggest that areas of the open ocean could be a relevant source to the atmosphere. It also goes on to say that water logged terrestrial soils are potential sites for MeHg production in the arctic. This is because in temperate environments, wetlands can be a major source of MeHg.

Macdonald, R. W., & Loseto, L. L. (2010, January 16). Are Arctic Ocean ecosystems exceptionally vulnerable to global emissions of mercury? A call for emphasised research on methylation and the consequences of climate change. *CRISO PUBLISHING*. Retrieved from www.publish.csiro.au/journals/env.

This article calls for further research into the processes that lead to MeHg production and bio-magnification Arctic Oceans. It outlines firstly that the Arctic oceans are especially vulnerable to climate change as well as the methylation of mercury. It then goes on to explain different processes such as the importance of post-depositional processes within the Arctic, mercury deposition onto and entry into the upper ocean, the methylation in sediments, transformation and delivery of Hg from terrestrial and freshwater systems, and transformations with the Arctic Ocean water column. The article concludes with the research question as to whether or not Hg recently deposited from the atmosphere is especially prone to methylation and biological uptake. The future research should focus on the ice-ocean interface that permits the entry of Hg into food webs, methylation in sediments and subsequent entry into food webs, inputs of mercury/methylmercury from river and costal erosion into food webs, production of MeHg within the Arctic's water columns, and the removal of Hg from the surface of the interior Arctic Ocean by vertical flux.

Stern, G. A., et al. (2011, November 21). How does climate change influence Arctic mercury? *Science of the Total Environment,* 30-31.

In this particular article, it outlines how methylmercury could impact the Arctic from gaining insight to research done in lower latitudes. Firstly, it says that higher temperatures often promote sedimentary Hg methylation. Secondly the melting of permafrost can also put more dissolved organic matter, nutrients, and Hg into watersheds in the arctic which can deliver it to sights were methylation occurs. With that said, "Arctic lakes with wetlands in their catchments would therefore be expected in general to exhibit increased concentrations of MeHg in lake water compared to those without wetlands." Thirdly, the increasing temperatures due to climate change would extend the period of ice-free oceans as well as an accelerated rate of melting permafrost into watersheds. This could lead to a longer season in which methylation occurs. Lastly, photochemical demethylation can also be affected by climate change. If more dissolved organic matter is introduced into the ecosystem as a result of climate change, this could protect the existing MeHg in water bodies against photo-demethylation. Considering this, all these factors can elevate the levels of methylmercury in biota affecting bioaccumulation in the food web.

<u>Experiments and Studies</u>

Braune, B. M., et al.(2014, November). Changes in Food Web Structure Alter Trends of Mercury Uptake at Two Seabird Colonies in the Canadian Arctic. *Envirnomental Science & Technology*. Retrieved from pubs.acs.org/est.

This study was to monitor diet and environmental contaminants in two thick-billed murre colonies in the Eastern Canadian Arctic. What was examined was how a shift in their diet's trophic position may affect their exposure to mercury. In the article's introduction, it is shown that there is some evidence that climate change is affecting biogeochemical cycles of many environmental contaminants in the arctic including Hg. In the conclusion it states that, "…other factors must be influencing concentrations of Hg at the base of the marine food web in the Canadian high Arctic, including changes in Hg decomposition, flux ratios, as well as changes in Hg bioavailability (i.e. methylation/demethylation processes) related to climate change and diminishing ice cover. (Braune et al., 2014, pg. E) It also goes on to say that, "Climate change has clearly already altered the structure and dynamics of food webs in the arctic and future impacts on contaminant and exposure pathways are inevitable." (Braune et al., 2014 pg. E)

Choi, A. L., & E. (2009, March). Methylmercuy Exposure and adverse Cardiovascular Effects in Faroese Whaling Men. Environmental Health Perspectives. Retrieved from JSTOR.

The goal of this study was to measure the effects of MeHg exposure in Faroese whaling men. The clinical study of male members was done because their diet exhibits a wide range of MeHg due to their diet of pilot whale meat as well as other types of seafood that contains lower levels of MeHg. The study concluded that highly increased MeHg exposure supports the notion that MeHg from seafood may promote the development of cardiovascular disease.

Evans, M., et al. (2013, October). Mercury trends in Predatory Fish in Slave Lake: The Influence of Temperature and Other Climate Drivers. *Environmental Science & Technology*. Retrieved from pubs.acs.org/est.

In this study, temperature and other climate drivers were used to measure mercury trends in predatory fish in the Great Slave Lake. Although the study found no evidence that their data trends were directly driven by increasing temperatures, the article did have something to say about Canada's rapid global warming rate and its relation to Hg emissions and cycling. It explains that, "Warming can also affect other aspects of local climate, potentially affecting Hg trends. Wind speeds are decreasing while precipitation trends are more variable. Precipitation affects wet deposition rates and hence the delivery of Hg to watershed and lake surfaces. Wind speed has many effects including: Hg dry deposition and evasion rates; thermal stratification and water mixing; and Hg methylation rates in the particulate-rich thermocline of the stratified water column and the sediment-water interface." (Evans et al., 2013, pg. A)

Verta, M., et al. (2010, May 6). Climate induced thermocline change has an effect on the methylmercury cycle in small boreal lakes. *Science of the Total Envrionment*, Conclusion.

In this experiment, the stratification pattern of a thermocline (a thin but distinct layer in a body of water in which temperature changes more rapidly than the layers above and below it) of a small boreal lake in Finland was manipulated to study the impact on the lake's mercury chemistry. In the article's conclusion, it states "…results support the hypothesis that possible oxygen related changes caused by climate change are more important than possible temperature changes in this type of small lakes with regularly occurring oxygen deficiency in hypolimnion. The response of MeHg cycle to climate change will probably be highly dependent on lake characteristics and stratification pattern." (Verta et al., 2010, Conclusion)

Ongoing studies

Chetlelat J. et al., A latitudical Investigation of Ecosystem Sensitivity to Methylmercury Bioaccumlation in Arctic Fresh Waters. http://www.science.gc.ca/default.asp?lang=En&n=ED7D11AF-1&offset=2&toc=show

Drevnick P., Influence of Climate Warming on Mercury Dynamics in High Arctic Lakes. http://www.science.gc.ca/default.asp?lang=En&n=ED7D11AF-1&offset=3&toc=show

Sheldon T., Impacts of Global Change and Industry on Methylmercury Exposures and Inuit Health. http://www.science.gc.ca/default.asp?lang=En&n=F2F84BB1-1&offset=8&toc=show