MEDWIN PUBLISHERS
Committed to create value for Researchers

Advances in Clinical Toxicology

Climate Change, One Health and Mercury

Duffy LK [1]*, Vertigan T[1], Dainowski B[1], Dunlap K[1,2] and Hirons AC[3]

[1]Department of Chemistry and Biochemistry, University of Alaska Fairbanks, USA

[2]Department of Veterinary Medicine, University of Alaska Fairbanks, USA

[3]Halmos College of Natural Sciences and Oceanography, Nova Southeastern University, USA

Commentary

Volume 2 Issue 1

Received Date: April 27, 2017

Published Date: June 27, 2017

***Corresponding author:** Lawrence K Duffy, Department of Chemistry and Biochemistry, University of Alaska Fairbanks, Fairbanks, AK 99775-6160, USA, Tel: 907-474-7525; E-mail: lkduffy@alaska.edu

Abstract

Climate change is occurring on both regional and global scales. The use and global distribution of toxic metals is increasing and affecting environmental, animal and human health as a result of air, water and food contamination. Mercury (Hg) in major forms Hg°, Hg^{2+} and methyl mercury (CH_3Hg^+) are increasingly available around the globe. Both metal and organic contaminants are impacting the health of all species on the planet. Mercury is an example of a metal that can cause or aggravate a disease state, for example, diabetes. Habitat stewardship is needed to maintain a healthy system, and selecting a keystone species as a bio indicator to monitor changes in contaminant levels over time and space is essential. Mercury can be used to monitor the flow of toxics through the food system. The structural organization of food webs and their sensitivity to disturbances are relevant to predicting the fate of Hg bioavailability related to climate change. Hg needs to be monitored across many ecosystems because it impacts not only human health but also the health of the plants and animals. Monitoring studies are needed to identify changes related to climate change. Increased precipitation and sea level rise will result in greater mercury mobility into the coastal and terrestrial food webs.

Keywords: Toxicology; Mercury; Climate Change; One Health; Bioindicator; Environmental monitoring

Abbreviations: DM: Diabetes Mellitus; CVD: Cardiovascular Disease; MeHg: Methylmercury; ROS: Reactive Oxygen Species; Hg: Mercury

Introduction

Climate change will have an impact on global environmental health and many regard climate change as a major global challenge to reducing disease [1-3]. Disease is part of the concept of health which is broadly defined as a state of dynamic balance in which an individual's or group's capacity to cope with the circumstances of living is at an optimal level. The freedom from disease or the risk of contracting one is only part of the modern concept of health, which involves complete physical, mental and social wellbeing [4]. The causes of human disease are varied and result from a combination of environmental, physiological, genetic, lifestyle, and socioeconomic factors acting over the lifetime of an individual. A changing environment is a factor in the initiation or spread of disease [4]. Recent research demonstrates the importance of socioeconomic factors in producing disease, and the recognition that these socioeconomic factors in combination with physical environments (light, temperature, seasonality and pollution) and biological phenomena, like pathogens, need to be understood in a holistic way.

The concept of a complex process is key to understanding environmental health for people inhabiting our planet, which includes marginal and extreme environments. Environmental health focuses on the interrelation between human wellbeing and the health of other species in an ecosystem. Water and air, contaminated with endocrine disruptors, toxic metals, and impacted by both biological terrorism and climate change, pose serious issues in a world in which human systems have become agents of change that affect rural and natural landscapes. Environmental wellbeing refers to the ability of the environment to support all life, including human economic and social systems. The efficiency and sustainability of environmental services, the cycling of materials and the maintenance of organismal balance are needed to reduce the incidence of disease. People have diverse cultural and social systems, but experience common health issues related to living in various environments with nutritional and seasonal stresses. A person or population's environment can shape the behaviors associated with poor health [5].

An example is Alaska Natives who were essentially free of Diabetes (DM) and Cardiovascular Disease, including stroke (CVD) many years ago [6]. The acculturation since that time involves the increasing consumption of specific store bought foods, often bought without guidance about effects on health. Studies have revealed that some of these foods contain large amounts of saturated and trans fats that are associated with Type 2 Diabetes and Cardiovascular Disease [5-7]. Alaska Natives who consume a diet based on fish and marine mammals are exposed to contaminants such as mercury, thus reducing the safety of their food supply [8]. Environmental change induced alterations in subsistence food consumption may also alter cultural identity. Culture and the environment are closely linked through food and subsistence in terms of how they reflect and represent cultural identity. Contaminants released by climate change affect food security in more than a physical sense. Because climate change, both physical exposure to contaminants and associated mental stress, can lead to an increase behavioral issues in Alaska Natives and other rural populations [4,5].

There is abundant evidence, acquired both via Western science and traditional knowledge, that indigenous peoples and ecosystems throughout the North are experiencing significant health impacts from the accumulation of metals, persistent organic pollutants, and rapid notable ecological, social and cultural impacts from changing climate and industrial development. The issue of climate impacts in the Arctic and sub-arctic raises the question of unequal distribution of burdens and benefits within more developed countries. Developing areas, like the North, stand in the center of two major forms of environmental injustice: 1) exposure to contaminants such as Hg [9,10] and 2) impacts of a changing climate [3,11-14] . These issues share a common feature with each other and with many past instances of environmental injustice, e.g. while negative impacts are experienced locally, the industrial source is distant [15].

One Health

This special closeness to the land, which is often lost in urban communities has led to a "One Health" approach to develop an interdisciplinary collaboration that focuses on the interactions between the physical environment, plants and animals and the human social system to understand the disease processes [16,17]. The health and survival of rural populations has traditionally depended on an extensive knowledge of the plant and animal species in their local environment. Seasonal harvest patterns have traditionally been a major community activity and are closely linked to a holistic culture and worldview. The local terrestrial, coastal and marine resources supply natural nutrients and phytochemicals for preventing disease and mitigating metabolic syndromes like diabetes. Understanding the concept of complex processes at both the local and global level is necessary to understanding the many factors in the toxicological process for people living in rural, marginal or polluted environments. One Health emphasizes the unity of an ecosystem [17]. Looking at a map or globe, it is easy to observe that populations living in proximity to marine and river ecosystems are at risk from sea level rise [18] and wet disposition [19,20] with Hg levels ranging from 10.2 to 22.3 ng/g.

River watersheds are among the most complex terrestrial features, performing valuable ecosystem functions and providing services for human society. Rivers are vital to both estuarine and aquatic biota and play important roles in biogeochemical cycles and physical processes. The functions of watersheds have been traditionally used as indicators for ecosystem health. River watersheds have a long history of human activity, but they have not been given the holistic and interdisciplinary research attention of the other ecosystems. Coupling ecosystem assessment with education creates resilience within the community. By monitoring key watershed indicators, for example, using wildlife, we can gain insights into regime shifting stresses such as increasing contaminants like Hg and industrial development [21-24]. Observations of impacts from a changing climate or mineral development can be assessed and inform adaptations to private, state, territorial, tribal and national ecosystem management approaches [25,26].

Heat stress, water cycle and quality and food security are other issues impacting human health [4]. Chemical exposure interferes with metabolic functions and homeostasis by interfering with enzymes or receptors [27]. Increased industrial development at low latitudes and global transport of air pollutants will lead to an increase in contaminant deposition. Legacy chemicals from early development efforts such as gold and silver mining and processing have been reported in the rural regions and their populations [25]. Industrial accidents related to development have led to immediate loss of wildlife and fish where populations remained depressed for over a decade [26,27]. Human psychological impacts were often reported.

Methylmercury and Toxicity

Methylmercury (MeHg) is an organic form of mercury that creates a lipophilic environmental contaminant that migrates up the food chain [26]. Bioaccumulation MeHg has been increasing in Northern latitudes due to global processes and climate change [26,28]. Studies have shown that MeHg causes cytotoxicity [9,27,29] in various cells and induced both apoptosis and the formation of reactive oxygen species (ROS) such as the superoxide anion and hydroxyl radicals [29,30]. Pancreatic islet cells are damaged by MeHg and high blood glucose levels can be induced by repeated doses. Toxic effects of methylmercury were also seen in 3T3-L1 adipocytes at exposures as low as 100ng/ml during stages of differentiation. Results also showed that VEGF secretion was elevated in adipocytes exposed to MeHg after differentiating into mature, fat-storing cells [31].

Mercury, Bio-indicator Species and Monitoring Exposure

Sentinel species, i.e. bioindicators, are usually animals that are higher trophic level predators and are keystone species in an ecosystem, which can be used to monitor risks to the ecosystem or humans [32,23]. Plants, fish [33,34] and lichens [15] with Hg in the range 20 ppb or greater have also been used as indicator species. As Burger reported, Pacific cod currently range around 0.25-.5 ppm Hg, while in the past its bone Hg ranged around 300 ppb to 500 ppb [33]. Sentinel species are useful in following the biomagnification process of mercury in both terrestrial and marine ecosystems [10,26,28,34-36].

Knowledge of the past can inform us on how bioindicator species might respond. An increase in mobility of mercury has the potential to be one of the impacts of climate change. Sea level changes and flooding events in high latitude coastal ecosystems could increase the bioavailability of contaminants such as mercury. Mercury concentrations have been used as an indicator of past exposure to heavy metals in ancient fish and animal samples [33]. Sea otters (Enhydra lutris) are common to the Gulf of Alaska's coastal areas and paleontological deposits of their bones have been identified as far back as the early Holocene [37]. In sea otters [37], current bone Hg levels are in the low (10 to 50 ppb) down from 200 to 400 ppm several thousands of years ago. Stable isotope ratios are used to reconstruct ancient food webs and help identify sea otter prey, which may have bioaccumulated high concentrations of the metal. Modern sea otters have δ^{13} C, δ^{15}N, and mercury values likely corresponding largely to a benthic diet. Conversely, higher δ^{15}N and mercury levels were found in ancient sea otter bones which may not only demonstrate higher trophic level foraging but also a large increase in the bioavailability of mercury in the coastal ecosystem. These large increases may be associated with rising sea level following the glacial maximum [38]. Paleontological remains of sea otters have been used to associate present day predicted climactic perturbations with past events like flooding of Beringia during the Holocene [33,37].

Red foxes can be used as a bioindicator species to monitor variation in mercury concentrations both within a species and between different species living in the local geophysical region or ecosystem [23,39]. Foxes can provide information on Hg biomagnification patterns and changes in exposure. Since foxes are omnivores like dogs [10], examining concentrations of Hg also provides feeding ecology data on the contaminant concentrations in other small mammals, birds and fish which they eat [34]. Fox bones and hair can also be used in forensic investigations [40]. Dogs along the Yukon River, Alaska, have Hg levels which varied from 2000ppb to 16000 ppb [32]. Foxes on the Kuskokwim River ranged around 1200 ppb [23,40].

Watersheds are closely linked ecosystems that are natural units of analysis and management [11], within which Hg can be mobilized and dispersed across the landscape, eventually entering the ocean. Rivers are a major component of socio-ecological systems which, in turn, have the potential to change because of chronic disturbances, i.e. the adaptive cycle [11]. Seven percent of the human population lives below the estimated future sea level, so coastal populations will be impacted by Hg when sea levels rise [18]. Some of the damage from sea level rise can be mitigated if there is a coordinated investment in developing a framework to monitor and understand the local cultural and environmental risks [41,42]. Importantly, Hg needs to be monitored in many locations throughout the world due to its impact on human health [8].

Conclusion

The structural organization of food webs and their sensitivity to disturbances are relevant to our ability to predict the fate of Hg bioavailability related to sea level rise on ecosystems. Climate change and movement of Hg by flooding can impact food systems. Hg needs to be monitored across many ecosystems due to its impact not only on human health, but also the health of the plants and animals that provide ecosystem services. Monitoring studies are needed to confirm preliminary observations related to the anthropological induced climate change leading to increased precipitation and sea level rise that will result increased mercury mobility into the coastal food web.

Acknowledgements

We appreciate the stimulating discussions and assistance from the following colleagues: Phil Loring, Peter McCroy, Maribeth Murray, S. Craig Gerlach, Arleigh Reynolds, Joanna Burger and Mary van Muelken. This research was supported in part by NSF DUE 0632397 and Alzheimer's Resource of Alaska.

References

1. McNutt M (2013) Climate Change Impacts. Science 341(6145): 435.

2. Ebi KL (2013) Is Climate change affecting Human Health? Environmental Research Letters 8: 031002(3)

3. Jonsson S, Andersson A, Nilsson MB, Skyllberg U, Lundberg E, et al. (2017) Terrestrial discharges mediate trophic shifts and enhance methylmercury accumulation in estuarine biota. Sci Adv 3(1): e1601239.

4. Duffy LK (2008) Diseases. In: Encyclopedia of Global Warming and Climate Change (Philander, SC, editor). Pp323-325.

5. De Palmer MT, Trahan LH, Eliza JM, Wagner AE (2015) The relationship between Diabetes self-efficacy and self-care in American Indians and Alaska Natives. Am Indian Alsk Native Ment Health Res 22(2): 1-22.

6. Murphy NJ, Schraer CD, Bulkow LR, Boyko EJ, Lanier AP (1992) Diabetes mellitus in Alaskan Yup'ik Eskimos and Athabascan Indians after 25 yr. Diabetes Care 15(10): 1390-1392.

7. Ebberson SO, Kennish J, Ebbesson L, Go O, Yeh J (1999) Diabetes is related to fatty acid imbalance in Eskimos. International Journal of Circumpolar Health 58(2): 108-119.

8. Burger J, Gochfeld M (2007) Risk to consumers from mercury in Pacific cod (Gadus microcephalus) from the Aleutians: fish age and size effects. Environ Res 105(2): 276-284.

9. Kim K, Kabir E, Jahan SA (2016) A review on the distribution of Hg in the environment and its human health impacts. J Hazard Mater 306: 376-385.

10. Duffy LK, Dunlap KL, Reynolds A, Gerlach SC (2013) Sled dogs as indicators of climate change and resultant contaminant fate and transport along the Yukon River. Int J Circumpolar Health Suppl 1: 508-510.

11. Tamabayeva D, Duffy LK, Loring PA, Barnes D (2013) Mitigation history of the industrial Hg contamination in the Nura River watershed of the Republic of Kazakhstan: Evolution of an Adaptive Management Approach. Environ Manage Sustain Develop 2: 187-194.

12. Loring PA, Duffy LK, Murray MS (2010) A risk benefit-analysis of wild fish consumption for various species in Alaska reveals shortcomings in data and monitoring needs. Sci Total Environ 408(20): 4532-4541.

13. Stern G, MacDonald RW, Outridge PM, Zdanowicz C, Wilson S, et al. (2011) How does climate change

influence Arctic mercury? Sci Total Environ 414: 22-42.

14. Douglas TA, Loseto LL, MacDonald RW, Outridge PM, Dommerque A, et al. (2012) The fate of Hg in Arctic terrestrial and aquatic ecosystems, a review. Environmental chemistry 9(4): 321-355.

15. Lokken JA, Finstad GL, Dunlap KL, Duffy LK (2009) Mercury in lichens and reindeer hair from Alaska: 2005-2007 pilot survey. Polar Record 45(4): 368-374.

16. Duffy LK (2011) Exposure Assessment. In Green Series: Green Business (Cohen, N, editor) pp: 250-253 SAGE Press, Thousand Oaks, CA.

17. Phillip RB (2013) Ecosystems and Human Health: Toxicology and Environmental Hazards. Boca Raton. CRC Press

18. Marzeion B, Levermann A (2014) Loss of cultural world heritage and currently inhabited places to sea-level rise. Environ Res Lett 9: 7.

19. Weiss-Penzias PS, Gay DA, Brigham ME, Parsons MT, Gustin MS, et al. (2016) Trends in mercury wet deposition and mercury air concentrations across the U.S. and Canada. Science of the Total Environment 568: 546-555.

20. White EM, Keeler GJ, Landis MS (2009) Spatial variability of mercury wet deposition in Eastern Ohio: Summertime meterological case study analysis of local source influences. Environ Sci Technol 43 (13): 4946–4953.

21. Sleeman JM (2013) Has the time come for big science in wildlife health? Eco Health 10:335-338.

22. Dunlap KL, Reynolds AJ, Gerlach SC, Duffy LK (2011) Mercury interferes with endogenous antioxidant level in Yukon River subsistence-fed sled dogs. Environ Res Lett 6: 1-5.

23. Dainowski BH, Duffy LK, McIntyre J, Jones P (2015) Hair and bone as predictors of tissular mercury concentrations in the Western Alaska red fox Vulpes vulpes. Sci Total Environ 518-519: 526-533.

24. Stokes PM, Wren CD (1987) Bioaccumulation of Hg by aquatic biota in hydroelectric reservoirs: a review and consideration of mechanisms. Lead, Mercury, Cadmium and Arsenic in the Environment 255-257.

25. Loring PA, Duffy LK (2011) Managing environmental risks: the benefits of a place-based approach. Rural Remote Health 11(3): 1800-1808.

26. Burger J, Gochfield M, Powers CW, Niles L, Zappalorti R, et al. (2013) Habitat protection for sensitive species: Balancing species requirements and human constraints using bioindicators as examples. Nat Sci 5(5): 50-62.

27. Newman MC (2015) Fundamentals of Ecotoxicology: the science of pollution (4th edition). CRC Press. pp: 654.

28. Boerleider RZ, Roeleveld N, Scheepers PT (2017) Human biological monitoring of mercury for exposure assessment. AIMS Environmental Science 4(2): 251-276.

29. Wu X, Cobbina SJ, Mao G, Xu H, Zhang L, et al. (2016) A review of toxicity and mechanisms of individual and mixtures of heavy metals in the environment. Environ Sci Pollut Res Int 23(9): 8244-8259.

30. Chen YW, Huang CF, Tsai KS, Yang RS, Yen CC, et al. (2006) Methylmercury induces pancreatic Beta-cell Apoptosis. Chem Res Toxical 19: 1080-1083.

31. Vertigan T, Dunlap K, Reynolds A, Duffy L (2017) Effects of Methylmercury exposure in 3T3- L1 Adipocytes. AIMS Environmental Science 4(1): 94-111.

32. Dunlap KL, Reynolds AJ, Bowers PM, Duffy LK (2007) Hair analysis in sled dogs illustrates linkage of mercury exposure along the Yukon River with human subsistence food system. Sci Total Environ 385(1-3): 80-85.

33. Murray MS, McRoy CP, Duffy LK, Hiron AC, Trocine RP, et al. (2015) Biogeochemical analysis of ancient Pacific Cod bone suggests Hg bioaccumulation was linked to paleo sea level rise and climate change. Front Environ Sci 3: 8.

34. Dietz R, Sonne C, Bosu N, Birgit B, Todd OH (2013) What are the toxicological effects of mercury in Arctic Biota? Science of the Total Environment 443: 775-790.

35. Bodkin J, Ballachey BE, Coeth HA, Esslinger G, kloecher K, et al. (2012) Long-term effects of the 'Exxon Valdez' oil spill: Sea otter foraging in the

intertidal as a pathway of exposure to lingering oil. Marine Ecology Progress Series 447: 273-287.

36. Blukacz-Richards EA, Visha A, Graham ML, McGoldrick DL, de Solla SR, et al. (2017) Mercury levels in herring gulls and fish: 42 years of spatio-temporal trends in the Great Lakes, Chemosphere 172: 476-487.

37. Hirons A, Duffy L (2017) Mercury in Ancient Sea Otters: Complexity in Climate Change Alaska Marine Science Symposium, Anchorage, AK.

38. Brinkmann L, Rasmussen JB (2010) High levels of Hg in biota of a new prairie irrigation reservoir with a simplified food web in southern Alberta, Canada. Hyrobiologia 641(1): 11-21.

39. Bocharova N, Treu G, Czirják GÁ, Krone O, Stefanski V, et al. (2013) Correlates between Feeding Ecology and Mercury Levels in Historical and Modern Arctic Foxes (Vulpes lagopus). PLoS One 8(5): e60879.

40. Dainowski BH (2017) An innovative stable isotope in internal tissues of wildlife in a changing western Alaska Environment. PhD thesis, University of Alaska Fairbanks.

41. Burger J, Gochfeld M, Kosson D, Powers CW, Friedlander B, et al. (2005) Science, policy and stakeholders: developing a consensus science plan for Amchitka. Environ Manage 35(5): 557-568.

42. Yeakel JD, Dunne JA (2015) Modern Lessons from Ancient Food Webs. American Scientist 103: 188-195.

43. Boerleider RZ, Roeleveld N, Scheepers P (2017) Human biological monitoring of mercury for exposure assessment. AIMS Environmental Science 4(2): 251-276.