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Heavy metal bioaccumulation and histopathological alterations in wild Arctic hares (*Lepus arcticus*) inhabiting a former lead-zinc mine in the Canadian high Arctic: A preliminary study

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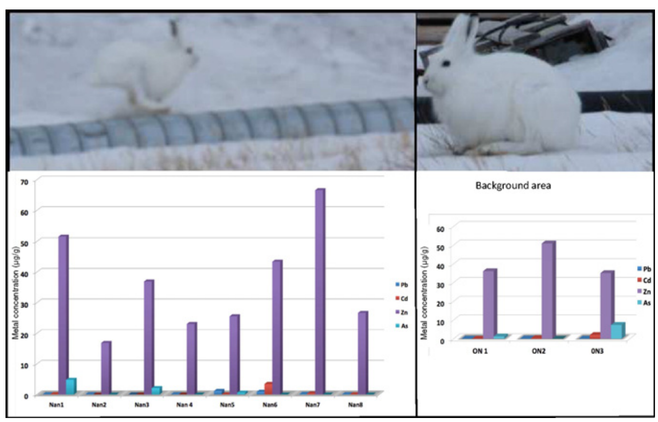
HIGHLIGHTS

- First assessment of metal-induced histological effects in Arctic hares from a mining area.
- Elevated levels of metals were noted in soils of the mine area compared to reference location.
- Tissue metal content in control and reference Arctic hares did not differ significantly.
- Case and control Arctic hares showed hepatic and renal lesions.

GRAPHICAL ABSTRACT



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ABSTRACT

A preliminary study was undertaken to determine post-mining baseline accumulation of selected trace metals, and histopathological alterations in free-living arctic hares (*Lepus arcticus*) inhabiting the vicinity of a former lead-zinc mine located on North Baffin Island in the Canadian High Arctic. Trace metal analysis included measurement of As, Cd, Fe, Pb and Zn in tissues, and histopathological assessment comprised of evaluation and scoring the severity of metal-induced hepatic and renal lesions. Metal contents in hepatic and renal tissues from hares from the mine area compared with the reference locations did not differ significantly suggesting that the animals are not uniformly exposed to background levels of metals in the environment. However, relatively higher accumulation pattern of Pb and Cd were noted in liver tissues of hare from the mine area compared to the background area, but did not induce increased lesions. Surface soils near the mine area contained relatively higher levels of trace metals (Zn > Mn > Pb > Cd > As) compared to reference soils, and with soil levels of Cd showing strong correlation with Cd accumulation in kidney tissues. Generally, both case and reference animals showed similar but varying severities of hepatic and renal lesions at the sublethal level, notably vascular congestion, occasional large

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[1] Note: Dr. Amuno's participation in this study was undertaken independently and apart from his work with the Nunavut Impact Review Board. The analysis and views expressed in the study remain solely those of the authors and do not constitute the views of the Nunavut Impact Review Board

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hepatocyte nuclei, binucleate hepatocytes, yellow-brown pigmentation in the cytoplasm of hepatocytes and clustering of lymphocytes. Only hares with relatively higher accumulation of Pb from the mine area showed evidence of renal edema and hemorrhage of the capsular surface. This study constitutes the first assessment of metal induced histopathological alterations in arctic hares exposed to a historical mining area in the high arctic.

1. Introduction

The Canadian arctic has attracted a lot of mining and exploration activities due to its natural geology known to host important economic minerals, such as gold, silver, nickel, iron and other base metals (Dewing et al., 2006; Bowes-Lyon et al., 2010). However, the changing global demands for mineral resources, and instability of the global mineral market, have consequently led to downsize, closure and eventual abandonment of several mining projects around the world, including in the arctic region. While the effects of closed and abandoned mines (collectively referred to as historical mining) have been analyzed in the context of socio-economic impacts, studies regarding their toxicological effects have not been fully studied against the backdrop of the environmental liabilities they introduce to the arctic environment. In order to address the potential ecological risks associated with historical mining activities, it is necessary to monitor quality of the natural environment in relation to legacy contaminants discharged from previous mining activities, and their effects on human health and wildlife (Koch et al., 2000; Bright et al., 1994). In the arctic environment for example, there is very limited empirical data regarding the toxicological impacts of historical mine waste residues on small mammal population. The absence of such bioaccumulation data, including general information regarding pathological status of small mammals have consequently led to uncertainty among indigenous population proximal to mines who still rely on certain species, particularly the arctic hare as an alternative food source when larger mammals are scarce (Department of Health, Government of Nunavut, 2013).

In previous arctic ecosystem studies, empirical data have mainly identified long-range transportation of airborne contaminants as the predominant route of wildlife exposure to pollutants (Ford et al., 1995; Martin et al., 2004; Bright et al., 1995); however, with growing industrial activities in the arctic, there is also increasing scholarly interests towards monitoring contamination due to mining and processing of ores (Dushenko et al., 1995; Elberling et al., 2003; Moiseenko and Kudryavtseva, 2001). In the Canadian high arctic or sub-arctic regions, studies specifically related to environmental monitoring of mine-related contaminants and their bioaccumulation in wildlife, have mostly focused on the marine environment (Lemly, 1994; Wagemann, 1989; Mudroch et al., 1989), with very limited information on terrestrial monitoring. Even where such terrestrial assessments have been undertaken, the resulting data are often focused on monitoring accumulation of contaminants in larger mammals such as caribou (Gamberg et al., 2005; Macdonald and Gunn, 2004) or in tundra vegetation and soils (Naeth and Wilkinson, 2008).

Small mammals can be utilized for monitoring the toxicological effects of contaminated sites, including mining areas and can serve as good bionidcator of environmental health given that they accumulate contaminants directly from soils, water and vegetation (Talmage and Walton, 1991; Ma, 1989; Shore and Douben, 1994; Ma et al., 1991; Wijnhoven et al., 2007). Additional studies have consequently shown that heavy metals can suppress the function of the immune system in a wide range of organisms, and increase the susceptibility of organisms to opportunistic parasites and diseases (Wayland et al., 2002; Sorvari et al., 2007; Fournier et al., 2000). Histopathological alterations can also be used as marker for assessing the effects of various pollutants on organisms and could provide additional information regarding the overall health status of wildlife population in the ecosystem (Damek-Poprawa and Sawicka-Kapusta, 2003; Au, 2004). Data regarding the contaminant burden and histological effects in small mammal population such as arctic hares are very limited, and has yet to be fully investigated in the context of environmental monitoring and assessment. Previous studies investigating impact of mining activities on wildlife in the arctic context have solely relied on measurement of contaminant levels in tissues as means to determine environmental effects (Quakenbush and Citta, 2009; O'Hara et al., 2003; Buhl and Hamilton, 1991; Wagemann, 1989). While this monitoring approach has provided useful scientific data with respect to exposure histories, and bioaccumulation trends, it does not explicitly identify whether contaminants has had toxic effects.

The purpose of this study is two-fold. The first is to determine the current levels of trace metals such as As, Cd, Fe, Pb and Zn in selected organ tissues of wild arctic hares inhabiting the vicinity of a former lead-zinc mine, and in a reference area located 30 kilometres (km) from the mine site. The second is to utilize histopathological markers to assess the extent and severities of alterations in selected organs (liver, kidney and testicles) of arctic hares. In this paper, the vicinity of the mine consist of the project development area, including footprint of the shipping terminal north of the mine site as well as the Nanisivik settlement area. The home range of arctic hares varies seasonally in winter and summer seasons, with previous studies showing that the home range of male hares is between 116 and 155 ha (ha), while that of females is from 52 to 69 ha (Best and Henry, 1994; and Hearn et al., 1987). The overall objective of this work is to compare extent of metal bioaccumulation, and tissue alterations in arctic hare population inhabiting the vicinity of the mine site, with those farther away from the Nanisivik site, to determine if significant differences exist between the two groups. The lead-zinc mine operated from 1976 to 2002, and generated several public concerns due to incidences of wind-blown tailings to the surrounding environment, and disposal of mine tailings containing Zn, Pb, Cd, Fe and As into adjacent lakes, which drained directly to the sea (Wagemann, 1989).

2. Materials and methods

Prior to field sampling, a Nunavut Research Licence, and Nunavut Wildlife Research Permit were obtained respectively from the Nunavut Research Institute, and Department of Environment-Government of Nunavut (GN), Canada. Through collaboration with the Ikajutit Hunters and Trappers Association, Arctic Bay, Nunavut (Canada), and pursuant to the requirement of the Wildlife Research Permit, a total of 11 adult wild arctic hares were captured for our study. Animals were trapped within and around the vicinity of the former Nanisivik lead-zinc mine area (Figs. 1 and 2), and euthanized similar to the procedures outlined in Pedersen and Lierhagen (2006). The community of Arctic Bay, an unindustrialized location with population of about 853 people (Department of Health-Government of Nunavut, 2013) was selected as the background area.

3. Background of study area and current status

The Nanisivik lead-zinc mine area is located 750 km north of the Arctic circle at an approximately latitude of 73° north, and proximal to the community of Arctic Bay, Nunavut, Canada (Lim, 2013). The Nanisivik deposit is a carbonate-hosted, zinc-lead sulfide zone occurring in dolostone of the society cliffs formation of middle Proterozoic age, with pyrite common throughout the deposit (Gait and Dumka, 1986).