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The interaction between bacterial abundance and selected pollutants concentration levels in an arctic catchment (southwest Spitsbergen, Svalbard)

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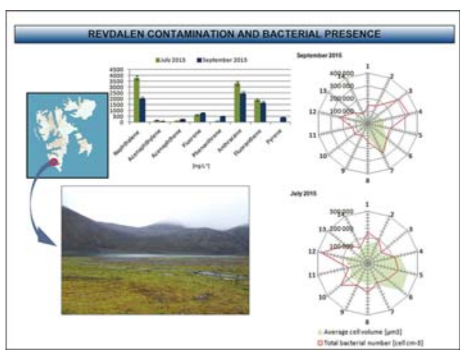
HIGHLIGHTS

- The Arctic is no longer considered as a highly pristine environment.
- The purpose of the research was to study interactions between pollutants and bacteria.
- Freshwater samples were manually collected from the Revelva catchment.
- The analytical procedures have been validated against certified reference materials.
- The biggest number of bacteria were detected at the estuary and in the Revvatnet lake.

GRAPHICAL ABSTRACT



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ABSTRACT

Persistent organic pollutants (POPs) have been a topic of interest in environmental sciences for >60 years. POPs in the Arctic have been investigated since the 1970s, when first atmospheric measurements revealed the presence of these pollutants in the polar regions. Major contaminant transport routes to the Arctic include atmospheric and oceanic transport, as well as inflow from rivers and sea ice. The sources of pollutants, such as industry, power generators, vehicle and ship exhausts, introduce the PAHs, phenols, formaldehyde or metals into the Arctic. Transport via sea currents, however, can take several years. The highest concentration levels of total PAHs were observed in two samples from the tributaries in July 2015 and were 1069 ng L^{-1} and 3141 ng L^{-1} and in September 2015, the highest concentrations were observed in samples collected from Revvatnet lake and were 978 ng L^{-1} and 1823 ng L^{-1}. The highest concentrations of trace elements in both months were 41 μg L^{-1} in the sample from the highest tributary (July 2015) and 79 μg L^{-1} in the same sample (September 2015). The purpose of this study was also to determine abundance of bacteria in the Arctic freshwater of different types. Microbes are omnipresent and represent diverse biological communities. In the freshwater ecosystems, microorganisms form the base of the food chain supporting higher trophic levels. Although microbes are generally thought to live in the warm regions of Earth, many of them develop in cold climates. In the Revelva catchment, the biggest number of bacteria were detected at the river estuary in July 2015 and at the sampling

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point located in the Revvatnet lake in September 2015. Generally, the bacterial abundance indices depended on nutrient levels to a small extent, showing the environment of the Revelva catchment not to be nutrient limited, which is in accordance with its rich biological life also in macroscale.

1. Introduction

The Arctic is no longer considered as a highly pristine environment, although the air, water, soil and sediment concentrations reveal considerably lower levels of contaminants as compared to those found in temperate regions (Kallenborn et al., 2012). Despite this, some characteristic features of the Arctic, e.g. low temperatures, snow precipitation, ice coverage, extended periods of darkness during winter, mean that is has the potential to accumulate certain globally transported contaminants including POPs (Hung et al., 2010).One of the most well-known hypotheses in global atmospheric transport of POPs is the process of global distillation, forcing contaminants out of the warmer regions (including temperate industrial areas) into the polar areas, resulting in a complex POP distribution cycle (Kallenborn et al., 2015). Under ambient temperature conditions, many contaminants have partitioning properties that would allow them to move from one environmental medium to another. Therefore, these chemicals tend also to vaporize at elevated ambient temperature and condense at lower air temperatures at higher latitudes (Kallenborn et al., 2015). In general, the air masses in the temperate zones strive for a temperature balance with the cold polar air masses. Due to low average annual temperature and the special seasonal daylight conditions in the polar regions, the deposition of persistent pollutants is favoured there (Kallenborn et al., 2012). Persistent organic pollutants (POPs) are toxic substances produced by industries or arising as a result of natural phenomena, and released to the environment. Within the environment, POPs are resistant to degradation and may be accumulated over long periods of time in liquid, solid or gas-phase reservoirs from which they enter food webs (Ma et al., 2016). Persistent anthropogenic pollutants can be transported via the atmosphere, ocean currents and rivers into the Arctic. After entering the polar environment, the chemicals are redistributed within the region by the same transport pathways, in addition to transpolar ice transport and the incorporation into the biological systems through accumulation in the food web. Each step along these transport and redistribution pathways to and within the Arctic is influenced by the current climate change due to its influence on adsorption processes, reactivity and accumulation processes (Kallenborn et al., 2015). The exchange of POPs between the Arctic reservoirs depends critically on physicochemical properties of a pollutant and environmental conditions. With respect to the redistribution of POPs, important intrinsic physicochemical properties including vapour pressure (P_A), Henry's Law constant (H), partition coefficients for octanol-water (K_{OW}), and partition coefficients for octanol-air (K_{OA}), and susceptibility to degradation or transformation (photolysis, hydrolysis, metabolism), provide kinetic controls on how long a chemical may remain in any given compartment. For example, rising temperatures will increase Henry's Law constant, promoting higher partitioning from water into air for POPs (Ma et al., 2016). The presence of every POP in the ambient environment of remote areas, such as the Arctic, shows the efficacy of atmospheric and oceanic transport to these remote regions from the temperate zones, where most of toxic substances have been released (Ma et al., 2016; Mackay and Wania, 1995). In addition to the POPs in the Arctic, there are also other chemical compounds including contaminants (e.g. metals, ions), which concentration levels are visible in polar environment. The knowledge of their concentration is a key element in the interpretation of the results for the presence of bacteria. Metals occur naturally in the environment and are present in the soil and rocks in many forms. They can be bound in organic and inorganic molecules or attached to particles in the air. Both, natural and anthropogenic processes have an impact on the changes occurring in the Arctic. Microorganisms depend on some metals as micronutrients but some forms of metals can be toxic for them, even in relatively small amounts (Kozak et al., 2016). Other contaminants that appear in the Arctic are phenols and formaldehyde. They should not be considered less harmful than polycyclic aromatic hydrocarbons or polychlorinated biphenyls. Besides anthropogenic sources, formaldehyde can be also emitted from the snowpack after polar sunrise (Sumner et al., 2002). The low annual average temperatures of the polar regions slow down the microbiological degradation of organic compounds to a minimum. That fact extends the lifetime of chemicals exponentially in the Arctic (Kallenborn et al., 2015).

Climate change is transforming ecosystems on an extraordinary scale, and at an extraordinary pace. As each species responds to its changing environment, its interactions with the physical world and the organisms around it change, too. It starts a cascade of impacts throughout the entire ecosystem. These impacts may include expansion of species into new areas, intermingling of formerly non-overlapping species and even species extinction. Rapid climate change in the Arctic has begun to affect the ecology of animals and plants throughout this polar region with impacts on species ranges, population dynamics and also food web interactions (Grebmeier et al., 2006). Despite this, little attention has been given to the impacts on the microorganisms living in the Arctic. Some of these organisms appear to be in a rapid decline, whereas others are shifting towards new states with implications for food webs and biogeochemical fluxes including pollutants emissions. Global warming leads to dwindling of the cryosphere, the ensemble of ice-containing environments on the Earth. The constant decline in annual sea ice is reducing the growing season for bacterial habitats that live in brine channels between the ice crystals and in the water column at the edge of the observed reduction in benthic respiration rates (Grebmeier et al., 2006). It may be expected that climate change will lead to the disappearance of many types of biota. In the Arctic, the number of freshwater reservoirs' is increasing. Melting sea ice combined with freshwater delivery from river inflows is affecting the physical characteristics of the Arctic Ocean by causing reductions in the salinity of the surface mixed layer, which, in turn, results in greater hydrodynamic stability of the water column. These changes have been accompanied by increased bacterial concentrations. Arctic climate change influence also freshwater bacterial ecosystems. Warmer water temperature, erosion and greater evaporation cause some polar lakes and ponds to dry up, which leads to the extinction of many bacterial communities. Furthermore, the bacterial communities inhabiting freshwater ecosystems have the potential to produce globally significant effluxes of greenhouse gases due to bacterial respiration and methanogenesis (Laurion et al., 2010). Finally, emission of POPs to the environment can have an impact on the bacteria living in the Arctic by modifying their local environment (physical aspect) and their nutrient sources and interactions in the food web (biotic aspect) (Boeuf et al. 2014).

The main purpose of the conducted research was to study the interactions between the pollutants and bacterial abundance. In particular, selected xenobiotics, such as PAHs, phenolic compounds and formaldehyde, were determined in an arctic catchment, as were the total number of bacteria, size and biomass. Statistical analysis has been applied to elaborate on their possible interactions.