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Bioaccumulation of hepatotoxins – A considerable risk in the Latvian environment

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ABSTRACT

The Gulf of Riga, river Daugava and several interconnected lakes around the City of Riga, Latvia, form a dynamic brackish-freshwater system favouring occurrence of toxic cyanobacteria. We examined bioaccumulation of microcystins and nodularin-R in aquatic organisms in Latvian lakes, the Gulf of Riga and west coast of open Baltic Sea in 2002–2007. The freshwater unionids accumulated toxins efficiently, followed by snails. In contrast, *Dreissena polymorpha* and most lake fishes (except roach) accumulated much less hepatotoxins. Significant nodularin-R concentrations were detected also in marine clams and flounders. No transfer of nodularin-R and microcystins between lake and brackish water systems took place. Lake mussels can transfer hepatotoxins to higher organisms, and also effectively remove toxins from the water column. Obvious health risks to aquatic organisms and humans are discussed.

1. Introduction

Cyanobacteria can produce a variety of bioactive compounds that affect aquatic organisms. Among these hepatotoxic microcystins (MCs) are the most common in freshwater environments, and are produced by several species of cyanobacteria of the genera *Microcystis*, *Planktothrix* and *Anabaena* (Sivonen and Jones, 1999). MCs are cyclic heptapeptides, occurring in more than 80 structural congeners of different toxicity (Dietrich and Hoeger, 2005). New MCs are still being discovered. An analogous pentapeptide hepatotoxin nodularin-R (NOD-R) is produced by the cyanobacterium *Nodularia spumigena* that occurs commonly in brackish waters (Ibelings and Chorus, 2007). In the liver, NOD-R and MCs inhibit the key regulatory enzymes: serine–threonine protein phosphatases (PPs) 1, 2A, and 3 that participate, e.g., in carbohydrate and lipid metabolism, regulation of apoptosis and cell divisions rates (Sipiä et al., 2002 and references therein). Baltic Sea cyanobacteria blooms consist of the non-toxic *Aphanizomenon*, the toxic *Nodularia spumigena* (Stal et al., 2003) and *Anabaena* (the latter is as a potential microcystin producer; Karlsson et al., 2005).

The territory of Latvia (64 589 km^2) is covered by 2256 natural lakes that are mostly small (<1 km^2) and shallow (70% are <5 m) (Klavins et al., 2002; Springe et al., 1999). Natural and anthropogenic eutrophication processes are characteristic for Latvia's inland waters. Runoffs of nutrients from the drainage area of lakes as well as recreational and fishing activities have increased in the 20th century, therefore intensive blooms of potentially toxic algae in eutrophic and hypertrophic lakes are observed every summer.

Riga is surrounded by a natural water system created by the rivers Daugava and Gauja, several lakes, and natural and artificial canals linking them to one another and to the Gulf of Riga. These conditions ensure water exchange through the river Daugava to lakes. Water is transported from the lakes via river Daugava to the Gulf of Riga, but due to the peculiar flow patterns and topographical features, water exchange in reverse direction can take place. During strong westerly winds events blowing from the Gulf of Riga, the sea level at the estuary of the river Daugava is rising, generating a backwater effect on the whole surface hydrodynamic system. Therefore, an increasing concentration of chloride ions in the lakes Lielais Baltezers, Mazais Baltezers and Kisezers are periodically observed (Springe et al., 1999).

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Summer phytoplankton in the Gulf of Riga mostly consists of nontoxic *Aphanizomenon flos-aquae* (dominance up to 41% of total phytoplankton biomass; Jurgensone et al., 2011). However, algal blooms of *M. aeruginosa* and *Anabaena* spp. are often abundant in the coastal areas. Toxic *Nodularia spumigena* occurs sporadically in the Gulf of Riga during late summer, but develops more frequently in the open Baltic Sea west of Latvian coast (Jurgensone et al., 2011; Balode and Purina, 1996). Cyanobacteria species frequently occurring in lake phytoplankton community include genera of *Microcystis*, *Anabaena, Aphanizomenon* and *Planktothrix* (Druvietis, 1998; Springe et al., 1999; Eynard et al., 2000; Balode et al., 2006). Despite the known water exchange with marine system, the brackish water cyanobacterium *N. spumigena* has not been found in phytoplankton community in these lakes.

Many publications report production and bioaccumulation of NOD-R in invertebrates and fish in the Baltic Sea (Sipiä et al., 2001a, 2001b; Kankaanpää et al., 2005; Mazur-Marzec et al., 2007; Sipiä et al., 2006, 2007; Persson et al., 2009) as well MCs in freshwater organisms (Lance et al., 2006, 2007, 2010; Chen et al., 2005; Gérard et al., 2009; Ibelings and Chorus, 2007). Except for lakes in Åland and northwest Germany (Lindholm et al., 1989; Contardo-Jara et al., 2008), hepatotoxin bioaccumulation in lakes within the Baltic Sea region has received little attention previously. Lindholm and coworkers (1989) examined bioaccumulation of (then unknown identity) cyanobacterial toxins from *Planktothrix aghardii* in Åland (South West Finland) in 1987–1988 and observed bioaccumulation at 30 μg toxin per gram dry weight mussel soft tissue. Only few studies have reported presence of MCs in Latvian waters. Eynard et al. (2000) found MC-LR in algal biomass from Lake Mazais Baltezers, while Balode et al. (2006) reported MC-LR, MC-YR, MC-RR and MC-LA in phytoplankton of 14 lakes located within and around Riga.

Health risks induced by hepatotoxins can be estimated by examining tolerable daily intake (TDI) values. The best applicable TDI has been outlined by the World Health Organisation (WHO), and sets limits for hepatotoxins that originate from drinking water and food or inhalation (WHO, 1996). This TDI is 40 ng microcystins d^{-1} kg^{-1} body weight (bw). 20% of this intake has been calculated to originate from food and inhalation (8 ng microcystins d^{-1} kg^{-1} bw). By comparing this TDI value against hepatotoxin concentrations in organisms' tissues one can calculate maximum daily intake (MDI) values. The MDI values, in turn, are helpful in assessing potential risk to consumers.

The aim of the present study was to assess the occurrence of and ecotoxicological risks posed by hepatotoxins in aquatic fauna of Latvian territorial waters and thereby increase understanding on bioaccumulation of phycotoxins in northern Europe lakes.

2. Material and methods

2.1. Sampling and preparation

Samples for phytoplankton identification were collected with bathometer, but algal biomass samples for toxin analyses with a plankton net (25 μm mesh size) from lakes near the City of Riga (Kisezers, Babelitis, Lielais Baltezers, Mazais Baltezers and Langstini) and lakes in northern Latvia (Burtnieks and Raiskums) in June–October 2002–2005 and June–October 2007 (Fig. 1). Phytoplankton samples for taxonomic identification and quantification were preserved with acid Lugol's solution. Fixed samples were settled in sedimentation chambers and counted according Utermöhl technique with inverted microscope (Utermöhl, 1958). The cell volume for phytoplankton wet weight biomass determination was determined using geometrical formulae for various suitable geometrical shapes (Edler, 1979). Biomass was expressed as wet weight units (mg l^{-1}). Algal biomass samples for chemical analyses were stored at −20 °C. Plankton-net concentrated samples

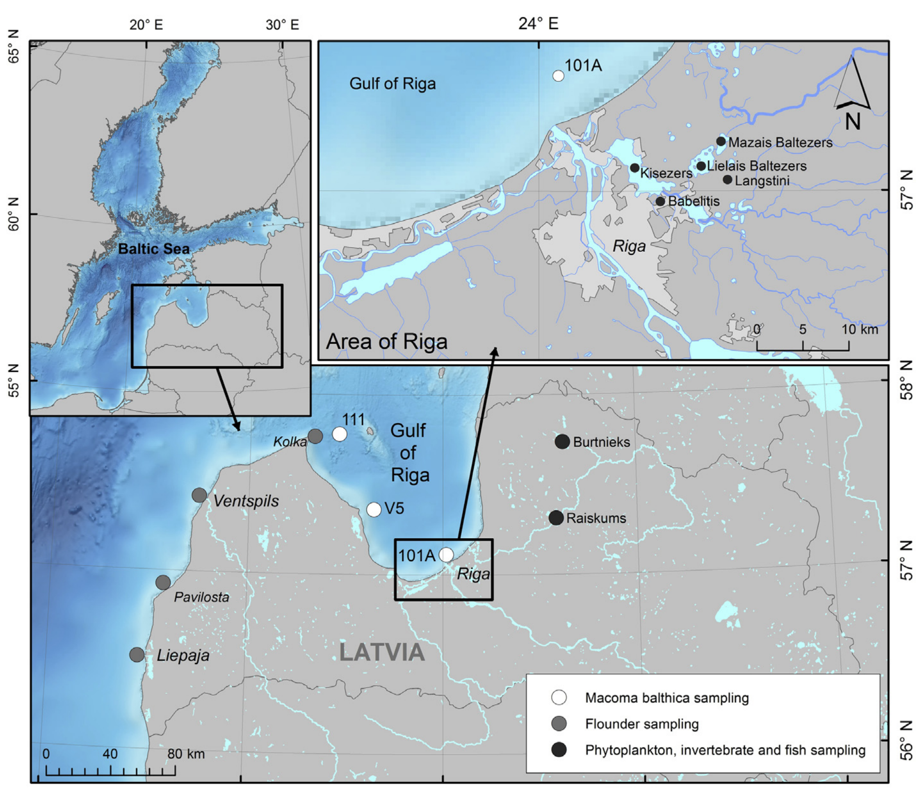

Fig. 1. Locations of biota samples collected from lakes and marine areas off Latvian coast in 2002–2007.