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Research Note

Effect of drought and fires on the quality of water in Lithuanian rivers

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Abstract

In August and September 2002, concentrations of heavy metals (copper, lead, and zinc) were 21-74% more than in previous years in Lithuanian rivers. Such a sudden increase in heavy metal pollution reduces the value of any water body for fishing or recreation and poses a potential risk to the environment and to human health. Droughts in the summer of 2002 led to forest and peat bog fires all over Lithuania and may have caused the increase in concentrations of heavy metals detected in Lithuanian rivers in August 2002. The fires could have changed the pH in the top layers of the soil, overcome geochemical barriers in the soil and enabled heavy metals to migrate from the soil to the groundwater and from river bottom sediments to the surface water.

Keywords: heavy metals, river water quality, Lithuania

Introduction

Increasingly, negative anthropogenic loading on the natural environment affects ecological functioning (Gleditsch, 1997). Also in the 21st Century, advances in technology have altered the geochemical properties of the natural environment (Commission of the European Communities, 1992; Rogers and Feis, 1998; Hill, 1997); changes in the amounts of trace elements are especially pronounced. More recently, unusual changes in the geochemical composition of the environment have been observed – chemical elements, not common in the natural environment and hazardous to biota, have increasingly been found in soil and river sediments (Wright and Welbourn, 2002). Secondary pollution of surface and groundwater may even occur (Rasmussen, 1996). Many dangerous chemical elements, if released to the environment, accumulate in the soil and sediments beneath water bodies (Schuurmann and Markert, 1998). Such pollutants may reach the soil with dust, precipitation, or otherwise and may accumulate there in various forms (Troeh *et al*., 1999), so that soil acts both as a depository and a transit medium (Kabata-Pendias and Pendias, 1994).

Under certain conditions, water may dissolve and leach these hazardous substances to surface or groundwater bodies (Campbell, 1995). Furthermore, hydro-geological changes may trigger migration of chemical elements accumulated in the silt and bottom sediments of water bodies back into the water (Bedient *et al,* 1993; Bear, 1996). Hence, silt can become a source of secondary heavy metal pollution (Crossland and LaPoint, 1992).

These processes may make water bodies unsuitable for human consumption and toxic to organisms living in the water. Heavy metals are harmful to biota at lower concentrations than nitrates, carbon and sulphur dioxides or oil products and the duration of their impact is unknown (NRC of Canada, 1986, Coale and Flegal, 1989). Water plants and plankton on which fish feed can absorb hazardous elements accumulated in the bottom sediments and in surface water (Suiter, 1995). This may result in the migration of such pollutants through the food chain and their accumulation in living organisms, including humans, causing multiple impacts (Callow and Finlay, 1996). Therefore, the concentrations of heavy metals in soil, water and sediments below water bodies are important geochemical environmental quality indicators that define the ecological status of a region (Thorton, 1995; WHO, 1995).

Negative anthropogenic processes take place on a global scale (Connell, 1999) and, hence, occur also in Lithuania (Svecevicius, 1999). Certain geochemical trace elements, including heavy metals have increased a hundredfold in the soil and in the silt in water bodies, while in certain places pollution has reached or even exceeded the limits of environmental tolerance (Davis *et al.,* 1988). Such zones are potential sources of secondary pollution.

Problem

The European Community Council Directive 76/464/EC of 4 May 1976 on pollution by certain dangerous substances discharged into the aquatic environment is incorporated, in part, in Lithuanian legislation. The maximum permitted concentrations in water bodies for zinc (Chemical Abstracts Service (CAS) – CAS 7440-66-6), copper (CAS 7440-50-8) and lead (CAS 7439-92-1)) are 100 $\mu g\ l^{-1}$, 10 $\mu g\ l^{-1}$, and 5 $\mu g\ l^{-1}$, respectively. The maximum permitted concentration of a pollutant, or a group of pollutants, in water is a concentration beyond which there are significant impacts on human health and the environment.

Compared with previous years, in 2002 concentrations of heavy metals (Fe, Cu, Zn, Cd, Cr, Ni, Mn, Pb, Hg) surged in all the Lithuanian rivers monitored by the State. Concentrations of zinc, copper and lead even exceeded the maximum values allowed by law.

Such a sudden increase of heavy metal concentrations in Lithuanian rivers necessitates research into the reasons for this phenomenon because it compromises opportunities to use a water body for fishing or recreation and even poses a risk to the environment and human health. Therefore, the questions arise: "What has caused these seemingly spontaneous increases in concentrations of heavy metals in river water if not industrial pollution point sources?" and "Is it possible to prevent this?"

Results

The State Monitoring Program of Surface Water Bodies of the Republic of Lithuania analyses river water for heavy metals (Cu, Zn and Pb) four times a year at 51 sites. Soils in Lithuania are grouped into twelve soil types (Figs. 1- 3). In the plains: I – Littoral, III – Middle Venta, IV – Lower Nemunas, V – Nevezis, VI – Musa-Nemunlis, VII – Suduva, XI – South-eastern. In the highlands: II – Zemaiciai, IX – Southern Lithuanian, X – Eastern Lithuanian, XII – Ašmena, VIII – Western Aukstaiciai Plateau.

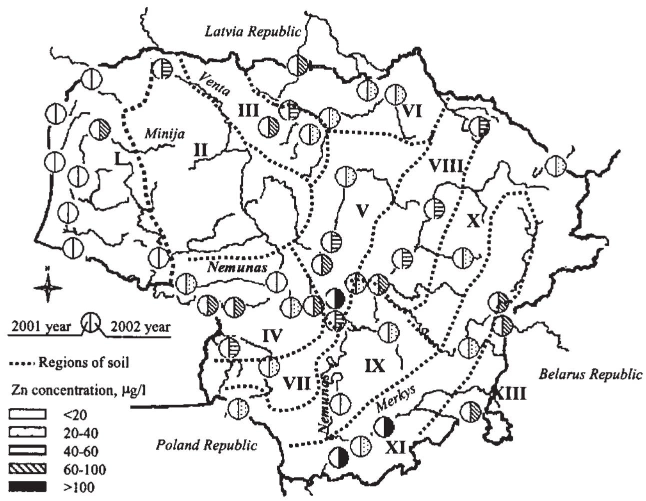

Fig. 1. *Zinc concentrations at some monitoring stations in Lithuania, 2001 and 2002.*

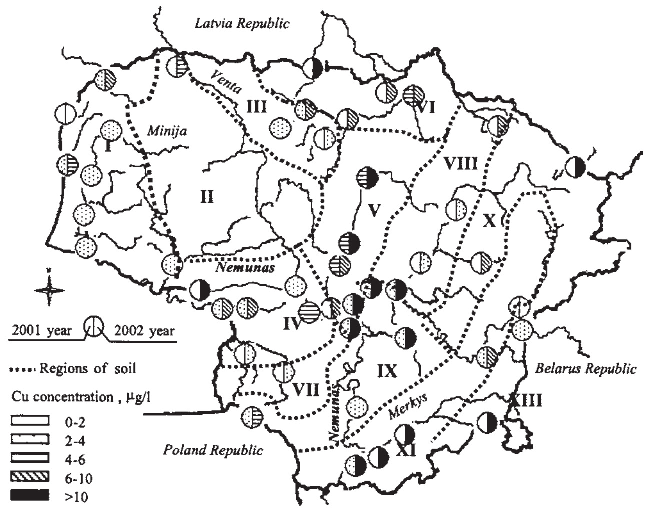

Fig. 2. Copper concentrations at some monitoring stations in Lithuania, 2001 and 2002.

The results of monitoring heavy metals (copper, lead and zinc) from August 1993-2002 are presented in Table 1 and in Fig. 4. Clearly, much higher concentrations of these heavy metals were measured in the surface water of Lithuanian rivers in August 2002.

In August and September 2002, concentrations of heavy metals (copper, lead, and zinc) increased by 21–74% compared with those averaged over the previous eight years in all the Lithuanian rivers that are subject to the State River Monitoring. Over the period 1993–2001, concentrations of

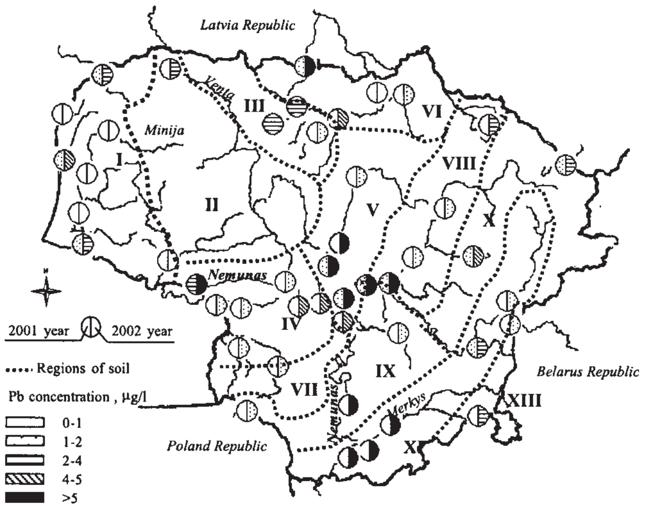

Fig. 3. Lead concentrations at some monitoring stations in Lithuania, 2001 and 2002.

zinc fluctuated between 2.9 and 26.0 µg l^{-1}, while in August and September of 2002 they ranged from 4.2 to 174 µg l^{-1}. The maximum allowed concentration (MAC) for zinc in surface water (100 µg l^{-1}) was exceeded in August of 2002 at the monitoring sites in the rivers of the south-eastern plain, the Nemunas River (174 µg l^{-1}) and the Merkys River (121 µg l^{-1}) (Fig. 1).

Over the period 1993–2001, concentrations of copper in the rivers ranged from 0.6 to 11.7 µg l^{-1}, while in August and September, 2002 the range was from 0.6 to 26.1 µmg l^{-1}. The MAC for copper (10 µg l^{-1}) was exceeded in 2002 in the rivers in: the south-eastern plain: the Neris River (25.3 µg l^{-1}), the Salcia River (13.2 µg l^{-1}), the Merkys River (26.1 µg l^{-1}), the Lower Nemunas plain: the Nemunas River (19.6–21.2 µg l^{-1}), the Nevezis plain: the Nevezis River (11.4 µg l^{-1} and 15.5 µg l^{-1}), the Musa-Nemunelis plain: the Sidabra River (13.7 µg l^{-1}), and the Western Aukstaiciai Plateau: the Sventoji River (21 µg l^{-1}) (Fig. 2).

In previous years, higher concentrations of lead were detected only in the most polluted Lithuanian rivers

Table 1. Statistical results of Lithuanian State River Monitoring of heavy metals (copper, lead and zinc) for the time period of August 1993-2002.

Chemical element/ Time period	*Number of samplings*	*Percentage of samplings that did not exceed indicated concentration (µg l^{-1})* 10%	25%	50%	75%	90%	99%
Cu							
1993-2001	122	1.1	1.5	2.3	3.4	4.3	7.7
2002	68	1.1	2.0	3.3	6.1	14.0	25.7
Pb							
1993-2001	122	0.1	0.4	0.8	1.2	1.6	3.0
2002	48	1.2	1.9	3.1	5.6	9.8	22.7
Zn							
1993-2001	104	5.1	6.1	8.6	13.5	18.5	21.6
2002	48	10.2	27.3	40.6	63.6	80.4	146.4

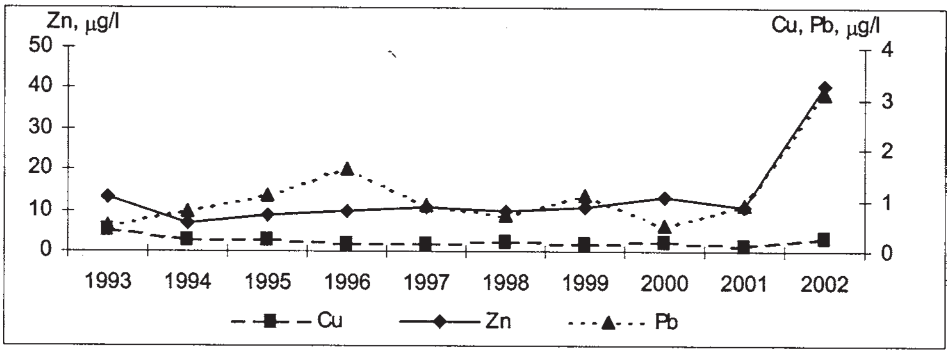

Fig. 4. Mean concentrations of zinc, copper, and lead in Lithuania, 1993 – 2002.

(Nemunas, Neris, Sidabra, Obele and Kulpe) but the maximum allowed concentrations were not exceeded.

From 1993–2001, concentrations of lead in the rivers ranged from 0 to 4.3 µg l^{-1}, while in August and September, 2002 they were between 0 and 26.7 µg l^{-1}. The maximum allowed concentrations were exceeded in the rivers of the following plains: Southeastern, Lower Nemunas, Nevezis, Musa-Nemunelis, Southern Lithuanian and Western Aukstaiciai Plateau. In fact, the maximum allowed concentration for lead (5 µg l^{-1}) was exceeded at 11 sampling sites in August –September 2002, in the Nemunas River (26.2 µmgl^{-1}), the Neris River (11 µgl^{-1}), the Susve River (6.2 µgl^{-1}), the Sventoji River (12 µmgl^{-1}), the Sidabra River (26.7 mgl^{-1}), the Obele River (5.9 µgl^{-1}) and the Merkys River (14.7 µgl^{-1}) (Fig. 3).

Discussion

The two pathways by which trace elements appear in the natural environment and in water bodies are from the atmosphere and from surface water pollution or ground water sewage (effluent). Since Lithuanian environmental control agencies have detected no emissions of industrial pollutants over the period under investigation and since there are no potential pollution sources of this type near the smaller rivers (like the Zeimena River or the Merkys River), the possibility of industrial emissions is minimal. Furthermore, agricultural emissions are unlikely because, in Lithuania in July and August, no use is made of fertilizers or other agricultural chemicals. Also, precipitation was very low in the summer of 2002, so Lithuanian rivers were 'fed' by groundwater during August.

Because of the drought, 123 forest and peat bog fires broke out in July and 374 in August.. Inevitably, fires result in large quantities of ash, which may acidify the soil. The acidic-alkaline indicator (pH) is important in determining background levels of trace elements. In August and September in Lithuania, days are quite warm, about 25–30°C but, at night, temperatures drop to +5 to –2°C. Therefore, dewfall is characteristic of this season. Ash sinks and interacts with dew and a nascent acidic solution results (Ernst, 2000; Duris 1999). Most heavy metals are inert and immobilised in soil and river sediments but, under acidic conditions, they may change into the ionic form and migrate into the water.

Hence, following intensive fires, the soils may became more and more acidic until, at pH values < 6, heavy metal cations can migrate from the soil to groundwater. Likewise, as river bottom sediments become more acidic, the cations of heavy metals may migrate into the river water (Nriagu, 1994).

Hence, a migration of heavy metals (i.e. secondary pollution) may be associated with a diminution in natural geochemical barriers between soil and groundwater as well as between river bottom sediments and surface water. All these may have facilitated increases in concentrations of heavy metals in August 2002 in the surface water of the rivers in Lithuania.

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