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To cite this version:

hal-00304792

HAL Id: hal-00304792
https://hal.science/hal-00304792
Submitted on 18 Jun 2008

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

G. Sakalauskiene\(^1\) and G. Ignatavicius\(^2\)

\(^1\)Institute of Mathematics and Informatics, Akademijos str. 4, 2005 Vilnius, Lithuania
\(^2\)Vilnius University, turlionio str. 21, 2009 Vilnius, Lithuania

E-mail for corresponding author: gaudenta.sakalauskiene@nt.gamta.lt

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 (Thornton, 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 μg l⁻¹, 10 μg l⁻¹, and
5 μg 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.

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
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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 µg 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-Nemenulis 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>
<thead>
<tr>
<th>Chemical element/ Time period</th>
<th>Number of samplings</th>
<th>Percentage of samplings that did not exceed indicated concentration (µg l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
<td>25%</td>
</tr>
<tr>
<td>Cu 1993-2001</td>
<td>122</td>
<td>1.1</td>
</tr>
<tr>
<td>2002</td>
<td>68</td>
<td>1.1</td>
</tr>
<tr>
<td>Pb 1993-2001</td>
<td>122</td>
<td>0.1</td>
</tr>
<tr>
<td>2002</td>
<td>48</td>
<td>1.2</td>
</tr>
<tr>
<td>Zn 1993-2001</td>
<td>104</td>
<td>5.1</td>
</tr>
<tr>
<td>2002</td>
<td>48</td>
<td>10.2</td>
</tr>
</tbody>
</table>

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

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

Table 1. Statistical results of Lithuanian State River Monitoring of heavy metals (copper, lead and zinc) for the time period of August 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 μg/l), the Neris River (11 μg/l), the Susve River (6.2 μg/l), the Sventoji River (12 μg/l), the Sidabra River (26.7 μg/l), the Obele River (5.9 μg/l) and the Merkys River (14.7 μg/l) (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 Zeimenas 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 the summer.

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 become 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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