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Paper reviews

INFLUENCE OF LAND FIRES ON INCREASE OF HEAVY METAL CONCENTRATIONS IN RIVER WATERS OF LITHUANIA

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Abstract. Comparison of long-term environmental monitoring data show that in August and September 2002 heavy metal (Cu, Pb and Zn) concentrations increased in Lithuanian rivers. Resent investigation has indicated that increase of heavy metals (Cu, Pb and Zn) by 60–81 % in all the rivers that are subject to the State River Monitoring and could be correlative with land fires. Fires of forests and peat bogs have outspread all over Lithuania in the summer and the first half of autumn of 2002. This paper attempts to prove an assumption that these fires could have caused a significant increase of heavy metal concentrations in the water of Lithuanian rivers in August 2002. It also means that land fires should be evaluated as an environmental risk factor with a serious impact on the state of aquatic environment and must be taken into account in calculations of environmental damage.

Keywords: environmental risk, heavy metals, land fires, river water pollution.

1. Introduction

Increasingly, negative anthropogenic loading on the natural environment affects the surrounding organic world [1]. Many environmental contaminants, that enter aquatic systems eventually deposit in the bottom sediments, where they can adversely affect benthic populations and cause changes in the structure and composition of resident communities [2].

A rapid growth of urban territories has led to an extensive residential and industrial expansion [3–5]. Anthropogenic activities associated with this expansion resulted in the movement of trace metals into rivers and streams [6].

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 biological diversity, have increasingly been found in the soil and river sediments [7]. Even secondary pollution of surface water and groundwater may occur [8]. Many dangerous chemical elements, if released into the components of the environment, accumulate in the soil and sediments beneath water bodies [9]. Such pollutants may reach the soil with dust, precipitation, or otherwise and may accumulate there in various chemical forms [10], so that soil acts as both a depository and a transit medium [11].

Under certain conditions water may dissolve and leach these very hazardous substances to surface or groundwater bodies [12]. Furthermore, hydro-geological changes may trigger migration of chemical elements accumulated in the silt and bottom sediments of water bodies back into water [13, 14]. Hence, silt can become a source of secondary heavy metal pollution [15].

These processes may make water bodies unsuitable for human consumption and toxic to organisms living in water bodies. Heavy metals are more dangerous to living organisms than nitrates, carbon and sulphur dioxides or oil products, and the duration of their impact is unsurpassable [16, 17]. Water plants and plankton on which fish feed can absorb hazardous elements accumulated in the bottom sediments and in surface water [18]. This may result in the migration of such pollutants through the food chain and their accumulation in living organisms, including humans, causing multiple impacts [19]. Therefore, the concentrations of heavy metals in the soil, water and sediments below water bodies are important geochemical environmental quality indicators that define the ecological status of a region [20, 21].

Negative anthropogenic processes take place on a global scale [22] and, hence, also occur in Lithuania [23]. 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 [24]. Such zones are potential sources of secondary environmental pollution.

2. Problem

The European Commmunity Council Directive 76/464/EC of 4 May 1976 on pollution by certain dangerous substances discharged into the aquatic environment [25] is partly incorporated in the Lithuanian legislation. Maximum allowed concentrations in water bodies for Zn (Chemical Abstracts Service (CAS) – CAS 7440-66-6), Cu (CAS 7440-50-8) and Pb (CAS 7439-92-1)) are 100 μgl^{-1}, 10 μgl^{-1}, and 5 μgl^{-1}, respectively. A maximum allowed concentration of a pollutant or group of pollutants in water is a concentration beyond which there are significant impacts on human health and the environment.

Compared with the 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 Zn, Cu and Pb even exceeded maximum values allowed by law.

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

3. Results

The State Monitoring Program of Surface Water Bodies of the Republic of Lithuania analyses river waters for heavy metals (Cu, Zn and Pb) four times a year at 51 sites. Soils in Lithuania are grouped into twelve soil types – in the following plains: I – Littoral, III – Middle Venta, IV – Lower Nemunas, V – Nevėžis, VI – Mūša – Nemunėlis, VII – Sūduva, XI – Southeastern; in the following highlands: II – Žemaičiai, VIII – West Aukštaičiai plateau, IX – South Lithuanian, X – East Lithuanian, XII – Ašmena (Medininkai).

The statistical results of monitoring heavy metals (Cu, Pb and Zn) for August in 1993–2002 are presented in Table 1 and Fig 1. Clearly, much higher concentrations of heavy metals (Cu, Zn and Pb) were measured in the surface water of Lithuanian rivers in August 2002.

In August and September 2002, concentrations of heavy metals (Cu, Pb, and Zn) increased by 21–74 % compared with those averaged over the previous 8 years in all the Lithuanian rivers that are subject to the State River Monitoring. Over the period 1993–2001 concentrations of Zn fluctuated between 2,9 and 26,0 μgl^{-1}, while in August and September 2002 they ranged from 4,2 to 174,0 μgl^{-1}. A maximum allowed concentration (MAC) for Zn in surface water (100 μgl^{-1}) was exceeded in August 2002 in the rivers of the Southeastern plain, the Nemunas river (174,0 μgl^{-1}) and the Merkys river (121,0 μgl^{-1}) (Fig 2).

Over the period 1993–2001 concentrations of Cu in rivers ranged from 0,6 to 11,7 μgl^{-1}, while in August and September 2002 the range was from 0,6 to 26,1 μgl^{-1}. In 2002 MAC for Cu (10 μgl^{-1}) was exceeded in the following rivers:

in the Southeastern plain: the Neris river (25,3 μgl^{-1}), the Šalčia river (13,2 μgl^{-1}), the Merkys river (26,1 μgl^{-1});

in the Lower Nemunas plain: the Nemunas river (19,6 – 21,2 μgl^{-1});

in the Nevėžis plain: the Nevėžis river (11,4 μgl^{-1} and 15,5 μgl^{-1});

in the Mūša – Nemunėlis plain: the Sidabra river (13,7 μgl^{-1});

in the Western Aukštaičiai plateau: the Šventoji river (21,0 μgl^{-1}) (Fig 3).

In the previous years higher concentrations of Pb were detected only in the most polluted Lithuanian rivers (the Nemunas, the Neris, the Sidabra, the Obelė and the Kulpė), but maximum allowed concentrations were not exceeded.

In 1993–2001 concentrations of Pb in rivers ranged from 0 to 4,3 μgl^{-1}, while in August and September 2002 they were between 0 and 26,7 μgl^{-1}. Maximum allowed concentrations were exceeded in the rivers of the following plains: Southeastern, Lower Nemunas, Nevėžis, Mūša–Nemunėlis, South Lithuanian and West Aukštaičiai plateau. In fact, a maximum allowed concentration for Pb (5 μgl^{-1}) was exceeded at 11 sampling sites in August – September 2002: in the Nemunas river (26,2 μgl^{-1}), the Neris river (11,0 μgl^{-1}), the Šušvė river (6,2 μgl^{-1}), the Šventoji river (12 μgl^{-1}), the Sidabra river (26,7 μgl^{-1}), the Obelė river (5,9 μgl^{-1}) and the Merkys river (14,7 μgl^{-1}) (Fig 4).

4. 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 smaller rivers (like the Žeimena or the Merkys), possibility of industrial emissions is minimal. However, burning is also a potential source of heavy metals that can be released into the atmosphere through volatilization trapped in smoke particles or distributed as fly ash after combustion [26, 27]. Agricultural emissions are unlikely because in July and August no use is made of fertilizers or other agricultural chemicals in Lithuania. Also, precipitation was very low in the summer of 2002, so the Lithuanian rivers were "fed" by groundwater during August.

Due to the drought 497 forest and peat bog fires broke out in Lithuania in July and August (Fig 5). Land fires inevitably result in large quantities of ashes which acidify the soil. The acidic-alkaline indicator (pH) is a very important factor in determining the background levels of trace elements. In August and September the days are quite warm in the territory of Lithuania – about 25–30 °C, but at night the temperature drops up to +5 – –2 °C. Therefore, dews are characteristic of this season. Ashes sink down and interact with dews resulting in an acidic solution [28, 29]. Most heavy metals are inert and immobilized in the soil and river sediments, but under acidic conditions they may change into an ionic form and migrate into water.

Heavy metals could move through aquatic environments via few mediums [6]. Predominantly trace metals are absorbed onto particulate matter, although they can form free metal ions and soluble complexes that are available for uptake by water habitants [30]. Metals associated with particulate matter are also available for biological uptake [31] and are deposited in river sediments [32]. Once deposited, binding by sulfides and/or ion hydroxides immobilizes heavy metals until a change in redox or pH occurs [32, 33]. Thus, surfical sediments, particularly the fine fraction accumulate heavy metals and induce a long-term accumulation of contaminants [32].

Hence, following intensive land fires, soils may become more and more acidic, and 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 river waters [34].

Taking into account the above factors, it is reasonable to assume that migration of heavy metals (i e secondary pollution), associated with reduction in natural geochemical barriers between the soil and groundwater as well as between river bottom sediments and surface waters, may have facilitated increase in concentrations of heavy metals in August 2002 in the surface water of Lithuanian rivers.

Accounting all the above mentioned factors, we should note that fires of large forests and peat bogs could initiate increase of heavy metal amounts in aquatic environment, and, therefore, they should be evaluated as an environmental risk factor with a serious impact on the state of aquatic environment and must be taken into account in calculations of environmental damage.

Table 1. Descriptive sampling statistics for Cu, Pb and Zn concentrations at Lithuanian river stations in 1991–2000 and August 2002

Period	Number of samples	Percentage of river water samples without excessive concentrations (μg/l)					
		10 %	25 %	50 %	75 %	90 %	99 %
Cu							
1991–2000	2588	0,005	0,01	1,3	2,9	5,13	14,8
2002	68	1,1	1,95	3,3	6,1	14,0	25,7
Pb							
1991–2000	2056	0,0	0,002	0,6	1,1	1,8	6,3
2002	48	1,2	1,9	3,1	5,6	9,8	22,7
Zn							
1991–2000	1815	0,03	0,007	6,4	11,0	16,2	25,6
2002	48	10,2	27,3	40,6	63,6	80,4	146,4

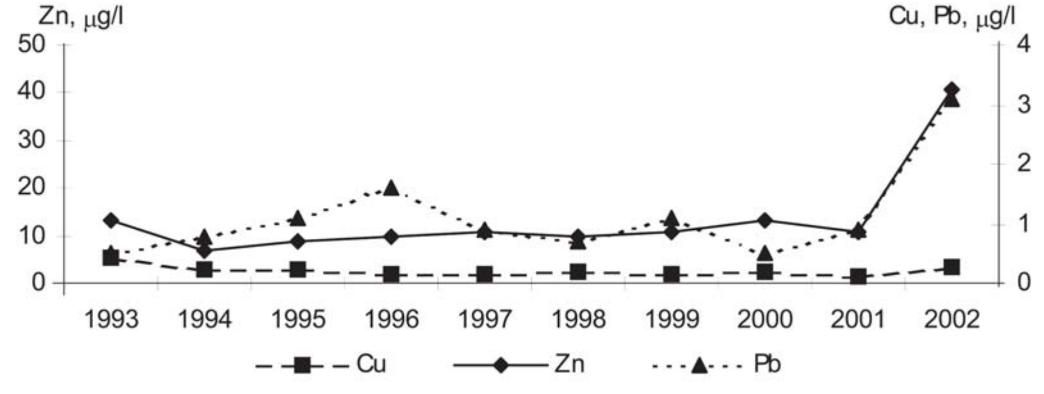

Fig 1. Mean concentrations of Zn, Cu and Pb in Lithuania, 1993–2002

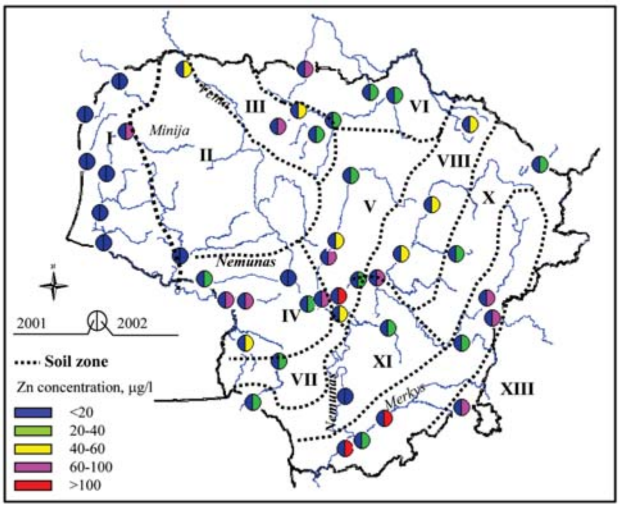

Fig 2. Zn concentrations at some monitoring stations in Lithuania, 2001 and 2002

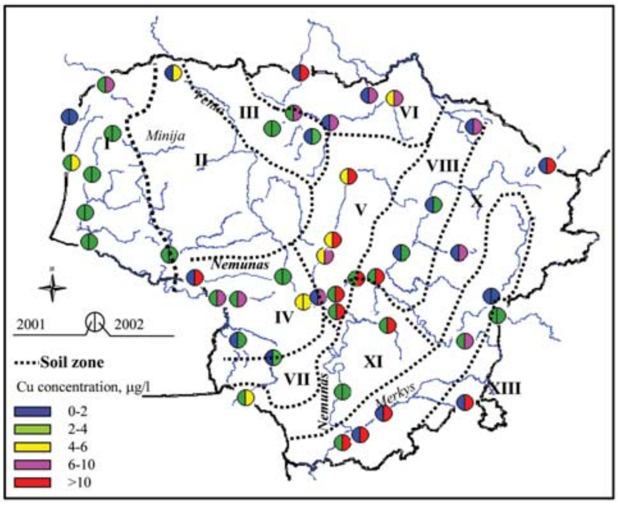

Fig 3. Cu concentrations at some monitoring stations in Lithuania, 2001 and 2002

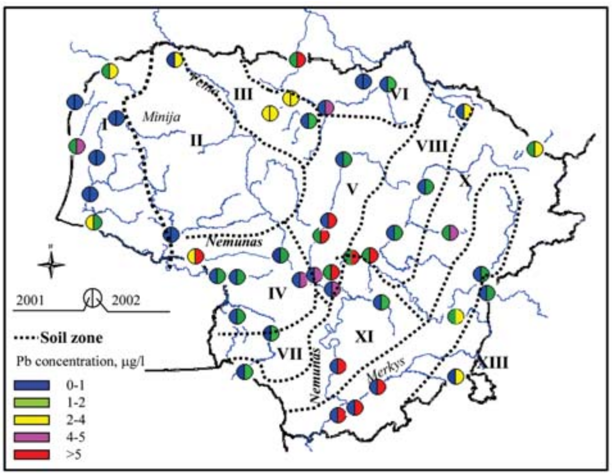

Fig 4. Pb concentrations at some monitoring stations in Lithuania, 2001 and 2002

5. Conclusions

1. In August and September 2002 concentrations of heavy metals (Cu, Pb and Zn) increased by 21–74 % compared with those averaged over the previous 8 years (1993–2001) in all the Lithuanian rivers that are subject to the State River Monitoring.

2. The acidic-alkaline indicator (pH) is a very important factor in determining the background level of trace elements. Due to the drought 497 fires of forests and peat bogs broke out in Lithuania in July and August 2002. Land fires inevitably result in large quantities of ashes which acidify the soil.

3. Migration of heavy metals associated with a reduction in natural geochemical barriers may have facilitated increase in concentrations of heavy metals in August 2002 in the surface water of the investigated Lithuanian rivers.

4. Fires of large forests and peat bogs could initiate increase of heavy metal amounts in aquatic environment, and, therefore, they should be evaluated as an environmental risk factor with a serious impact on the state of aquatic environment.

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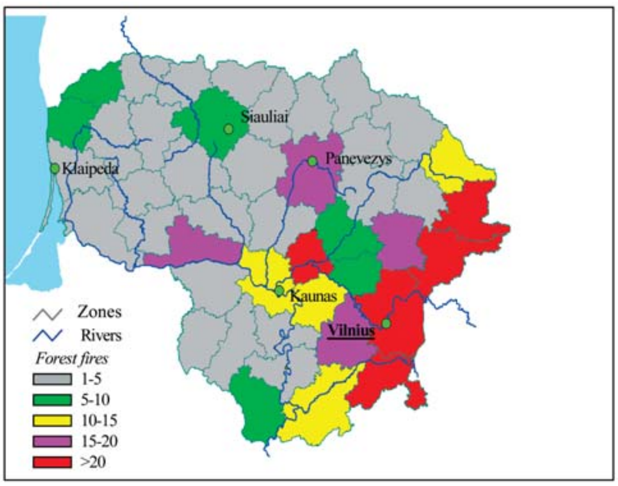

Fig 5. Distribution of forest and meadow fires in Lithuania in August 2002

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SAUSUMOS GAISRŲ ĮTAKA SUNKIŲJŲ METALŲ KONCENTRACIJŲ PADIDĖJIMUI LIETUVOS UPIŲ VANDENYJE

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S a n t r a u k a

Aplinkos ministerijos Jungtinio tyrimų centro duomenimis, 2002 m. rugpjūčio ir rugsėjo mėnesių upių vandens kokybės rodiklius palyginus su 1991–2000 m. laikotarpio duomenimis, visų upių, kurių valstybinis monitoringas vykdomas, vandenyje nustatytas sunkiųjų metalų (vario, švino ir cinko) koncentracijų padidėjimas 60–81 %. Toks staigus pokytis verčia ieškoti šio reiškinio priežasčių, nes, padidėjus taršai, iš esmės keičiasi vandens telkinių tinkamumas žuvininkystei ir rekreacijai, kyla papildomas pavojus aplinkai ir žmonių sveikatai. 2002 m. liepos ir rugpjūčio mėnesiais dėl anomalios sausros Lietuvoje išplito miškų ir durpynų gaisrai. Straipsnyje bandoma pagrįsti prielaidą, kad 2002 m. rugpjūtį sunkiųjų metalų koncentracijų padidėjimui Lietuvos upių paviršiniame vandenyje įtakos galėjo turėti gaisrai, pasikeitęs paviršinių grunto sluoksnių pH ir dėl to išnykę gruntiniai geocheminiai barjerai. Dėl šių priežasčių iš dirvožemio į gruntinius vandenis bei iš upių dugno nuosėdų į paviršinius vandenis migravo sunkieji metalai, t. y. prasidėjo antrinė tarša.

Prasminiai žodžiai: aplinkos taršos rizika, sunkieji metalai, sausumos gaisrai, upių vandens tarša.

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