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Collembolan response to red mud pollution in Western Hungary

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ABSTRACT

Effects of red mud pollution on the community structure of *Collembola* were studied in soils from open grassland and forest habitats following the red mud disaster in Western Hungary. Nearby unpolluted control plots of each habitat types were selected for comparative purposes. Analyses revealed that soil became strongly alkaline and, even nine months after the disaster, pH exceeded a value of 9.0 in the polluted forests. Water soluble Na content found to be 50–160 times greater in the polluted area, and total content of metals (e.g. Fe, Al, Mn, Zn, As, Cr, Cu, Ni, Pb, Zn) also increased considerably. Nevertheless, owing to the high alkalinity and red mud's adsorption capacity, bioavailable forms of heavy metals were lower in comparison to the acid control soils. *Collembola* species richness was about the same in the polluted and control forests (31 and 32, respectively), but lower in the polluted meadows compared to the control plots (21 and 27, respectively). Total community abundance changed differently in the open habitat and in the forest. Its value dropped by 45% in the polluted meadows, while almost tripled in the polluted forests. Changes in the abundance of individual species involved both decrease/elimination of sensitive species (e.g. *Isotomiella minor, Sminthurinus aureus*) and displacement of species tolerant to pollution (e.g. *Micranurida pygmaea*) into higher abundance classes. Certain species (e.g. *Folsomia manolachei, Sphaeridia pumilis*), following the pollution, showed a reverse pattern of abundance in the two habitat types; increasing in the forest while decreasing in the meadow. This study has suggested that soil alkalinity and salt (Na) toxicity were presumably the two most important factors determining the structure of *Collembola* communities in the area affected by red mud pollution. Despite the high toxicity risk associated with this accident, no adverse effect has been observed in *Collembola* abundance. Nevertheless, as a consequence of soil re-acidification, re-mobilisation of fixed metals may occur in the long term, constituting to a potential risk to soil *Collembola*.

1. Introduction

Legacy of the 20th century has left us with two significant ecological questions for the new century:

- How can we validate an ecologically conscientious view in economical decision making?
- How can we put a stop to the dramatic decline of biodiversity?

The strong interconnection between these two questions has enforced the need for rapid action especially in light of detrimental industrial disasters. Unfortunately, large scale industrial disasters continue to occur even in the 21st century. The most well known international incident of the "new era" is the Japanese Fukushima disaster; however, there have also been local incidents, where the affects were localised, but their ecological impact could not be neglected. One such localised disaster occurred in 2010 in Hungary which became known as the "red mud" incident in international news. The nature of this disaster – spillage of red mud from a reservoir – has directed focus onto soil conservation and protection of soil biodiversity. One major reason for the increased interest in soil biodiversity was related to the fact that from very early on it became apparent that the red mud contaminated soil can only be utilised and inhabited after complete soil removal. This point of view considered the benefits to *Homo sapiens* alone. But what happens to the soil biodiversity in those areas where the contaminated soil cannot be removed—for example: in forested areas? The answer will probably be found in soil fauna recolonisation which will most likely originate from surrounding habitats where contamination did not reach and from so called "survival spots". However, how soon this can happen and how will all this take place nobody can predict for as long as this sadly unique "in situ experimentation" does not stop.

On October 2010, in Western Hungary, one of the dykes of a red mud reservoir of an aluminium processing factory breached and more than 1.3 million m^3 of toxic sludge broke free, flooding the surrounding area (Szépvölgyi, 2011). This event destroyed nearly 1000 hectares of land, including nearby rivers, where practically all aquatic life was destroyed (Mayes et al., 2011); forests and

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agricultural fields, where the soil surface was covered with an average 5–10 cm thick red mud layer after the flood (Anton et al., 2012). This red mud disaster turned out to be one of the most severe ecological disasters ever experienced in the country (Burai et al., 2011), leaving behind long-term environmental impacts which are impossible to assess at the present time.

The red mud is a fine fraction by-product of the so-called Bayer alumina process which uses sodium hydroxide for recovering substantially pure alumina from bauxite (Liu et al., 2007; Power et al., 2011). Red mud is therefore strongly alkaline with a pH of 9–12.5 (Milačič et al., 2012). Its main components typically include residual minerals and oxides, such as hematite, goethite, boehmite, quartz, sodium aluminosilicates, titanium dioxide, calcium carbonate/aluminate and magnesium oxide (Mayes et al., 2011). Further components in lower concentrations also include heavy metals such as copper, zinc, chromium, cadmium, arsenic, mercury, lead, nickel and vanadium; and a few rare-earth metal elements (Cablik, 2007).

To assess the environmental impact of the red mud disaster, some investigations have already been carried out. Gelencsér et al. (2011) focused on the potential health effects of red mud dust, while other studies evaluated the impact of red sludge pollution on water quality and aquatic life (Harka, 2011; Mayes et al., 2011; Klebercz et al., 2012). Effects of red mud on plant growth and plant composition have been extensively studied (Friesl et al., 2003; Koulikourdis et al., 2005; Ruyters et al., 2011a); however, in regards of soil fauna, no investigations have been carried out.

It is without doubt that red mud had considerable effect on soil properties and soil biodiversity (Ruyters et al., 2011b; Anton et al., 2012). The high sodium content and the extremely fine grain size of the red mud can deteriorate soil structure (Ruyters et al., 2011a). Further risks associated with red mud that affect soil properties are related to alkalinity, heavy metal content and radioactive material contamination (Klauber et al., 2011; Anton et al., 2012). High pH itself can be a source of direct toxicity to soil organisms (Mertens, 1975; Hutson, 1978), as well as, heavy metal pollution also tends to affect, often adversely, soil animal communities (Hodson, 2013). Effects of individual pollutants on soil *Collembola* have been widely studied (e.g. Hågvar and Abrahamsen, 1990; Hopkin, 1994; Gillet and Ponge, 2003; Lock et al., 2003; Smit and van Gestel, 1996); however, studies examining the toxic affect of complex mixtures of pollutants, such as sludges, on these organisms are less widely documented (Cole et al., 2001; Domene et al., 2008, 2010; Natal-da-luz et al., 2009).

The objectives of the present research were to (i) determine whether there are signs of revitalisation and recolonisation by *Collembola* of the selected red mud polluted area not affected by remediation; (ii) evaluate the changes in *Collembola* community species composition and abundance in polluted compared to unpolluted plots selected as control from nearby locations; and (iii) collect new information on pH tolerance of *Collembola* species in field. The study was conducted 9 months after the red mud disaster.

2. Materials and methods

2.1. Study area

The study was conducted in the area of the Torna stream valley, which was the main area affected by the toxic red mud flood. The site is located near the village of Tüskevár (Fig. 1); it is characterised by a variety of semi-natural and agricultural habitats such as forests, grasslands and arable lands. Sampling was carried out in both forest and open meadow habitats. Of each habitat type, three polluted and three unpolluted plots were selected for sampling and

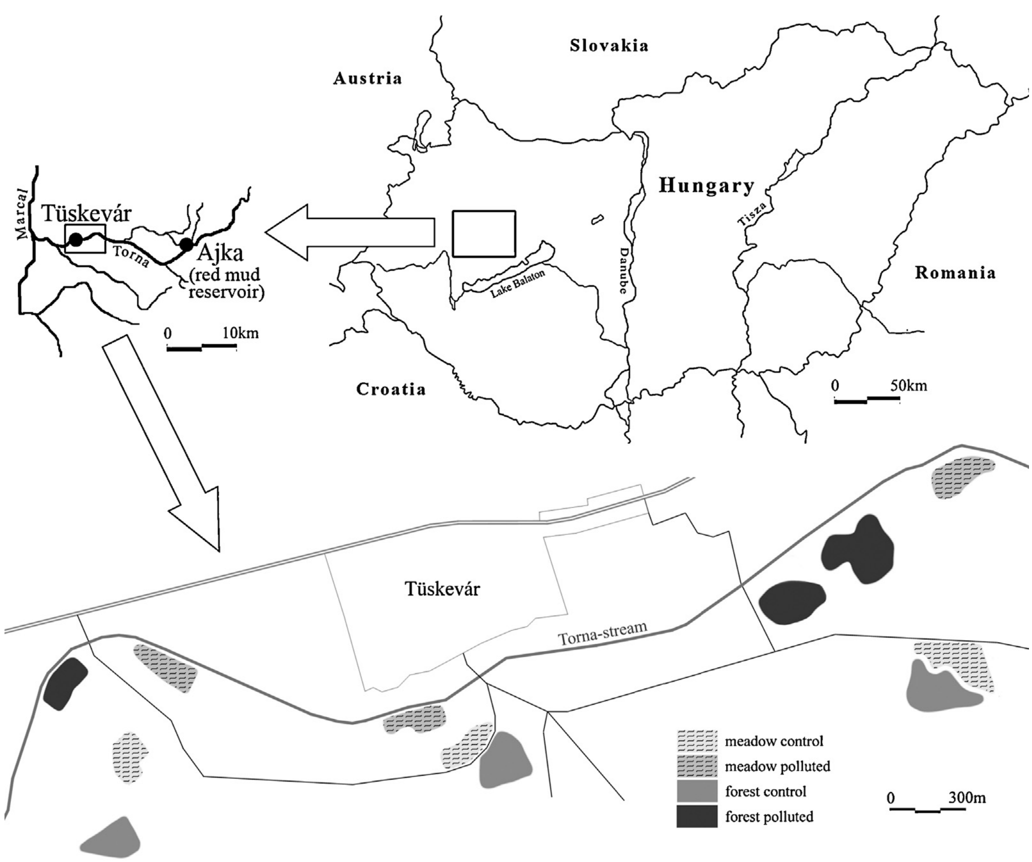

Fig. 1. Study area, location of sampling plots.