Full-field 3D XRF-imaging study of metal accumulation, distribution and effects in aquatic invertebrates exposed in complex environments

J. Garrevoet, D. Deruytter[1], L.T.H. Nguyen[1], L. Van De Voorde, B. Vekemans, M. Vandegehuchte[1], G. Falkenberg[2] C.R. Janssen[1], and L. Vincze

Department of Analytical Chemistry, Ghent University, Krijgslaan 281 S12, B-9000 Ghent, Belgium
[1]Department of Applied Ecology and Environmental Biology, Ghent University, J. Plateaustraat 22, B-9000 Ghent, Belgium
[2]DESY, Notkestr. 85, D-22603 Hamburg, Germany

Metals are aquatic pollutants of concern and the environmental risk assessment of metals is a process which is continuously being improved in order to increase ecological relevance. Many challenges are faced in order to get more refined Environmental Quality Standards (EQSs) or risk assessments for metals in complex environments [1]. The toxicity of metals in sediment is known to be affected by abiotic factors such as the acid volatile sulphide concentration (AVS) [2]. To better understand the influence of AVS on Ni toxicity three species (Tubifex tubifex, Lubriculus variegatus and Chironomus riparius) were exposed to two different sediment types (high and low AVS) spiked with Ni concentrations between 0 and 5600 mg/kg sediment. Adverse effects of Ni were seen in both sediments, but they were more severe in the low AVS sediment. To understand if these differences in Ni toxicity are due to a difference in Ni accumulation or a difference in Ni sensitivity 48 specimens were prepared for SR-XRF measurements at petra III beamline PO6.

As opposed to using a single-element energy-dispersive detector and scanning type of micro-beam excitation in e.g. a confocal arrangement, a novel 3D elemental micro-imaging method was used for the elemental micro-analysis, based on full-field micro-XRF detection technology [3]. Vertical cross sections of the sample were obtained when excited using a linearly focused X-ray beam, by using only the horizontally focusing mirror of the Kirkpatrick-Baez (KB) mirror system of the P06 beamline, and monochromatised using a Si(111) monochromator, obtaining a primary X-ray beam of 11.5 keV and dimensions of 5 micron (H) and 1.2 mm (V) FWHM. The experimental setup is shown in figure 1.

For all three species and in both sediments, a clear increase in accumulated Ni was observed. However the preliminary results indicate a clear difference between the two sediments with an equal Ni concentration indicating that an increase in AVS decreases Ni uptake, not a change in Ni sensitivity (see figure 2). Further analysis of the data will give further insights if Ni accumulation is proportional to the Ni concentration in the soil, if the distribution of Ni changes with an increased Ni accumulation or changes in soil chemistry and whether there are differences between species. This will finally result in a better understanding of Ni toxicity in aquatic sediments and an improvement of the Ni risk assessment.

References

[1] D. Deruytter, J. Garrevoet, M.B. Vandegehuchte, E. Vergucht, B. De Samber, B. Vekemans, K. Appel, G. Falkenberg, K. Delbeke, R. Blust, K.A.C. De Schamphelaere, L. Vincze, and C.R. Janssen, Env. Sci. Tech. 48, 1 (2014).

[2] L.T.H. Nguyen, B.T.A. Muyssen, C.R. Janssen, Chemosphere 87, 1 (2012)

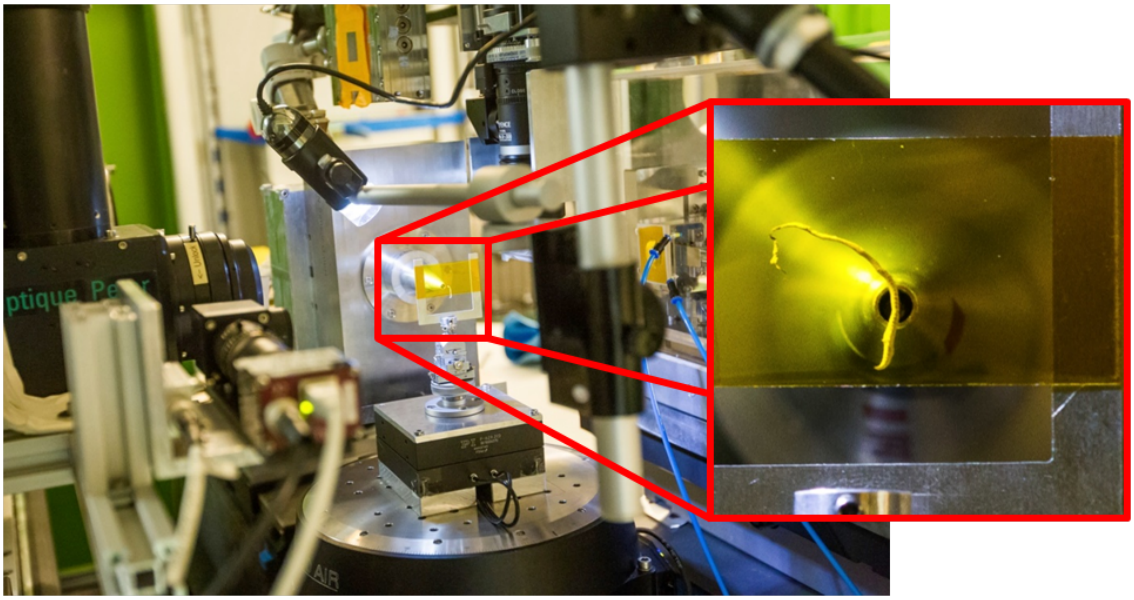

Figure 1: A Tubifex tubifex mounted on a kapton foil in front of the 6:1 polycapillary lens of a 2D energy dispersive detector (SLcam®) during the XRF measurements at the P06 beamline at the Petra III synchrotron, DESY, Hamburg, Germany.

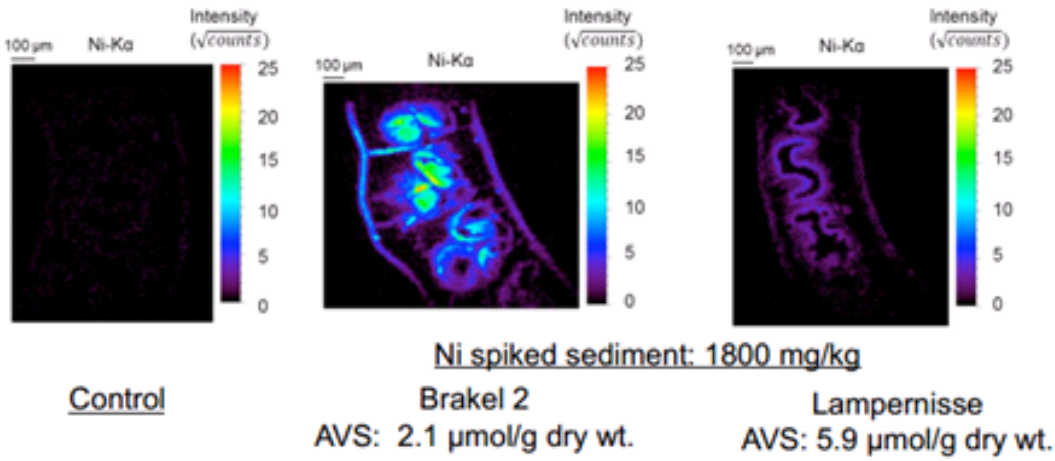

Figure 2: Showing vertical cross sections of Tubifex worms, showing the influence of exposure of Ni and AVS of the sediment on the uptake of Ni in the organism.

[3] J. Garrevoet, B. Vekemans, S. Schmitz, F.E. Brenker, G. Falkenberg, U. Boesenberg, G. Wellenreuther, B. De Samber, Photon Science - Highlights and Annual Report 2012.