High-resolution 3D and (sub-)cellular level LA-ICP-MS imaging approaches: accumulation of toxic metals in biological material

Stijn J. M. Van Malderen,1* Thibaut Van Acker,1 Eva Vergucht,1 Laszlo Vincze,1 Maarten de Rijcke,2 Colin Janssens,2 Frank Vanhaecke1

1Department of Analytical Chemistry, Ghent University, Krijgslaan 281-S12, Ghent, BE-9000, Belgium
2Department of Applied Ecology and Environmental Biology, Ghent University, Plateaustraat 22, Ghent, BE-9000, Belgium

*E-mail: Stijn.VanMalderen@UGent.be

Novel approaches for elemental mapping via LA-ICP-MS have emerged in cellomics, metallomics and proteomics, induced by the progress achieved in the development of low-dispersion setups characterized by improved detection limits and sample throughput. These approaches include the mapping of the trace-level nuclide distribution within structures < 10^4 μm^3 in volume, using a laser beam waist size of 1 − 3 μm ∅, and rapid 3D imaging. This work demonstrates both approaches in selected applications related to metallotoxicity. In a first study, a photosynthetic dinoflagellate (Scrippsiella trochoidea), was exposed to Cu concentrations at 12 different levels, ranging from 0.5 to 100 µg/L, and treated with a critical point drying protocol. ~100 cells of each population were individually ablated using a single-point ablation protocol, permitting the Cu distribution in the entire population across different exposure levels to be evaluated. LA-ICP-MS imaging (2 × 2 μm^2 beam size) of the Cu distribution in individual cells was cross-validated with in vivo optical tweezers-based synchotron radiation confocal X-ray fluorescence (XRF) imaging. In a second study, the 3D distribution of heavy metals in wheat (Triticum dicoccum, Triticum aestivum) and rye (Secale cereale L.) grains at typical exposure levels was visualized (20 × 20 μm^2 beam size) and quantified. Grains embedded in an epoxy block were analyzed via serial sectioning, followed by image registration for volume reconstruction. Calibration was performed via standard addition using a set of spiked matrix-matched pellets.

Figure 1(left) 3D reconstruction of Secale cereale L. Mn distribution at typical exposure levels. (right) Single cross-section of the 3D volume.