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Toward Total Metal Quantification Using a Biosensors platform: Compatibility of Acid Digests with Bacterial Bioavailability

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Biosensors offer major advantages over conventional spectrometric approaches through lower cost, portability, and suitability for field deployment. Their biological detection mechanisms provide direct insight into metal bioavailability, linking chemical speciation with ecological relevance. When integrated into analytical workflows, biosensors can evaluate metal bioavailability across environmental conditions such as pH, salinity, and organic content.

In natural and industrial solid matrices, however, trace metals such as cadmium are partitioned among heterogeneous mineral and organic phases, rendering them partially or entirely inaccessible to biosensors. In established analytical techniques, such as inductively coupled plasma (ICP)–based methods, complete acid digestion is routinely applied to solubilize matrix-bound metals prior to quantification, thereby ensuring that all cadmium is converted into soluble ionic species. Because this ionic form is also the one recognized by biological uptake and metal-responsive regulatory systems, digestion constitutes a common prerequisite for total quantification. However, acid digests are characterized by high ionic strength and extreme acidity—conditions that can disrupt cellular physiology, alter metal speciation, and compromise biosensor bioavailability. Consequently, for biosensors to access total cadmium, this conventional digestion workflow must be adapted for biological operation to preserve bioavailability.

The general problem addressed in this study is whether acid digestion can be rendered compatible with biosensor bioavailability to enable accurate quantification of total cadmium from solid samples while preserving analytical reliability.

Here, we show that buffering concentrated phosphoric and nitric acids, doped with trace amounts of cadmium to emulate an acid-digested matrix, keeps cadmium bioavailable. By keeping cadmium fully solubilized while controlling the time of exposure to environmental stress, we were able to maintain metal bioavailability for many hours, allowing the generation of calibration curves. This approach establishes a methodological framework that could eventually enable the total quantification of trace metals in solid samples using biosensing platforms.

More broadly, this work expands the role of biosensors from tools of bioavailability assessment to platforms capable of total metal quantification. Integrating controlled digestion with biological detection provides a pathway toward more accessible, field-deployable monitoring strategies and strengthens the analytical basis of environmental regulation and industrial compliance.