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Water bodies pollutants screening by nanostructured optical biosensors

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Heavy metals are one of the most serious environmental pollution problems of our time, threatening global sustainability as being non-biodegradable. Heavy metal exposure causes serious health effects, including reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Consequently, growing environmental awareness has led to strict regulations on the maximum metal concentrations allowed in natural waters. Traditional methods to analyze heavy metals with high sensitivity include diverse spectroscopy techniques: cold vapor atomic absorption spectroscopy, inductively coupled plasma – mass spectroscopy/atomic emission spectroscopy (ICP-MS/AES), UV-VIS, X-ray and others. Although these methods have high precision (as low as part per-trillion concentrations), these techniques are expensive, require sophisticated instrumentation, and can only performed in a centralized lab. Thus, the objective of this research is to develop a generic integrated biosensing platform for rapid and on-site detection of heavy metal pollutants in water by enzymatic activity inhibition. First, we show a general detection assay by immobilizing horseradish peroxidase (HRP) within the oxidized PSi nanostructure and monitor its catalytic activity in real-time by reflective interferometric Fourier transform spectroscopy. Optical studies reveal high specificity and sensitivity of the HRP-immobilized PSi towards three metal ions (Ag^{+}>Pb^{2+}>Cu^{2+}), with a detection limit of 60 ppb. Next, we demonstrate the concept of specific detection of Cu^{2+} ions (as a model heavy metal) by immobilizing Laccase, a multi-copper oxidase, within the oxidized PSi. The resulting biosensor allows for *specific detection and quantification* of copper ions in real water samples (e.g., surface and ground water) by monitoring the Laccase relative activity. The optical biosensing results are found to be in excellent agreement with those obtained by the gold standard analytical technique (ICP-AES) for all analyzed water samples. The main advantage of the presented biosensing concept is the ability to detect heavy metal ions, at environmentally relevant concentrations, using a simple and portable experimental setup, while the specific biosensor design can be tailored by varying the enzyme type.

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