Concours de l'Ecole Doctorale de Chimie de Lyon – 2025

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Titre : Développement d'une plateforme électrochimique à base d'aptamères connectée à un smartphone pour la multi-détection d'ions métalliques lourds dans l'eau (Water-on-chip)

Title : Development of a Smartphone-Connected Aptamer-Based Electrochemical Platform for the Multi-Detection of Heavy Metal Ions water contaminants (Water-on-chip)

Keywords : Copper-free click chemistry, Aptamers, water contaminants, Electrochemical impedance spectroscopy, Android App

Context and objectives:

With the rapid development of industry and the improvement of urbanization, more and more chemical substances are used in daily life and agricultural production. Increasingly frequent industrial activities such as mining, metallurgy, and oil extraction produces many toxic and harmful substances. These toxic and harmful substances, even after purification treatment, will still leave some residues in the natural water system, including heavy metals, inorganic salts, and agricultural veterinary drugs, which causes pollution and damages the water environment [1–3]. Unlike organic pollutants, heavy metals cannot be biodegraded under natural conditions [4] and will be passively ingested by plants through drinking and irrigation, and eventually, will enter the human body through continuous accumulation in the food chain. Mercury, cadmium, lead, Chromium, Thallium, Antimony, and arsenic are the most common heavy metal pollutants. According to WHO standards, they usually do not exceed 2 ppb. The heavy metals ingested into the human body are likely to form complexes with biological substances such as proteins, enzymes, and nucleic acids. The formation of such complexes alters the molecular composition and mechanism of biological matter, causing it to fail to perform its original physiological function or causing distortion [5]. The accumulation of these elements can cause serious damage to the gut, bones, central nervous system, liver, kidneys, and reproductive system. Since these elements cannot be removed by normal removal methods, even trace amounts of heavy metals can pose a serious threat to living things [6]. In these cases, detection of heavy metal ions in environmental and water systems to prevent heavy metal pollution from the source of the food chain is a vital need. In recent years, many detection methods for heavy metal ions have been developed.

Traditional detection methods mainly calculate the concentration of an atom based on its characteristic spectral intensity, including atomic absorption spectroscopy (AAS), inductively coupled plasma mass spectroscopy (ICP-MS), X-ray fluorescence spectrometry (XRF), neutron activation analysis (NAA), and inductively coupled plasma-atomic emission spectrometry (ICP-AES) [7]. These methods can perform accurate qualitative and quantitative analyses of heavy metal ions with high sensitivity, but they are also expensive and require laborious pre-processing [8]. Therefore, a cost-effective, fast, and efficient detection method for heavy metal ions needs to be developed.

The aim of this thesis project (Water-on-chip) is to address the aforementioned challenges by developing an automated, rapid, and portable electrochemical aptasensor platform for the simultaneous detection of heavy metal ions (Cd^{2+}, Pb^{2+}, Co^{2+}, and Zn^{2+}) in water contaminants. The platform is based on functionalized gold microelectrodes with specific aptamers, connected to a commercial potentiostat that is directly inserted into a smartphone and controlled via the Android app PStouch. A novel aptamer immobilization strategy will be employed, combining photocrosslinking followed by copper-free click chemistry. Electrochemical Impedance Spectroscopy (EIS) will be used to analyze saliva samples.

This thesis project will be carried out through the following tasks:

1. Development of a novel labeling strategy for aptamers using dibenzocyclooctyne (DBCO) or azide group labels via a photocrosslinking process.

2. Immobilization of labeled aptamers on functionalized gold microelectrodes using a novel copper-free click chemistry approach.

3. Characterization of the functionalized surface using contact angle measurements, FT-IR, XPS, and AFM techniques.

4. Electrochemical characterization of the developed platform for the detection of water contaminants, assessing sensitivity, selectivity, and other key parameters.

5. Validation of the obtained results by comparison with those obtained through Inductively Coupled Plasma (ICP) analysis.

References:

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