Abstract

Due to the increase in urbanization and industrialization, the load of toxicants in the environment is alarming. The most common toxicants, including heavy metals and metalloids such as hexavalent Chromium, have severe pathophysiological impacts on humans and other aquatic biotas. Hexavalent chromium or Cr(VI) is highly toxic for humans as it causes high oxidative reactions inside cells, leading to diseases like chronic ulcers and damage to the kidneys, mucous membranes, throat, skin, and respiratory tract. Due to various anthropogenic activities, Cr(VI) comes into our food chain through unmonitored and uncontrolled application in agriculture fields, refineries, mills, the tanning industry, automobiles, road works, etc. Presently, the standard Cr(VI) detection is done using conventional processes, which, though accurate, has severe drawbacks in on-the-spot rapid detection in the field. Therefore, developing a portable rapid detection device for such toxicants in the aquatic environment is necessary.

This work portrays the development of a field-portable image analysis device coupled with 3,3’,5,5’-tetramethylbenzidine (TMB) as a sensing probe for chromium(VI) detection in the aquatic ecosystem. Sensor parameters, such as reagent concentration, reaction time, etc., were optimized for the sensor development and validation using a commercial UV-Vis spectrophotometer. The chemoreceptor integrated with a uniform illumination imaging system (UIIS) revealed the system’s applicability toward Cr(VI) detection. The calibration curve using the R-value of image parameters allows Cr(VI) detection in the linear range of 25 to 600 ppb, which covers the prescribed permissible limit by various regulatory authorities. Furthermore, the adjusted R2 = 0.992 of the linear fit and correlation coefficients of 0.99018 against the spectrophotometric method signifies the suitability of the developed system. This TMB-coupled field-portable sensing system is the first-ever reported image analysis-based technology for detecting a wide range of Cr(VI) in aquatic ecosystems to our knowledge.

Further, a handheld potentiostat has been developed in the present study for the detection of trace-level Cr(VI) in aquatic environments. A Cr(VI) specific DNA aptamer immobilized screen printed electrode (SPE) has been used as the main biosensor. The device operates on an electronic peak current dumping event through mass deposition in the presence of an aptamer coupled with Cr(VI) onto the working electrode. The working range of the developed prototype is in the range of 0–1000 ppb Cr(VI), where the maximum linearity has been observed in the range of 0–500 ppb with a limit of Detection (LOD) as low as 10 ppb. The device has exhibited an excellent correlation with commercially available electrochemical workstations with a coefficient of 0.972. Moreover, the applicability of the developed device has been validated for seven different types of water samples. To our knowledge, this is the first-ever reported simplistic resource-limited on-spot aptasensing device for Cr(VI) detection in an aquatic environment.