Use of electrochemical sensors based on biochar in environmental samples analysis

Research related to monitoring the concentration of environmentally important compounds gained great importance after evidence of their potentially harmful effects on the environment and living organisms. Various research areas focus on the development of analytical methods, with the aim of qualitative and quantitative determination of various environmentally important compounds. The development and optimization of analytical methods are an indispensable part of basic research before analyzing analytes in different types of samples. The development of simple and inexpensive analytical methods for pesticide detection utilizing electrochemical sensors with the potential to modify those using sustainable materials has drawn increasing attention [1].

The unique properties of carbon-based materials allow for the development of sophisticated sensing systems that can precisely identify a wide variety of pollutants. The traditional carbon paste electrode is the most often used working electrode among the many electrode materials available today because of its unique characteristics, which include a broad potential range, long-term stability, high conductivity, a renewable surface, and ease of preparation and modification [2].

In contrast to alternative carbonaceous materials that require more complex and expensive preparation processes, biochar is a versatile and sustainable solution that can deal with environmental contaminants, including pesticides, in environmental samples. The usage of biochar as an active layer or component/modifier in electrochemical sensing platforms has increased recently for the detection of electroactive analytes [3–6], in an effort to increase the sustainability and "greenness" of electrochemical sensors [7, 8].

The use of a carbon paste electrode modified with biochar is highly recommended since it may enhance the sensitivity of trace-level detection of various electroactive analytes. Since biochar is a very effective sorbent material, an increase in surface area and an effective interaction between the surface of the biochar and the analyte through various mechanisms may be linked to the improvement of the voltammetric signals obtained for the carbon paste electrode based on biochar [9]. Because of the polyaromatic sheets in its structure, biochar has remarkable hydrophobic properties that can be used to encourage favorable interactions with hydrophobic pesticides, which can have a considerable impact on analytical performance [10]. Furthermore, the pyrolysis temperature above 550 °C during the biochar production process emphasizes the hydrophobic characteristics of the biochar due to the significantly higher loss of O content [11], which may result in advantageous binding affinities to hydrophobic pesticides [12]. Last but not least, biochar's affinity for the target analyte is greatly influenced by the presence of suitable functional groups on its surface [8].

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Electrochemical sensing is based on the quantifiable electrical signal produced by the analyte's redox process (oxidation or reduction reaction). Derivatization or other preparation procedures can be necessary to transform an analyte into a detectable form if it is not electroactive. In the electrochemical analysis of some analytes, pre-concentration can occasionally be a crucial step, particularly when analyzing trace levels. In order to increase the developed method's sensitivity and limit of detection, a larger amount of the target analyte could be accumulated onto the electrode surface prior to the actual measurement of the analytical signal [11].

Successful environmental applications, such as the ability to detect and monitor pollutants with high sensitivity and selectivity, depend significantly on the sensors/ working electrodes that are developed with appropriate specifications. Thus, to ensure precise detection and quantification of target analytes in complicated sample matrices with very low concentration levels of contaminants, there is a need to develop a sensor with an appropriate selectivity and sensitivity [8].

The main attractive feature of the voltammetric method and prepared biochar-based carbon paste electrode is their simplicity and low cost, which makes them applicable even in laboratories with limited resources. In addition, it has been proven that biochar can significantly improve the intensity of the current peak of the analyte, which can be attributed to the catalytic effect and favorable interactions with the investigated electroactive analyte. This can open up the possibility of applying biochar-modified carbon paste electrodes in various real samples, as well as for monitoring electrochemically active pollutants in environmental samples, even in the field. The designed biochar-based electrochemical sensors showed good stability with excellent reproducibility of the analytical signal of the target analyte. Compared to other analytical methods, the proposed voltammetric methods, as the main advantage, provide the possibility of simple, fast, cheap, reliable, and sensitive determination of target analytes. To conclude, integrating biochar as electrode materials in voltammetric method development holds great promise for advancing sustainable practices, reducing waste, and fostering a greener future [8].

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