Innovative graphene oxide sensor detects low concentrations of nitrate in water

OPTIRAS Project has been working towards the optimization of water quality control in Recirculating Aquaculture Systems. Now, a new study published in the Chemosensors journal introduces a novel approach.

A new study published in the Chemosensors journal introduces a novel approach to nitrate ion detection using all-solid-state ion-selective electrodes enabled by graphene oxide as an ion-to-electron transducer.

Nitrate ions play a critical role in the nitrogen cycle in natural ecosystems, such as in soils and aquatic environments. However, their levels have dramatically increased due to modern agricultural practices. The excessive use of inorganic fertilizers has led to high concentrations of nitrate in surface and groundwater, posing significant environmental and health risks.

Eutrophication, which is a phenomenon caused by nutrient overload in water bodies, results in uncontrolled algae growth, oxygen depletion, and poor water quality. This negatively impacts biodiversity, fisheries, and recreational activities. Moreover, if nitrate concentration exceeds a certain level (the value established by the European Union is 50mg/L), water may become unsuitable for consumption, potentially leading to severe health issues such as colorectal cancer and thyroid disease.

INL researchers have developed an innovative sensor that can robustly detect low concentrations of nitrate in water. Despite being effective, traditional methods for nitrate detection are time-consuming and expensive. Electrochemical sensors offer a promising alternative due to their simplicity, cost-effectiveness, and rapid response time – particularly potentiometric ion-selective electrodes.

However, early designs of these electrodes relied on internal filling solutions, making miniaturization and maintenance challenging. This led to the development of all-solid-state ion-selective electrodes, which replace the inner liquid solution with a solid substrate, enhancing portability and usability.

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In this study, INL researchers from the Water Quality group explored the use of graphene oxide as a novel transducer material, i.e., a novel material as an intermediate layer between the conductive surface and the sensing membrane of the nitrate sensor. Renato Gil, the first author of the paper, says, "Unlike graphene in its native form, the insulating properties and hydrophilicity of graphene oxide posed questions about its stability and electrochemical performance. However, its pseudo-capacitance effect and functional groups capable of ion exchange made graphene oxide an attractive candidate for our hypothesis".

The researchers at INL demonstrated that graphene oxide could effectively serve as an ion-to-electron transducer in all-solid-state nitrate sensors. The proposed sensors exhibited the absence of a water layer, which contributed to their excellent potential stability and extended lifetime.

Additionally, these sensors demonstrated an impressive reproducibility between equally prepared electrodes and showed equivalent analytical performance to previously reported nitrate sensors.

Raquel Queirós, the leader of this research study, adds, "We tested the developed sensors on several water samples, including drinking (bottled and tap) and environmental water collected from domestic wells, and our results confirmed the sensors' accuracy in determining nitrate levels".

INL's work represents a significant step forward in the field of electrochemical sensors, showcasing the potential of graphene oxide as an alternative material for constructing stable and durable solid-contact sensors. This development not only enhances nitrate detection methods but also broadens the use of carbon-based materials as a new generation of solid-contact potentiometric sensors.

The full paper is available in the June 2024 issue of Chemosensors journal. This research was funded by the projects OPTIRAS (PT-INN-0076), NGS-New Generation Storage (C644936001-00000045), and FCT (2020.04021.CEECIND).