Extended Abstract

Exploring the Potential of Graphene Oxide Functionalized with Ionic Liquid as Sorbent in Micro Solid Phase Extraction Towards Steroids in Water Sample

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ABSTRACT

Corticosteroids are widely used anti-inflammatory drugs but act as endocrine-disrupting compounds (EDCs), even at trace levels, posing serious health risks such as hormonal imbalances, reproductive issues, neurological disorders, and cancer. These contaminants enter water bodies mainly through improper disposal and household effluents, requiring efficient removal strategies. Conventional sorbents like silica have shown limited effectiveness, highlighting the need for a greener, more selective sorbent. Ionic liquids (ILs), with low volatility and high tunability, offer a promising approach to enhance sorbent performance. This study developed an Ionic Liquid-Graphene Oxide (IL-GO) sorbent for micro-solid phase extraction and evaluated its efficiency in removing hydrocortisone, dexamethasone, and fluocinolone acetonide from water samples. Results showed that IL-GO achieved significantly higher extraction efficiencies for hydrocortisone and fluocinolone acetonide, along with remarkable adsorption capacity for dexamethasone, outperforming GO alone. These findings demonstrate the potential of IL-GO as an effective and selective sorbent for corticosteroid removal, contributing to improved water quality and environmental safety.

Keywords: Graphene oxide, ionic liquids, selectivity, corticosteroids, green sorbent.

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1.0 Introduction

The occurrence of steroids in the aquatic environment and their potential effects have garnered significant attention among researchers and the public. This is because steroids are designed to be persistent and highly active towards human and animal receptors (1). Continuous discharge from various sources will eventually reach the wastewater treatment plants, which cannot effectively treat steroids due to their limited efficiency. This will amplify the impact of steroid contamination over time. According to the Guidelines for Drinking Water Quality by World Health Organization (WHO), routine monitoring of pharmaceuticals (including steroids) in drinking water is not considered necessary as the concentrations of these compounds are typically below the lowest therapeutic doses (2). However, long-term exposure to steroids has been shown to have detrimental effects on human health and the environment. Studies have demonstrated that steroids are susceptible towards mimicking the activity of endogenous hormones that can confuse the human body (3). Sample preparation is a vital step in analytical procedures, as it determines the accuracy and reproducibility of analytical results (4). Dispersive micro solid phase extraction(D-µ-SPE) is one of the sample preparation techniques used to extract steroids at trace concentrations, as it can effectively concentrate analytes in a short time (5). In this regard, a sorbent that is selective towards steroids should be developed for implementation with D-µ-SPE.

2.0 Innovation

The integration of ionic liquids (ILs) with graphene oxide (GO) offers a promising alternative sorbent for extracting specific corticosteroid drugs—hydrocortisone (HYD), dexamethasone (DEX), and fluocinolone acetonide (FLA)—from aqueous solutions. This sorbent demonstrates a high affinity, effectiveness, and selectivity comparable to commercial sorbents. Combining a simple extraction method with the advantages of this novel material (IL-GO) is anticipated to successfully isolate and extract a wide range of steroid drugs with wide polarities in aqueous environments. Table 1 describes the advantages of graphene oxide (GO) and ionic liquids (ILs) that are implemented to innovate good sorbent with high selectivity and improved efficiency.

Table 1: The Features of GO and IL for the Sorbent Development

Materials	Features
Graphene oxide (GO)	▪ Rich in oxygen containing functional groups that form H-bond, π-π interactions and Van der Waals forces between sorbent and steroids (6). ▪ High possibility to be functionalized with other materials to improve its features (5).
Ionic liquid (IL)	▪ Improve the selectivity and sorption of material upon impregnation (7).

The efficiency of this sorbent was tested using 100 parts per billion (ppb) of HYD, DEX, and FLA. The peak areas for all corticosteroids, as shown in (b), exhibited higher intensity when the IL-GO sorbent was used in the D-µ-SPE technique, indicating that the IL successfully improved adsorption when impregnated onto GO. Meanwhile, the chromatogram comparison in (a) clearly demonstrated the elimination of interference peaks from the water sample.

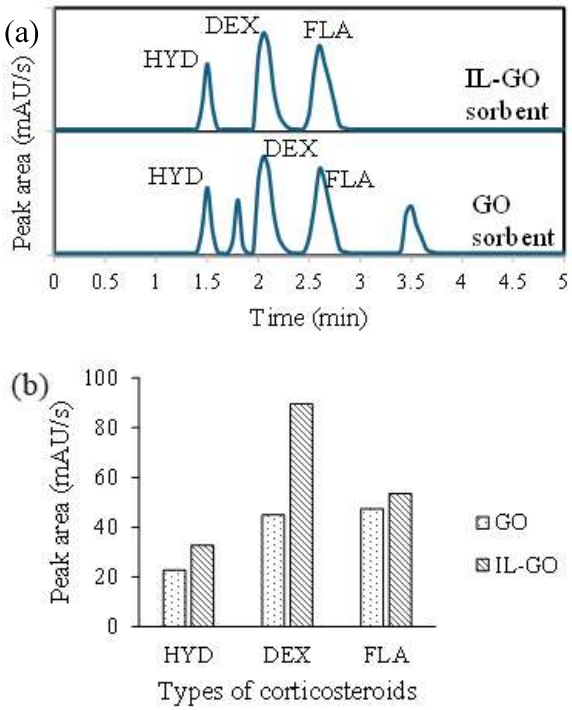

Figure 1: Comparison of corticosteroid extraction performance using Graphene Oxides (GO) and Ionic Liquid-GO (IL-GO) sorbents. (a) Chromatograms showing the separation of hydrocortisone (HYD), dexamethasone (DEX), and fluticasone (FLA) (b) the adsorption efficiency of IL-GO and GO sorbents.

3.0 Uniqueness

The integration of ILs with GO enables novel and innovative functionalization opportunities. ILs are known for their high cost. However, this innovation utilizes in-house ILs synthesized using inexpensive Brønsted acids and bases through a simple procedure. Furthermore, by impregnating ILs onto GO, the poor selectivity of the GO sorbent is enhanced, making it highly selective toward steroids. With the implementation of in-house ILs, a promising and effective IL-GO sorbent is realized at a significantly lower cost.

4.0 Commercialisation Potential

IL-GO sorbent offers significant commercial potential due to their superior ability to selectively adsorb organic pollutants like steroids attributed to their large surface area and tuneable ionic liquids, which enhance efficiency over conventional sorbents (8, 9). Derived from abundant graphite and biodegradable ionic liquids, IL-GO minimizes waste and aligns with green practices (10). The application of this promising sorbent can also be expanded to various emerging contaminants (EC), making it highly applicable in diverse industries.

5.0 Impact on Quintuple Helix

The IL-GO sorbent profoundly impacts the Quintuple Helix framework, positively impacting society, academia, government, industry and, more importantly, the environment. It enhances public health by ensuring safer water and pharmaceutical products by effectively removing pollutants. In academics, it drives significant advancements in environmental and pharmaceutical research, fostering innovation. Governments rely on its efficacy to enforce stricter environmental regulations, promoting sustainability and public safety. Industries benefit from improved processes and product quality, while its environmental contribution lies in reducing contamination, supporting ecological preservation, and advancing sustainability. This sorbent is essential to modern social development across all sectors.

6.0 Conclusion

Over the past decade, the consumption of steroids has increased exponentially, driven by the discovery of new drugs and population growth. The continuous discharge of steroids will inevitably lead to adverse effects, if not managed thoughtfully. With the invention of this green and selective IL-GO sorbent, it is hoped to provide valuable information on steroid levels in local water bodies. This will

enable authorities and local communities to take serious actions toward raising awareness about steroid usage and disposal, as well as preserving the health of the ecosystem.

Authorship contribution statement

RMY: Laboratory work, data analysis, resource person, draft correction. **EE:** Visualization, novelty. **NR:** Innovation features, commercialization. **NSMH:** Supervision, funding acquisition. **MAAR:** Ionic liquid contributor. **MSM:** supervision, review & editing.

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Conflict of Interest

The authors declared that they have no conflicts of interest to disclose.

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