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EDITORIAL

The Innovative Applications of Carbon Nanomaterials, Nanocomposites, and Related Carbon-Based Materials in Separation Science

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Welcome to another in the series of virtual issues of *Chromatographia* highlighting publications of particular interest within specialist fields or applications of separation science. These articles are taken from those published within *Chromatographia* over the past 2 years (2021–2022), and as such represent the state-of-the-art and most recent advances being reported within these areas. This particular virtual issue includes seven papers which have been selected based upon their innovative development and application of carbon nanomaterials, nanocomposites, and related carbon-based materials, here specifically in areas of extraction and selective separations, including solid-phase extraction (SPE), solid-phase micro-extraction (SPME), membrane-based extraction, magnetic solid-phase extraction (MSPE), and capillary affinity chromatography.

The selected papers within this virtual issue highlight how separation science is at its very core a materials-based science, wherein separation selectivity is typically obtained or enhanced through uniquely structured and chemically functionalized materials and surfaces. It is fair to say that over the past two decades we have witnessed an explosion in the applications of carbon nanomaterials across many branches of science, with no sign of slowing in the 2020's. Separation scientists have always been quick to exploit significant developments in material science, and explore new extraction, separation, and detection technologies based upon these new materials and new surface chemistries. Therefore, it is no surprise that carbon nanomaterials (and related carbon-based materials) represent one class of material which has witnessed particularly significant levels of interest and diverse applications, within and across the separation sciences.

The articles included in the collection that have been published within *Chromatographia* over the past 2 years demonstrate how advances in separation science often go hand in hand with advances in the material sciences. There is still a great deal of potential in the selectivity nanocarbon and nanocarbon composites offer, particularly in the various formats of micro- and solid-phase extraction, and so we continue to watch this space with excitement.

The full list of articles can be found here: https://link.springer.com/collections/hhajfdbaae. First within this virtual issue, we highlight the work of Hou et al., who, in early 2021, reported upon the microwave-assisted preparation of zirconium intercalated expanded graphite for chlorpyrifos determination in honey. Expanded graphite is a relatively new carbon-based adsorbent, with a unique porous structure allowing insertion of organic and inorganic species to affect changes in physical structure and selectivity. In this paper Hou et al., apply microwave radiation to facilitate intercalation with Zr (IV), and following simultaneous oxidation of the expanded graphite phase, successfully apply the material to the SPE of chloropyrifos, with a high degree of selectivity.

A little later in 2021, Kazemi et al., explored the hydrothermal formation and application of novel graphene oxide nanoribbons in headspace SPME, targeting phthalate esters from aqueous samples, with determination by GC-FID. The nanoribbons were formed from the hydrothermal edge-oxidation of multi-walled carbon nanotubes (MWCNTs), and then coated upon stainless steel wires using epoxy resin. The new SPME fibers were compared with both MWCNT and PDMS-based fibers for recovery of phthalate esters with impressive results.

The use of MWCNTs in SPME was also explored by Luo et al., in a more recent article, on this occasion applying a new nanocomposite material, consisting of o-aminobenzene sulfonic acid self-doped polyaniline (SPAN) and MWCNTs.

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This unique composite exhibited an increase of ~ 340% in surface area compared with common polyaniline SPME coatings, and an increased thermal stability of + 130°C. When applied to the SPME of 2,4-dichlorophenol, the new composite phase also showed an increased extraction efficiency of ~ 320%, when once again compared to the standard polyaniline-coated fiber.

Zulkipli et al., explored MWCNTs in an alternative format, in an article exploring their selectivity when encapsulated within gellan gum (GG) membranes, and applied to the μ-SPE of selected polyaromatic hydrocarbons from natural waters and beverages. The biodegradable gellan-based membrane was formed through a simple mixing procedure using hot GG solution and crosslinked with glutaraldehyde. When used in the μ-SPE applications with HPLC-based determination, it was reported to be a sensitive, accurate, and green methodology.

A highly topical and very different application of MWCNTs was recently reported by Guillaume and André, who were exploring how the immobilization of dexamethasone onto MWCNTs affected its orthosteric binding with angiotensin-converting enzyme 2 (ACE2) and the Main protease (Main pro) affinity columns (these being proteins of the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2)). As dexamethasone is a widely used treatment today for adults hospitalized with SARS-CoV-2, the use of MWCNTs to enhance and stabilize its protein binding, as indeed shown here by the authors by applying this nano-affinity chromatography technique, could prove highly impactful.

Magnetic solid-phase extraction (MSPE) obviously requires a magnetic core nanomaterial for magnetic extraction, but there have been several impressive articles exploring various carbon-based nano-coatings on such materials to impart improved extraction selectivity to these nano-sorbents. In two recent papers in this area, we see carbon-layers immobilized upon iron-oxide nanoparticles, and their subsequent application to the selective extraction of various natural products. First, Arkaban et al., reported upon a polyphenol-coated cobalt iron-oxide ($CoFe_2O_3$) magnetic nanoparticles, their synthesis, characterization, and application to lawsone (2-hydroxy-1, 4-naphthoquinone) isolation, a natural pigment used as skin and hair-dye, and found within the leaves of *Lawsonia inermis*. Second, and most recently, using a similar approach, Zixin et al., prepared poly(2-thiopheneacetic acid)-coated magnetite (Fe_3O_4) nanoparticles, claiming the formation of magnetic nanoparticles with only a single carbon layer coating (Fe_3O_4@1C NPs). This group applied this new material to the MSPE of cathine-6-one alkaloids, derived from stems of *Eurycoma longifolia*, demonstrating high recoveries and practically relevant enrichment factors.