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Analytica 2022

This year, Messe München is hosting the world’s leading trade fair for laboratory technology, analysis, and biotechnology live and in person. The conference will take place 21–24 June 2022 in Munich, Germany. Here the Exhibition Director, Armin Wittmann, highlights what chromatographers can look forward to.

No laboratory can be imagined without chromatography. From 21–24 June 2022, Analytica will provide information on innovations and trends in this universal method. Of the approximately 900 exhibitors at the world’s leading trade fair for laboratory technology, analysis, and biotechnology, almost 140 companies will be offering instruments and accessories for chromatographers. In addition to industry giants, many other manufacturers will be presenting innovative chromatographic technologies.

**Analytica Conference—Chromatography as a Highlight Topic**

Anyone interested in GC should make a note of the first day of the scientifically oriented Analytica conference. Under the title “Gas Chromatography: Boring or is There Something New?”, speakers from Germany, Belgium, and Australia will provide information in the morning on hyperfast GC, multidimensional GC, and the determination of mineral oil contaminants (June 21, 9:30 to 11:30 a.m. at the ICM, Room 5). In the afternoon, experts from Germany, the United Kingdom, France, Austria, and Switzerland will focus on coupling chromatography to ion-mobility mass spectrometry (June 21, 12:30 to 14:30 and 15:00 to 17:00 in ICM, Room 5). Attendance at the conference, which will be held 21–23 June at ICM in close proximity to the exhibition halls, is free for all Analytica visitors. With nearly 200 presentations, the complete programme on all aspects of modern analysis, bioanalysis, and diagnostics can be found on the official website: [www.analytica.de](http://www.analytica.de)

**Special Show Digital Transformation in the Laboratory**

In the special show “Digital Transformation/Lab 4.0” visitors will learn how laboratories are making themselves fit for tomorrow. Here, the focus is on topics such as artificial intelligence, big data, digital solutions, and smart networking. Complex holistic automation concepts and efficient interface solutions provide answers to new challenges such as dealing with huge amounts of data and the digitalization of laboratory processes and structures. The special show will take place daily from 10:00 a.m. in Hall B2, Booth B2.525 and will have an integrated forum.

For more information, tickets, and registration, please visit [www.analytica.de](http://www.analytica.de) or to view the conference programme please visit [https://analytica.de/en/supporting-program/conference/program/](https://analytica.de/en/supporting-program/conference/program/)

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www.chromatographyonline.com
Trends and Developments

Kate Jones and Lewis Botcherby, Managing Editor and Associate Editor, LCGC Europe

A snapshot of key trends and developments in separation science according to selected panellists from the chromatography sector

GC/GC–MS

What trends do you see emerging in GC or GC–MS?

Alessandro Baldi Talini: The major trends for gas chromatography (GC) and GC–mass spectrometry (GC–MS) in laboratories right now can be found in the features of the Industry 4.0 era, which includes digitalization and smart and automated technologies fuelled by data and machine learning. In pre-pandemic times, interest in the benefits of smart and automated technologies was high. With the necessity to protect people and also keep science and business going during the pandemic, however, the new normal of social distancing, working from home (WFH), hybrid working shifts, and labour shortages have greatly accelerated the adoption and implementation of digitalization. For laboratories it has become very important to integrate new ways of operational efficiency. Remoteness and connectivity of GC workflows will be lasting trends.

Sustainability, from an environmental and operational perspective, is another topic that is seeing a lot of interest. For example, given supply chain dependencies, disruptions, and rising costs coming from world events, the use of helium is shifting to less costly and greener alternatives. The use of hydrogen generators is a perfect example of how technology can address sustainability and market shifts. There is no handling of gas tanks, no shipments, you never run out of gas, and water generates a carrier that facilitates fast and safe chromatography.

James Gearing: One emerging trend is the focus on sustainability and the strive for more efficient laboratory operations. Instrument design and manufacturing is taking sustainability into consideration, from product inception to decommissioning and disposal. Everything from materials chosen, manufacturing processes, and shipment are evaluated. Many instruments now have environmental impact scores to help enterprises make informed decisions when it comes to sustainability.

Another trend is the strong interest in alternative carrier gases, particularly switching from helium to hydrogen due to increased helium costs and shortages. System features also contribute to the sustainability goals of the laboratory, for example, gas saver and direct column heating ovens reduce gas and power usage. In the area of sample introduction and sample preparation, the trend is towards more automation, with popular techniques such as headspace, purge and trap, and thermal desorption. Pyrolysis extends the range of GC, opening up new application areas.

Full sample characterization with fast GC is driving more class-based analysis. New regulations for environmental applications, dioxins, and genotoxic impurities are driving new waves of adoption of GC–MS.

Hansjoerg Majer: While relaxing at home, I like to watch the old forensic TV series such as “Medical Detectives”. I am amazed at how the new and innovative technology “gas chromatography” is often celebrated as solving the case. Forty years later, some consider the technology mature, pointing to the recently added light inside the GC oven as the latest innovation.

Scientists and technicians use gas chromatography daily to solve their challenges. For the manufacturers of chromatography systems, the column remains the centrepiece. Technical expertise in chromatography may be decreasing; however, the complexity of the test and sample load is increasing. Gas chromatography has become the workhorse, and the focus is on the robustness of the process. Equipment and consumables are expected to operate 24/7. Instruments are found in high-throughput routine laboratories, production facilities, glove boxes, ocean-going research vessels, and in space. The European Space Agency’s Rosetta mission put columns on the Philae lander to sample the comet surface.

There is a clear trend towards faster processes and miniaturization. The combination of gas chromatography with newer, smaller detectors, such as ion mobility spectroscopy (IMS), makes “handheld” systems seem possible for complex applications such as food safety or environmental protection.

Old and new approaches to chromatography have taken advantage of the rapid increase in instrument
sensitivity and acquisition speed. For example, low-pressure GC (LPGC) decreases runtimes by decreasing the elution temperature of compounds in a vacuum—a technology that has existed for many years but has been reinvented now.

On the other hand, new technology such as flow-field thermal gradient GC (FF-TG-GC) allows precise control of the temperature and thermal gradient, producing narrower peak widths and faster runtimes. Big data handling capacities will give more complex systems like two-dimensional gas chromatography (GC×GC) another chance to enter the routine analysis area.

Massimo Santoro: While GC is still widely used for very common applications, it’s interesting to see its use gaining ground to complement the information needed for challenging applications that can’t be addressed exclusively with other techniques. I’m referring to the increased interest in volatile per- and polyfluoroalkyl compounds (PFAS), where GC–MS and sample introduction by thermal desorption (LC) are used alongside liquid chromatography (LC) for its capacity to investigate volatile species that would simply be missed otherwise, or when GC–MS is used alongside spectroscopic techniques for quantitative determination of microplastics in water, air, and materials.

What is the future of GC or GC–MS?

Alessandro Baldi Talini: The future for GC and GC–MS lies in implementing the Industry 4.0 blueprint by looking at: how labs can become digitally-enabled by being connected and allowing remote work; how automation can be integrated into repetitive tasks, enabling lab staff to be more focused on data analysis and insightful action; and how GC, GC–MS, and chromatography data systems (CDS) can mitigate training and adoption costs for new technologies by considering new “digital-skills” of lab staff, driven by the spread of digital devices.

James Gearing: The recent introductions of smart and connected intelligent instruments has set the path for the future. Containing powerful microprocessors, GC and GC–MS systems will continue to be enhanced with even more advanced algorithms and capabilities to eliminate routine operator tasks, simplifying diagnostics and troubleshooting, and with software systems automating data review with artificial intelligence (AI) and machine learning. Analysis is being driven closer to the sampling location with mobile, remote, at-, or near-line applications, especially with micro-GC. For example, reaction gas monitoring is growing as alternative fuel research is increasingly funded. Instruments are becoming more self-aware and can perform analysis in the background and alert users of exceptions requiring attention.

Hansjoerg Majer: Rapid on-site screening of chemicals continues to advance with the miniaturization of mass spectrometers and other detectors. For example, ion trap mass spectrometry (IT-MS) systems measure only around 1 mm in diameter. There are portable GC–MS systems with a low thermal mass (LTM) column that weighs only about 15 kg and produces similar data to a benchtop system. Chemical sensor technology incorporates multiple detectors on a chip and customized polymers coated onto a sensor platform targeting compounds with different polarities/solubilities that can be analyzed from the atmosphere in real-time.

Massimo Santoro: They have a bright future. Most of the common emerging contaminants are very volatile species, for which GC and GC–MS are the ideal choices. Additionally, technological advances in sampling techniques, sample introduction, and MS detection have meant that entire workflows can be miniaturized, reducing sample and solvent waste, moving away from the use of non-renewable helium as carrier gas, and making GC and GC–MS more environmentally friendly.

What is the GC or GC–MS application area that you see growing the fastest?

Alessandro Baldi Talini: There is an expansion of GC and GC–MS applications in growing industries, in particular, batteries and recycled polyethylene terephthalate (PET). It will be interesting to see the adoption of well-established methods, slightly modified, to accommodate the need for these new types of samples.

James Gearing: There is a shift in focus towards renewable fuels and a growing need to expand hydrocarbon composition testing capabilities to better understand these molecules. GC×GC is receiving growing attention as a potential all-in-one fuel composition analyzer with the proliferation of low footprint non-cryogenic flow modulation technology. While conventional fuel product quality focuses primarily on physical property and performance-based testing, renewable molecules are being qualified as fuel blend components initially by composition. Synthetic paraffinic kerosenes (SPKs) are an example of renewable fuels that currently require “per-batch” analysis of molecular classes by pre-fractionation and GC–MS. GC×GC provides the same analytical fidelity without cumbersome sample preparation, and the initial GC×GC consensus test methods are targeting SPK fuels. This lays the foundation for GC×GC to potentially consolidate existing conventional fuels composition testing currently spread between high performance liquid chromatography (HPLC), supercritical fluid chromatography (SFC), GC, and GC–MS into a single platform.
Hansjoerg Majer: In North America, cannabis testing has expanded from pesticides to terpene characterization.

Food fraud detection and food quality control via fingerprinting and data handling is an emerging topic.

Nitrosamines have taken centre stage globally as an impurity in medications, but they are also found in the environment, food, beverages, cosmetics, and cigarette smoke; these compounds are strong carcinogens and have garnered worldwide attention.

Persistent organic pollutants (POPs), which are known by many other acronyms (persistent mobile organic compounds [PMOC]; persistent, mobile, toxic [PMT]), will continue to garner attention and funding for research and future regulation. These compounds include legacy compounds as well as emerging compounds of interest.

In addition, there is a clear trend to combine methods into so-called multi-multi-methods. These are screening methods in which different component classes are combined. Such methods place high demands on the tuning of separation column selectivity.

Nontarget screening is another methodological approach that is dependent on the newest big data handling capacities, and will become more popular in different areas of interest such as environmental or food analysis.

Massimo Santoro: I would say every application that has an impact on human health is going to grow fast in the coming years. From environmental applications looking for emerging contaminants to food quality/food adulteration, all the way to monitoring the air we breathe in and out—GC–MS is the technique of choice for early diagnostics of diseases. Most of these applications didn’t exist 10–15 years ago, or were not as challenging for GC–MS in terms of sensitivity and throughput requirements. Now every result has to be provided in a timely manner, and that offers another chance for GC–MS robustness to shine.

What obstacles stand in the way of GC or GC–MS development?

Alessandro Baldi Talini: Rather than focus on obstacles, I would refer more to opportunities when we develop new GC platforms. Laboratories are looking more than ever for ease of use and pre-defined workflows to minimize time to data and to be able to easily adopt new applications. The challenge is to be able to provide a user experience similar to what we all expect every day when interacting with our mobile devices, computers, and cars. The commoditization of GC technology calls for intuitiveness, interactive/updated graphics, fast data access, and easy collaboration, making the experience and the data the focus versus, the actual instrument and technology working behind the scenes.

James Gearing: GC/GC–MS systems serve a broad range of markets and application areas, often with long time frames of historical data and workflows. It requires compelling business justification to modify existing methods or workflows. For example, the recurring shortages of helium and increased costs are driving a change towards hydrogen-based methods. GC and GC–MS users are also facing ever-increasing measurement demands because of new regulations or stricter quality assurance/quality control (QA/QC) product requirements. Broader use of tandem mass spectrometry (MS/MS) or GC×GC, along with more advanced software processing, could help simplify the overall workflow and deliver actionable results.

Hansjoerg Majer: Gas chromatography is dependent on the carrier gas. Over many years helium has proven to be particularly suitable, both because of its inertness in the chromatographic system and because of its properties in the ionization sources of mass spectrometric detectors.

From time to time, we are reminded that helium is not always available in unlimited quantities. As a result, some analytical methods have to be switched to other carrier gases, such as nitrogen or hydrogen, especially when information has to be delivered without interruption.

Nowadays, such conversions can be accompanied by computer programs, but they are not without risks.

The so-called “big markets” in analytics, namely, the pharmaceutical sector with its trend towards large biological molecules, makes instrument providers more likely to invest in the GC sector, so innovations in the GC sector may not progress as fast as they could.

Massimo Santoro: None, really. I think there will always be a need for GC–MS to be adopted more widely, and that’s an excellent opportunity for developing smaller, smarter, more integrated GC–MS solutions.

What was the biggest accomplishment or news in 2021/2022 for GC or GC–MS?

Alessandro Baldi Talini: The most relevant news of 2021 has been the return of strong market demand. Although the pandemic is still hitting some market areas, we have seen the market going back to 2019 levels pretty much in every segment. With that, we have seen a profound change in demand, with a large focus on remote capabilities and for technologies that foster collaboration across teams.

James Gearing: A new GC–MS ion source allows the wider use of hydrogen as a carrier gas in GC–MS applications. As I mentioned before, we see a continued acceleration of users adopting hydrogen as a carrier gas. Due to hydrogen not possessing the same inert qualities as helium, this can pose a challenge, especially in the high energy environment of a GC–MS ion source. The new ion source greatly reduces the potential reaction between susceptible analytes and the hydrogen carrier gas.
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A big accomplishment has been the continued development of smart-connected technology. New intelligent instrument features based on chromatographic data enable more advanced diagnostics, trending, and troubleshooting. Remote interfaces allow laboratory users more flexibility, resulting in less unplanned downtime and more efficient operations.

**Hansjoerg Majer:** The expansion of both FF-TG-GC and LPGC substantially increases sample throughput and can take advantage of the recent advances in mass spectrometer technology, that is, benchtop (BT)-TOF, orbital traps.

**Massimo Santoro:** Thermal desorber systems independently certified for the use of hydrogen carrier gas while still maintaining compatibility with conventional carrier gases such as helium and nitrogen are an important technological advancement. These can increase productivity by as much as 40–50% compared to the use of helium.

**Alessandro Baldi Talini** is Director Product Portfolio – Gas Chromatography at PerkinElmer, Inc.

**James Gearing** is Associate Vice President, Marketing Gas Phase Separations Division at Agilent Technologies, Inc.

**Hansjoerg Majer** is Senior Business Development Manager Europe at Restek.

**Massimo Santoro** is Director of Business Development for Schauenburg Analytics and Markes International.

**SAMPLE PREP**

**What trends do you see emerging in sample preparation?**

**Dirk Hansen:** We see multiple and diverse trends in sample preparation. On the one hand, next-generation mass spectrometry (MS) detectors allow for the analysis of low concentrated samples without prior enrichment, but on the other hand, regulatory agencies continuously ask for lower detection and quantification limits, putting more pressure on the laboratory scientists for results. Due to these trends, we see more solutions, such as protein precipitation and phospholipid removal, being developed for a quick removal of matrix components to achieve a level of cleanliness in the sample with good recovery and relatively simple procedure. Other trends we are seeing are more sophisticated sample preparation like multi-layer solid-phase extraction (SPE), automation of the extractions, and integration of the sample preparation to the analytical workflow in the case of on-line SPE or two-dimensional liquid chromatography (2D-LC) in combination with MS detection.

**Oliver Lerch:** I am frequently in contact with customers from industry and academia working to meet their needs. All of this feeds into our perspective on requirements and future developments. I am also specifically involved in automating sample prep processes.

In the Analytica Virtual Update: 2020, I “complained” that users stick to tried and trusted products and concepts, mainly relying on manual sample preparation. This seems to have changed since then. Companies are investing in automation for sample preparation, starting with simple yet effective things like preparing standards based on liquid handling, agitation, as well as vial de-capping and capping steps. The idea of automating sample preparation has clearly arrived in laboratories throughout the world in all application areas and markets. For users it is beneficial to rely on an automation platform on which they can start with basic workflows and extend functionalities over time as new challenges arise.

In that context, downscaling is often needed to enable automation. Standard operating procedures (SOPs) were until recently frequently written around manual sample processing and therefore employed large amounts of sample, solvents, and reagents. Automation and downscaling help to cut cost for chemicals, including for their safe disposal. In addition, automation reduces the exposure of laboratory personnel to hazardous substances. A greener and more cost-efficient chemical analysis is the result. A recently developed method for the determination of perfluoroalkyl and polyfluoroalkyl substances (PFAS) in water also profits analytically from smaller sample vessels because these can be efficiently flushed with limited amounts of solvent and the rinse effluent added to the SPE step, eliminating loss by adsorption on surfaces.

**Ritesh Pandya:** As more high-throughput laboratories tend to employ automation for sample clean-up, miniaturization of the starting sample and corresponding solvent volumes has become possible. Coupling various instruments used in sample preparation has gained popularity, because it adds convenience to the overall user experience. A good example would be processing samples on well plates using a liquid handler combined with a manifold. Products that allow routine complex workflows to be simplified without sacrificing analyte recoveries are also attracting analysts from all industries.

Filtration columns and tips with certain chemistries allow for a reduction in the number of steps while removing matrix components to an acceptable level.

Also, with an increase in the legalization of marijuana for recreational and medical...
use, demand for extracting and separating tetrahydrocannabinol (THC) isomers from challenging matrices has been on the rise. To better understand the impact of PFAS toxicity on the environment and human health, more emphasis than ever is being put on analyzing PFAS in various water and food samples.

**Elia Psillakis:** In my opinion, more and more analysts engage towards a greener and more sustainable future for sample preparation. “Going Green” in sample preparation is not a trend; it is a necessity. Current global challenges and stressors highlight the urgency at which sustainability issues must be addressed. Going in this direction, the application of environmentally benign sample preparation methods should be a priority for all researchers, practitioners, and routine analysts for the benefit of the environment, human health, and society. Green sample preparation is sample preparation. It is not a new subdiscipline of sample preparation but a guiding principle towards sustainability.

**In your opinion, what is the future of sample preparation?**

**Dirk Hansen:** With a focus on sustainability across the globe, we expect further miniaturization and reduced environmental impact (solvent consumption) as some of the main drivers for new developments in sample preparation solutions. In addition, we believe that in the clinical diagnostics space, there will be a greater number of LC–MS/MS methods replacing classical immunoassays. Based on this assumption, we expect a larger need for easily automatable sample preparation solutions for some of these assays.

**Oliver Lerch:** Sample preparation will remain important for the foreseeable future. For many matrices, sample preparation is indispensable. A colleague of mine likes to point out that “an LC–MS system has no door through which the lettuce can be introduced for pesticide analysis”. That is why we need sample prep! For other applications, sample preparation makes sense as well because we need to ensure that we arrive at accurate results using rugged analysis methods while continuing to have long maintenance intervals and high throughput.

Two years ago, I described the seamless integration of different manufacturers’ instruments into one software control platform as a trend. In this matter, having been overly optimistic, I have to correct myself. We are at the early stages of such a development, in which “all” laboratory equipment will be integrated into one control software connected to a laboratory information management system (LIMS) using generic interface standards. This setup will eventually allow us to generate comprehensive automated workflows with robots that fetch samples from the refrigerator before transferring them to a sample preparation platform and finally to the analysis system. Alternatively, workflows with human intervention, such as a manually executed weighing step, are possible. The analysis results are finally transferred to the LIMS. Today, customers are requesting interaction and synchronization between instrument control software and LIMS. For example, vials can simply be placed in the autosampler tray, the barcode scanned, the sample ID established, and the correct analysis method and sequence table set up and executed automatically.

**Ritesh Pandya:** Advances in automation appear to guide the future of sample preparation. SPE products that are compatible with various components integrated into an all-in-one workstation will significantly maximize productivity. Liquid handlers ensure consistent and accurate pipetting of extremely small volumes, overcoming critical errors that would be introduced when using a manual approach. Apart from saving time, the robots minimize the risk of exposure to chemicals on a daily basis and drastically reduce solvent consumption, contributing to a cost-effective method set-up. Treating all the samples the same way without many variations leads to reliable results and excellent reproducibility. The ability to modify the extraction procedures stored on the software is another favourable feature of automation.

**Elia Psillakis:** Sample preparation will continue to grow in importance, with sustainability issues guiding future trends in speed, automation, energy, materials, chemicals, and size. Meanwhile, cooperation and coordination with national and international standardization bodies will be established with the aim of replacing hazardous official standard sample preparation methods with green high-performers. Sample preparation will most likely become increasingly interdisciplinary to promote problem-driven research and address the world’s increasingly complex and interconnected problems. Tearing down disciplinary walls will also facilitate knowledge transfer from other “distant” disciplines and increase our understanding of the fundamentals underlying sample preparation. We should also expect breakthroughs in low-cost, robust, and networked sensors for remote all-in-one sampling, sample preparation, and analysis. This foreseen rise in remote analysis could also lead to the much-discussed fusion with big data and artificial intelligence (AI), creating miraculous benefits.

**What obstacles do you think stand in the way of sample preparation development?**

**Dirk Hansen:** There is a tendency to avoid sample preparation by using more sensitive detectors. This is driven by the fact that in many cases sample preparation is still a manual process and requires a thorough method development and method validation. Even with advances
to the detectors, sample preparation is a vital step that needs to be performed by experienced laboratory scientists to ensure reliability and to provide accurate results. **Oliver Lerch:** Many companies develop and manufacture innovative sample preparation equipment. Nevertheless, the majority of the “big” gas chromatography (GC)–MS and LC–MS instrument manufacturers have less focus on sample preparation, preferring to market (high-end) mass spectrometers and to omit sample preparation wherever possible, using a “dilute-and-shoot” or direct injection approach. This strategy may lead to less robust analysis methods and an increased need for instrument maintenance, leading to instrument downtime. A closer collaboration between instrument manufacturers and sample preparation equipment manufacturers could benefit all parties because customers today are asking more and more frequently for comprehensive solutions from the sample as received to the final analysis result.

**Ritesh Pandya:** Highly sensitive modern analytical instruments leave no room for residual contamination that would have usually gone under the radar. It becomes tremendously vital for the companies to closely monitor the manufacturing process and for the laboratories to ensure a contamination-free environment with no carryover issues. While some matrices are exceptionally difficult to work with, more realistic expectations need to be held, especially when it comes to achieving high recoveries and minimal matrix effects for a large panel comprised of analytes with varying chemistries.

**Elia Psillakis:** The biggest obstacle to sample preparation is the weak connection between academia and the private sector. Research in sample preparation is blooming, but perhaps left unnoticed by outsiders. We have not been effective enough at projecting these advances and have acquired the image of a slow-paced discipline developing laborious and time-consuming procedures. The lack of a coherent strategy to promote the criticality and benefits of modern sample preparation technologies has resulted in many official standard methods still relying on old-fashioned and hazardous analytical procedures. Newer, more powerful, and greener sample preparation methods are ignored in favour of more traditional and standard approaches, which may not fully address the analytical challenge at hand. Private and industrial laboratories see new and green sample preparation alternatives as an extra burden, rather than an opportunity to adopt powerful techniques that have a shared value for both the productivity and society. Strengthening the interface between academia and the private sector is an obstacle that has to be overcome and this is a major task of the EuChemS-DAC Study Group and Network Force, which I have the honour of leading.

What one recent development in the area of sample preparation would you say is the most important?

**Dirk Hansen:** The biopharmaceutical market has consistently had strong growth for the past couple of years, especially with the global distribution of the COVID-19 vaccine. Biopharma laboratories need to be able to consistently clean up their biological samples without losing their sample while also maintaining high recovery. By using, for example, a magnetic bead as a reproducible sample preparation option, this addresses both those needs, but can add a lengthy amount of time to the workflow.

**Oliver Lerch:** I do not see one single most important development in particular in techniques or applications. The quest for greener analysis and greener sample preparation techniques seems to be gathering momentum. The good news is that there is progress in that area in terms of underlying concepts as well. In that context I would like to recommend the article “The ten principles of green sample preparation” in *Trends in Analytical Chemistry* by Angela I. Lopez-Lorente et al. (https://www.sciencedirect.com/science/article/pii/S0165993622000139), in which 10 fundamental principles are described that the sample preparation of the future should stick to. The authors plan to develop metrics for assessing “greenness” of sample preparation steps. Further, the IUPAC project “Greenness of official standard sample preparation methods” (https://iupac.org/project/2021-015-2-500) is guaranteed to become recommended reading.

**Ritesh Pandya:** The recently developed QuEChERSER Mega-Method is an upgrade over the regular QuEChERS procedure, as it covers analytes within a broader polarity range. This new approach seems to be a significant development and eliminates the need for using separate methods to analyze pesticides, veterinary drugs, environmental contaminants, and mycotoxins in food. **Elia Psillakis:** Early sample preparation methods were a major source of the total negative impact of analytical methodologies on the environment, mainly due to the large energy demands and quantities of hazardous substances used and generated. For this reason, the first of the 12 Green Analytical Chemistry (GAC) principles suggested applying direct analytical techniques to avoid sample preparation. The first principle of GAC was commonly misinterpreted and created the false impression that omitting the sample preparation step was a green approach, fully neglecting the “green” technological advances in the field. The “exclusion” of sample preparation from GAC also created a gap, since removing this step was practically impossible for complex samples and when high sensitivity is needed. I think that the most important recent development was the formulation of
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the ten principles of green sample preparation and the introduction of AGREEprep, the first metric tool focusing on sample preparation. Defining sample preparation within the context of green chemistry and GAC was a great necessity in the area of sample preparation. We now have the approach formulated in hand and a metric to evaluate the environmental impact of methods. Currently, decisions about methods are based on method performance and price. Thanks to these developments, they can now be complemented by a sustainability factor, which is a measure of how green the method is.

What was the biggest accomplishment or news in 2021/2022 for sample preparation?
Dirk Hansen: The development of products that are able to solve multiple problems in one extraction for scientists—combining two different sorbents or products to help create a faster solution.

Oliver Lerch: The sample preparation community is increasingly organized; for example, the “Sample Preparation Study Group and Network” was installed in the Division of Analytical Chemistry of the European Chemical Society in 2020. This group held European Sample Preparation e-Conferences in 2021 and 2022, and this year the conference was even accompanied by the 1st Green and Sustainable Analytical Chemistry e-Conference. Moreover, Advances in Sample Preparation, a dedicated open-access scientific journal was established in 2021. This shows that the community is active and is receiving more and more attention in the analytical chemistry world. These are the big accomplishments of the last two years.

Ritesh Pandya: EPA 1633 draft method for the analysis of 40 PFAS in non-drinking water matrices was a piece of important news this year.

The sample clean-up is accomplished using weak anion exchange (WAX) and graphitized carbon black (GCB) in powder or cartridge format.

Elia Psillakis: In my opinion 2021–2022 was a landmark year for sample preparation, as this was the launch year of Elsevier’s open access journal Advances in Sample Preparation (SAMPRE). SAMPRE was the first academic journal dedicated to sample preparation. The launch of this new journal is of particular importance to our scientific community, as it recognizes the extraordinary technological and scientific growth in the area. For many years, senior members of our community were proposing the creation of this journal but major publishers could not identify the niche to fill. At that time the growth was not sufficiently large and new papers could be absorbed into existing journals. The launch of SAMPRE formalized sample preparation as a discipline and illuminated the dynamics, importance, and impact of the field.

Dirk Hansen is Regional Market Development Manager, Europe at Phenomenex.

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LC/LC-MS

What trends do you see emerging in LC or LC-MS?
Runsheng Zheng: Recent years showed the increased demand for the separation and analysis of diverse and complex samples in virus research, vaccines development, large-scale translational research studies, precision medicine, and analysis of single cells. This significantly extended the use of different types of liquid chromatography and columns. The anion exchange, cation exchange, supermacroporous, micro-pillar array, HILIC columns are serving the needs for efficient separation of oligonucleotides, intact proteins, peptides, glycans, and lipids. In addition, the focus on uncommon and complex analytes accelerated the adoption of mass spectrometry in quality control, such as with multi-attributed method (MAM) for biotherapeutics. Charged Aerosol Detector (CAD) became a hit in quality control of vaccine excipients. Ultra-low nano-flow coupled with high-resolution accurate mass (HRAM) mass-spectrometers (MS) opened the door for single-cell proteomics that was not even possible a few years ago. Standardized micro-flow LC–MS workflows are combining high-sensitivity with high robustness for rapid profiling of biological liquids, ready for the analysis of thousands of samples.

Gesa Schad: Apart from the general desire for miniaturization, flexibility, and faster results, combined with the need for simplification and automation, the trend goes towards more user-friendly data handling solutions. That combined with smart instrument features that support preventative maintenance, reduce system down-time and offer ease-of-use for non-experts make the technique more accessible to less experienced scientists, so that anyone is able to produce meaningful, reliable data, without
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excessive training needs. The possibility of working remotely, being able to control the instrument and access data from anywhere, also became an urgent requirement with the changes the pandemic brought to the work environment. And with an increased environmental awareness and rising cost of energy, of course manufacturers have to consider sustainability and more eco-friendly solutions in all aspects of new developments.

**Ronan O’Malley:** LC–MS means different things to different people – for researchers, it is a means of testing a hypothesis; for a pharmaceutical manufacturer it can be a tool to test a product attribute, and for a clinician, a ‘closed’ diagnostic system.

More and more, we see these customer segments demanding product offerings that are more targeted to their individual needs. For a research scientist schooled in LC–MS and comfortable with system complexity, demands might include interchangeable ionisation sources, precise control over means and modes of fragmentation, great flexibility in software options and fast turnaround of software enhancements. For them technical innovation remains at the top of the list.

A laboratory manager at a pharmaceutical company or contract development and manufacturing organization (CDMO) prioritises serviceability, total cost of ownership, reliability and integration into existing good laboratory practices (GxP) compliant workflows more highly.

In one of the biggest potential markets, clinical diagnostics, the requirements are for systems to be “fault tolerant” and to provide reproducible results and consumer-electronics-levels of usability. Pulling back on the focus a bit, as an instrument manufacturer we see that all customer segments demand secure interoperability with their own data systems. Staying with the software theme for the moment, changes in analysts’ expectations with respect to working remotely gives vendors the opportunity to differentiate their product offerings by adding and improving options for remote use which is among the reasons for transitioning to cloud-based informatics.

**Rohit Shroff:** Industrial sustainability agendas are increasingly a driving force behind decision making for new products and new methods. Goals to reduce solvent consumption have increased interest in reduced column internal diameters (i.d.’s) to increase efficiency and encouraged development of methods using shorter column lengths to reduce run times per sample. In addition, reversed phase chromatography’s heavy reliance on acetonitrile and methanol mobile phases means new approaches to mobile phases have moved up the agenda. As a result, there is a renewed interest in greener technologies such as SFC, whilst research into alternative solutions such as purely aqueous mobile phases run at elevated temperatures provides a glimpse as to how LC methods may be adapted in the future.

Additionally, domains such as proteomics and metabolomics have focussed on development of methods for very complex sample analysis. This high-resolution, “fingerprint” type approach to sample identification is now generating more interest from industries such as food analysis where product integrity and authenticity testing are increasingly adopting LC–MS for these types of investigations.

**What is the future of LC or LC–MS?**

**Runsheng Zheng:** Liquid chromatography should become a multi-tool that can resolve almost any analytical challenge from small molecules analysis to the separation of large proteins and protein complexes detected by advanced MS and UV/Vis technologies. The deployment of artificial intelligence/machine learning (AI/ML) and building interconnected laboratory infrastructure with automation of all sample handling steps, will make LC and LC–MS even more robust, predictable, and easier to use. The LC cycle times will shrink to several minutes so the technique will enable large-scale pharmaceutical and medical research projects with thousands of samples required for reliable statistical analysis.

**Gesa Schad:** The increased desire for an automated workflow, from sample registration, pre-treatment to analysis, data processing and reporting will drive the development in the future. This is not only due to the lack or the cost of qualified personnel, but also owing to the requirement of data integrity and complete control of the entire process, in an effort to eliminate the risk of human error at every step of the way.

**Ronan O’Malley:** A foundational criterion for many grant-awarding bodies is sustainability—not just in energy usage but in recyclability of components as well as environmental costs incurred in all aspects of use—from packaging materials and delivery overhead to minimising the use of solvents and other consumables. Others, along with industry, will very soon follow suit in specifying these as non-negotiable purchasing criteria.

Beyond near-term challenges, the LC–MS user of the future—interested only in the answers to questions such as: “What is this substance?” and “How much of it do I have?”—will benefit from advances in UX research and engineering and, more importantly, systems designed for precisely defined purposes, to the extent that one day, perhaps, they may be completely unaware that their device uses LC–MS at all.

**Rohit Shroff:** There is an increasing need for field-based analysis across a variety of industries, meaning that miniaturization of technology has been a trend for a number of years. Improved usability and reduced cost of MS technology is
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supporting the development and interest in chromatography in this area and placing them in new settings offering opportunities for improving real-time monitoring. This is also driving innovation in the column technology as manufacturers look at alternatives to the classic column format, with designs being influenced by the growing field of microfluidics, where the manufacturing methods result in more reproducible technology compared to traditional formats based on silica beads packed into columns.

What is the LC or LC–MS application area that you see growing the fastest?

Runsheng Zheng: With LC and LC–MS becoming more efficient, sensitive, and reliable for the analysis of complex biological samples the areas of translational research and precision medicine show the fastest growth. The promise to change our daily lives with early disease detection, efficient treatment, and real-time patient recovery monitoring is driving investment and advanced LC and LC–MS hardware and software. Another area that is already a hot topic for several years is automated and in-depth quality control of biotherapeutics. There is a fast adoption of MAM workflows in the regulated environment by large biopharma companies.

Gesa Schad: For some time now there has been a shift in focus of pharmaceutical companies towards novel biologic medicines, which got an additional boost in the race for a COVID-19 vaccine and the emergence of novel mRNA technology for this purpose. Therefore, in recent years we have seen an increasing demand for system solutions for analysis and/or purification of biopharmaceuticals, such as intact proteins, oligonucleotides, antibody–drug conjugates, or monoclonal antibodies.

Ronan O’Malley: As LC–MS continues its drive towards ubiquity, applications—from monitoring levels of environmental pollutants, such as PFAS or food safety testing—will continue to proliferate. The past couple of years have, for obvious reasons, seen an acceleration in the adoption of systems for biopharmaceutical research, development and manufacture, however, the greatest unmatched challenge remains efficient characterization of the interactome and its impact on human health and well-being.

Rohit Shroff: Emerging contaminants is an application area of growing importance to pharmaceutical, environmental and food analysis as the understanding of the biological toxicity and lifetimes of certain contaminants increases. Increasing consumer awareness because of the media attention that some of these substances attract has also applied an increasing level of visibility in this area as well.

Recent examples include nitrosamines which, have led to mass recalls of certain pharmaceuticals, and perfluoro alkyl substances (PFAS), which has led to the evolution of regulations around these compounds. In order to support scientists in these evolving situations, manufacturers have looked to provide application specific solutions where practical.

In clinical contexts, drugs of abuse are an ever-evolving area and scientists are adapting their methods for identification of new drugs and treatment purposes. To optimise testing efficiency, end users are looking more and more to high-throughput solutions from column manufacturers.

What obstacles stand in the way of LC or LC–MS development?

Runsheng Zheng: There are three key requirements to LC and LC–MS instrumentation that don’t change over many years: robustness, performance, and ease of use. On top of this, there are application requirements that combine high-throughput and high-sensitivity. After several years of neglecting the importance of chromatography, we see a grown interest towards more efficient stationary phases and unique chromatographic selectivity that are needed in many research areas like proteomics, metabolomics, and lipidomics, as well as routine quality control in food and pharma. LC improvements are focusing on precise injections, faster cycle times, advanced carryover removal, and flow range versatility to accommodate diverse workflows. The crucial factor is removing the barrier for setting up, operating, and maintaining the “state-of-the-art” LC–MS platform so a lot of work has been done in the direction of making reliable, leak-free connections and LC electrospray ionization (ESI) MS integration.

Gesa Schad: In my opinion, the biggest obstacle in the way of innovation and the implementation of new developments is the fear of change and the reluctance to change the status quo. Manufacturers work relentlessly in trying to build the “ideal” solution and overcome customers’ challenges with new and advanced equipment, however, the road from new development, to established technique and eventually routine-use is long and winding. If you just look at the move from HPLC to UHPLC, meaning not only change of equipment, but education of the users, method development or transfer, method validation, and the cost associated with it—to this day UHPLC has not been adapted in many areas where it could be a game-changer. And if a new technique doesn’t take off right away or shows some “teething problems”, it may never get a second chance, as it requires confidence in a product to make that investment.

Ronan O’Malley: LC–MS as a technique is amenable to the same opportunities, and subject to the same constraints, as other sophisticated analytical instrumentation—or indeed any other complex manufactured system. As such, periodic shortages in the global supply of noble gases, specialty electronic components, and raw materials may drive innovation in engineering and production in unexpected ways. Provided
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these challenges can be overcome, and Moore’s law holds, advances in electronics will see time-of-flight mass spectrometers (free of the charge capacity limitations of ion trapping devices) re-emerge as the technology of choice for the analysis of the most complex biological samples. For the more routine applications, we will see the MS technology hidden from view and providing data behind the scenes in the same way we now accept routine video calls on handheld devices or facial/fingerprint recognition to activate smartphones.

Rohit Shroff: In biopharmaceutical production, there remains a discrepancy between the technologies often used in research & method development laboratories compared to those used for QC purposes. Currently, the technology used in the early stages is often more advanced than for the latter stages as regulation & the associated costs of equipment upgrades reduce the impetus to move in this direction. This means the vast number of chromatography users do not necessarily have the experience with more advanced techniques resulting in much of the technology available often being far advanced of the experience level of the standard user, similar to many fast-paced industries. To solve this, more accessible options are being developed by manufacturers, offering “black-box” solutions so that technology makes it simpler for users to transition across. Encouragingly, we also see that chromatographic awareness is still growing at the grass roots level and its advantages are being applied to a growing number of application areas where previously other analytical techniques dominated.

What was the biggest accomplishment or news in 2020/2021 for LC or LC–MS?
Runsheng Zheng: A low-flow analysis covering nano-, capillary-, and micro-flow LC–MS applications became mainstream in 2021. It moved from instrumental research and development laboratories to start-ups and core facilities, where advanced analytical services are delivered for drug discoveries and clinical research. This significant leap forward became possible due to the standardization of LC–MS applications, particularly in proteomics, and improved reliability of LC hardware. Low-flow LC–MS was brought beyond discovery, enabling experts and novice users to get high-quality biologically meaningful results every time.

Gesa Schad: I personally welcome the trend to a more “environmentally friendly” industry and the efforts I can see going towards that objective. Manufacturers adopt the United Nations Development Programme (UNDPs) Sustainable Development Goals, reducing their carbon footprint, saving energy and the impact on the environment in all stages of development and production. Eco-labels now are a means for customers to identify environmentally-conscious companies and hopefully make a difference in the purchase decision.

Ronan O’Malley: Technologies such as ion mobility spectrometry (IMS) (a rapid gas-phase orthogonal separation) offer structural insights into large biomolecules as well as providing an additional dimension of separation to help spectral decongestion of complex samples. This improves specificity and selectivity and, as such, contributes to significant improvements in analytical peak capacity. It is the common denominator for comparing the analytical horsepower of LC–MS systems and we’ve seen a number of companies incorporate IMS into commercially available systems to enhance peak capacity. Couple that with an effort to push the power of time-of-flight detection, one can envision a near future where high resolution and mass accuracy MS coupled to bio-inert LC will change the game in the analyses of complex biomolecular systems.

As we see advances in new treatment modalities and a wider acceptance of genetic therapies, new technologies such as charge-detection mass spectrometry will play a role in the characterization of these new medications.

Rohit Shroff: Over the last few years, the development of mRNA based vaccines and their mass production in relation to COVID-19 has been an effective demonstration of the need for chromatography at all stages of the development process, including R&D, assays of the raw materials, and characterization of the final products. This has led to increased focus on the use of analytical chromatography as part of the Process Analytical Technology (PAT) systems within the biopharmaceutical and pharmaceutical industries, which has long been dominated by spectroscopic techniques such as fourier transform infra-red (FTIR), raman and ultra-violet (UV), as the diagnostic tools for on-line and in-line analysis.

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Rohit Shroff is Senior Vice President of Portfolio strategy for Global Lab Products at Avantor.
DATA HANDLING

What is currently the biggest problem in data management for chromatographers?
Christoph Nickel: Currently one of the major challenges is the increasing number of samples to run, analyses to conduct, and data to review while keeping data quality high and detecting any potential error. A major driver for this is increasingly complex separation and detection techniques that are required to analyze biotherapeutics. The result being that the chromatographer increasingly needs to use mass spectrometry. Furthermore, the consolidation of all this information into an easily viewable and sharable format at a central location is a massive challenge. This is particularly important for information that is required to take an informed final review and approval. A typical example is the weighing results for calibration standards generated from a balance that should be connected to the calibration data in the chromatography data system (CDS) for confirmation of proper calibration and eventual accurate quantitation of the unknown compounds.

Ofrit Pinco: One of the biggest challenges for chromatographers is that data from different vendors cannot be incorporated together and analyzed collectively due to a lack of a unified data format. Chromatographers can only review data from one system at a time and answer specific questions. This makes it harder to access and conduct secondary analysis across multiple data systems. To address this challenge, several pharmaceutical companies have sponsored the Allotrope Foundation whose initiative is to unify data formats. In addition, some start-ups are building tools to translate data into a common format. However, both initiatives will take some time and collaboration to overcome this challenge.

Anne Marie Smith: Chromatographers use a variety of different instruments from various vendors each with their own proprietary data formats. One big problem area is bringing together and managing the data from the different electronic systems. The ability to normalize all that disparate data while retaining the ability to interrogate it, as though in native data processing software, is very beneficial to chromatographers. Since chromatography data is so ubiquitous, effective management in a central, accessible place is essential.

Björn-Thoralf Erxleben: Handling large quantity of data requires a lot of time for data processing and interpretation. Additionally, depending on the local situation, secure data storage and archiving can be time consuming, and administration of these processes gets more and more complex.

Although there are network-based multi-instrument capable CDSs, all vendors support and maintain their proprietary data format first, data file formats for PDA and for MS instruments are closed. Even providing drivers to other CDS systems, still several requests/wishes are not satisfied. Hybrid configurations, hardware wise, may contain different operation workflows, parameters cannot easily be transferred between vendors. Direct comparison of data between different instruments can be difficult.

What is the future of data handling solutions for chromatographers?
Christoph Nickel: I see three main trends: Firstly, radically streamlined and simplified user experience with more “fit-for-purpose” applications, second an agglomeration of data from different sources in a single central repository in a consolidated format—often referred to as a Data Lake. This will reduce the time for data review/analysis because it eliminates any manual data transfers or manual consolidation of spreadsheets or PDF files. Thirdly, more and more automation of routine tasks using machine learning (for routine reviews) and algorithm-assisted data mining to identify patterns, trends, outliers or deviations.

In addition, data will continue to become available anywhere, anytime, so there will be no further need to be in the laboratory or at the instrument to analyze your data, and no need for installation and maintaining software applications on your device. Everything will be available online.

Ofrit Pinco: The future of data handling goes well beyond acquiring and analyzing data generated by a single chromatography system. As new tools and solutions are being developed, and as researchers are being expected to extract more information from their samples, chromatographers will need to access and analyze data from multiple instruments and data systems simultaneously. Right now, chromatographers have multiple tools to help them focus on multiple areas, but future tools will allow them to review information from the whole workflow in one space. This has potential to enable researchers to answer more questions. This will also be valuable as requirements and regulations for compliance become stricter. New tools will also give research teams insight into historical instrument performance data, leading to increased operational efficiency and even predictive maintenance. Data handling will only continue to become more streamlined and more advanced through the utilization of these types of tools combined with
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**Anne Marie Smith:** The cloud is the future of data handling. All systems will connect to the cloud. It’s secure, simplifies the infrastructure reducing costs, provides better performance, and is scalable. Depending on the system you choose, it can also be “future proof”. It is important, however, that systems architects take into account the scientists’ data access requirements. Whether the data needs to be accessed immediately upon generation, or at a later date, should inform how data management solutions are architected to ensure a seamless transition to cloud-based data access.

**Björn-Thoralf Erxleben:** We already see cloud-based data storage options at several CDS installations, this trend will continue as it renders data access and sharing far easier. At the same time, this will require a new level of data security and data protection. A positive aspect is, that data storage and archiving is outsourced and will not bind IT resources on-site.

AI software will be implemented in ‘standard’ software: for peak picking, processing, and identification using database packages. Self-learning algorithms will support method optimisation and provide an estimation of retention time, based on structural information of the analyte.

Developing and maintaining special programs and databases for research use is a time and resource extensive task. If such a standard is being accepted and used in the industry, instrument vendors have to provide data compatible with these programs. There might be also agreements about new standard data formats, which will be used or supported via conversion.

Last, but not least—it would be nice to see that workflows and parameter definition is adjusted between the vendors and that data processing, at least for 2D data, becomes a common piece of software accessible via the web, to be used by all chromatographers, after logon to the dedicated cloud.

**What one recent development in “Big Data” is most important for chromatographers from a practical perspective?**

**Christoph Nickel:** While it might sound boring, the biggest impact on the analytical laboratory is the ability to bring data together from all instruments and all devices working on the same function, the same research or the same discipline. The availability of data in one location is a mandatory prerequisite for every analysis, insight or application of algorithms. So, any effort that chromatographers can make to bring their data together brings them a major step closer to fast, efficient and error-free analysis, moving from reactive review or error handling to pro-active problem prevention. This can be realized from the availability of unlimited computing power in the cloud which is becoming more mainstream for deployment of globally connected systems.

**Ofrit Pinco:** Artificial intelligence (AI) and machine learning (ML) have been growing rapidly in the last few years and people are realizing more of their advantages on daily basis. Take search engines for example, Google has drastically changed the way we search for answers, plan our travels, and consume news. As AI and ML technologies mature, more scientists with this skillset will enter the chromatography field and apply these technologies to the lab.

In the current state, chromatographers analyze data based on specific questions with the aim of confirming predefined hypotheses. Through AI and ML, chromatographers may be able to uncover new trends and patterns from a large set of unstructured data, giving chromatographers insights they didn’t know existed. This will greatly facilitate the progress of scientific research in the long run.

**Anne Marie Smith:** Artificial intelligence (AI) and machine learning (ML) can help find relationships and insights in an otherwise overwhelming amount of data, providing potential predicted outcomes. While AI and ML can drastically improve processes, it is only as good as the data that is input. For instance, for chromatographers where there are a multitude of possible instrument combinations, if data collection is of poor quality or incomplete, the results may be biased.

**Björn-Thoralf Erxleben:** Analytical intelligence features such as auto-recovery, start-up, self-check and feedback. Apart from additional automation, this enables quick and easy hardware diagnostics and helps to decrease downtime of the systems.

Applying more process analytical techniques (PAT) features and more feedback from the system to the central server, chromatographers can focus on their work and need to care less for the hardware.

**What obstacles do you think stand in the way of chromatographers adopting new data solutions?**

**Christoph Nickel:** One of the greatest challenges is the need to comply with good manufacturing practice (GMP) and Data Integrity guidelines. The validation guidelines were drafted for on-premise deployment of software and laboratories now need to transform their validation principles into a more decentralized, globally connected world with often
As a result, adopting new solutions needs to be minimized. Another significant obstacle is the potential delay of data access driven from the need to transfer the data from the laboratory to the central location/center and access it there. While the internet and cloud are fast enough to provide a positive user experience, the in-house infrastructure is often the rate-limiting step. As one example, a single low-performance element in your local area network like an old 10 MB switch can slow down your entire data traffic by a factor of 10. Suitability of the infrastructure is a critical prerequisite for transferring the data into the central repositories and increases dependency on your IT infrastructure.

**Ofrit Pinco:** A few factors contribute to this slow adoption. First is the complex laboratory ecosystem. Due to the interconnectedness of systems and solutions, any change must be evaluated for its impact on all components within the ecosystem. Also, downtime needs to be minimized as many labs are in operation and operate on a 24/7 schedule. After implementation, regulated labs require validation for the change. Additional training is also required for technicians to adopt new SOPs and avoid errors. As a result, adopting new solutions is difficult and time-consuming.

**Anne Marie Smith:** Adopting new data solutions is a daunting task. It involves time to setup the system in a useful way, time for validation and implementation, ensuring the system meets the data integrity requirements, ensuring the data is secure, and time to learn the new system. These factors often lead to reluctance to change which can stand in the way of adoption of useful solutions.

**Björn-Thoralf Erxleben:** Changing an established workflow is a critical matter for analytical laboratories and operators. Operation workflow, and in worst case, new definition for known parameters in the software cause a lot of training for the users until a new solution is finally adapted. Risk of longer downtime is high. Right now, we are confronted with objection for installation of necessary service packs or patches to be compatible with modern operating systems and virus protection.

New features and functionality need to prove its advantage first before new software is rolled out and established. Another aspect is the data comparison and transfer, what happens with the ‘old’ data? Legislations require that old data and results have to be kept and provided for inspection if needed—is maintaining a piece of the old software a good solution? Especially when it means some knowledge of how to operate it needs to be available.

**What was the biggest accomplishment or news in 2020/2021 for data handling?**

**Christoph Nickel:** The adoption of the cloud with unlimited storage, computing power that enables data agglomeration, and new levels of advanced and super-fast data analysis.

**Ofrit Pinco:** In the past two years, more data scientists have entered and brought changes to the analytical industry. Data scientists are skilled at analyzing and extracting insights from structured and unstructured data by using scientific methods, algorithms, and systems. They can be good complementary partners to application scientists, who have backgrounds in chemistry and understand the use cases and workflows in the lab. Together with application scientists, data scientists can utilize models and algorithms to analyze and visualize historical data and let application scientists relate new findings to workflows and experiments.

In addition to scientific findings, data scientists may also improve laboratory operation efficiency by evaluating instruments performance and data management metrics. Data scientists may provide new perspective on how labs can better store, organize, and manage data.

**Anne Marie Smith:** Streaming live data as it’s acquired locally and storing it in a cloud instance of a CDS has improved IT systems. With the recent development in Big Data this simplifies data movement for downstream data analytics.
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Analytica Munich will finally be held in Munich again from 21 to 24 June 2022. It will be accompanied by the renowned Analytica conference, which features 45 English-language sessions in five lecture rooms between 21–23 June 2022.

On 21 June three consecutive sessions in Hall 5 of the International Congress Center Munich (ICM) will be organized by the Separation Science Division of the Society of German Chemists (GDCh) under my chairmanship.

The first session **Gas Chromatography: Boring Or Is There Something New?** will start on 21 June at 9:30am focusing on interesting developments in gas chromatography. In a 1941 publication, Martin and Synge suggested replacing the liquid mobile phase of their developed column chromatography with a suitable gas and the idea of gas chromatography was born. However, the first real laboratory arrangement for gas chromatography was made by a woman, Erika Cremer, who was born in Munich.

Cremer came to the University of Innsbruck in 1940 and worked there on the catalytic hydrogenation of acetylene. She lacked a rapid determination method for ethene and ethyne. Erika Cremer submitted a first note to the journal *Naturwissenschaften* for publication on 29 November 1944. In it, she described the rate of migration of chromatographic zones by boats drifting down a river, occasionally reaching the shore and being stuck there for varying lengths of time depending on the type of boat. The chaos of the last days of the war prevented the article from appearing. Therefore, it was not until 1951 that she and a former colleague, Fritz Prior, published a paper in which gas mixtures could be separated and detected in a continuous stream of hydrogen using a glass apparatus consisting of a gas sample inlet, a U-tube column and a heat conduction cell. A total of three articles by Erika Cremer from 1951 thus marked the birth of gas chromatography. But it was not until the following year that the publications by Anthony T. James and Archer J.P. Martin on “Gas-liquid Chromatography” triggered a lively development and rapid spread of this analytical method (1). Thus, 71 years have passed since the first publication on gas chromatography and this session will critically examine whether there are still innovations worth mentioning in this field.

The first presentation in this session is given by Peter Boeker from the University of Bonn, Germany, on his development of flow-field thermal gradient gas chromatography (FF-TD-GC). This novel technique enables a reduction of analysis times from 20 min to less than one minute with GC, and is a fascinating development. Visitors will have the opportunity to talk to a pioneer in this field, Peter Boeker, personally.

Following this, Giorgia Purcaro from the University of Liège in Belgium will give a presentation on a novel coupling of LC with GC×GC–TOF-MS for the analysis of mineral oil contaminants (MOSH and MOAH) in food. She will show a fully integrated and automated platform for qualitative and quantitative purposes, along with an efficient extraction step using microwave-assisted saponification and simultaneous extraction of contaminants of interest from different food and feed samples before LC–GC×GC analysis. This coupling shows outstanding separation performance and high selectivity due to TOF-MS detection.

The last lecture in this session will be given by the internationally renowned Philip Marriott from Monash University in Australia, who will make a plea for 2D-GC. In his talk he will show that a one-dimensional chromatographic analysis cannot provide sufficient results to comprehensively describe and understand the sample above a certain complexity.

To return to the title of the session, I think it will be anything but boring.

This session will be followed by the awarding of the Eberhardt Gerstel Prize with a talk by the prize winner. After a lunch break, which can also be used to visit the poster exhibition, the second session of the Separation Science Division will start at 12:30 and, after a short coffee break, the third session will start at 15:00 with the title **Chromatography Coupled to Ion Mobility-Mass Spectrometry: Potential and Challenges?**
The beginnings of ion mobility date back to the late 19th century. Here, the first studies on the ionisation of air were performed with X-rays (2) and radioactive ion sources. In the following years, Langevin recognised the effect of, among other things, temperature, pressure, acceleration voltage and ion-molecule interactions on mobilities and published a kinetic model describing the movement of ions in electric fields (3,4). Tyndall summarized the knowledge and refined technologies on ion mobility gained in the following decades in his monograph “The Mobility of Positive Ions in Gases” in 1938 (5). Van de Graaff published the first ion mobility spectrum with a modern drift time axis as early as 1929 (6). First chemical analyses based on ion mobility took place in the mid-1960s (7–9). The first couplings with a mass spectrometer in the early 1960s provided the impetus for the steady further development of ion mobility mass spectrometry (IM-MS) (10,11). With the devices commercially available since 2006, the IM-MS technique developed into a research tool with constantly growing fields of application. This session aims to give an update on the situation regarding ion mobility mass spectrometers and their potential for the analysis of complex samples.

In the second session, starting at 12:30, speakers from selected MS manufacturers will first report on their ion mobility couplings with mass spectrometry. Yue Xuan from Thermo Fisher will talk about high field asymmetric waveform ion mobility spectrometry (FAIMS) and demonstrates an optimized cylindrical geometry, which substantially increases ion transmission to the mass spectrometer. Jakub Ujma from Waters will present on cyclic travelling wave ion mobility (cTIMS), where notable improvements in resolution have been demonstrated, and discuss developments in instrumentation.

Holger Stalz from Agilent will talk about improving resolution in the IM dimension as an important area of active investigation and developments in instrumentation in this area to improve sensitivity and resolution. He will illustrate that structures for lossless ion manipulation (SLIM) can achieve higher resolution with practical examples. Oliver Raether from Bruker will demonstrate a method for a high sample throughput (including a proteomics application that achieves 40 samples per day) coupled with the trapped ion mobility mass spectrometry (TIMS-TOF) for proteomics analyses to peptide loads of below 250 pg.

After the subsequent coffee break, users from various universities and research centres will then have the opportunity to present their work on all the ion mobility mass spectrometers previously presented by industry representatives in the third session.

Dr. David Ruskic from the University of Geneva, Switzerland, will give a presentation on modifier assisted differential mobility spectrometry for qualitative and quantitative LC–MS/MS analysis. He will show the potential of DMS in multidimensional separation. Perhaps a possible alternative to LC×LC?

This will be followed by Dr. David Ropartz from INRAE in Nantes, France, who will talk about an application with cyclic travelling wave IM-MS coupled with liquid chromatography for structural characterization of oligosaccharides. He will demonstrate how IM-MS is able i) to identify the presence of isomers in complex biological media, ii) to characterize the intrachain alpha/beta anomomerism of atypical oligosaccharides and iii) to provide unique spectra fingerprints that can be used for molecular networking of glycomic datasets.

The penultimate talk of the session will be given by Stephan Hann from BOKU in Vienna, Austria. In this talk the confidence of compound identity confirmation by introducing the collision cross section (CCS) of a molecular entity will be discussed. Stephan Hann and co-workers were investigating this quantitative measurement in terms of the validation parameters trueness and precision, with the final goal to reliably assess measurement uncertainty (MU). In fact, all CCS values should be currently regarded as conditional because they are depending on instrument type and measurement conditions. To investigate the intercomparability of these values, they have conducted a systematic comparison of CCS values of steroids derived from all major commercial IM-MS technologies, with drift tube ion mobility employed as a reference standard.

And last but not least Uwe Karst from the University of Münster in Germany will talk about the analysis of adduct formation of proteins and xenobiotics. He will show a rapid method for the investigation of metal binding to proteins based on liquid chromatography combined with trapped ion mobility mass spectrometry.

I would like to cordially invite you to visit analytica Munich and the accompanying conference and look forward to stimulating discussions with our speakers.

References
Multidimensional GC: Where It’s At and Where It’s Going

Alasdair Matheson, Editor-in-Chief, LCGC Europe

Phil Marriott reveals the latest developments in two-dimensional gas chromatography (2D-GC).

Phil Marriott: I would like to start this interview with a short comment. Recently, Yada Nolvachai and I published a “Viewpoint” in the Journal of Agricultural and Food Chemistry called “Separation Multidimensionality for Improved Sample Characterization—Is it Worth the Effort?” (1). Taking the position that comprehensive two-dimensional gas chromatography (GC×GC) is most assuredly worth the effort, we concluded by stating, “If you are not using GC×GC, you will never know what you are missing!” This seems to me to be precisely why GC×GC should attract any GC user. We have the opportunity to add much more understanding to our sample analysis.

So now, I’m delighted to have the opportunity to talk to LCGC Europe about GC×GC, our impressions, and our research.

Q. What is two-dimensional gas chromatography (2D-GC), and is there a distinction between the terms 2D-GC and multidimensional GC (MDGC)?

PM: 2D-GC should relate to having a two-column analysis (each column being a “dimension”) where each column provides an independent separation. This distinguishes it from a simple, directly joined column arrangement. The independent operation requires an operation or device such as a Deans switch to isolate a section of a first column (“1D”) elution and transfer it to the second (“2D”). Classically or commonly, MDGC involves a two-column experiment, though we—and others—have used more columns, for example, up to four columns: “1D, 2D, 3D, or “4D. So we could say 2D-GC is the same as MDGC if only two columns are involved. But 2D-GC is not comprehensive two-dimensional gas chromatography (GC×GC). To distinguish the latter, we have to state “comprehensive”, which involves applying the two-column separation to the total sample. We now know how this is to be achieved: Liu and Phillips’ seminal research paved the way for what is now a truly exciting and vibrant research area (2).

Q. What applications is GC×GC most commonly used in? Are there any applications where the technique is steadily growing?

PM: We would usually “hand wave” and say that complex samples, that is, those with a very large number of components, are those best suited to GC×GC. This is true, but there are always exceptions! It is definitely true when we wish to profile the total sample. Hence, metabolomics should be ideal to use with GC×GC methods. However, in our research we have demonstrated that GC×GC is required in order to best study some particular processes, such as isomer interconversion during GC elution, and this has been used for simple mixtures. Of course, analysis of complex samples by itself does not demand GC×GC. It depends on the question to be answered. Target analysis in complex samples...
samples, where the target analytes are perfectly measurable by tandem mass spectrometry (MS/MS) methods—for example, analyzing selected pesticide residues—does not require GC×GC. Recent work in breath analysis, and metabolomics in general, is particularly interesting, and in the life sciences should be an expanding opportunity (3). However the application areas of GC×GC are essentially the same as those of GC, and as an example, food analysis is also a productive research area for GC×GC (4).

Q. Is GC×GC more commonly used as a research tool than routine analysis? Are there any examples of it being used on a routine basis that you are aware of?

PM: Sadly, it seems the penetration of GC×GC into the routine analysis sector has not been as robust as the excitement and interest in the technique initially generated. This is a great pity because there is much information available in the 2D separation space that is simply not displayed in a 1D-GC analysis, courtesy of the significant increase in peak capacity. And certainly, just having a GC−MS instrument does not guarantee that “everything” will be measured, if you are not aware of what is there. This became apparent in discussions about background pesticides analysis in environmental samples, such as sediment. If the analysis technique targets certain known or legacy pesticides, for example, by GC−MS/MS, then this is all that is there. This became apparent in discussions about background pesticides analysis in environmental samples, such as sediment. If the analysis technique targets certain known or legacy pesticides, for example, by GC−MS/MS, then this is all that will be measured. But if the total sample and all pesticides are (or should be) measured, MS/MS will miss any that are not included in the MS/MS scan protocol. So there very well could be surprises from unexpected pesticides or contaminants if a less informative technique is used. The same applies to drugs for doping control.

Whilst there seems a preponderance of research users in the GC×GC community rather than industrial routine users, some organizations use it either routinely or as part of a strategy to decide the best technique to employ based on an initial GC×GC screen of a typical sample. Petrochemical companies appear to be more ready to invest in GC×GC technology, presumably because they require the detailed chemical analysis of samples that GC×GC provides.

Q. GC×GC has a reputation for being a complicated technique to use in practice. Is this reputation deserved, and if not, what have been the advances that make it easier for the analyst to use since the technique was first discovered?

PM: This is a concern. We might call it a “hoary old chestnut.” But it is important to try to face this perception directly. After 20 years of commercially available systems, the understanding of modulators, principles, familiarity of the 2D separation space, managing the setup of the instrument, and the inherent value of improved separations and quantification should all be apparent. The use of GC×GC purely for its better resolution and better coverage of compounds, plus quantification, is readily accessible through the software now available with commercial systems. This is largely what general users of GC−MS require. But GC×GC has capabilities that far exceed just the simple high resolution solution, and these may demand more skills than a routine user is comfortable with. It may be that research presentations inadvertently represent a more difficult aspect of GC×GC. Today, we can say that through the efforts of software developers, competent and reliable basic information suited to routine analysis is deliverable.

Q. Can you recommend any useful resources/conferences for analysts to learn more about GC×GC?

PM: Without a doubt the specialist conferences in this area, the Multidimensional Chromatography Workshop, and the International GC×GC Symposium, are excellent introductions to the science and technology of GC×GC, supported by half-day workshops suited to basic and advanced users, plus specialist lectures across fundamental studies and applications. Add to this the ability to share experiences and learn strategies with other users. As we move to face-to-face meetings, these will be increasingly important ways to gain knowledge, and engage fully with the science and technology of GC×GC. Commercial vendors offer a range of seminars and workshops largely focused on applications and should always be scanned. There is a lot of useful information in this review article (5).

Q. You published a paper called “Comprehensive Two Dimensional GC−MS: Toward A Super-Resolved Separation Technique” (6). What do you mean by the term “super-resolved”? What were your main findings and what benefit does this approach offer the analyst?

PM: We are all attracted to the incredible high-resolution capabilities of GC×GC. Perhaps it is possible to recognize up to 10,000 resolvable peaks—as measured by peak capacity—in the 2D plot. Compared to 1D-GC, that already seems a “super” result. But we can do better. Some years ago, we proposed a strategy to calculate a precise retention time on the ’D column, that is, tR1. This was based on the idea that from the modulated peaks it is possible to predict the original peak parameters of the ’D peak, one of which is tR1. Retention time is such a fundamental metric for all chromatography experiments that we are obliged to search for a suitable way to provide accuracy to the first column retention. Combined with the 2tR value, it is now possible to locate a very precise set of position.
coordinates ($t_1$, and $t_2$) to the peak in the 2D space. By doing this at the peak maximum point, we can generate a full GC×GC result with centroiding of each peak as a “super-resolved” result. It has a similarity with what we call the peak apex plot; however, using centroiding and accurate $t_2$ values, peak capacity is now significantly enhanced. We expect that sample-to-sample comparison and identifying closely overlapping peaks will be improved.

**Q. Have you used this approach for any other applications since you published this paper?**

**PM:** The paper was quite recent, and as we know, the pandemic has slowed down much research. There are still other studies we have identified that require investigation related to super-resolved GC×GC concepts, and we have new ideas to add further identification strategies to our research. Hopefully—watch this space!

**Q. What has been your most cited paper on GC×GC?**

**PM:** Our most cited paper (275 citations, Scopus) on GC×GC was an early paper (2000) in *Nature* (7) called “A Larger Pool of Ozone-Forming Carbon Compounds in Urban Atmospheres”, with Ally Lewis and others at the University of Leeds, UK, arising from his visit to my laboratory in Melbourne. The important message here was that GC×GC allowed much better profiling of urban atmospheres, and provided better compositional characterization of, for example, total aromatic content, which translates into improved modelling.

This is closely followed by a review paper (256 citations) (2002) in *TrAC* (8) called “Principles and Applications of Comprehensive Two-Dimensional Gas Chromatography”, with Rob Shellie. But our 2003 paper with 205 citations (and 43 citations for our 2012 update) in *LCGC Europe* “Nomenclature and Conventions in Comprehensive Multidimensional Chromatography” is one that I think is important to the field (9,10).

**Q. What other GC×GC projects are you currently working on?**

**PM:** We are currently working on using GC×GC including enantioselective eGC×GC, to profile the chemical changes in various modified essential oils. We are keen to provide innovation in development of new modulators. Improved identification of compounds in highly resolved 2D separations is exercising our thoughts. And dynamic molecular behaviour in GC×GC continues to fascinate us; we are working on new observations of this process.

**Q. What is the future of GC×GC?**

**PM:** Hardly surprising if I come down strongly in favour of a robust and rosy future for GC×GC! All the factors point to this conclusion. There is a very strong cohort of users who are dedicated to the technology and believe in the value of the research and applications they undertake. There are a number of select commercial manufacturers who “cultivate and curate” their instruments and software, supporting their customers, and promoting understanding of technologies to demonstrate their commitment to GC×GC. However, all that and more must continue, and continue to expand, to provide growth, development, and sustainability for GC×GC. The message is there—it is incumbent on us to actively sell it!

**Q. Anything else you would like to add?**

**PM:** Through the efforts of researchers and technologists, a super high resolution method for volatile chemicals has been laid at the feet of GC users. It is not just a curiosity; it obeys established GC principles, it is informative, it is quantitative, it provides an immediate profile of the total sample composition—and it is available! Just do it!

**References**


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**Phil Marriott’s research journey**

Commenced in Melbourne (Ph.D.) then continued at Bristol (postdoc). Academic appointments were at the National University of Singapore, then RMIT and Monash University, both in Melbourne. He was recent awarded the COLACRO 2019 medal at the XVII Latin American Symposium on Chromatography and Related Techniques, Brazil, and the Halász Medal 2021 of the Hungarian Society for Separation Sciences. His primary research is in comprehensive 2D and multidimensional gas chromatography, mass spectrometry, covering fundamental development and novel processes, and a broad applications base, including petrochemicals, essential oils and allergens, foods and flavours, drugs and pesticides.
Q. Ion mobility spectrometry (IMS) is increasingly in the spotlight these days and more instruments are being commercialized. What is IMS and what types of IMS are available?

Uwe Karst: IMS comprises a group of separation methods, which are based on the different mobility of ions in the gas phase. Molecules of interest are first ionized and then separated in a drift region due to differences in their collision cross sections. Users have their choice from a large number of ionization techniques and instrumental designs, which allow for many applications from explosives monitoring at the airport to high performance bioseparations in combination with mass spectrometry.

In all of these methods, the ionization source, the gas-filled drift tube and the use of an electrical field are the common aspects.

Q. Why is IMS receiving more attention? What benefits can it offer the analyst?

UK: IMS is not really a new group of techniques, but it is rather established in some technical and forensics applications. As a “stand-alone” method, IMS offers only moderate separation power compared to what we are used to see from chromatographic separations and mass spectrometry. Therefore, its established applications often focus on sample matrices with limited complexity. On the other hand, its unique features are the ease of use and the high speed of separation, particularly when compared to chromatography.

However, its combination with mass spectrometry has directed the focus of analytical chemists on IMS in recent years, and this has resulted in a series of exciting applications. There is also the potential for significant future development.

Q. You have focused on using trapped ion mobility spectrometry-mass spectrometry (TIMS-MS) to analyze electrochemically generated isomeric oxidation products. Why are these products important and what are the benefits of using TIMS in this area?

UK: TIMS is an IMS-based technique with particularly high separation power, and this allows to combine it with chromatography to obtain two-dimensional separations. In other cases, it may even replace chromatography to obtain extremely fast separations.

When we are using electrochemistry combined with mass spectrometry to simulate the metabolism of drugs, TIMS instead of HPLC separations allows us to analyze electrogenerated reaction products much faster, reducing analysis times from minutes to seconds.

Q. You also developed an innovative automated chiral analysis method involving chiral derivatization and TIMS. What was the rationale behind this research and what benefits does it offer the analyst?

UK: While we were not the first to use chiral derivatization for the analysis of enantiomers using ion mobility coupled to mass spectrometry, the rationale is to provide fast separations of enantiomers after their rapid and easy derivatization to diastereomers, which can be separated by IMS. The method competes with chiral liquid chromatography coupled to mass spectrometry, which has higher resolution with respect to the separation, but is characterized by significantly longer analysis times.

Q. Is there any advice you would offer scientists using TIMS in practice?

UK: Actually, we were quite surprised how many areas of research can benefit from ion mobility spectrometry, and if you have access to such an instrument, some “out-of-the-box” thinking may provide you with great opportunities. When we obtained the instrument, we had some applications in mind, but most of those we are reporting about now were a result of realizing how much this technique may add to the portfolio of our previously available analytical methods. Therefore, my advice to new users would be to re-think their current projects in the light of the added separation power of TIMS. I am sure that many exciting future applications have not even been thought about at this moment!

Q. Your group has also hyphenated TIMS with electrochemistry and HRMS in an elaborately titled technique called chipEC-TIMS-ToF-HRMS. What application did you devise this technique for and can you elaborate on your findings? Could this approach be useful in other applications?

UK: To my opinion, rapid microchip-based (electro)chemistry shows a great potential
to be combined with TIMS, as the speed of both chip-based reactions and TIMS separations feels like a perfect match. In our respective projects, we cooperate with the group of professor Mathieu Oclijk from the University of Twente in The Netherlands, who is a renowned expert in the design and development of microchips for (bio)chemical applications. We combine his expertise in the microchip area with our mass spectrometric methods to simulate possible metabolic reactions of xenobiotics in the body. Using this method combination, electrochemical conversion products can be identified much faster compared to using established liquid chromatography/mass spectrometry-based methods and with similar separation power. We are convinced that there are many other applications in the pharma and omics fields, which should benefit equally from these techniques.

Q. What chromatography systems can IMS be linked to?
UK: There is almost no limitation in coupling chromatography with IMS. Pioneers in this field like Gary Eiceman from New Mexico State University have shown for example that gas chromatography with atmospheric pressure chemical ionization and differential mobility spectrometry is a powerful tool to even separate and identify the constituents of biodiesel and diesel from fossil fuels (1). David Clemmer’s group from Indiana University pioneered electrospray ionization combined with ion mobility and time of flight-mass spectrometry to study complex mixtures of biomolecules (2). These and several other groups deserve the credit to open up this field prior to the emergence of commercial IMS-MS instrumentation, while the readily available IMS-MS instruments have triggered many new applications more recently.

Q. At Analytica you present data on the separation of metal species by TIMS. How and why do you achieve a selectivity for these compounds and what could be potential applications?
UK: Metal speciation analysis is a major topic in our group, and its challenges, the identification and quantification of metal species, are often addressed with a combination of liquid chromatography coupled to electrospray mass spectrometry and inductively couple plasma-mass spectrometry. However, if we are, for example, looking for adducts of methylmercury cations to proteins in the human body, we approach the search for a needle in the haystack: Only a very minor fraction of tryptic peptides from a protein will be modified and finding the respective signals in a large number of signals from highly concentrated tryptic peptides is difficult. Here, TIMS enters the game: A methylmercury cation increases the mass of a modified peptide massively, while its collision cross section will only increase slightly. Therefore, projections of the mobility of ions versus the mass-to-charge ratio result in signals for heavy metal species, which are far away from the typical trajectories of unmodified peptides. Therefore, these modified peptides can rapidly be identified using TIMS-MS.

Q. What other projects are you planning to work on using IMS? Will you be exploring hyphenation further?
UK: To my opinion, there is a lot of untapped potential in TIMS for MALDI-MS imaging. Even with high resolution mass analyzers, isobaric and isomeric compounds have to be expected in complex samples as biological tissue slices. In contrast to the analysis of tissue extracts by liquid chromatography coupled to electrospray mass spectrometry, MALDI-MS imaging does not allow any pre-ionization separations, resulting in severe selectivity limitations. Therefore, we would like to further explore the unique potential of TIMS as post-ionization separation technique for MS imaging, with possible applications in the fields of cannabinoids, metabolites and lipids, just to name a few.

Q. Cannabinoid analysis is an area of interest globally. Which particular application are you focusing on?
UK: A major challenge in the analysis of cannabinoids is the fact that there are isomeric cannabinoids in relevant concentrations. For example, the psychoactive tetrahydrocannabinol (THC) is an isomer of cannabidiol (CBD), which is not psychoactive, but rather discussed as a potential pharmaceutical drug. While chromatographic separations resolve these isomers, mass spectrometric imaging analyses either require different fragmentation patterns of the analytes or a gas phase separation. With TIMS, we are able to separate the isomeric precursors of THC and CBD in leaf samples post ionization on a MALDI-MS instrument, thus allowing us to discriminate both compounds in a spatially resolved manner.

References

Uwe Karst was Full Professor of Chemical Analysis at the University of Twente in the Netherlands between 2001 and 2005, before he accepted his current position as Chair of Analytical Chemistry at the University of Münster in Germany in 2005. His research interests focus on hyphenated analytical techniques and their (bio)medical and pharmaceutical applications, including elemental speciation analysis, metallomics, mass spectrometric imaging, and electrochemistry/MS.
PFAS ANALYSIS

Airborne PFA and FTS Detection Using Online SPE-LC–HRMS

Researchers have developed and validated a sensitive analytical method for the determination of 16 polyfluorinated alkyl substances (PFAS) in fine airborne particulate matter (PM$_{2.5}$) using online solid-phase extraction (SPE) coupled with liquid chromatography (LC)–negative electrospray ionization high resolution mass spectrometry (−) (ESI-HRMS) (1).

There is great concern over PM$_{2.5}$, as these small particles can penetrate deep into respiratory systems, leading to cardiovascular and respiratory diseases as well as lung cancer. The World Health Organization (WHO) provides guideline values for PM$_{2.5}$. However, PM$_{2.5}$ mass concentration alone is not indicative of the risks from exposure to fine particles, as the toxicity of those particles is not accounted for. They are chemically complex and the typical composition of ambient PM$_{2.5}$ particles contains thousands of individual organic compounds that can be extremely toxic, even when present at low concentrations. PFAS are one such class of contaminant to be concerned about in this regard. They were widely used in a broad range of consumer products and industrial applications for decades, and persist within an environmental context for a long time—even gaining notoriety as “forever chemicals”. Their use has been phased out in many countries, with less toxic alternatives replacing them; however, even these replacements, such as fluorotelomer sulfonates (FTS), have been found to persist in the environment, and there is emerging evidence that their impact on human health is similar to that of banned PFAS.

The analysis of PFAS in environmental samples is challenging because of trace-level concentrations requiring highly sensitive analytical methods. Currently, only a few publications have reported analytical methods for the identification of PFAS in atmospheric samples; however, there are issues surrounding these methods, such as interference from matrix effects. As such, researchers aimed to develop a sensitive online SPE-LC–HRMS technique for the analysis of PFAS in atmospheric aerosol particles that would not only eliminate issues from previous methodologies but also expand the analyte detection range for 4:2 and 8:2 FTS’s, and utilize the developed method to analyze ambient PM$_{2.5}$ samples collected in urban environments. Results indicated that the developed method provided limits of detection (LODs) in the range 0.08–0.5 pg/mL of sample extract. This enabled detection of selected PFAS in aerosol particles at low fg/m$^3$ levels, with a high tolerance to the considered PM matrix. When applied to the analysis of PFAS collected at two urban locations in Ireland, the method found several PFAS above the detection limit as well as FTS’s. The detection of PFAS in the environment despite them being phased out from productions in the European Union (EU) two decades ago only highlights their ability to remain in the environment for long periods of time. The detection of FTS’s also raises concerns about their suitability as alternatives to PFAS, with their potential impact on human health and environmental well-being yet to be fully explored.

Reference


MICROPLASTICS ANALYSIS

Analyzing Road-Associated Microplastics Using Py-GC–MS

News of microplastic particles in the environment has become more and more common, however, there...
is still a significant deficit of data on one of the largest sources of these particles, as well as a lack of harmonization on how to analyze, quantify, and report study findings. Tyre and road wear particles could well constitute the largest source of microplastic particles into the environment, but without adequate analytical methodologies there will continue to be huge uncertainties surrounding their impact. As such, researchers have presented a new methodology utilizing pyrolysis gas chromatography–mass spectrometry (Py-GC–MS), which aims to improve the analysis of tyre and road wear particles (1).

Currently, visual analysis coupled to a chemical analysis step, such as Fourier-transform infrared spectroscopy (FT-IR), is the most commonly applied method for microplastics. Unfortunately, the black pigment (carbon black) within tyre particles prevents the use of FT-IR, as the infrared light is absorbed, thereby preventing the identification of the rubber content (2). Thermal methods such as Py-GC–MS or thermal extraction desorption (TED-) GC–MS are instead being favoured. These methods use the products of thermal decomposition as markers to identify and quantify polymers and rubbers that can be potentially used to identify specific tyre and asphalt markers, as well as assess the amount of rubber released into the environment.

The composition of the tyre and road asphalt adds a further layer of complexity to this analytical challenge, with a wide range of ingredients, production variability, and other factors combining to present a conundrum to analysts.

Which compounds represent the best markers for analysis? Researchers chose to analyze styrene-butadiene rubber (SBR), butadiene rubber (BR), and styrene-butadiene styrene (SBS), with SBR and SBS having never been explored as potential markers using pyrolysis. The study aimed to quantify the total mass of these products in environmental samples, combining multiple pyrolysis products for the quantification to compensate for the individual differences between tyre manufacturers. Furthermore, the method also explored the ability to calculate the total mass of tyre and polymer-modified bitumen (PMB)—the latter being used in asphalt—using different calculation approaches based upon available traffic data, sample locations, and the sample time.

The results indicated that the method provided high recoveries of 83–92% for a tyre matrix and from 88% to 104% for road sediment. When the validated method was applied to urban snow, roadside soil, and gully-pot sediment samples, the concentrations of tyre particles in these samples ranged from 0.1 mg/mL to 17.7 mg/mL in snow and from 0.6 mg/g to 68.3 mg/g in soil/sediment. The concentration of PMB ranged from 0.03 mg/mL to 0.42 mg/mL in snow and from 1.3 mg/g to 18.1 mg/g in soil/sediment.

By combining large datasets of tyres with a prediction simulation, researchers believe that this method is an improvement on current methodologies. Predicting the possible tyre values based on the variation in rubber content offers a mean value and a standard deviation of that value. This in turn decreases the uncertainty found in methodologies that use fixed rubber concentrations to calculate the mass of tyres in the environmental samples. The team highlight the importance of clearly communicating the difficulties in analyzing tyre matrices but also how the use of locally adapted values could improve data and provide relevant information to environmental researchers.

References

Development of New Centroiding Algorithms for High-Resolution Mass Spectrometry
Researchers have developed two new algorithms capable of converting centroided data—generated during high-resolution mass spectrometry (MS) analysis—to mass peak profile data and vice versa (1).

Liquid chromatography and gas chromatography coupled with high-resolution mass spectrometry (LC/GC–HRMS) are ubiquitous when comprehensive chemical characterization of complex samples is necessary, generating extremely information-rich datasets on everything from environmental matters to biological problems. However, while the amount of data generated is often a benefit, the actual processing of that data becomes a challenge. This is particularly the case when dealing with unknown chemicals in highly complex sample matrices. One commonly employed strategy for the reduction of data size and information density is centroiding in which the distribution of the mass profile peak is represented with one point that is commonly associated with
the mass peak apex. This approach is either performed by the instrument during data acquisition or as a step in a data processing workflow. Data can often be reduced 10-fold using this process, however, the price is the loss of information related to mass peak distribution—this provides valuable insights into the mass accuracy and precision. There is also a wide range of issues associated with the software packages used for centroiding, both vendor specific and open source. These issues can lead to uncertainty in results, and in particular analysis of complex matrices can be a struggle. The overall result is often a lack of reproducibility and issues with identification of unknown chemicals of interest.

One solution to these problems would be to introduce access to information related to the peaks in both time and mass domains, which has been shown to improve reproducibility and reliability in other techniques. Currently, most existing centroiding algorithms do not produce such information, and there is no algorithm that can estimate the peak mass widths from centroided data. As such, researchers have sought to develop and validate new algorithms capable of being seamlessly converted to profile data and vice versa.

The successfully developed algorithms, named the Cent2Prof package, was developed in Julia language and tested using seven previously analyzed datasets from three different vendors in both positive and negative modes. For evaluation purposes, the new algorithms were tested against an existing algorithm called MZmine.

Researchers found rates of false detection were reduced by ≤5% with the new algorithm package, with the MZmine algorithm having a 30% rate of false positives and 3% rate of false negatives. The error in profile prediction was found to be ≤56%, independent of the mass, ionization mode, and intensity. This was six times more accurate than the resolution-based estimate values, according to the authors.

All of the algorithms are open source and open access, with the current model only being based on quadrupole time-of-flight (QTOF) data, which limits the application of the algorithms for orbital trap data. Researchers believe an additional model is needed for orbital trap data and will work on this in the future alongside optimization to improve the currently required time to run the package, which is around 16 min for a chromatogram consisting of approximately 2000 scans.

Reference

MINIATURIZATION

Portable GC Coffee Analysis
Researchers have performed a volatile organic compound (VOC) analysis of coffee beans using a person-portable gas chromatography–toroidal ion-trap mass spectrometry (ppGC–TMS), and then compared it to a benchtop GC system (1).

Coffee canephora and Coffea arabica beans are amongst the most highly traded global agricultural commodities, with the beverages created from those beans incredibly popular. On top of the stimulating effects of caffeine, coffee offers a wide variety of aromas and taste profiles, with an entire sub-culture emerging to revere this plant product. A roasted coffee bean will have a complex composition from a combination of VOCs, including alcohols, esters, acids, pyrazines, phenols, and furans, amongst other compounds. All of these are a result of the many variables present in the life cycle of the food product, from plant to final brewed product. Coffee variety, growing conditions, fermentation, processing, roasting conditions, and brewing all contribute to the emergence of these unique VOC profiles. The assurance and consistency of that unique VOC profile is one of the key challenges for coffee producers. Currently, benchtop GC–MS is used for quality control and provides the gold standard for nontargeted, qualitative detection and identification of complex mixtures of VOCs. However, the separation and identification of compounds is only one half of the battle, with suitability, cost, time, and ease-of-use of the technique for implementation during the roasting process all requiring consideration.

As such, researchers investigated ppGC–TMS as an alternative solution. Theoretically, ppGC–TMS should be able to provide fast GC analysis, adequate sensitivity, and adequate selectivity, as well as the ability to be implemented at near real-time over the duration of a coffee roasting process without the need for additional infrastructure. The researchers then compared the capabilities of ppGC–TMS to conventional GC–quadrupole time-of-flight MS (GC–QTOF-MS) and GC–quadrupole MS (GC–QMS) to contextualize the capabilities of the portable instrumentation and how associated design features alter the separation and detection of analytes.
The results of the study indicated that pGC–TMS with headspace solid-phase microextraction (SPME) sampling provided a suitable compromise of reduced analytical capabilities for rapid and on-site analysis that could be used for VOC formation monitoring during the coffee roasting process.

Reference

LIPIDOMICS

Lipidomics Using UHPSFC–MS
The analysis of lipids in biological systems, also known as lipidomics, is an incredibly diverse area of research, with wide-reaching consequences, from the understanding of cell signalling to unravelling the complexities of diseases, such as cancer or neurodegenerative disorders. Chromatography plays a key role in lipidomic analysis, with three main approaches emerging in the form of separation coupled to mass spectrometry (MS), direct infusion of the sample to MS (shotgun), and desorption ionization techniques coupled to MS. The separation prior to MS is generally performed using either gas chromatography (GC) or liquid chromatography (LC), but both techniques have their limitations and strengths. In the case of GC, the necessity of derivatization, and in LC the characteristic polarity ranges depending on the separation mode. However, researchers from the University of Pardubice, in Pardubice, Czech Republic, believe a third technique, which combines the advantages of GC and LC, is worth consideration and have recently published a paper making the case (1).

Known since the 1980s, supercritical fluid chromatography (SFC) uses a supercritical fluid as the mobile phase. The physicochemical properties of the supercritical fluids lead to low back pressures, allowing the use of high flow rates and good solubility properties when used as the mobile phase. However, SFC has struggled over the years to gain acceptance because of instrumental issues in the early stages of its development. However, modern ultrahigh-performance supercritical fluid chromatography (UHPSFC) systems now offer stable and reproducible results and the researchers believe the technique can be utilized effectively across the ‘omics fields.

“The reproducibility was a problem in the past for SFC, and for me, this is the main aspect why now SFC can reach the level where the full potential of this methodology can be explored and used by researchers worldwide,” said Michal Holčapek. “The advantages of UHPSFC–MS over ultrahigh-pressure liquid chromatography (UHPLC)–MS are based on the physicochemical properties of the supercritical fluid or eventual subcritical fluid, which is often the case in real operating conditions. The polarity of supercritical carbon dioxide as the most prevailing SFC solvent is comparable to that of hexane and, therefore, the method is perfectly suited for all nonpolar molecules. This results in an outstanding sensitivity for nonpolar molecules. The speed of analysis is a highly appreciated feature, especially for high-throughput analysis. The van Deemter curves for UHPSFC and UHPLC clearly explain why we can increase the flow rate without loss of performance and with reduced risk of system overpressure. Moreover, there is still space for improvement when the pressure limit of current systems is increased. In some cases, UHPSFC offers different selectivities, which may be an example of ultrafast chiral separations of some pharmaceutical compounds.”

For those considering using UHPSFC–MS, the researchers believe the methodological switch from UHPLC–MS is not too difficult, as both techniques are very similar, plus the potential benefits, especially for nonpolar lipid classes as well as polar phospholipids and sphingolipids, are well worth consideration.

“I think that the methodology itself is ready to be immediately adopted by the wider research community,” continued Holčapek. The robustness and high-throughput of UHPSFC–MS potentially makes it ideal for routine clinical laboratories with thousands of samples; despite its past difficulties, SFC could be worth a second consideration.

Reference

FOOD ANALYSIS

Investigating Ciguatoxins Using LC–MS/MS
Researchers from Japan have used liquid chromatography tandem mass spectrometry (LC–MS/MS) to investigate the ciguatoxins (CTXs) responsible for ciguatera fish poisoning (CFP), commonly known as ciguatera (1).

Common within the tropics and subtropical Indo-Pacific region as
well as the Caribbean Sea, CFP affects people when they have ingested seafood infected with CTXs, which are produced by the algae dinoflagellates. These algae are found in shallow coastal waters on the surface of seaweed and other marine plants such as corals and are subsequently consumed by herbivorous fish. Carnivorous fish then go on to consume these smaller species, and this continues up the food chain with the toxins becoming more and more concentrated in a process known as biomagnification.

Once the toxins have been consumed a wide range of symptoms are possible, with acute symptoms appearing within 48 h and affecting almost all organ systems. These include fatigue, generalized pain, nausea, vomiting, diarrhoea, low blood pressure, and heart rhythm disorder. Unfortunately, most of these symptoms are quite general and could hint towards other food poisonings, which is one of the main issues when attempting to estimate the global burden of the disease, as there is widespread under-reporting and misdiagnosis. However, in regions where the poison-producing dinoflagellates grow, such as the Pacific Islands, estimates are that up to 10% of the local population is affected each year. Furthermore, at least 20% of affected persons can continue to have symptoms for months or even years after the initial poisoning, with neurological, neuropsychiatric, and memory disturbances.

Recurrence can be triggered by certain foods, by behavioural situations, such as fatigue, or even external factors, such as sun exposure (2). While CFP is endemic to the regions where the dinoflagellates grow, it is also increasingly a global problem because of the international seafood trade, with the European Rapid Alert System for Food and Feed issuing several alerts for ciguatoxins in the past few years, all stemming from chilled and frozen fish imported from other continents.

The causative toxins of ciguatera pose several analytical challenges. They are ladder-shaped cyclic polyethers, classified into four groups based on their skeletal structures and the place of occurrence (1). However, they are oxidized in fish while moving up the food chain, thereby further diversifying their structure (3,4,5). Furthermore, their lipophilic features and vast diversity in polarity further increases their analytical challenge.

In this study, researchers focused on specimens collected from the Ryukyu Islands, an area of around 1000 km extending from a region near Taiwan to Kyushu Island, Japan. They targeted the grouper fish, Variola louti, as it is frequently implicated in CFP cases in this region. Using LC–MS/MS they analyzed the flesh of 154 individuals across various locations, detecting CTX in 99 (64%) specimens. In 65 specimens (43%) the toxin levels exceeded the FDA guidance level of 0.01 µg/kg. Researchers also confirmed the results of a study performed around a decade ago that indicated three analogues as the primary toxins in this fish species, namely CTX1B, 52-epi-54-deoxyCTX1B, and 54-deoxyCTX1B, indicating a consistent toxin profile in this species. Interestingly, the study found that skinnier fish contained more toxins than fatter fish, confirming fishermen folklore in the Ryukyu Islands that claims exactly that.

In summary, the researchers believed that the current FDA recommendations were too strict based on their data relating to toxin levels and the number of CFP cases. However, they acknowledged that further investigation and more data accumulation related to human CFP cases and fish toxicities are both needed.

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ZOOARCHAEOLOGY

Zoom MS Identification Of Australian Fauna

Australia is home to an extremely rich and unique animal life, with more than 85% of its terrestrial mammal species being found nowhere else. Famous members of Australia’s wildlife, such as kangaroos, wallabies, koalas, and wombats, play key roles in the ecosystems they inhabit, and were important both culturally and for survival to aboriginal communities, as their bones were used as raw materials for the creation of tools and other artefacts. Researching these animals and the artefacts derived from them can give valuable information on early human activity on the Australian continent, as well as insights into biodiversity shifts and the reasons for them.

Animal remains are frequently uncovered in Australia, dating from the late Pleistocene to the historical period. However, the continent’s harsh
environmental conditions, along with other factors such as scavenging by marsupial carnivores, frequently results in many highly fragmented, morphologically unidentifiable bone fragments. This, combined with the scarceness of reference materials and osteological similarities between species, complicates the study of animal remains from Australian sites.

Zooarchaeology by mass spectrometry (ZooMS) offers a means to improve taxonomic identifications of fragmented bone material at sites around the world, and presents an exciting opportunity to address these challenges in Australian contexts. ZooMS is a high-throughput, proteomics-based approach that uses differences in the collagen type I (COL1) protein sequence to identify remains. COL1 is the most abundant protein in bone, skin, antler, and dentine. Researchers used matrix-assisted laser desorption-ionization tandem time-of-flight mass spectrometry (MALDI-TOF-MS) and liquid chromatography–tandem mass spectrometry (LC–MS/MS) to analyze a selection of modern reference samples taken from known collections and archaeological specimens consisting of 2922 bone fragments (1).

Researchers identified novel peptide markers for 24 extant marsupial and monotreme species, which allowed for genus-level distinctions between these species utilizing the ZooMS methodology. The utility of these new peptide markers was demonstrated by using them to taxonomically identify bone fragments from a nineteenth century colonial-era pearlshell fishery at Bandicoot Bay, Barrow Island, in Western Australia. Researchers believe the suite of peptide biomarkers presented in the study, which focus on a range of ecologically and culturally important species, have the potential to significantly amplify the zooarchaeological and paleontological record of Australia.

Reference

ENVIRONMENTAL ANALYSIS

Analysis of Environmental Contaminants Accumulation in Orcas Using LC–MS/MS

Emerging and legacy contaminants within the environment are a constant topic of research, with numerous studies investigating their impact on ecosystems and the animals that inhabit them. However, most studies focus on the animals that make up the base of the food chain, with top predators rarely being studied because of the difficulties involved in such research. As such there is a lack of data regarding the movement or presence of unregulated emerging and legacy contaminants in top predators.

Research conducted in Norway aimed to conduct the first screening of legacy and emerging contaminants in multiple tissues of killer whales (Orcinus orca) to shed light on the impact of persistent chemical contaminants in the wild (1). The research also included samples that were collected from a neonate to investigate whether contaminants are being transferred from mother to child (maternal transfer).

Orcas are considered to be sentinel species, providing advanced warning of risks to humans as they prey on animals from the higher trophic levels, such as seals. There are only a few studies to have investigated legacy pollutants, such as polychlorinated biphenyl (PCBs) (2,3), and only two to have investigated levels of perfluoroalkyl and polyfluoroalkyl substances (PFAS) (4,5)—intended to replace the previously banned PCBs. The forced reliance on opportunistic sampling from stranded whales limits research opportunities; furthermore, the data collected from such specimens always comes with a number of caveats that must be adjusted for.

Pollutant levels are regularly higher in stranded animals, as demonstrated by Jepson et al. (2), and as PCBs are associated with immune suppression, individuals with higher PCBs are more likely to die from infectious diseases and thereby get stranded. PCBs are also lipophilic and will concentrate in the blubber, highlighting the importance of sampling multiple tissue types. Decomposition and the unknown cause of death are also prominent issues with this type of sampling.

However, with little other options, researchers aimed to conduct a thorough screening of legacy and emerging contaminants in stranded killer whales found in Norway using liquid chromatography coupled to tandem mass spectrometry (LC–MS/MS) and a sample preparation process using graphitized nonporous carbon. In particular, they were investigating tissue partitioning of contaminants and their ability to transfer from mother to child during pregnancy.

Researchers screened for four PFAS and found pentabromotoluene (PBT) and hexabromobenzene (HBB) at low levels in the blubber of all individuals. Levels of PBT and HBB were twice as high in the blubber than the muscle for each individual, confirming the accumulation of such chemicals in lipid-rich tissues. These chemicals are replacements for banned substances and their long-term effects on ecosystems have yet to be fully examined and understood. However, their accumulation in tissues in a
similar manner to previously banned substances is a worrying find. Data collected from the neonate found that perfluoroalkyl substances and total mercury levels were lower in the infant than adults, which suggested an inefficient transfer of those substances from mother to child.

PCB levels in the blubber exceeded 9 µg/g lipid wt, which is the threshold for the onset of physiological effects in seven of the eight whales, including the neonate. The continued existence of these banned substances in the ecosystem is no surprise, and they represent a tremendous source of risk to the population growth of orcas around the world as they have been linked to the impairment of the immune and reproduction systems in the species (6).

The data collected by scientists highlights the worrying impact contaminants are having on marine ecosystems, providing further evidence of the damage of previously legal substances and hinting towards the similar impact their replacements are having.

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Food Fraud Analysis

Identifying Illegal Dyes in Red Spices Using UHPLC–MS/MS

Researchers from the University of Barcelona in Barcelona, Spain, have developed an ultrahigh-performance liquid chromatography tandem mass spectrometry (UHPLC–MS/MS) method to determine eight banned dyes in turmeric, curry, and chili products (1).

The use of dyes to improve the aesthetic qualities of food is a common practice in food industries, however, certain types of dyes have been banned because they have been deemed unsafe for human consumption. Dyes such as Sudan I–IV, Sudan Orange, Sudan Red 7B, Para Red, and Rhodamine B have been banned in many countries because they have been linked to genotoxic and carcinogenic properties. However, not all countries have implemented such regulations and the monitoring of imported food products for such compounds is therefore of great importance, requiring new sensitive methods.

In this study, the feasibility of electrospray ionization (ESI), atmospheric-pressure chemical ionization (APCI), and atmospheric pressure photoionization (APPI) for the ionization of the dye compounds was evaluated. The tandem mass spectrometry (MS/MS) fragmentation of dye compounds was evaluated and used to establish fragmentation pathways and common fragmentation behaviours, with the most significant, characteristic, and abundant product ions being selected for a UHPLC–MS/MS method targeting those compounds from the spice samples.

The study identified that out of the three atmospheric pressure ionization sources APCI performed the best, with matrix effect (ME) values ranging from 2 to 25%. Furthermore, the proposed method performed well, providing low method limits of detection (MLODs) (1–48 µg kg⁻¹), good intra-day precision (RSD % < 15%), and accurate quantitation (relative error % < 15%).

Researchers went on to demonstrate the applicability of the method through the analysis of turmeric, curry, and chili product, with the results showing that the method was able to detect the compounds in the low µg kg⁻¹ range.

Reference
Researchers collated the results of these studies so far and analyzed them critically to bring about a greater understanding of the disease.

One of the key findings when interacomic results were analyzed was the range of cellular housekeeping functions, such as nucleic acid metabolism or protein trafficking, affected by COVID-19. The array of changes the virus was capable of goes some way to explaining its possible fatal outcome.

Several studies on the varying grades of severity of COVID-19 found that the disease’s progression was mediated by commonly dysregulated pathways of the innate immune response. Furthermore, most COVID-19 patients exhibit up-regulation of the inflammation axis, with a strong antiviral interferon response causing the fever found in COVID-19 patients. The chain reaction caused by this ultimately leads to the well-documented lung damage found in cases of severe COVID-19 infection, which ultimately exacerbates the symptoms of COVID-19.

Similarly, as a result of the excessive inflammation in the lungs, the blood coagulation pathway is disturbed. The consequences of which may be the exposure of the liver to pro-inflammatory molecules. Researchers noted that the Shu et al. recommendation of targeting these molecules could be a therapeutic option to manage COVID-19-related complications.

Proteomic analyses concluded that the most damage during severe COVID-19 infections was brought about through hyperinflammatory milieu coupled with tissue hypoxia that develops into acute respiratory distress syndrome (ARDS).

Results from the meta-analysis of significantly altered biomolecule profiles in COVID-19 patients revealed alterations in the immune response, fatty acid, and amino acid metabolism, as well as other pathways. These in turn manifest in symptoms such as hyperglycaemia and hypoxic sequelae.

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NONTARGETED SCREENING

Nontargeted Chemical Fingerprinting of Phytotoxins in Environmental Matrices
Researchers from the University of Copenhagen (Denmark) have developed a novel, sensitive, and reliable analytical method to analyze phytotoxins in environmental matrices using reversed-phase liquid chromatography with electrospray ionization high-resolution mass spectrometry (RPLC–ESI-HRMS).

Phytotoxins have been classified as chemicals of emerging concern (CECs) (1). This class of secondary plant metabolites has gained attention because of their impact on the environment and potential adverse affects on human health. The development of new analytical methods to analyze these compounds is therefore highly desirable, and new methods for the targeted and nontargeted screening analysis of phytotoxins in environmental samples are in demand. The researchers from Copenhagen developed a nontargeted RPLC–ESI-HRMS method to identify five major groups of phytotoxins—steroids, alkaloids, flavonoids, terpenoids, and aromatic polyketides—in environmental matrices.

A novel, sensitive method for the targeted and nontargeted screening of phytotoxins was developed. This new non-targeted screening method was 40 times more sensitive than previous methods, according to the researchers, and allowed more than 30 phytotoxins to be identified from soil and water samples. The researchers suggested that for a balance between sensitivity, number of compounds detected, high-throughput, and peak capacity, a mobile phase consisting of 5 mM fumic acid at pH 3.0 with a gradient of 0.95% acetonitrile over 30 min should be used for both ESI + and ESI – with a column temperature of 25 °C.

In this study, the researchers also established that the negative ionization of phenols was assisted by the number of hydroxyl groups present on the ring rather than on their substitution position. This new RPLC–ESI-HRMS method will help to understand the fate of phytotoxins in the environment and assist in developing guidelines to monitor phytotoxins for public health, according to the researchers.

Reference

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