ARTICLE

How to enable sustainable GC lab operations?

Introduction

Sustainability strategies are being integrated into a growing number of businesses and their operations. Laboratories are no exception. Following the goals of the United Nations 2030 Agenda for Sustainable Development[1], laboratories have begun adopting and implementing strategies that support business viability and growth in an environmentally sustainable way.

Although the necessity to reduce the environmental impact of laboratory operations is recognized, it cannot be disengaged from the economic viability of labs. Rather, these two goals can move forward in parallel and support each other in such a way that the business and the environment both benefit.

Some of the benefits of adopting sustainable practices in the gas chromatography (GC) lab include improved energy efficiency, reduced carrier gas usage, and reduced operational costs. GC technological advancements can enable laboratories to adopt such practices, helping them future-proof their operations.

This article discusses ways in which laboratories can improve both their business and environmental sustainability, and how advanced GC technologies support labs in their efforts, particularly in the following areas:

- Carrier gas selection and use
- Laboratory efficiency, scalability, and flexibility

TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries – developed and developing – in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.[1]

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Carrier Gas Selection and Use

In gas chromatography, the carrier gas acts as the mobile phase and moves the vaporized solutes through the column. The most widely used carrier gases for GC systems are nitrogen, hydrogen, and helium. Carrier gas selection will impact the resolution, retention time, and throughput of the workflow. The primary benefits and limitations of these three gases are:

- Nitrogen provides the highest efficiency but is extremely slow as a carrier gas due to its low and narrow linear velocity range; it is not recommended for temperature- programmed use.
- Hydrogen provides the fastest analysis time over a broad linear velocity range; safety concerns tied to its high reactivity must be addressed.
- Helium is a compromise between nitrogen and hydrogen in terms of efficiency and analysis times. It is highly stable but is a non-renewable resource that is becoming a concern from cost and sustainability perspectives.

Challenges with the use of helium have been a growing topic of discussion over the past several years, including its decreasing availability, the need for sustainable production processes, and finding effective alternative gases.

Helium Strategies

Historically, helium has been recovered primarily during the extraction of natural gas deposits. The helium is separated from the bulk gas and purified in a complex process. However, less than 3% of natural gas deposits contain more than trace amounts of helium, and 0.35% helium is considered a high concentration for a bulk gas source.[2] These characteristics make helium production, availability, and cost susceptible to the often dramatic natural gas market fluctuations.

HELIUM RESOURCES

The leading helium-producing countries and their production in 2021 are[3]:

- United States: 71 million cubic meters (m3)
- Qatar 51: million m3
- Algeria: 14 million m3

A University of Oxford research team developed a technique to actively look for helium deposits that are not necessarily associated with natural gas. In 2016, they found a massive helium deposit in Tanzania's Rift Valley. Their technique is being further evaluated and may help to steady the world helium market.[4]

In addition, helium is an inert gas that does not form molecules with other elements, and it readily moves into space when released to the air. Thus, helium is a non-renewable resource with currently unknown amounts of remaining deposits. There is a crucial need for helium-conserving and recycling technologies and alternative gases.

Laboratories are looking for ways to use less helium in their operations and find alternative gases in an effort to overcome helium shortages and price instability. Recent advances in laboratory instrumentation have made it possible to reduce helium use. For example, the PerkinElmer™ GC 2400™ Platform has an optional gas saver mode that helps minimize the use of gas during and between runs and when the system is not in use. The gas saver mode is controlled by the PerkinElmer SimplicityChrom™ Chromatography Data System (CDS) Software, providing automated control based on instrument use and idling periods.

Hydrogen Opportunities

The challenges with helium have increased the focus on hydrogen and its potential as an effective and sustainable alternative carrier gas for GC workflows. From an analytical performance perspective, hydrogen offers high separation efficiency and faster separations at lower pressures than any other carrier gas. Hydrogen's faster elution time means it is not necessary to increase the column temperature run rate. Thus, lower maximum temperatures and shorter heating intervals are required, reducing energy usage and increasing the sustainability of the workflow and business.

Using hydrogen as a carrier gas also increases the longevity of the GC column. The hydrogen-related lower run temperatures lead to less phase breakdown or "column bleed." Plus, because hydrogen is a reducing gas, it removes acidic sites within the column that can cause column bleed. Both of these outcomes increase the usable lifetime of the column, providing cost savings and improving the sustainability of lab operations.

Hydrogen has historically been produced using fossil fuels. Newer, more sustainable hydrogen production techniques include[5]:

- Electrolysis in which electricity is used to split water molecules into hydrogen and oxygen
- Microbial biomass conversion
- Waste stream fermentation

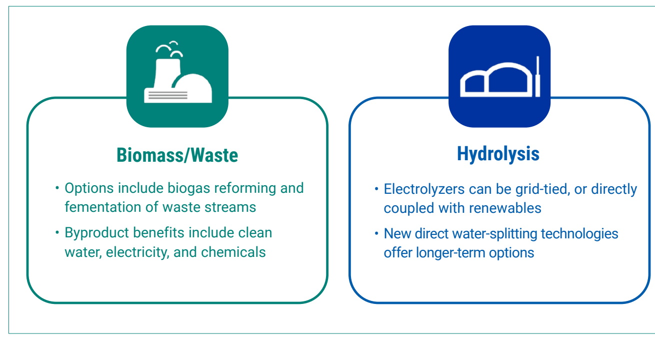
These pathways enhance the sustainability of carrier gas production by recycling waste streams, using renewable biomass, and often being powered by renewable solar power. For instance, hydrogen can be produced in situ in the analytical lab using a hydrogen gas generator, thereby overcoming the shortages and availability challenges that are typical for helium.

While the advantages of using hydrogen as a carrier gas for GC are clear, the greatest concern is about its safe use. Hydrogen is quite flammable in air and its flame is nearly invisible. Labs need procedures, training, instrumentation, and software that help them safely monitor their hydrogen carrier gas use and storage.

Standard Operating Procedures (SOP) for carrier gas handling and staff training are important first steps in promoting safety. In addition, the design of the laboratory must include adequate ventilation, and experimental workflows must include leak detection capabilities.

Innovations in GC instrumentation are addressing safety concerns associated with hydrogen. For example, the PerkinElmer GC 2400 Platform has a built-in hydrogen sensor that is controlled by the SimplicityChrom CDS Software. When a hydrogen leak is detected, the system is immediately set in safety mode. Innovations such as this provide laboratories with the ability to use the more sustainable hydrogen as an alternative to helium in a safety-conscious manner.

Sustainable Hydrogen Production Pathways[5]



Laboratory Efficiency, Scalability, and Flexibility

Sustainability can be built into a lab at any number of stages, such as when it is being designed, reconfigured, or expanded. Operational and business aspects to be considered include the efficient use of space to accommodate the workflows being used, selection of space-efficient and scalable instrumentation, and ensuring there is room for expansion/scale-up based on industry trends and business growth plans.

Adaptable Hardware and Software

Selecting instruments that have a small footprint frees up bench and floor space to allow scale-up of existing workflows or adding of new workflows. In addition, selecting hardware and software that are capable of supporting multiple workflows improves space efficiency by eliminating the need for duplicate instruments. It also improves resource use and business sustainability.

For example, the GC 2400 Platform is a comprehensive workflow with a small footprint that saves valuable bench space. The platform is also easily reconfigured with different autosamplers and injectors, with the SimplicityChrom CDS Software auto-recognizing and auto-configuring them. Flexibility and automation such as this not only increases efficiency, it also allows for adoption of scalable solutions to match growing laboratory needs.

Considerations for lab design that enhances sustainability

- Economies of space, including analytical instruments footprints
- Adaptable analytical workflows
- Flexible work settings (work-from-home, onsite, hybrid)

Flexible Work Scenarios

Another means of improving the sustainability of a laboratory is having flexible work-from-home and hybrid work scenarios. This is easily accomplished when the laboratory is digitally enabled and workflows are automated. Laboratories that are able to remotely run, monitor, and control their workflows via smart devices and web apps have more flexibility in the use of lab space as well as enhanced real-time decision-making capabilities.

For instance, the GC 2400 Platform has a detachable touchscreen that can be used to remotely monitor and control workflows, including each instrument, from any location in the lab. The platform's web app is another option that can be used to monitor and control workflows from any location in the lab and beyond. Additionally, the SimplicityChrom CDS Software enables intuitive data acquisition, processing, and review via both the detachable touchscreen and the web app. These capabilities enable accelerated, on-the-go decision making and maximize lab productivity and sustainability.

Conclusion

Laboratories are adopting strategies that support both business viability and environmental sustainability. These two goals are being achieved, and even support each other, thanks to a new way of thinking about the lab workspace, instrumentation, and work schedules. The PerkinElmer GC 2400 Platform is helping laboratories flourish in these and areas thanks to its efficiency, flexibility, and scalability.

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PerkinElmer, Inc.
940 Winter Street
Waltham, MA 02451 USA
P: (800) 762-4000 or
(+1) 203-925-4602
www.perkinelmer.com

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