SPECIAL FEATURE

Carbon dioxide purity and CCS

Stephen B. Harrison explains the essential link to a safe and sustainable CCS sector

One of the most promising routes to take the next steps on the road to full decarbonisation is carbon capture and storage (CCS) from existing combustion processes, such as cement production or electrical power generation.

In the mid-term, there are also several pilot project proposals to construct steam methane reformers, or auto thermal reformers to produce hydrogen for heating and mobility applications. CCS is an integral part of these schemes to ensure that they produce blue hydrogen and play a role in sustainable decarbonisation.

The concept of CCS is to recover carbon dioxide (CO_2) from industrial process gas emissions and inject the CO_2 deep into the ground for long-term storage. We can thereby reduce CO_2 emissions to our atmosphere and slow down climate change. For sure, when we use CO_2 to freeze food or carbonate beverages the need for using a high purity gas is abundantly clear. But with the basic idea of pumping CO_2 underground, why would 'purity' ever come into question?

The fact is that there are equally compelling, but different reasons that CO_2 purity is also a critical issue when it is pumped underground in CCS. However, at present there is no common standard to define the quality of CO_2 that should be used in CCS projects. To address this gap, many of the brightest minds in industrial gases metrology, gas analysis and energy gas standards are working hard behind the scenes.

> "…there are equally compelling reasons that CO2 purity is a critical issue in CCS"

Learning from other applications

In patient healthcare, as has been highlighted by the many thousands of respiratory treatment cases caused by Covid-19 worldwide, oxygen is also used extensively as a medical therapy. It is directly inhaled by vulnerable people and its purity must be tightly controlled. In this medical application, there are also rigorous standards set by the main international Pharmacopeia which govern the production, identification and assay of medical oxygen to ensure that it will help to cure, not harm patients.

European and US Pharmacopeia require the use of a paramagnetic oxygen gas analyser to perform the identification of oxygen and assay of oxygen purity when medicinal oxygen is produced through the cryogenic distillation of air. The Japanese standard refers to gas chromatography as being the required method of identification and specifies volumetric gas absorption apparatus as the required method of assay. For European and Japanese Pharmacopeia, the purity of cryogenically produced medicinal oxygen must be greater than 99.5%, and for the US Pharmacopeia it must exceed 99%. Toxic impurities such as carbon monoxide and carbon dioxide must also be analysed using an infrared gas analyser or tested using a gas detection tube.

International standards also govern the use of nitrogen (and its purity) in pharmaceutical drug manufacturing applications. In some cases, nitrogen is used as an active pharmaceutical ingredient and in other applications, such as packaging, it is used as processing aid.

Meanwhile, the purity of hydrogen for use in fuel cell electric vehicles (FCEVs) is also subject to an international standard, namely 'ISO14687: 2019 – Hydrogen fuel quality – product specification'. Impurities such as carbon monoxide and hydrogen sulfide are capped at levels that will guarantee the hydrogen is compatible with standard modern fuel cells and does not poison the sensitive catalysts. The maximum combined argon and nitrogen concentration is also specified to avoid the long-term accumulation of these inert air gases in the fuel cell, which would result in a potentially dangerous loss of vehicle power.

The examples above focus on three different gases: oxygen, nitrogen and hydrogen. What they share are a minimum purity for the gas and maximum concentrations of impurities which could be harmful to the application. Some also specify the analytical method to conduct the purity assay or the analysis of trace impurities. So, in the consideration of a future standardised purity specification for CO_2 in CCS applications, there are some parallels from existing standards to learn from.

Carbon dioxide purity in CCS

Food safety regulations[1,2] tightly control the purity of carbon dioxide to protect human health. Within the industrial gases industry, these are referenced and summarised in 'EIGA Doc 70/17, Carbon dioxide food and beverages grade, source qualification, quality standards and verification'. The EIGA document also includes a table to typical impurities that may be found in CO_2 according to the source: be it combustion, coal gasification or steam methane reforming associated with ammonia and hydrogen production. Perhaps these insights can lay a foundation for a CCS CO_2 purity standard.

In the realm of international metrology, many issues are being considered as the debate about the requirement for a CCS CO_2 standard is taking place. Dr. Arul Murugan, Senior Research Scientist for Energy Gases at NPL in the UK says that, "When considering the purity standards for food ingredients, public health is the major concern. For CCS, public health and safety are also of concern and there are additional issues to consider."

"For example, in some CCS schemes, the idea is to liquify the carbon dioxide either for immediate storage or to enable its transportation by ship to an offshore platform where it will be further processed. Incondensable gases such as nitrogen or methane could reduce the efficiency of this process by increasing the required energy input. Furthermore, these gases do not behave in the same way as CO_2 when injected underground and they take up valuable storage space."

Murugan adds, "In other CCS schemes, the proposal is to compress CO_2 to a high pressure so that it can be cost-effectively transported in long distance pipelines before being injected into suitable geological structures deep underground. These compressor stations and pipelines are highly valuable assets which must be protected. If there are combinations of gases in the CO_2, that can result in corrosion, such as ammonia and moisture or hydrogen sulphide and moisture they may cause irreversible damage to the pipeline or even the storage site itself. This corrosion of the CCS infrastructure would be costly to repair."

"Corrosion could also pose a safety risk if it went unnoticed and caused a pipeline rupture. In these cases, detection of these trace contaminants is essential to prevent problems escalating."

Process performance and gas distribution asset integrity are not the only reasons for careful analysis and control of CCS CO_2 purity. The safety of the personnel operating the CCS equipment and the general public are also of paramount importance. Murugan continues, "CO_2 intended for CCS may also contain trace levels of highly toxic chemicals such as mercury or hydrogen cyanide. Whilst we cannot always prevent these molecules being present at tiny levels, we can monitor their concentrations to ensure that they exist in the gas only in minute traces which would ensure that any potential CO_2 leak from the CCS processing equipment or storage site does not pose a health risk. With all of these considerations in mind, my team at NPL are starting to develop the analytical methods and traceable reference materials required for performing these important purity analyses."

The case for an international standard

Current CCS projects are taking place within national borders. However, the future of CCS is likely to become international.

The UK, Netherlands and Norway, for example, have spearheaded the extraction of fossil fuel reserves from the North Sea for many years and are three countries at the forefront of developing CCS schemes in Europe which would rely on underground CO_2 storage locations within their jurisdiction. Many nations in Europe may also wish to participate in CCS schemes, but if their country does not have the appropriate geological profile, they must rely on exporting their CO_2. So, for several reasons the trade in CO_2 for CCS will inevitably become international. Likewise, the onshore and offshore oil and gas fields in North America are close to international borders with Mexico, Canada and other nations and, in the future, it may be desirable to transport CO_2 for CCS across some of these national borders. gw

REFERENCES

1. EC Directive 2000/63/EC amending Directive 96/77/EC laying down specific purity criteria on food additives other than colours and sweeteners, 98/83/.
2. INS No. 290, JECFA –Joint FAO/WHO Expert Committee on Food Additives.