INTERNATIONAL LITHIUM ASSOCIATION (ILiA)

THE LITHIUM VOICE

The journal of the International Lithium Association (ILiA)

ISSN 2755-3558

Lithium, water and you

Salars: A short introduction

The colour of lithium

SPECIAL EDITION 2025

Discover the world of lithium

Lithium extraction ponds in Catamarca Province, Argentina (Image: Shutterstock)

VALOR PÚBLICO

Lithium Business 2025

LITHIUM VALLEY JEQUITINHONHA

It is with great pride and happiness for the R2 Valor Público team to support the 2025 edition of The *Lithium Voice* in Brazil.

It's a good time for this edition to be in the hands of the Brazilian public attending Lithium Business 2025, the largest lithium event in Brazil, which has been supported by the International Lithium Association (ILiA) from the outset.

Lithium Business is taking place in the city of Araçuaí, in the Jequitinhonha Valley, a region that has been recognised worldwide for the quality of its spodumene-rich pegmatite. The richness of Araçuaí is completed by its culture, its hospitable people, its music, its handicrafts and its cachaça.

The R2 Valor Público team remains steadfast in its two great purposes: to create public value and to radiate knowledge in the Jequitinhonha Valley, which would not be possible without the wide range of support surrounding Lithium Business.

Our sincere thanks to AMG, Companhia Brasileira de Lítio - CBL, PLS, Lithium Ionic and Sigma Lithium for making this moment a reality, and to all the sponsors!

We thank ILiA for their support, and we look forward to a continuous partnership so we can remain firm in our purpose, where responsible mining is essential in the context of a just and inclusive energy transition.

Prof. Rossandro Ramos

Federal University of the State of Rio de Janeiro and founder of Lithium Business

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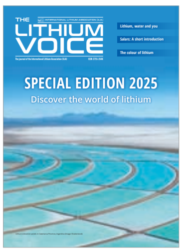

Special Edition 2025

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Chair's WELCOME

One of the main visions and pillars of the International Lithium Association (ILiA) is education. To be recognised as a trusted source of knowledge on all aspects of the lithium industry. The Lithium Voice is a result of this vision.

The *Lithium Voice 2025* is a collection of special articles that appeared in the quarterly editions between September 2024 and May 2025.

ILiA members and industry participants collaborated in establishing the lithium industry's first Guidance to determine the Product Carbon Footprint (PCF) last year. Its success is in its acceptance and implementation across the lithium supply chain. This will help to create further transparency and sustainability of the lithium industry.

Lithium is not only central to the energy transition, but it is everywhere, including in your body! I am sure you did not know about this, or about its colour. Or about Salars? These featured articles were well received by the lithium community and reproduced here for wider circulation.

The International Lithium Association (ILiA) is the not-for-profit industry association that provides a representative, global voice for the entire lithium value chain. ILiA has over 75 members that produce around 90% of the current total lithium supply. The membership is across the complete lithium value chain. Join us to strengthen the voice of the global lithium industry.

The *Lithium Voice* is published quarterly in English, Spanish and Chinese and is free to subscribe.

We hope that you enjoy this edition and appreciate the role of lithium in our daily lives. Your feedback is always welcomed!

This is the lithium century!

Anand Sheth
Founding Chairman

LITHIUM, WATER AND YOU

Regular readers of *The Lithium Voice* will know that lithium is produced industrially from rocky minerals and saline brines. But where else can you find lithium in the natural world? The answer is almost everywhere, including in you!

How did it get there?

Lithium is the 30th most common element in the Earth's crust, averaging 0.002% or 20 parts per million (ppm). Lithium atoms are very small, light and highly soluble in water. In addition, some of them have been around since the Big Bang, 13.8 billion years ago, which has given them plenty of time to become widely dispersed in nature.

Life first appeared on Earth about 4 billion years ago in oceans containing dissolved lithium salts (0.17 ppm). Over millennia, as life evolved, lithium has always been present in and around all living creatures, including humans. In fact, our bodies naturally contain lithium and we all consume trace amounts of it every day, in the food we eat and in the liquids we drink.

Whenever we make a cup of coffee using tap water (which is often groundwater), rehydrate with branded mineral waters in a gym, or enjoy a glass or wine or beer after work with friends, we will take in a tiny amount of lithium too. But don't be alarmed, this is quite normal and safe; after all, our ancestors have survived for millions of years on a similar diet.

Lithium in your body

"Lithium is an important micronutrient in the human diet", Dr Romain Millot, a French geochemist and expert in lithium isotopes, explained to *The Lithium Voice.*

The average 70kg adult human body is estimated to contain about 7 milligrams of lithium (about 0.1 ppm), which is mostly found in your brain, kidneys and bones. This amount is thought to remain fairly constant; what we consume passes through us and out again relatively quickly.

Water at Szechenyi Baths in Budapest, Hungary, contains 0.2ppm lithium.

"The exact molecular function of lithium as an essential trace element is not fully understood yet", Dr Millot explained. Perhaps because of this uncertainty the World Health Organisation (WHO) does not currently list lithium as an essential nutrient or give a recommended daily intake. However, several studies have suggested a correlation between higher levels of lithium in our diet and lower risks of dementia, reduced Alzheimer disease mortality and less suicide risk.

But while the role of lithium might be unclear, a recent paper by Dr Gerhard Schrauzer at the University of California, San Diego, in the US, claimed that an adult human does have a daily requirement of lithium, but only of ~1 mg per day.

Perhaps the fashion for lithium-enriched spas and drinks from the 1860s to the 1920s was on the right track, after all?

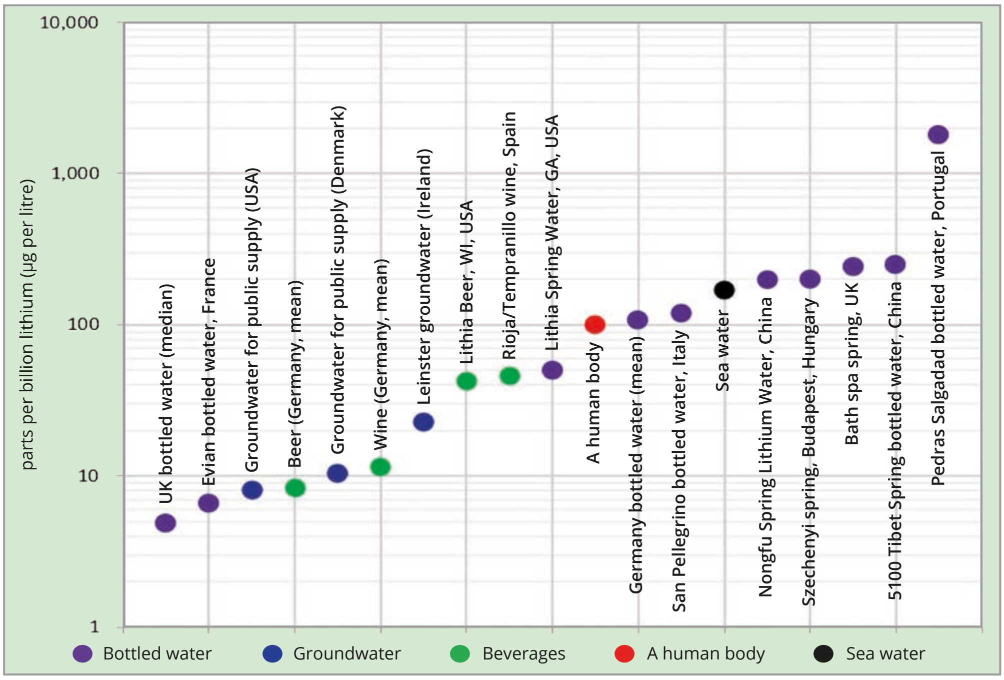
Lithium-rich waters

Since prehistoric times sources of clean water have been highly valued and arguably none more so than natural springs and wells, which were often the only safe sources of water that could be drunk without boiling it first. The association between spring water and health is therefore deeply rooted.

In Europe natural mineral waters were first bottled and traded in the mid-16th century, for example at Spa in Belgium and Vichy in France. In the 1860s techniques were developed to analyse the minerals dissolved in water and lithium was found to occur in many natural springs across the world, including at Baden-Baden in Germany, Bath in the UK, Lithia Springs in Georgia, USA, and the Uchinomaki Onsen on Mount Aso, Japan.

Often spas, hotels and public baths were built for tourists to "take the water" at natural springs and by the late 19th Century they were big business. Adverts would prominently feature the unique chemical analysis of the water at that resort; "proving" the health benefits with science, or so it was claimed.

Each natural water is unique in composition and taste, and not all of them contain lithium. A comprehensive study of groundwaters used for public and domestic use in the US found that lithium levels varied widely, with concentrations ranging from less than 1 part per billion (ppb or µg/L) to 1,700 ppb. Higher concentrations of lithium in the groundwater were typically found in arid regions and older groundwater, and the study suggests that natural influences, such as local rock chemistry, climate and mixing with saline waters, are the primary contributors to increase lithium levels.



Lithium in selected liquids and a human body (ppb or µg/l) *(Sources available on request)*

'Healthy' drinks

In the late 19th century as the railway network expanded, shipments of mineral water from springs to cities increased rapidly, popularising the 'healthy' waters far and wide. To take advantage of this trend many lithium-enriched drinks were developed which claimed similar health benefits but often tasted a lot better. By the early 20th Century in the US one could purchase Lithia Coke (Coca-Cola syrup mixed with lithium-bearing water), Lithia Beer (brewed in West Bend, Wisconsin) and Bib-Label Lithiated Lemon-Lime soda (which today we know as 7Up, but which no-longer contains lithium).

Lithium in modern drinks

If you are seeking a lithium-containing bottled water then it is not hard to find, although admittedly lithium is rarely listed on the contents label as the level contained is usually far lower than magnesium, sodium and other elements. Examples of lithium-rich bottled waters include the Italian water San Pellegrino (0.12 ppm) and from China 5100 Tibet Spring (0.25ppm) and Nongfu Spring Lithium Water (>0.2ppm).

Lithium is common in other drinks too. A 2020 study of 160 different drinks in Germany found that on average the lithium content in red wine was 17 parts per billion (ppb), white wine 8 ppb, cola drinks 8 ppb, energy drinks 24 ppb and beers ranging from 3 to 20 ppb.

Should we take lithium as a dietary supplement?

No, this is not necessary since we naturally consume sufficient lithium to meet our bodies' requirements. Nor are such supplements easily available; in the author's experience France is the only country where you can buy lithium dietary supplements without a prescription (as ampules of lithium citrate or lithium gluconate).

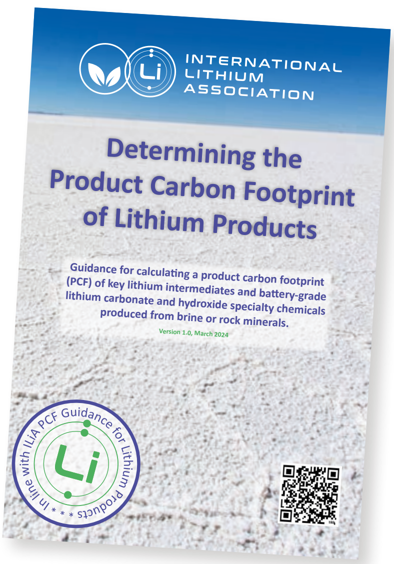
In conclusion, lithium does appear to play an important role as a micronutrient in the human diet, even if scientists are still trying to identify what that role is. The good news is that we need very little dietary lithium and it is freely available in many types of food and drink. Lithium occurs throughout the universe, all over the world and even in our bodies (100 ppb). Lithium is natural, everywhere and (for reasons doctors still don't fully understand) an important element for life.

Medical notice: The level of dietary lithium discussed in this article is approximately 1/1000th the typical daily dose of medical lithium, a powerful mental health medicine which should only be taken after professional medical advice. Medical lithium should never be taken as a dietary supplement.

THE FRAMEWORK AND VERIFICATION PROCESS FOR ILiA'S PRODUCT CARBON FOOTPRINT STAMP

ILiA's landmark "Determining the Product Carbon Footprint (PCF) of Lithium Products" (the Guidance) was published in March 2024 as the first globally standardised way to measure the carbon dioxide generated during the production of the lithium that is used in electric vehicles (EVs) and other applications.

Addressing this was an urgent challenge for the industry, not only because of the rapid growth of lithium production, but also because of the demands from regulators and the automotive industry to report the greenhouse gas (GHG) emissions of all the raw materials used in the batteries of EVs (see *Lithium Voice* #5).



The Guidance was published after extensive consultation with a wide range of stakeholders and it allows practitioners to create a PCF assessment for key lithium intermediates and battery-grade lithium carbonate and hydroxide specialty chemicals produced from brine or rock minerals in a standardized way as part of their PCF, whether it is stand-alone or part of a Life Cycle Assessment (LCA).

The Guidance is well received

Over the last 14 months it has been well received by industry and regulators alike. The Guidance has even formed the foundations of two proposals for new ISO standards. This positive reception was testament to all the hard work which went into making it.

Mark de Boer, Chair of the Sustainable Lithium Subcommittee and Vice President Sustainability at Albemarle Corporation, said, "It is great to see such a large interest in applying the Guidance. Not only by ILiA members, as we had hoped for, but also by non-ILiA members too."

In recent months ILiA has been approached by several leading lithium facilities which reported using the Guidance to determine the PCF of their lithium products. This raised the question of how to differentiate Guidance-compliant PCFs and prevent someone falsely claiming compliance.

It was decided that to recognise a PCF (or LCA) which has been created in compliance with the Guidance ILiA will award a unique, non-transferable, numbered ILiA PCF Stamp ("Stamp") that states "In line with ILiA PCF Guidance of Lithium Products".

The Stamps have been welcomed by the industry, but as a consequence, also raised the demand for ILiA developing a verification procedure to confirm that the Guidance has been adhered to, prior to awarding a Stamp for a PCF.

The challenge of verification

This challenge was taken up by ILiA's Sustainable Lithium Subcommittee (SLS). The task was to create a verification mechanism that was transparent, consistent and efficient. It needed to be rigorous, but not unnecessarily complex since a high cost could discourage use of the Stamp. The end goal was to allow all PCFs that are awarded a Stamp to be meaningfully comparable, regardless of when, where and by whom they are created.

Verification in practice

To assure the correct application of the Guidance, the SLS decided that prior to ILiA awarding a Stamp to a PCF, an independent review of that PCF would be required. However, since ILiA was not well-placed to do this in-house, so the SLS developed criteria for approved independent experts. Using third parties had the additional benefit of preventing ILiA from seeing confidential PCF data, which is a perennial concern for an association.

The team initially developed a set of competence criteria for independent verifiers based on the guidelines of the International Environmental Product Declaration (EPD) System but tailored them to meet the specificities of the lithium industry.

The competence criteria for an independent verifier are listed on ILiA's website, www.lithium.org, and include:

- Performing at least 10 PCFs/LCAs within the five years prior to the application.
- Having a thorough knowledge of the ISO Standards for LCA 14040, 14044 and 14049.
- Demonstrating knowledge of PCFs/LCAs for metals and mining products.
- Having high proficiency in English or Spanish or Chinese.

Individuals who fulfil the criteria can become an ILiA-approved verifier, empowered to verify lithium PCFs for compliance with the Guidance. A list of approved verifiers is available at **www.lithium.org** and if you are interested in applying to become a verifier please contact the Association.

Verification starts!

In May 2025 the initial approved independent verifiers are:

- Lorraine Amponsah (Loram Consulting)
- Sophie Myers (Minviro Ltd)
- Rob Rouwette (start2see Pty Ltd)
- Joris Šimatis (Minviro Ltd)
- Sébastien Taillemite (Ecovamed)
- Phoebe Whattoff (Minviro Ltd)

The list of verifiers is maintained by ILiA's Sustainable Lithium Subcommittee and once a verifier has been approved their status will be valid for three years, after which they will be considered for renewal.

Verifying a PCF

An organisation requesting the PCF and/or LCA for one of its operations to be verified as compliant with the Guidance can contact any approved verifier directly and contract them to undertake an independent review. The agreement will be between the approved verifier and the contracting organisation, not ILiA, and the cost of verification will be covered by the organisation in full.

Once the approved verifier has checked the PCF for compliance with the Guidance, and assuming it does comply, the verifier will submit a brief summary to ILiA and the contracting organization can request a unique Stamp to be awarded to the confirmed PCF.

Each Stamp is numbered and is only applicable to a specific PCF. Stamps are not transferable to another company, facility or PCF, which means that a large organisation with multiple PCFs for its various facilities will need to have each PCF verified in turn and will be awarded a unique Stamp for each one.

The record of Stamps

ILiA's website carries a record of every Stamp which is awarded, so that third parties can check if a PCF which claims to be verified, really is.

The record shows:

- the company that owns the facility that was analysed by the verified PCF/LCA (and the group to which that company belongs)
- the location of that facility
- the date of the independently verified PCF/LCA
- the verifier name and company
- the date of the verification

ILiA aims to publish this information within six months of a Stamp being issued to provide a clear record to the public and to prevent false claims or the use of invalid Stamps.

Organisations may decide to provide further information about their PCF, but this is on a voluntary basis.

The first Stamps are awarded

At time of print, four PCFs have already been confirmed and awarded ILiA Stamps:

Stamp 1.0 - **Tesla**:
Battery-grade lithium hydroxide monohydrate at its lithium refinery in Corpus Christi, Texas, USA.

Stamp 2.0 - **Talison Lithium Pty Ltd**:
Spodumene concentrate from the Greenbushes mine in Western Australia, Australia.

Stamp 3.0 - **Albemarle Corporation**:
Lithium hydroxide monohydrate 99.5% production at its Xinyu plant, China.

Stamp 4.0 - **Albemarle Corporation**:
Lithium hydroxide monohydrate 99.5% production at its Qinzhou plant, China.

On receiving Stamp 2.0, Rob Telford, Chief Executive Officer, Talison Lithium, said "Talison Greenbushes Operation is very proud to be the first mine site in the world, and the first lithium operation in Australia to receive the ILiA Stamp. Completion of a life cycle assessment in line with the ILiA PCF Guidance means we have a solid, credible and independently verified baseline from which to understand our impacts and opportunities to improve as we expand our operations for a cleaner energy future."

Astrid Karamira, ILiA's Sustainability & Governance Manager said "With the accreditation process having started, we expect many more organisations to undertake their LCAs and PCFs in accordance with the ILiA Guidance".

If you are currently performing an LCA or PCF for any of your lithium operations and would like confirmation that it is compliant with the Guidance, or if you have any related questions please email ILiA at **ILiA@lithium.org**

We look forward to seeing more lithium facilities' PCFs to be certified against the ILiA Guidance and to issuing many more Stamps in the future.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INTERNATIONAL LITHIUM ASSOCIATION (ILiA)
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SALARS: A SHORT INTRODUCTION

Authors: **Rowan Halkes, Andrew Hughes, Evi Petavratzi at the British Geological Survey (BGS)**

Introduction

Forecasts for lithium demand over the next few decades suggest an exponential growth in production. Half of global lithium resources are found in the salar deposits of South America, an area known as the "Lithium Triangle". This region, spanning parts of Argentina, Bolivia and Chile (Fig. 1), will be crucial in providing the lithium required for global decarbonisation and electrification. This article will briefly introduce how these deposits are formed, where they are found, how lithium is produced, and also touch upon on some of the associated complexities.

An introduction to salars

Salars are the remains of ancient lakes that formed over hundreds of thousands of years, driven by the climate cycling between wetter and drier periods. Not all salars contain lithium resources, in the form of lithium-rich brine, those that do are referred to as salar deposits. The formation of salar deposits is a complex process, requiring specific geological and environmental conditions as well as long time periods.

Salars are some of the most complex natural systems in the world, combining interactions between the atmosphere, the hydrosphere and the lithosphere.

Broadly, there are six factors needed to form a salar deposit; 1) arid climate; 2) closed basin containing a salar (salt crust) and/or a salt lake; 3) associated igneous and/or hydrothermal activity; 4) tectonically driven subsidence (creating space for continued inflow/infill); 5) suitable lithium sources; and 6) sufficient time to concentrate lithium.

The salar is divided into the nucleus (centre) and the transitional (or marginal) zone at the edges, contained within a wider basin (Fig. 2).

Notable salar deposits include the Salar de Uyuni in Bolivia, Salar de Atacama in Chile, and Salar del Hombre Muerto in Argentina (Fig. 1). Lithium is also produced from salar deposits in China, as well as North America; but it is those of South America that are of most significance to global lithium supply, providing 34% in 2022.

Located at 2,300 – 4,000m above sea level in the Andes, the combination of elevation, solar irradiation, and aridity make the salars some of the most extreme environments on Earth. These conditions mean salars have unique flora and fauna, including microbes, which in turn form diverse and rare ecosystems. They also frequently host communities of Indigenous

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people, who have strong social and cultural relationships with the salars. Given the aridity of the area, access to and use of water for all users in the watersheds where salars are located (which can include other mining projects, tourism and agriculture) is a concern. Furthermore, salars are often situated within or adjacent to protected areas for wildlife, e.g. internationally recognised RAMSAR wetland sites.

Geologically, salars consist of sedimentary rocks, such as clays, silts, sands and evaporite minerals like halite (NaCl) salt. These are one of the most important features of salars, as the pores (small spaces) within these rocks can store the brines and freshwater*. Furthermore, it is the connection between these pores that allows fluid movement, enabling the brines and freshwater to move and collect over time, as well as to be pumped out.

The salars of the Lithium Triangle were formed, and are hosted in, a highly active geological system. The surrounding Andes were created above a tectonic subduction zone, where significant amounts of magma were generated to form these volcanic mountains.

The volcanic rocks, which surround salars, have elevated levels of lithium, although not enough to merit being mined. Over time, lithium is leached from them and transported into the salar by surface waters, groundwaters, and geothermal waters at depth (Fig. 2, page 8). Due to the high elevation, aridity and solar irradiation these waters are significantly concentrated by evaporation, forming brines with high levels of lithium and other salts such as potassium, sodium, and magnesium (Table 1). The lithium concentration varies across the region from, 16 - 1,570 mg/l, with an average of ~336 mg/l. This variation can be attributed to several factors, including the variance in the volcanic rocks, and the variation of the chemistry of the magma that they were formed from.

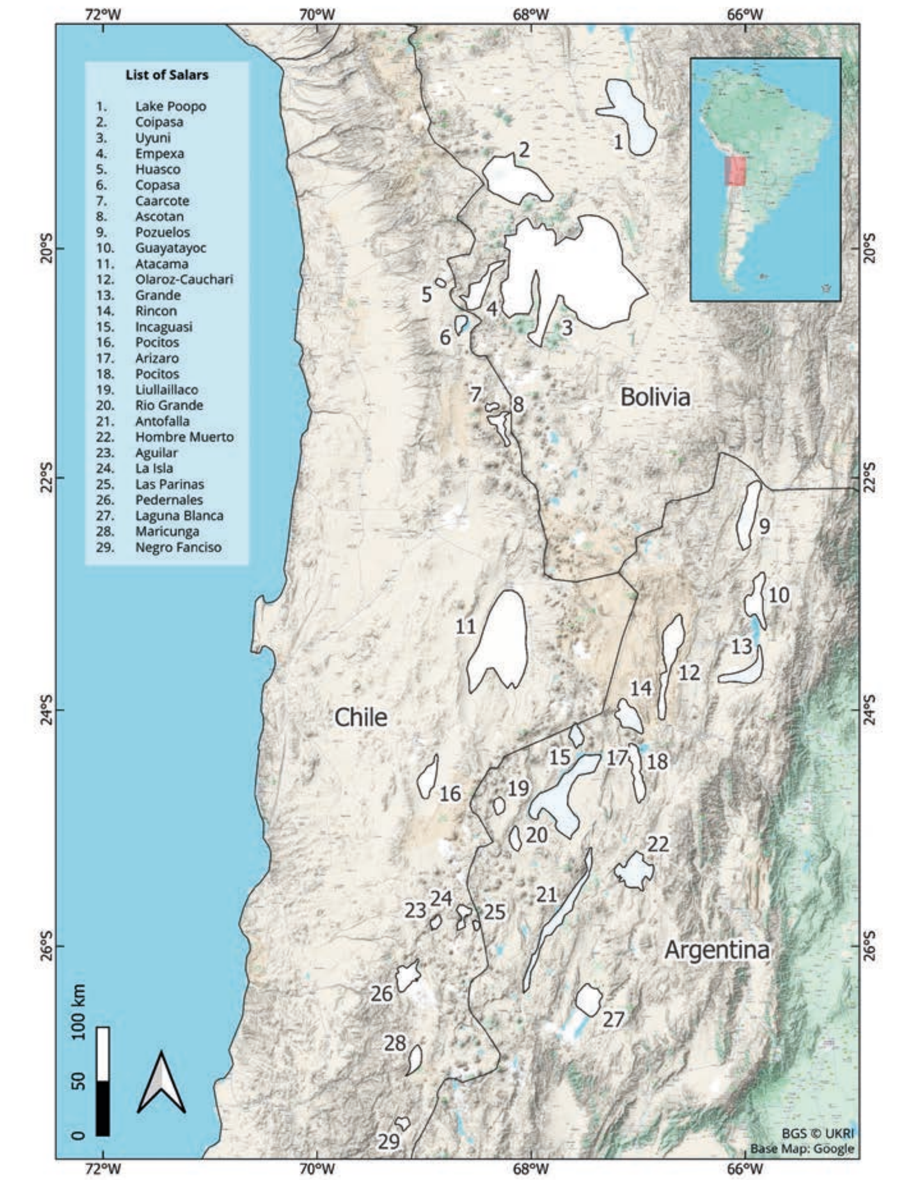

Figure 1: Map of the Lithium Triangle of South America, covering parts of Argentina, Bolivia and Chile with key lithium-bearing salars deposits highlighted. Note the list of salars is non-exhaustive. Base topography sourced from Google Earth.

Broadly, there are two types of water found in salars: brine and freshwater. Whilst brine is being formed continuously, the lithium takes hundreds of thousands to millions of years to become concentrated to economic levels, and surprisingly lithium constitutes only a small amount of these brines (<1%), with water comprising ~75% (Table 1). This water contained within the brine, in addition to freshwater, means salars contain significant amounts of water. However, the brines are extremely saline (Table 1), and are not usable as drinking water or for irrigation. Whilst lithium can increase in concentration with depth, lithium-bearing brines are primarily pumped out from shallow wells, typically 20 – 40m below the surface of the nucleus, but this varies (Fig. 2); the nucleus is where the

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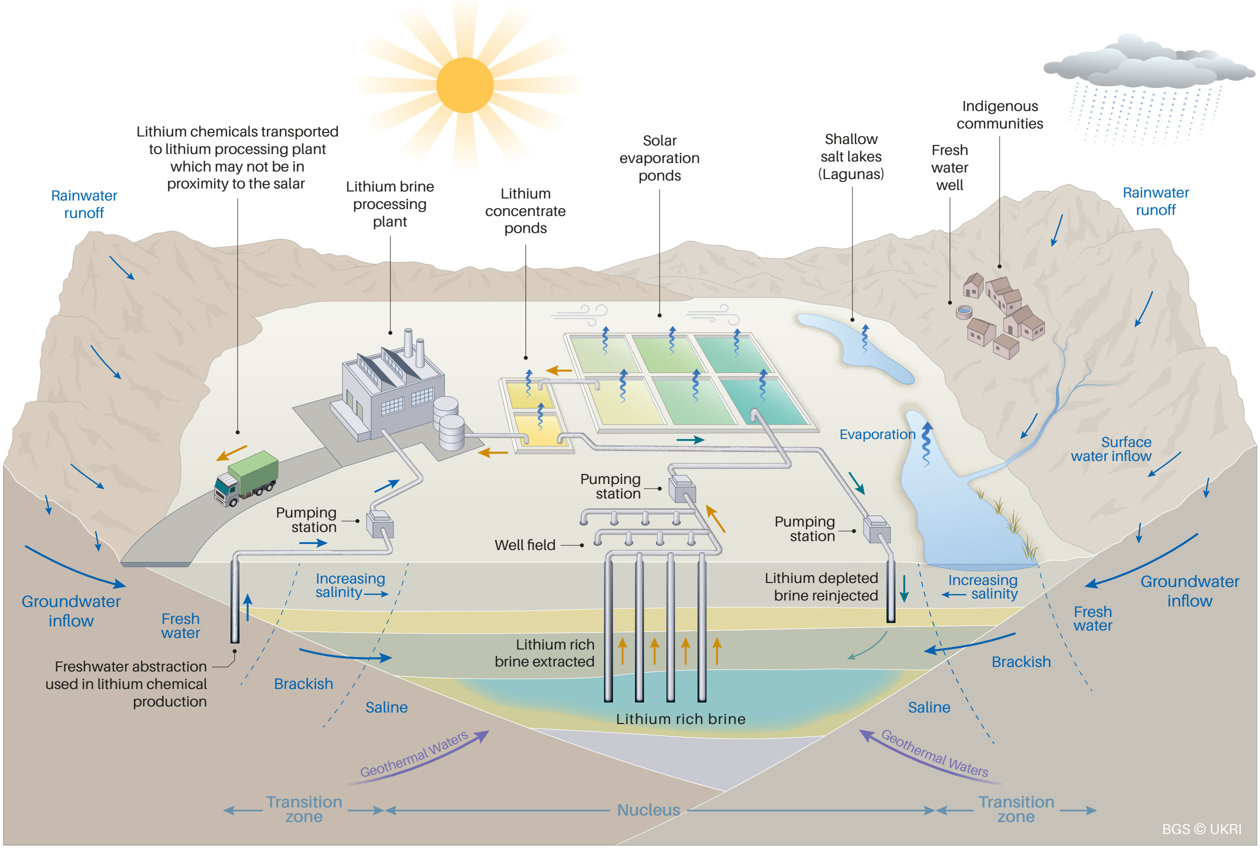
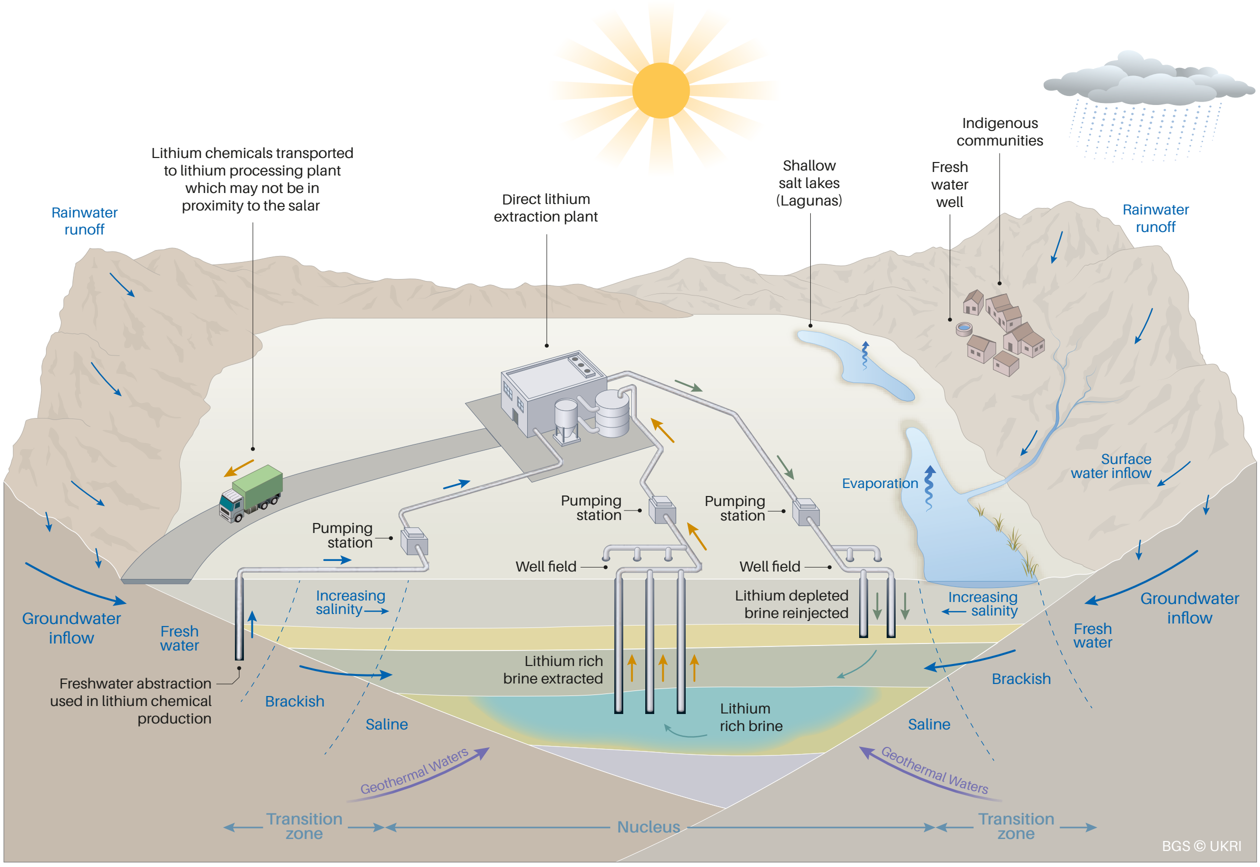
*In this article 'freshwater' refers to water that has a low concentration of dissolved solids and may be generally acceptable for withdrawal and/or conventional treatment to produce drinkable water.



Not to scale. Diagram is schematic and may not accurately represent all scenarios.



Not to scale. Diagram is schematic and may not accurately represent all scenarios.

Figure 2: Schematic block diagram of a salar illustrating brine extraction and concentration with a) evaporation processes (EP), b) direct lithium extraction (DLE). Hydrogeological and other salar features are also displayed. Note diagram is not to scale and is schematic, so may not accurately reflect all scenarios. The position and nature of extraction and reinjection is indicative.

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greatest lithium concentrations and extraction operations are located.

Salar complexity

Salars are some of the most complex natural systems in the world, combining interactions between the atmosphere (e.g. rainfall patterns), the hydrosphere (e.g. groundwater and surface water) and the lithosphere (e.g. lithium release and transport from rocks) along with solute concentration by evaporation.

The size and source of water inputs are hard to determine and each salar differs in the type and amount of freshwater inflow. Usually the main sources of freshwater are surface and ground waters, which whilst small, can be significant for the salars' water balance and maintaining lagunas (ponds or small lakes, Fig. 2). Precipitation is typically very low, but periodic flooding can also help sustain the water balance. Evaporation is the main natural outflow, and in some cases, this can exceed present-day inputs. Evaporation is also key for cycling freshwater through the system and concentrating brines, while geochemical processes can be important in brine evolution and determining the subsequent distribution of lithium.

Contrasting landscapes at Salar de Rincon, Argentina (above) and Salar de Uyuni, Bolivia.

There are complex interactions between these inflows, outflows and water types in salars. For example, brine is not static within the nucleus. Large-scale convection cells form (due to the sinking of the denser brine) and influence freshwater inflows and brine-freshwater interactions in the transitional zone. This area, made up of lagunas, wetlands and peatlands, is the most environmentally sensitive part of salars. The lagunas, key parts of ecosystems, are created when fresh groundwater encounters the high-density brines forming an effective barrier and/or convection cells from the nucleus and is forced to the surface. They are therefore sensitive to any changes in inflows as well as to variations of brine levels in the nucleus.

The complexity of salars also extends beyond three dimensions, they are highly dynamic with temporal aspects ranging from hourly (rain events) to millions of years (brine and halite formation). They are in flux from the influence of climate change, which is likely to increase temperatures but have variable impacts on rainfall. It may also cause changes in the balance of water inflows and outflows over time. However, the exact impact that climate change is likely to have, now and in the future, upon salars is unclear.

While there are similarities between salars in the Lithium Triangle, there are also significant differences. Each is unique in terms of brine and water chemistry (Table 1), microclimate, geomorphology, geology, hydrogeology, elevation, and the surrounding socio-economic situation to name but a few examples. It is also worth noting that the Salar de Atacama in Chile, where much of our understanding comes from, while not an outlier, is an "end member" on the distribution of salars – being hotter, drier, at lower elevation and having higher lithium concentrations than others. Therefore, care needs to be taken when transferring understandings from here to other salars.

Table 1: Comparison of different salar brines and water types

Salar/Water Type	**Region/Country**	**Total Dissolved Solids (TDS)** (% w/v)	**Li** (mg/l)	**Mg** (mg/l)	**Ca** (mg/l)	**K** (mg/l)	**Na** (mg/l)
Uyuni	Potosi, Bolivia	35.10	694	15,365	540	12,197	88,641
Atacama	Antofagasta, Chile	37.50	1,570	9,650	450	23,600	91,100
Hombre Muerto	Salta/Catamarca, Argentina	34.09	535	1,091	766	4,681	43,376
Sea water	-	3.50	0.18	1,300	400	380	11,000
Bottled water	-	0.03	0.005	26	80	1	6.5

Salar brine data is drawn from varied sources and is not directly comparable. This table is to demonstrate variability, rather than make comparisons.

Uyuni data: Risacher and Fritz, 1991; Atacama data: López Steinmetz and Salvi, 2021; HM data: López Steinmetz et al., 2020; Brine TDS data: Ericksen and Salas, 1987; Sea water data: Riley and Tongudai, 1965; Petrowiki; Bottled water data: Evian; Parnell and Armstrong, 2023.

Just as ***'All people are different people', 'All salars are different salars'***.

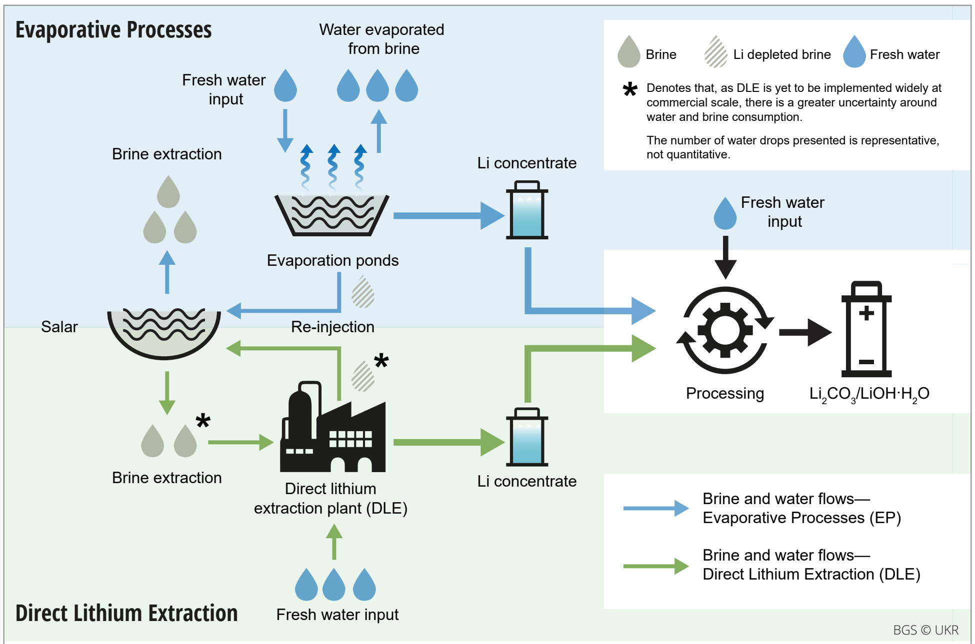

Figure 3: Schematic diagram showing the different lithium production pathways and brine/water usages per unit of lithium battery chemical production from salars using Evaporative Processes and DLE. The number of drops used is representative of the quantity that is thought to be used, it is not quantitative.

Lithium production from salars

The discovery and extraction of lithium in the salar brines of South America revolutionised the sector, providing abundant resources that are relatively easy to extract via a low-carbon process. However, production from salar deposits differs from 'traditional' mining projects with the system hosting the ore, or brine in this case, being very much still in flux and a 'live' system.

The salars with the longest history of lithium production are the Salar de Atacama in Chile and Salar del Hombre Muerto in Argentina. Initially, potassium nitrate was produced at Atacama, before lithium production was added later in the late 1980s / early 1990s, while Hombre Muerto has been producing since 1997. Operations within the Lithium Triangle have seen rapid expansion with the growth of electrification and lithium demand over the last decade. Over time, as pressures have mounted over environmental concerns and given the need to increase production there has been a greater focus on processing technologies used to recover lithium from the brines, alongside a growth in responsible mining practices.

Most operations in South America follow a common processing framework:
1) brine abstraction (pumping),
2) concentration and purification, and 3) chemical processing to produce lithium carbonate or hydroxide. Concentration and purification typically occur 'on-site' at the salar, while chemical processing usually takes place 'off-site' at a separate facility. Two types of technologies are used in the concentration and purification stage, evaporative processes (EP) and direct lithium extraction (DLE) (Fig. 3). EP is the most common and traditional method, with DLE being a somewhat newer alternative, but they can be applied together, such as at Salar de Hombre Muerto. With each brine having a unique composition, a tailored processing method is required. What may be appropriate, or optimal, for one salar may not be elsewhere.

During EP, after brine pumping, solar and wind-driven evaporation progressively concentrates the brine in a succession of evaporative ponds (Fig. 2). This process is made possible by the naturally high aridity, altitude and solar irradiation, resulting in low energy requirements and carbon footprint. Different salts may be harvested as they precipitate e.g. potassium, and impurities removed. The process takes 12 – 18 months with a lithium recovery rate of 30 - 50%, while 85 - 95% of the water contained within the brine is evaporated.

DLE is a blanket term used to refer to several different technologies, which actively concentrate lithium. Although the direction of travel is towards the use of DLE over EP, as it is not yet widely implemented at a commercial scale in South America, there a degree of uncertainty regarding its efficiency and impacts. DLE has a recovery rate of 70 - 95% and the potential to reduce brine use, shorten production timelines and allow development of deposits that were previously uneconomic. Challenges include freshwater and energy requirements, embodied environmental footprint, and greater reinjection of depleted brine. For more information about DLE see the *Lithium Voice Volume 6*.

After concentration and purification, lithium-depleted brine may be reinjected into the salar (Fig. 3). For EP, this can be ~15–20 % of the original brine. DLE is expected to offer a higher return rate of lithium, though exact values vary for each process type and between each salar. Reinjection returns the majority of the brine pumped out albeit depleted in lithium, helping maintain the system's chemical properties. Additionally, reinjecting between the wellfield and sensitive

continued on page 14

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locations (lagunas) may partially mitigate the impacts of brine pumping by reducing water/brine table drawdown and subsequent effects (Fig. 2). However, depleted brines will be of a different chemical composition to raw brine, especially those from DLE due to the chemical interactions and processes. This may alter the geochemistry of the system resulting in difficulties in returning the brine to the salar; there are also concerns reinjection could cause dilution of the lithium in the brines and/or disruption to the stratigraphic structure (layers of rock & sediment).

When considering the overall sustainability benefits of EP and DLE, there is currently no clear advantage to one or the other, in terms of the overall impact on the hydrogeology of salars or availability of water to communities and ecosystems. These impacts will not only be influenced by the technology used, but also by lithium concentration and impurities in brines, local hydrogeology and climatic conditions, among others. Thus, the technology used, and its merits and drawbacks, require thorough assessment on a case-by-case basis.

Impacts of lithium production

The future development of lithium production in South America has the potential to deliver significant positive impacts, economically and also at the local, regional and global scales. There have been promising improvements in responsible mining practices, though work remains to be done.

There are significant concerns regarding brine and freshwater use, and the associated environmental and social impacts, of lithium production. Numerous salar features need to be considered in understanding environmental impacts, including the quantity and nature of water inflows and interaction with lagunas, the nature and properties of the salar, and the characteristics of abstraction (pumping). As with all extractive industries, to maximize benefits for local communities and avoid disputes, communication and consideration are required to ensure projects can be 'good neighbors'.

Any impacts will be unique to each salar and project. The hydrogeology, hydrology, geomorphology, geology, elevation and technology used will all influence how impacts may materialise. Furthermore, determining impacts is difficult due to the aridity of the region, system complexity, variation of climate conditions and the system's response potentially taking years or even decades to materialise at sensitive environmental features such as lagunas.

Additionally, human-derived impacts can only be accurately understood and attributed after accounting for the influence of natural variations and climate change. Impacts also require consideration in the wider context of other water users, such as tourism, agriculture and other mining projects e.g. copper mines. It is also vital to take into account the potential cumulative impacts that can arise from multiple lithium projects in the same salar.

In conclusion

Once the lithium has been concentrated and purified it is transported, usually in the form of a lithium chloride solution, to a processing facility. Here it is turned into lithium carbonate, and then lithium hydroxide if desired. These compounds are then exported into global supply chains to go on and be used in batteries, ceramics, and medicines among other uses.

The time available for scaling up this lithium production process to meet decarbonisation demands is soberingly short with the rapid electrification of industry and transport. Lithium from the salars of the Lithium Triangle has a pivotal role to play in global decarbonisation. However, complex economic, environmental, social and governance matters need to be navigated carefully and collaboratively, striking the right balance between a suitable business environment, equitable development, environmental protection and social justice if this opportunity, for both the Lithium Triangle countries and the world, is to be realised.

This article represents the opinions of the authors and does not necessarily reflect the views of the British Geological Survey or ILiA.

ILiA Connections

Roland Chavasse represented ILiA at the LevertonHELM New Chloride Plant unveiling on April 15th. Seen here with Stephen Elgueta-Wallis and Axel Viering from the company. (Image: LevertonHELM)

During the Future Mineral Forum in Riyadh, Saudi Arabia, ILiA's Roland Chavasse shared a panel with (left to right) Ken Hoffman (McKinsey), Daniel Abdo (Sigma Lithium), Raju Daswani (Fastmarkets), Eng. Turki Al Babtain (Deputy Minister of Mining Development, Ministry of Industry and Mineral Resources of Saudi Arabia), and Frank Li (Tianqi Lithium). (Image: Beacon Events)

ILiA's Founding Chairman, Anand Sheth, gave a keynote speech at the 2024 China International Lithium Industry Conference in Sichuan Province, China. (Image: China Nonferrous Metals Industry Association)

In March ILiA hosted a networking dinner for members and guests in Brussels, Belgium. It was held to coincide with the Benchmark Mineral Intelligence GIGA Europe 2025 conference.

In October we held our first networking lunch in Salta, Argentina. It was fantastic to catch up with members from across the region and hear about all the new lithium developments in Argentina.

Astrid Karamira visits Companhia Brasileira de Lítio (CBL) in the Jequitinhonha Valley, in northeastern Minas Gerais, Brazil. (Credit: CBL).

Feature

THE COLOUR OF LITHIUM

All over the world fireworks are a popular way to celebrate important occasions including birthdays, the new year and public holidays, but did you know that many of the red fireworks are based on lithium?

What is the colour of lithium? White? Silver-grey? Purple? Green?

Well, in different forms of lithium all of these colours are possible. In metallic form lithium is a shiny silver-grey colour, similar to most other metals (see page 8). In its carbonate form lithium is a brilliant white crystalline powder which looks very similar to table salt.

The main lithium-containing minerals, spodumene, petalite and lepidolite, show a remarkable variety of pinks, greens, purples, and pale grey-yellows (the inspiration for ILiA's colour palette), while some of the more exotic minerals, for example tourmaline-rubellite, are truly spectacular.

There is more to the colour of lithium than meets the eye. And wait, we only scratching the surface!

The burning question

Have you have ever sat around a campfire at night watching the wood slowly burn and noticed unusually coloured flames? Perhaps there was some metal litter thrown into the fire? What you witnessed was probably the subject of optical emissions spectroscopy, or the science of different metallic elements burning with different coloured flames.

In chemistry, the 'flame test' is an old but reliable way of testing for the presence (or absence) of different elements, especially alkali metals such as lithium, sodium and potassium. Each of these metals burns with a unique colour signature, clearly visible to the human eye.

The reason that different elements appear to burn with different colours is down to their fundamental atomic properties.

When an atom is heated its outer electrons move into a higher state of energy and the atom becomes 'excited'. If the atom is allowed to cool down again it will return to its usual 'ground' state and emit some energy in wavelengths that appear as visible light.

Lithium ions react in the flame of a Bunsen burner. Lithium is unusual as it reacts with both the oxygen to form lithium oxide (Li_2O) and nitrogen to form lithium nitride (Li_3N).

(Image: Charles D. Winters / Science Source)

Because each element has a different atomic structure, the emission spectrum for each type of element is unique and universally consistent. Most emit more than one wavelength of visible light, the dominant wavelength determining the unique flame colour seen with a naked eye.

For example, copper produces a blue flame, calcium an orange flame, sodium a yellow flame, and barium a green flame. For the emission spectrum of lithium, the strongest line is at ~670.8 nanometres (nm) and a second at ~610nm, which together appear as a brilliant crimson-red flame.

This is the colour of lithium.

Seeing lithium atoms for the first time

It was crude flame tests that arguably first prompted and then later confirmed the discovery of lithium.

In the days before the invention of dynamite mining often involved building a fire directly on an ore body, heating the rocks and then rapidly quenching them with water. This would cause the hot rock to crack and splinter into manageable lumps that could be removed and processed. This fire quench (or fire-setting) method of mining was in use at an iron ore mine on Utö island in Sweden in the late 18th century when it was visited by a Brazilian polymath, Joze Bonifacio de Andrada e Silva.

It is said that Andrada was shown a white mineral which gave off an intense red flame when it was thrown into a fire. Fascinated, he collected a sample for analysis and later demonstrated that it was a previously unrecorded mineral. This was the mineral petalite. (However, since petalite was an unwelcome impurity in Utö's iron ore deposit, it seems plausible that those early miners would have cursed whenever they saw red flames appear in the fires that they built in the mine!)

Two decades later a young Swedish scientist called Johan Arfwedson demonstrated that petalite contained a previously unknown element and named it lithium. The discovery was independently confirmed a year later when a German chemist, Christian Gottlob Gmelin, observed that the new element burned with an intense crimson-red flame, a colour which had never seen before in laboratory flame tests.

Practical applications

Today flame tests are still widely used due to their simplicity and reliability. A basic flame test can play a useful role in analysis, for example field testing crude mineral samples. They are also excellent for inspiring the next generation of young chemists in school science classes.

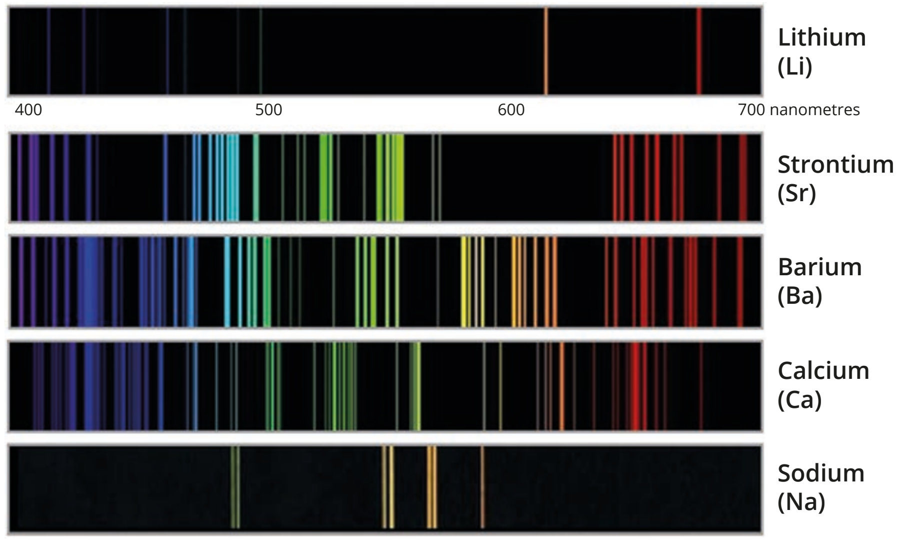
The principle behind flame testing also forms the basis for atomic emission spectroscopy (or flame photometry), a highly technical analytical technique which uses a spark or hot plasma to energise a sample and measure its emissions.

Having fun and saving lives

Fireworks are undoubtedly the most visible use of the emission spectrum of lithium and probably one which we have all witnessed, although perhaps without realising it. The fact that different elements burn with different colours is fundamental to fireworks; to make yellow fireworks add sodium salts, for blue add copper, for orange add calcium and so on.

Traditionally red fireworks were mostly made using strontium salts – strontium also has a strong emission spectrum in red wavelengths – but in the last

The emission spectra of lithium and selected elements



decade there has been a growing trend to replace it with lithium due to concerns in the US and elsewhere about the effect of traces of strontium on human health. An added advantage of using lithium salts in pyrotechnics is that by modifying the recipe slightly, pinks and oranges can also be produced.

However, the practical applications of lithium as a red pyrotechnic colorant are not purely for fun, they save lives too.

Red emergency flares have a long history of attracting attention in times of distress. Historically these too were based on strontium salts, but are seeing a move towards lithium, especially in the United States where work was led by the U.S. Army Research Laboratory in partnership with the Ludwig Maximilian University in Germany. While electronic red lights (using lithium batteries) are increasingly popular, pyrotechnical flares are still widely used and have a number of applications, including as location beacons in military exercises and as emergency 'SOS' flares for ships and mountaineers.

Lithium minerals, salts and applications come in a multitude of colours, but one stands out as representing a fundamental, inimitable property of lithium: scarlet-red. This unique colour not only helps geologists to identify lithium in minerals, but brings joy to millions of children watching firework displays and even helps to save lives too.

Not many elements can say that!

THE CURRENT

Catch up with ILiA's work at a glance

A Special Report on the Expert Roundtable

In March 2025, ILiA hosted an expert roundtable in London, bringing together leading toxicologists, epidemiologists, and psychiatrists to evaluate the evidence underlying the proposed classifications of lithium compounds as alleged reproductive toxicants. This project reflects ILiA's commitment to ensure that regulatory decisions affecting lithium are based on transparent, science-based discussions.

This program was generously supported by eight leading lithium companies: Albemarle Corporation, Arcadium Lithium (prior to the acquisition by Rio Tinto), Ganfeng Lithium, Imerys Lithium France, LevertonHELM Ltd, Rio Tinto, Sibanye Stillwater Ltd, and SQM. The Association greatly appreciates their involvement in this project.

The roundtables focused in particular on a proposal by the European Chemicals Agency's Risk Assessment Committee (RAC) to classify lithium carbonate, hydroxide, and chloride as Category 1A/1B reproductive toxicants. Experts examined the available data on fertility and developmental toxicity and raised concerns about the robustness of the evidence underpinning the proposal.

Key findings

1. Fertility

Experts identified major shortcomings in key studies, including:

- Excessive dosing leading to systemic toxicity, confounding reproductive effects.
- Missing or implausible animal data (age, weight, maturity).
- Methodological flaws like poor tissue handling, unsuitable animal strains, and inconsistent dosing.
- Failure to account for systemic toxicity's influence on fertility outcomes.
- The study with the most reliability and relevancy was discussed by the RAC, but was not reflected with the appropriate weight in the RAC's final conclusion.

Based on a full review, experts agreed that the evidence might support a Category 2 classification (suspected human reproductive toxicant), but not Category 1B, which requires "clear evidence."

2. Developmental toxicity experts concluded that existing human data do not demonstrate a causal link between lithium exposure and developmental harm.

Specifically:

- Studies linking lithium to congenital heart defects (CHD) lacked adequate controls for confounding variables.
- Bipolar disorder patients face multiple co-occurring CHD risks (e.g. medications, obesity, alcohol/drug abuse).
- Small sample sizes and rare outcomes reduced statistical power.
- Surveillance bias may skew outcomes, as lithium-exposed pregnancies receive more monitoring.

The experts also discussed considerations related to medical uses and emphasised that therapeutic lithium use involves much higher doses than environmental or occupational exposure. Benefits for bipolar disorder outweigh potential reproductive risks, and misclassification could stigmatise essential treatment and hamper the development of green technologies.

Recommendations

Experts advised a more scientifically grounded and balanced approach, including:

- Additional animal studies on fertility.
- Improved meta-analyses and pharmacoepidemiologic studies controlling for confounders.
- Better transparency and data quality in human studies.
- Applying a weight-of-evidence methodology, prioritising study quality and context.
- Engaging regulators to ensure proper use of available evidence.
- Advocating for classification decisions that reflect actual risk, not theoretical concern.

Conclusion

The panels concluded that current evidence does not support classifying lithium compounds as Category 1A/1B reproductive toxicants.

Concerns primarily relate to high-dose medical use, not environmental exposure. An overly cautious classification would risk undermining patient care and clean energy goals while providing limited real-world benefit. Experts outlined the need for a more proportionate, evidence-based regulatory approach.

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