ECONOMIC IMPACTS OF LITHIUM EXTRACTION FROM WATER SOURCES AND DEPOSITS

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Abstract. *Today, the demand for lithium and its compounds is growing rapidly. One of the main reasons for this is the significant increase in the production of electric vehicles. This article provides information on lithium reserves, areas of its use, economic scale and technologies for producing lithium compounds. The production of lithium compounds worldwide is also taken into account separately and expressed in precise figures. In the future, as the production of lithium and its compounds increases, one of the main problems is the raw material base. This article is devoted to solving these problems.*
Keywords: *evaporation, lithium recovery, precipitation, lithium chlorate, system of salts, magnesium chloride.*

INTRODUCTION

With an atomic weight of 6.939 [1], a density of 0.534 g/cm^3, a high electrode potential of 3.05 in, and the highest specific heat capacity of all solid elements [2-4], lithium is the lightest alkali metal and ranks third in the periodic system of chemical elements after hydrogen and helium. Lithium compounds are appealing to many different sectors because of their qualities. In addition to being used to make glass, ceramics, batteries, and refrigerants [5], lithium and its compounds are also used to make greases more resistant to high temperatures, to make aluminium and catalysts for the rubber and pharmaceutical industries, to make air conditioning systems, and to make drainage systems.

Lithium resources are classified into two main categories: liquid and solid. Liquid waters include seawater, brines of salt lakes, and geothermal waters; solid waters include deposits of mineral ores and secondary raw materials in the form of waste from lithium-ion batteries and the electronics industry [5-7]. Lithium is a rare element; its content in the earth's crust is 0.007% [8].

An estimated 14–15 million tons of lithium are available worldwide [8, 9]. Russia, China, Canada, Serbia, the Congo, and Afghanistan are home to the majority of the world's mineral reserves which include lithium compounds [10, 11]. There are more than 150 minerals and clays that contain lithium, and it is not found in nature in a free state [9].

The sea, ocean water, salt lakes, and geothermal waters have enormous concentrations of lithium, accounting for 70–80% of the element's total resources. [10].

Despite having a content of over 2600 billion tons, sea and ocean waters are not yet of interest for the commercial production of lithium due to their low concentration of 0.1–0.2 ppm [11-18]. Geothermal waters contain 1 to 100 parts per million of lithium [19]. Processing and producing lithium from geothermal fluids is complicated by the presence of several contaminants and a high concentration of other metals [20].

The concentration of lithium in saline lakes ranges from hundreds to thousands of parts per million. Brine processing is challenging because of the high concentration of contaminants, particularly magnesium [21]. All of this makes it more difficult to isolate lithium from natural fluids, particularly when alkaline and alkaline earth element concentrations are high [22]. One of the primary inorganic salt minerals, lithium borate, exhibits a variety of exceptional physical characteristics, including a broad range of transparency and a diverse structure. moreover, chemical characteristics include chemical stability and strong heat resistance.

Presently, mineral concentrates, lithium hydroxide, which commands 80% of the market, and lithium carbonate are the primary lithium-based products [23]. Spodumene rows and brines from salt lakes are extracted and processed to produce lithium carbonate [24]. Because a system that uses sustainable energy is required, lithium is more important in the development of electric mobility than it is in the production of batteries. Furthermore, it enables us to raise the displacement in proportion to the cost of transportation [25].

The first raw material utilized in industrial manufacturing is spodumene. This one is present in pegmatite rock. Lithium concentration in these rocks ranges from 1-4 per cent, and 60–70% of the rock has been extracted [26].

Lithium-containing aqueous solutions must be used in industrial processes due to the depletion of lithium-containing ores. Brine from salt lakes, geothermal fluids, and water from the seas and oceans are among the water supplies for lithium [27].

This approach is more promising because of its widespread availability and simplicity of processing, even if lithium concentrations in aqueous solutions are modest [28]. The review covers the extraction of lithium from aqueous solutions using a variety of techniques as well as the establishment of the industry's continued growth for the creation of lithium compounds that are inexpensive, environmentally friendly, highly selective, and have straightforward technical solutions.

MINERALOGY AND GEOLOGY

Due to lithium's extensive usage in hybrid electric cars and batteries for portable electronic gadgets, the market for the metal has grown dramatically in recent years. Lithium extraction from ores is a significant economic activity related to the progressive switch to economically clean energy fuels. Consequently, particular attention is paid to the behaviour of lithium and associated minerals in specific ore rocks [29].

Therefore, quick and efficient procedures are required for the investigation and finding of new resources. Maps of mineral resources need to be created using affordable exploration technology. Large-scale regional quartering is provided via satellite and aerial photos.

It is preferable to achieve this using hyperspectral imaging (HIS), a fast-evolving technology that makes mineral mapping possible and facilitates the study of the Earth's surface at different scales [30]. This allows for a wide spectrum range of data collection thanks to the sensors employed. With a precision of millimetres to centimetres, this allows information on the amount and spatial arrangement of ore and fossil minerals in the core, hand samples, and outcrops to be obtained.

In geology, precise housing is a challenging issue, particularly in remote areas. To map lithium-containing minerals and determine their spatial variability in pegmatites at three scales, a multi-scale approach to hyperspectral imaging was used [31]. This method succeeded in producing a three-dimensional map of quarry minerals that is spatially continuous and demonstrated the potential for precise processing in three dimensions. It is suggested that hyperspectral pictures may be used for production optimization and the study of additional raw material kinds [32].

RESOURCES, RESERVES, ECONOMY, AND LITHIUM COMPOUND REQUIREMENTS

The last ten years have seen a rise in the demand for lithium and its compounds due to the expanding use of lithium in automobile batteries, lithium-ion batteries, and the electronics sector. As a result, it is referred to as “white oil” or “new gold” [29]. Batteries account for 46% of lithium’s usage, followed by ceramics and glass (27%), greases (7%), polymer products (5%), air treatment (2%), and miscellaneous products (9%) [33].

In comparison to 2017, the demand for lithium climbed by 18% in 2019 to reach 58 thousand tons [33]. The demand for lithium is expected to rise by 60% in the upcoming years [34]. The need for electric car manufacturing and usage has soared. Forecasts indicate that sales of electric vehicles will rise to 10 million by 2025, 28 million by 2030, and 56 million by 2040, when they would represent more than half of all automobiles produced in 2040 [35]. It is predicted that by 2027, the world's need for lithium will amount to around 1.5 million tons of lithium carbonate equivalent [36]. In addition, 38% of lithium is mined from mineral rocks and 62% is extracted from aqueous brines [37].

Geothermal waters are being investigated more and more for their potential role in the manufacture of lithium, even though lithium is currently extracted from brine and spodumene ores. Based on projections, the amount of lithium extracted and supplied from these sources may account for 4% to 8% of the total lithium supply in the US [37].

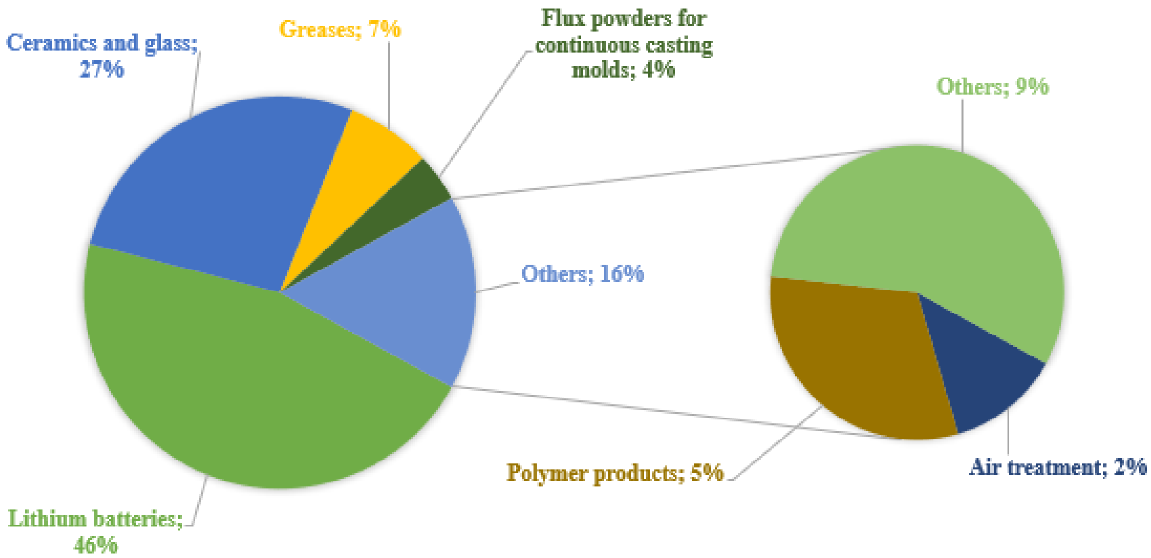

Figure 1. Jaskula (2017) lists the primary applications of lithium in terms of the proportion of Li metal equivalent that is utilized.

In the scientific and technical literature, there is sufficient information on the extraction of lithium from aqueous solutions by various methods and the establishment of further industrial development for the production of lithium compounds characterized by environmental purity, high selectivity, economically feasible and simple technical solutions. Lithium production is currently dominated by hard rock mining in Australia and brine mining in Chile, as shown in Figure 1. These countries account for a significant portion of the world's economically extractable resources at the time of determination [38].

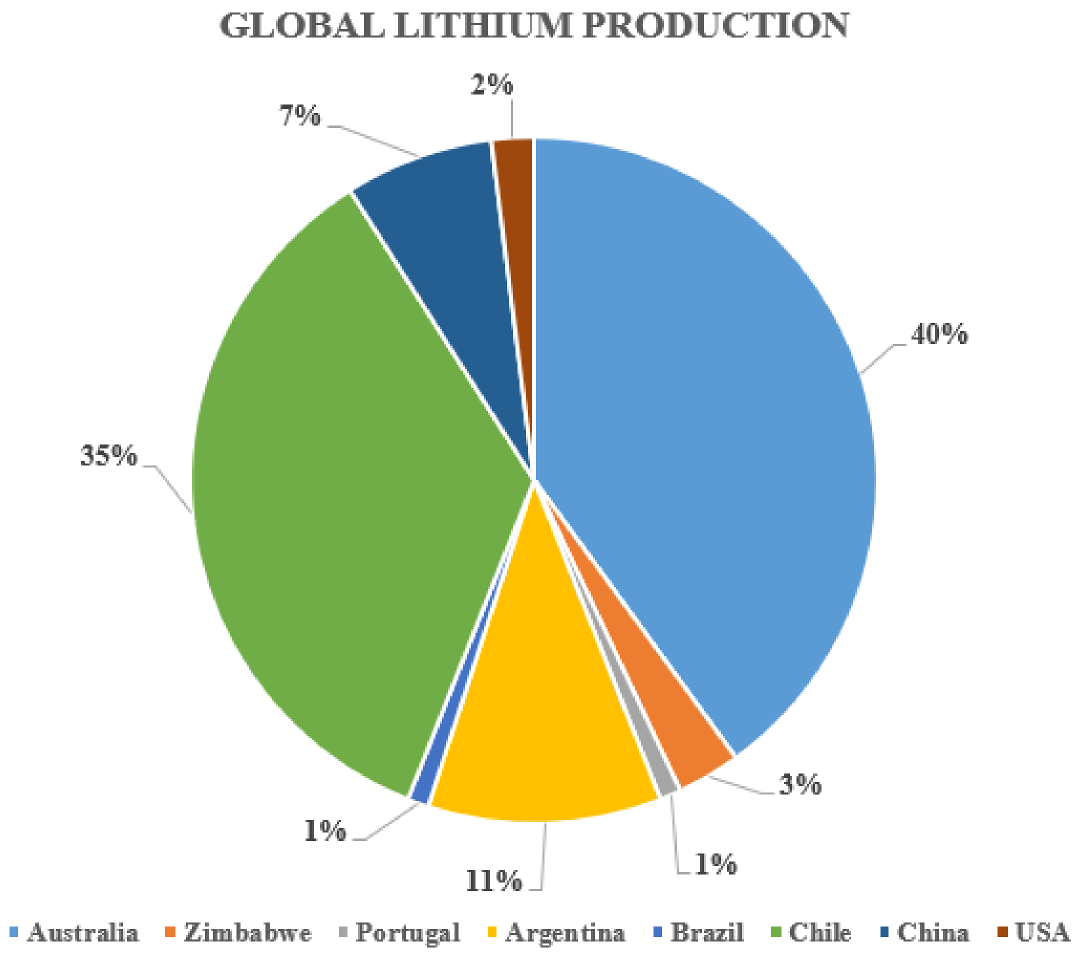

Figure 2. Global lithium production by country

Increased use of batteries will lead to an expected increase in lithium demand of 8–11% per year. It is estimated that lithium demand to satisfy all markets will reach 20 million metric tons by 2100.

The USGS 2017 Mineral Commodity Summary estimates global lithium resources at 40 million tons. According to the 2018 summary, global lithium resources have increased to approximately 53 million tons [39]. The discovery of new resources is the result of exploration teams seeking to capitalize on rising demand for lithium and rising lithium prices. Although lithium resource estimates currently exceed lithium demand estimates, not all lithium resources are equally favourable for lithium extraction. The most economically attractive lithium resources are developed first, with more challenging lithium resources extracted later when technological developments reduce the cost of extraction. Meanwhile, bridging the gap between supply and demand will depend on recycling, the development of new resources and the replacement of materials [40].

In 2009, the U.S. Department of Energy awarded $9.5 million to a U.S. lithium metal and lithium-ion battery recycler to help build a lithium-ion automotive battery recycling plant in the United States. It is expected that by 2050, lithium recycling will replace 25 per cent of the world's lithium supply. It is believed that lithium can be recycled indefinitely, but today less than one per cent of lithium is recycled [41].

The reason for the poor market for lithium recycling can be attributed to the ever-evolving and complex chemistry of LIB, which is hindering the development of a profitable path. Additionally, due to the small amount of lithium used in LIB compared to other valuable metals such as cobalt, other metals are subject to recovery and recycling. The process of extracting other valuable minerals from the LIB may result in the loss of lithium from the LIB, further reducing the recovery potential and resulting in inefficient lithium recovery [42].

The production of large automotive batteries could overcome the barriers facing lithium battery recycling by creating a standard application for lithium-ion batteries. Battery recycling programs for large vehicles will be modelled after the existing lead-acid battery recycling system. Unlike traditional lead-acid batteries used in vehicles, large car batteries can last up to 20 years from the date of purchase [43].

Despite advances in lithium processing, new resources must be developed to meet growing demand. A selection of 15 new hard rock and brine lithium projects is presented in Table 1. The projects have a target start date of 2020 or earlier and have a total production capacity of approximately 320.000 metric tons per year of lithium carbonate equivalent (ECL) [44].

Using a conversion rate of 5.31 metric tons of ECL to one metric ton of lithium, global annual lithium production over the last 5 years could reach 162.000 metric tons. It is noted that one of the projects listed in Table 1. involves the extraction of lithium from petroleum brine.

Table 1. New projects to produce lithium from brine and mineral resources

Country	Company	Project	Source type	Production capacity (t/year)
Argentina	Galaxy Resources.	Sal de Vide	Continental brine	25.000
Argentina	Lithium Americas	Cauchari-Olaroz	Continental brine	20.000
Argentina	Orocobre	Olaroz lithium plant	Continental brine	17.500
Argentina	Rodonia	Salar de Diablillos	Continental brine	15.000
Australia	Reed Resources	Mount Marlon	Pegmatite	25.000
Australia	Altura	Pilgangoora	Pegmatite	19.000
Bolivia	Comibol	Salar de Uyuni	Continental brine	30.000
Canada	Nemanska Lithium Inc.	James Bay	Pegmatite	47.000
Chile	Albermarle	La Negra	Continental brine	20.000

Finland	Kliber Oy	Ostrobothnia	Pegmatite	4.000
Mexico	Bacanora Minerals Ltd.	Sonora	Hectorite clay	35.000
USA	Western Lithium	Kings Valley	Hectorite clay	26.000
USA	Standard Lithium	Arkansas	Oil field brine	20.000
USA	Symbol	Salton Sea	Geothermal brine	16.000
Total				**319.500**

Lithium was consumed worldwide in 2019 at a rate of 58 thousand tons, up 18% from 2017 [45]. With the US excluded, however, lithium output fell by 19% globally, from 95 thousand tons in 2018 to 77 thousand tons in 2019. The main cause of this is a decline in lithium prices brought on by a decline in the market for the metal, which is explained by a decline in the number of electric car sales.

The global lithium market size was valued at US$6.83 billion in 2021 and is expected to grow at a compound annual growth rate of 12.0% from 2022 to 2030. Vehicle electrification is projected to attract significant volumes of lithium-ion batteries, which is expected to drive the market over the forecast period. The automotive applications segment is expected to witness significant growth during the forecast period, driven by stringent regulations for automakers with government regulations imposed to reduce carbon emissions from vehicles. This has shifted automakers' interest to producing electric vehicles, which is expected to improve demand for lithium and related products. Government subsidies for electric vehicles, along with investments in this space, are likely to provide additional impetus for market growth [46].

The US ranks second to China in battery production, making it one of the key lithium-consuming countries in the world. The country has huge reserves of this important metal. Lithium resources from brines and minerals in the United States totaled 7.9 million tons in 2020, according to the USGS. However, the country produces only about 1.0% of the world's total demand. In 2020, production took place in only one location in the United States, namely Nevada. However, the country is expected to expand its mining capacity in the industry in the coming years [47].

Manufacturer's dependence on lithium, along with cost optimization through mass production of large batteries, will further reduce prices [40; P. 1-20]. In addition, upcoming improvements in lithium production capacity (Table 1.) will increase the supply of lithium in the market and create market competition.

Predicting the future price of lithium is challenging due to the unknown impact of materials science improvements in batteries and various constraints on supply growth. The price of lithium will likely continue to rise until additional lithium projects come online in 2020. Subsequently, prices are unlikely to fall below US$10,000 per metric ton of ECL [48]. This is a price that will allow marginal producers (high-cost hard rock mining operations) to bring in the additional lithium capacity needed to meet the growing demand that low-cost brine operations simply cannot meet.

CONCLUSION

One of the most sought-after, scarce elements with a suitable amount of raw materials is lithium. It is present in over 150 minerals and does not arise naturally in a free state. The rising demand for electric vehicles explains why lithium is becoming more and more in demand each year. Currently, geothermal, brine, and saltwater are the main sources of lithium mining, accounting for more than 60% of the world's lithium deposits, which range from 70% to 80%.

Consequently, it is a critical and urgent issue to look for ways to acquire lithium from water sources appropriate for making lithium compounds.

Lithium compounds can be extracted from water resources using a variety of techniques, such as solvent extraction, liquid extraction, ion exchange adsorption, precipitation, selective membrane separation, and electrodialysis.

Since it enables the extraction of lithium from solutions with low quantities of lithium and large concentrations of other elements, the adsorption of ion sieves is the most promising of them. The technique is both ecologically benign and energy-efficient. High-ion screening functionality selective adsorbents are lithium-ion sieves.

Ion sieves, however, lose sorbent and have poor stability and comparatively limited ion exchange capacity.

Many scientific efforts are being made to raise the sorbents' stability, boost their selectivity and capacity, and shorten the sorption period to address this issue. Numerous techniques, such as organo-chemical, synergistic, binding, and composites, are employed for this. However, none of these permit the lithium adsorption process to become industrialized. As a result, finding strategies to enhance the lithium adsorption process is still a challenging endeavor.

A different approach to address future demand, energy sustainability, environmental preservation, and the circular economy might be lithium adsorption recovery.

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