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Lithium And It Is Extraction Technologies- A Brief Review

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Abstract: Lithium, a highly reactive metal, is widely used in rechargeable batteries for electric vehicles and portable electronics due to its high energy density. Extraction of lithium involves various technologies depending on the source. For lithium brine deposits, the most common method is evaporation, where brine is pumped into large evaporation ponds, allowing water to evaporate, and leaving behind lithium-rich salts. Hard rock lithium deposits are extracted through open-pit or underground mining, followed by crushing and flotation processes to obtain lithium concentrate. Additionally, innovative techniques such as direct lithium extraction from geothermal brines and lithium recovery from seawater are being explored to meet the growing demand for this critical resource.

I. INTRODUCTION

Lithium is a highly reactive alkali metal known for its low density and excellent conductivity. It is widely used in various industries, most notably in batteries for electric vehicles and portable electronic devices. The demand for lithium has increased significantly due to the growing popularity of clean energy technologies.

Lithium extraction typically involves two primary methods: brine extraction and hard rock mining. Brine extraction involves pumping lithium-rich underground water into large evaporation ponds, allowing the sun and wind to accelerate the concentration of lithium. The concentrated lithium solution is then further processed to extract lithium carbonate.

Hard rock mining, on the other hand, involves extracting lithium from lithium-rich minerals such as spodumene through crushing, grinding, and flotation processes. The resulting concentrate is then treated with chemicals to produce lithium carbonate or lithium hydroxide. Efficient lithium extraction technologies are crucial for meeting the increasing global demand for lithium and supporting the transition towards a sustainable and electrified future. The present review provides an overview of lithium and it is extraction technologies. The extraction from salt lakes with different hydro chemical types, hard rock lithium ores (spodumene, petalite, zinnwaldite, lepidolite).

II. LITERATURE REVIEW

2.1. Hydro chemical classification of salt lakes

The hydrochemical properties and classification of salt lakes play a crucial role in determining the extraction process of lithium from these lakes. The concentrations of various ions present in salt lakes serve as the basis for categorizing them into different hydro chemical types. These ions include cations such as Na+, K+, Ca2+, Mg2+, and Li+, and anions such as Cl-, SO4^2-, CO3^2-, and HCO3^-. Several studies, including those by Wu et al. (2005), Zheng and Qi (2006), Zheng and Liu (2010), and Ye and Zheng (2016), have utilized the corrected Kurnakov-Valyashko method to classify lithium-containing salt lakes in the Tibet Plateau. These lakes have been divided into four major types: chloride type, magnesium sulfate subtype, sodium sulfate subtype, and carbonate type. The carbonate type has further been subdivided into three subtypes based on the total alkalinity ratio and the presence of different saline mineral assemblages. These subtypes are the strong carbonate subtype, moderate carbonate subtype, and weak carbonate subtype.

The distribution of hydro chemical types of salt lakes in the Tibet Plateau demonstrates specific characteristics in terms of their spatial arrangement. The lakes exhibit an east-west distribution pattern and are arranged in belts running from north to south. There are five main belts identified in this region. Belt I is known as the carbonate belt, Belt II is the sodium sulfate subtype belt, Belt III is the magnesium sulfate subtype belt, Belt IV is the chloride-sulfate type belt, and Belt V is the sodium sulfate subtype leakage belt. Overall, the classification of salt lakes based on their hydro chemical properties is crucial for the selection of appropriate lithium extraction technologies. By understanding the composition of ions present in these lakes and their distribution patterns, researchers and industry professionals can devise extraction methods that are best suited for each hydro chemical type. This knowledge allows for more efficient and sustainable lithium extraction processes, which are essential considering the growing demand for lithium in various industries such as battery manufacturing for electric vehicles and renewable energy storage.

III. OVERVIEW OF LITHIUM RESOURCES AND LITHIUM EXTRACTION PROCESS

The global lithium resource reserves are estimated to be 22 million metric tons (Mt) of metal. About 34% of these reserves come from hard rock lithium mines, with notable deposits in Australia (Greenbushes), Canada (Quebec), China (Jiajika), Zimbabwe (Bikita), and other pegmatite lithium deposits. While there are over 150 types of lithium minerals, only a few have commercial value, including spodumene, lepidolite, petalite, and zinnwaldite. Spodumene is the main lithium-bearing mineral worldwide, with a theoretical lithium oxide (Li2O) content of up to 8.03%. Lepidolite, with a theoretical Li2O content of 7.7%, is a potential resource for lithium production. Lepidolite extraction has gained importance in China due to rising lithium carbonate prices. Petalite and zinnwaldite are also important lithium-bearing minerals but have significantly lower Li2O content compared to spodumene and lepidolite.

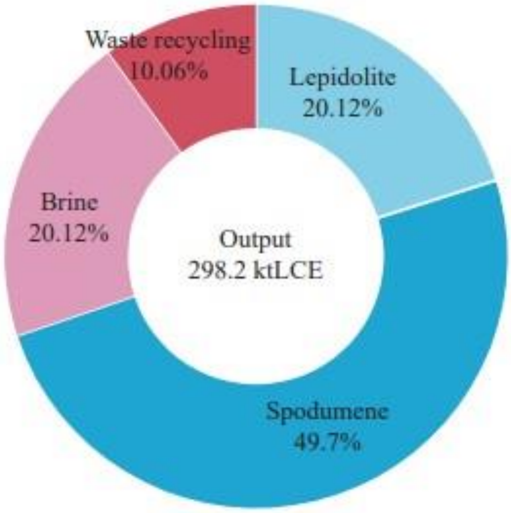

Fig. 1. Lithium production structure in China (2021).

Lithium minerals are often found alongside gangue minerals like quartz and feldspar, resulting in low lithium oxide content in the ore. Beneficiation processes, such as gravity separation, magnetic separation, and foam flotation, are used to enrich the useful components and obtain lithium concentrate. Spodumene, typically occurring in the α-phase, can be converted into the β-phase through calcination, followed by reaction with acid or alkali to form soluble lithium sulfate or hydroxide. Lepidolite is monoclinic mineral rich in potassium, fluorine, rubidium, cesium, and aluminum oxide. It undergoes roasting at high temperatures to activate its structure and liberate lithium. Similar extraction routes are followed for zinnwaldite and petalite, involving the removal of impurities from the leaching solution to obtain a lithium purification solution for the precipitation of lithium carbonate.

Different methods, such as acid method, alkali method, salt roasting method, and chlorination method, are used for extracting lithium from ores, depending on the media used for calcination and leaching. Lithium precipitation is generally achieved by reacting the lithium purification solution with sodium carbonate to obtain lithium carbonate, which can be further carbonized to produce battery-grade lithium carbonate. As a byproduct, anhydrous sodium sulfate is also produced during this process.

3.1 Salt roasting method

The salt roasting method has low cost, less corrosion to equipment, and fewer impurities in the leaching solution compared with the acid process, which is easy to purify. Salt reagents used by scholars mainly include carbonate such as calcium carbonate, sodium carbonate, and sulfates, such as potassium sulfate, sodium sulfate, and calcium sulfate.

The limestone roasting method, initially proposed by Lileev et al. in 1968, was successfully employed in industrial lithium extraction. The process involves roasting a mixture of spodumene and limestone, followed by water leaching to remove impurities and precipitate lithium carbonate. Scholars have investigated the relationship between limestone demand and lithium recovery, finding that the optimal CaO: SiO2 ratio is 2.4-2.6 for achieving the highest lithium recovery rate. Exceeding this ratio reduces the recovery rate but lowers the roasting temperature. Sintering conditions were also studied, and it was found that a spodumene/CaO ratio of 1:1.25, a sintering temperature of 1150°C, and a sintering time of 60 minutes yielded a lithium leaching rate of 92.14%.

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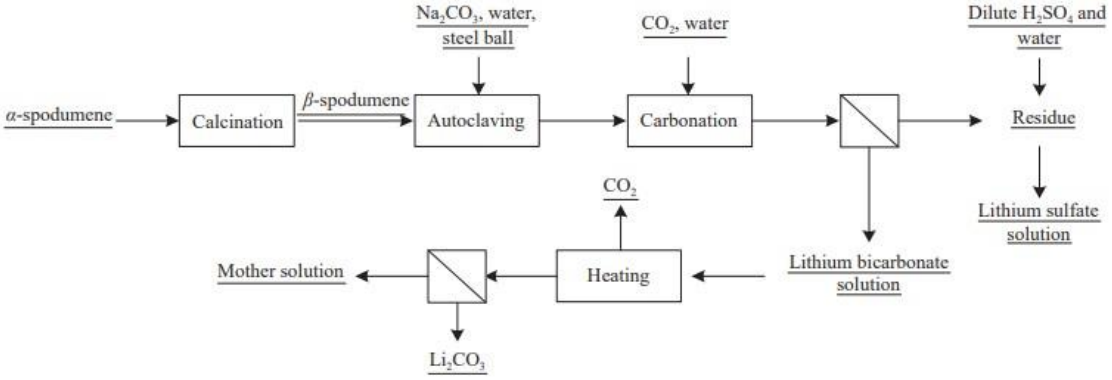

Fig. 4. Lithium recovery process of β-spodumene by sodium carbonate autoclave method (modified from Chen Y et al., 2011a, 2011b).

However, the limestone roasting method has several issues, including low lithium concentration, high energy consumption, large slag production, and poor economic viability. As a result, it has been largely replaced by the sulfuric acid method. The sulfate method, an alternative to the sulfuric acid method, involves converting lithium minerals into lithium sulfate, which is subsequently leached with dilute sulfuric acid to obtain lithium carbonate. Scholars have explored various sulfate compounds and operating conditions for extracting lithium from different minerals such as spodumene, lepidolite, zinnwaldite, and petalite. The sulfate method offers the advantage of not requiring scarce reagents and utilizing standard equipment. However, it has drawbacks such as high energy consumption, low lithium recovery rate, and resource wastage. The sulfate method is mainly used for lepidolite extraction, with potassium sulfate commonly employed. Substituting sodium sulfate for potassium sulfate can reduce costs.

The chlorination method involves using chlorination agents to convert lithium and other valuable metals in ore into chloride for extraction. The chloride method utilizes potassium chloride, sodium chloride, ammonium chloride, or other chlorates to convert lithium in spodumene into soluble lithium chloride at high temperatures. Overall, these methods have their advantages and disadvantages, including energy consumption, recovery rates, cost, and environmental considerations. Researchers continue to explore and optimize these methods to enhance lithium extraction efficiency and reduce environmental impacts.

3.2 Carbonate method:

The limestone roasting method, first proposed by Lileev et al. in 1968, has been successfully applied to industrialized lithium extraction processes. This method involves roasting a slurry of spodumene and limestone, followed by water leaching, removal of impurities, and lithium carbonate precipitation. The amount of limestone required for roasting depends on the spodumene grade, with lower grades requiring higher limestone consumption. The optimal CaO: SiO2 ratio for maximum lithium recovery is 2.4-2.6. However, exceeding this ratio decreases the lithium recovery rate but reduces the roasting temperature. Tu et al. found that under optimal sintering conditions, a spodumene/CaO ratio of 1:1.25, a sintering temperature of 1150°C, and a sintering time of 60 minutes, a leaching rate of 92.14% could be achieved. The limestone roasting method for lithium extraction from spodumene has drawbacks such as low lithium concentration, high energy consumption, large slag production, and low economic viability. Consequently, it has been replaced by the sulfuric acid method.

This roasting method can also be used for extracting lithium from lepidolite. Sun YR studied the influences of various operating conditions and found that the roasting temperature had the greatest impact on lithium leaching rate, with a narrow temperature range of 830-850°C. The effects of particle size, mass ratio, and time on lithium recovery gradually decrease within the optimal temperature range. Under favorable conditions, lithium leaching rates above 89.6% can be achieved. Roasting zinnwaldite concentrate with limestone and subsequent water leaching resulted in more than 90% leaching rates for both lithium and rubidium. However, studies by Siame and Pascoe failed to replicate these results due to the formation of an amorphous glass phase at calcination temperatures exceeding 835°C, limiting lithium and rubidium leaching. The feasibility of extracting lithium by roasting sodium carbonate and spodumene has been confirmed, with nearly complete leaching of lithium, silicon, and 75% of aluminum achieved under specific conditions. Sodium carbonate roasting has also been tested for extracting lithium from lepidolite, yielding a conversion rate of lithium in sulfate leaching solution of 99.2%.The carbonate roasting method offers universality, utilizing common equipment and not requiring scarce reagents. However, it has drawbacks such as high energy consumption, low lithium recovery rates, and significant resource waste. When extracting lithium from lepidolite, the method faces challenges related to a narrow range of suitable reaction temperatures and difficulties in controlling operating conditions.

IV. EXTRACTING LITHIUM TECHNOLOGY

4.1. Belt I

Zabuye Salt Lake, located in Tibet, China, is the sole Salt Lake used for lithium extraction in the carbonate hydrochemical belt of the Tibet Plateau. With an area of 247 km2, the lake consists of two separate lakes, and it is in the late stage of salt lake evolution. The south part of the lake has become a semidry salt lake, containing rich reserves of lithium carbonate and other mineral elements. The extraction process at Zabuye Salt Lake involves halogen production and crystallization steps. Salt gradient solar pond technology is utilized in the crystallization stage to concentrate and precipitate lithium carbonate, which is then purified by the carbonation method.

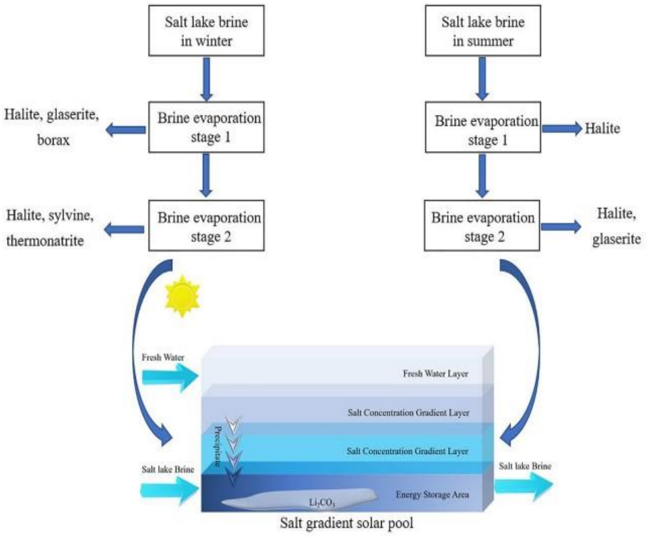

Fig. 4. Production process of lithium extraction in Zabuye Salt Lake.

The initial production at Zabuye Salt Lake faced challenges such as brine process loss, harsh climatic conditions, and limited production capacity. To enhance the production of lithium carbonate, technical improvements were made based on the lake's hadrochemical characteristics. A PAN-Li/Al-LDH composite adsorbent was synthesized and used for efficient lithium-ion adsorption from the lake's brine. Quantum chemical calculations and various characterization methods were employed to analyze the adsorption process. Additionally, a new mineral carrier adsorption material was developed by intercepting the functional groups of crown ether with specific adsorption effects on lithium ions, showing promising results for industrial application. Overall, Zabuye Salt Lake serves as a vital source for lithium extraction, and continuous advancements in technology aim to improve the production capacity and efficiency of lithium carbonate extraction from the lake's brine.

4.2: Belt II:

Currently, Only Jiezechaka Salt Lake is conducting pilot tests in Belt II for the extraction of lithium. Due to the low Mg/Li value in salt lakes, the main technology adopted for extraction is the extraction method. The process involves using tributyl phosphate (TBP) and diisobuty-rone (DIBK) as extraction agents, as first reported in a 1968 patent by an American lithium company.

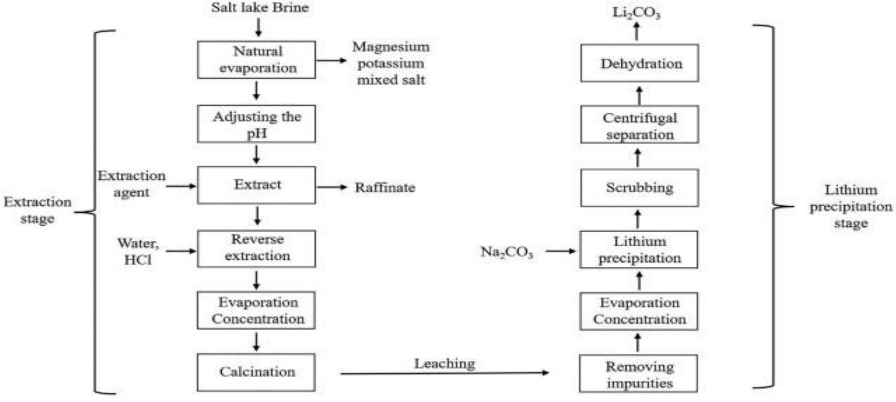

Fig. 10. Lithium extraction process.

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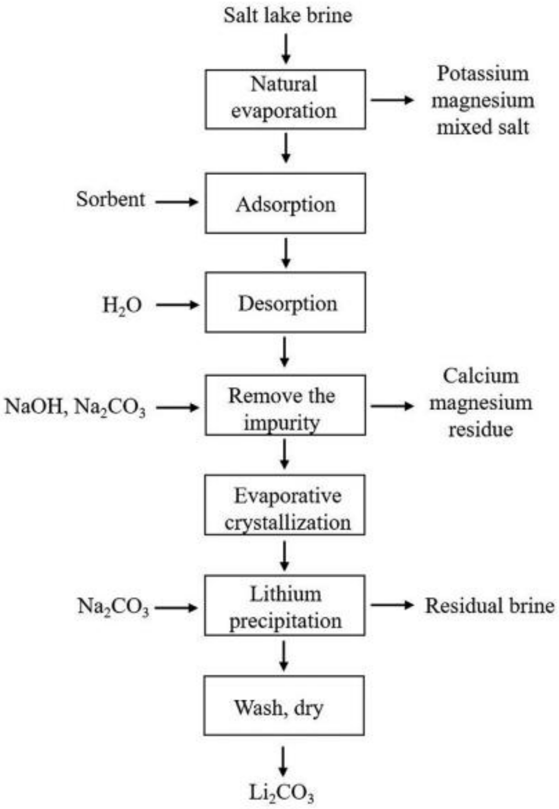
However, this extraction process is complex and expensive, with an extraction rate of 80% after seven extractions. The Shanghai Institute of Organic Chemistry improved the TBP extraction system in 1975 by adding TBP, N-503, and kerosene to extract lithium from saturated magnesium chloride solution. The pilot test achieved a total recovery rate of over 96% and a production cost of approximately 40,000 yuan per ton of lithium carbonate.

However, TBP used in this method has certain toxicity. In 1979, the Qinghai Salt Lake Research Institute developed a process using TBP-200 sulfonated kerosene extraction system, achieving a lithium extraction rate of 99.1% and a separation coefficient of lithium and magnesium of 1.87 x 105. When stripping with water, Li+ in the extract [Li(TBP)2] [FeCl4] was released to achieve the stripping effect. Compared with the traditional TBP-FeCl3 extraction system, the stripping process reduced the use of concentrated acid and promoted the green process of lithium extraction to a certain extent. Recycling and reusing TBP is necessary to avoid environmental pollution and human harm. Further studies have been conducted to optimize the lithium extraction process, including the addition of P507 to the TBP/FeCl3 extraction system, reducing the use of concentrated acid and promoting a greener process.

4.3: Belt III:

Longmoor Salt Lake has successfully conducted a pilot production of lithium extraction in belt III using an innovative method. The process involved utilizing an aluminum-based adsorbent to capture lithium ions from the original brine. Subsequently, a nanofiltration membrane was employed to produce high-quality lithium carbonate products suitable for battery applications. This production technique demonstrates significant potential as a lithium extraction technology applicable to various settings, offering advantages such as simplicity in operation, easy recyclability, and environmental friendliness. The selective adsorption of metal ions from liquid solutions through adsorption is a prominent area of research in the field of environmental and energy recovery. Different adsorbents have been explored for lithium extraction in salt lakes, including manganese-based ion sieve adsorbents, titanium-based ion sieve adsorbents, surface-ion imprinting adsorbents, and aluminum-based adsorbents. Among them, ion sieve-type adsorbents exhibit the highest adsorption capacity, particularly manganese-based materials with a maximum adsorption capacity of 49.6 mg/g. However, the instability of manganese-based adsorbents during the adsorption process due to the Jahn-Teller effect has hindered their industrial application. Researchers have therefore sought to develop more stable alternatives. One such alternative is the titanium-based ion sieve, which demonstrates stable properties, low dissolution loss, good acid resistance, large adsorption capacity (15-25 mg/g), and high lithium elution rate. However, challenges associated with the high cost of titanium raw material, poor permeability during synthesis, consolidation issues, and reduced adsorption capacity after granulation have limited its further development.



Ion imprinting technology has proven effective in creating adsorption materials with specific selectivity for target ions, but current methods rely on costly functional carriers like crown ether and require the use of strong acids during the elution process, making large-scale application difficult. In contrast, aluminum-based adsorbents developed through the aluminum salt precipitation method are currently the only adsorbents used for industrial lithium extraction from salt lakes. These adsorbents, specifically LiX2Al(OH)3nH2O, exhibit selective adsorption for lithium ions, with Cl- often used as the anion. However, the adsorption capacity of aluminum-based adsorbents is relatively low (typically 1-3 mg/g), and traditional binder molding and granulation further decrease their effectiveness. Consequently, many adsorption towers are required for industrial use, resulting in low lithium recovery rates, increased production costs, and decreased efficiency. To overcome these limitations, the development of a novel aluminum-based adsorbent with high selectivity for lithium ions and devoid of chemical reagents in the extraction process is crucial. Such an advancement would enable efficient lithium extraction from brine resources, ensuring minimal ecological impact on the delicate plateau environment. The design and implementation of such a material hold significant theoretical and practical value.

4.4 Belt IV and V:

The Qarhan Salt Lake, Western Taijinar Salt Lake, and Yiliping Salt Lake are all located in China and are known for their lithium extraction and production. Qarhan Salt Lake, situated in the mid-eastern Qaidam Basin, has the highest total lithium resource in China, with 1.2 million tons of LiCl resources. Initially, aluminum adsorbents were used for lithium extraction, but in 2014, nanofiltration membrane separation technology was introduced, which improved the separation efficiency of magnesium and lithium. Western Taijinar Salt Lake is a sulfate-type high-magnesium-lithium-specific salt lake. The lithium extraction process in this lake involves evaporation, precipitation of potassium magnesium mixed salt, boron removal, and further evaporation and crystallization to remove magnesium. The calcination method was initially used, but later, nanofiltration technology was combined with the calcination process to improve the quality of lithium carbonate and reduce production costs.

Yiliping Salt Lake is also a sulfate-type high-magnesium-lithium-specific Salt Lake. Initially, electrodialysis technology was used for the separation of magnesium and lithium. However, this method had maintenance issues and required frequent membrane washing. Therefore, the lake implemented the adsorption method in combination with existing lithium carbonate production technology to directly separate lithium from other elements. The production technology is still being improved in the pilot stage. Overall, these salt lakes have adopted various technologies such as nanofiltration, calcination, and adsorption to extract lithium, improve separation efficiency, reduce production costs, and enhance the quality of lithium products.

V. ENVIRONMENTAL IMPACT AND ECONOMY OF LITHIUM EXTRACTION FROM ORES

5.1: Environmental impact:

The sulfuric acid method is widely employed in industrial spodumene lithium extraction processes due to its numerous advantages. It boasts a high yield of 88%, making it highly efficient (Kuang G et al., 2018; Rosales s GD et al., 2014). Additionally, this method is suitable for low-grade ores with a lithium content of 1%–1.5% and yields a leaching solution with a high lithium content of 33–55 g/L (Peng JZ, 2019). The raw materials required for this process include spodumene concentrate, sulfuric acid, sodium hydroxide, calcium hydroxide, sodium carbonate, and water. The consumption intensity of these raw materials in a typical enterprise is 8.67 t/t, 3.02 t/t, 0.55 t/t, 0.65 t/t, 2.26 t/t, and 49.46 t/t, respectively (Jiang SY et al., 2020). The energy consumption includes fossil energy in the transformation and acidification stages, as well as electricity and steam in the purification and evaporation stages. The comprehensive energy consumption of China's ore lithium extraction enterprises is reported to be 2.87 tce/t (Gu GZ and Gao TM, 2021). Pollutants generated during the sulfuric acid method include NOx, SO2, sulfuric acid mist during calcination and acidification, and waste residue during leaching and purification stages. The emission intensity of these pollutants is 6.67 kg/t, 7.52 kg/t, 0.90 kg/t, and 10.93 t/t, respectively (Gu GZ and Gao TM, 2021; Fig. 7). However, emission intensities may vary depending on the type of fossil fuel used and research boundaries.

Moreover, the sulfuric acid method can recover about 2.5 t/t of anhydrous sodium sulfate as a by-product (Gu GZ and Gao TM, 2021).On the other hand, the extraction of lithium from lepidolite using the sulfuric acid method faces challenges in purifying the leaching solution, resulting in low lithium yield and the production of silicon aluminum slag that is difficult to utilize. Therefore, large-scale industrialization of this method is lacking. In China, the sulfate process is commonly used for lithium extraction from lepidolite. This involves calcining lepidolite at temperatures of 800–1000°C with potassium sulfate, calcium carbonate, and sodium sulfate, followed by leaching, purifying, evaporating, and precipitating. The consumption intensity of lepidolite concentrate produced by lithium carbonate in this process is 17.86 t/t. The consumption intensities of potassium sulfate, calcium carbonate, and sodium sulfate are

1.43 t/t, 3.03 t/t, and 16.3 kg/t, respectively. Furthermore, the consumption intensities of natural gas and electricity are 2952 m3/t and 767 kWh/t, respectively. The lithium recovery rate is 84.83%, and the emission intensity of pollutants such as NOx and SO2 in this process is lower compared to the spodumene sulfuric acid method. However, the production intensity of hydrofluoric acid and waste residue is significantly higher, with intensities of 12.70 kg/t and 23.22 t/t, respectively. In summary, extracting lithium from ores requires substantial energy and resources, resulting in significant pollutant emissions. The environmental impact of these pollutants is 9.3–60.4 times higher than that of extracting lithium from brine (Jiang SY et al., 2020). For instance, in terms of global warming potential, the intensity of lithium extraction from ore is 15.69 tCO2eq/t, which is 47.7 times higher than extraction from brine (0.33 tCO2eq/t) (Jiang SY et al., 2020).

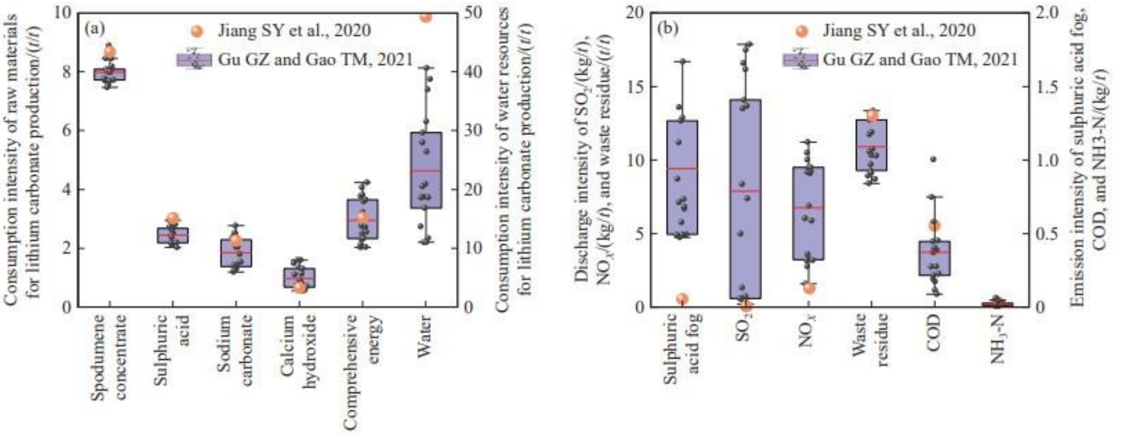


Fig. 7. Resource consumption (a) and pollutant emission (b) of lithium extraction from spodumene by the sulfuric acid method.

5.2 Cost and composition:

According to the analysis conducted by Peng JZ in 2019, the processing cost of extracting lithium from spodumene ores using the sulfuric acid method is estimated to be around $3030 per ton (equivalent to 20,000 RMB per ton). This cost is comparable to the processing costs of lithium extraction projects in Europe and North America, such as the Cínovec project in the Czech Republic ($2914/t) and the Whabouchi project in Canada ($2785/t) as reported by Sterba et al. in 2020.

It is also similar to the production costs of major brine lithium extraction enterprises like ALB and SQM, which range from $3030 to $3787 per ton. In contrast, the processing cost of extracting lithium from lepidolite ores using the sulfate method is relatively higher, estimated to be around $4545 per ton (equivalent to 30,000 RMB per ton) according to Peng JZ (2019). The main contributors to the processing cost of both spodumene and lepidolite ores are auxiliary materials such as fuel power and sulfate, accounting for over 75% of the total cost.

The production cost of lithium carbonate, a key lithium product, is heavily influenced by the price of lithium concentrate. For example, when the price of spodumene concentrate is $1000 per ton, the production cost of lithium carbonate is approximately $12.12 to $13.64 thousand per ton (Hu Z, 2019). However, the price of spodumene concentrate in the first auction of Pilbara in 2022 was $5650 per ton, leading to an estimated production cost of lithium carbonate exceeding $53,030 per ton.

Similarly, when the price of lepidolite concentrate ranges from $227 to $303 per ton, the production cost of lithium carbonate is about $10.61 thousand per ton (Hu Z, 2019). The research highlights that the production cost of extracting lithium from ores is closely tied to the price of lithium concentrate, which is significantly higher compared to extracting lithium from brine. Although the processing cost of lepidolite is higher than that of spodumene, lepidolite offers the advantage of comprehensive development.

The comprehensive utilization of other metals like rubidium, cesium, and potassium from lepidolite can greatly enhance its overall value and reduce the production cost of lithium carbonate. By adopting an integrated approach to extract multiple elements from lepidolite instead of solely focusing on lithium, the value of each ton of lepidolite can be increased from $454 to $1060-$2197, as reported by Yi M et al. in 2014. This comprehensive development of lepidolite significantly enhances its competitiveness in lithium extraction.

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VI. CONCLUSIONS

In conclusion, the hydro chemical classification of salt lakes plays a crucial role in determining the extraction process of lithium. Various ions present in salt lakes, including Na+, K+, Ca2+, Mg2+, and Li+, and Cl-, SO4^2-, CO3^2-, and HCO3-, are used to categorize them into different hydro chemical types. The distribution of hydro chemical types of salt lakes in the Tibet Plateau shows specific characteristics in terms of their spatial arrangement.

The global lithium resource reserves are estimated to be 22 million metric tons (Mt) of metal, with spodumene being the main lithium-bearing mineral worldwide. Different lithium minerals, such as spodumene, lepidolite, petalite, and zinnwaldite, are found in ores but require beneficiation processes to obtain lithium concentrate. Various extraction methods, such as the acid method, alkali method, salt roasting method, and chlorination method, are used depending on the media used for calcination and leaching.

The salt roasting method and carbonate method are commonly used for lithium extraction. The salt roasting method involves roasting a mixture of spodumene or lepidolite with salt reagents, while the carbonate method includes roasting a slurry of spodumene or lepidolite with limestone. Both methods have their advantages and disadvantages in terms of cost, energy consumption, and resource wastage.

In the Tibet Plateau, Zabuye Salt Lake is a significant source of lithium extraction in the carbonate belt. It utilizes halogen production, crystallization, and salt gradient solar pond technology for lithium carbonate extraction. Jiezechaka Salt Lake conducts pilot tests for lithium extraction in the sodium sulfate subtype belt, using extraction methods with tributyl phosphate (TBP) and diisobutyrone (DIBK) as extraction agents.

Longmoor Salt Lake successfully conducts a pilot production of lithium extraction in the magnesium sulfate subtype belt. It utilizes an innovative method involving aluminum-based adsorbents and nanofiltration membrane separation technology. The Qarhan Salt Lake, Western Taijinar Salt Lake, and Yiliping Salt Lake are known for their lithium extraction in the chloride-sulfate type belt and sodium sulfate subtype leakage belt. These lakes utilize various technologies, such as nanofiltration, calcination, and adsorption, to extract lithium and improve separation efficiency.

The environmental impact of lithium extraction from ores involves the generation of pollutants such as NOx, SO2, and waste residue. The emission intensities of these pollutants are higher compared to extracting lithium from brine. The cost of lithium extraction from ores depends on the price of lithium concentrate and is influenced by factors such as auxiliary materials and processing methods.

Overall, understanding the hydro chemical properties, distribution patterns, and extraction technologies of salt lakes is crucial for efficient and sustainable lithium extraction. With the growing demand for lithium in industries like battery manufacturing and renewable energy storage, continuous research and optimization of extraction methods are necessary to enhance efficiency, reduce environmental impacts, and improve economic viability.

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