Thoughts on the Development of Potassium Resources in China

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Abstract. Potassium is one of the three major nutrients (nitrogen, phosphorus, potassium) necessary for crop growth. Most of the potassium needed for crop growth is mainly provided by potassium fertilizer, which plays an irreplaceable role in promoting the development of food and agricultural production. This paper systematically analyzes the relationship between potassium and agriculture development, the status quo of potassium resources, and the status quo of potassium industry development, and conducts an in-depth analysis of the development of the potash fertilizer industry from two aspects: market demand and guarantee demand, and finally puts forward some suggestions for the sustainable development of potassium resources. Increase the leading role of the government and the comprehensive utilization of salt lake potash mines, strengthen the research and utilization of insoluble potassium resources to produce potash fertilizers, and continue to promote the construction of overseas potash fertilizer base industries in order to meet China's urgent demand for potash fertilizers in the future.

Keywords: potassium salt; potash fertilizer; development.

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1 Introduction

Fertilizer is a key factor in agricultural production [1], and as an important part of the "green revolution", it has contributed greatly to increasing crop yields and reducing hunger worldwide [2]. Nitrogen, phosphorus and potassium fertilizers are the three most used fertilizers in the world, and according to the Food and Agriculture Organization of the United Nations (FAO), fertilizers contribute up to 40% of food production, are the "food" of food, and have an irreplaceable role in promoting the development of food and agricultural production [3]. of the world's population is supplied by food produced from fertilizers [4]. Currently, affected by the New Crown Pneumonia epidemic and the Russian-Ukrainian geopolitical conflict, coupled with the severe impact of the Northern Hemisphere drought on the world food supply chain since 2021 [5], the steady and continuous growth of the global population over the past decade or so [6], the oversupply of food and the continuous rise in global food prices[7]. Farmers' willingness to grow food has increased, and in this context the importance of increasing food production and improving quality has become increasingly important, which has directly led to a significant increase in demand for chemical fertilizers, which have become an important basis for safeguarding the food and agriculture industry.

2 Potassium Industry Status

2.1 Potash and Agricultural Development

Potassium (Kalium), with the elemental symbol K, is a soft, silvery-white chemical element that does not exist in nature in a monomeric form and is widely distributed in the form of salts on land and in the ocean[8].Potassium is one of the three essential nutrients (nitrogen, phosphorus and potassium) for crop growth [9]. It can promote the activation and conversion of enzymes and effectively participate in biochemical processes such as photosynthesis, carbohydrate metabolism, protein synthesis, and transport of assimilated products, and can improve the efficiency of photosynthesis and the transport of photosynthetic products [10]. In surface soils, the total potassium content generally ranges from 0.1% to 3.0%, but the bulk of it (about 90%) exists in the form of non-water-soluble potassium (mineral potassium) that is not easily absorbed by plants [11]. Therefore, most of the potassium required for crop growth is mainly provided by potassium fertilizer, which is more sensitive than other factors such as pesticides and land in increasing crop yield and improving planting profitability. According to the National Compilation of Agricultural Cost and Benefit Information for 2020, fertilizer costs in 2019 accounted for 13.3%, 6.7%, and 15.2% of the total cost of corn, soybean, and wheat, respectively, in China. Potassium chloride, potassium sulfate and potassium nitrate are the main types of potassium fertilizers, of which, potassium chloride is the largest, accounting for more than 95% of the total amount of potassium fertilizers, which is suitable for grain, cotton, beans and other crops; potassium sulfate accounts for 4% to 5% of the amount of potassium fertilizers, mainly used for hemp, tobacco, sugar cane, sugar beets, citrus fruits and other economic crops, potassium fertilizers can be applied as a base fertilizer, but also as a follow-up fertilizer and foliar spray. As a base fertilizer, it is mainly used before planting crops, and is usually applied in strips and holes.

2.2 Status of potassium resources

The world potassium resources can be divided into two major categories based on their water solubility, water-soluble potassium-bearing minerals and non-water-soluble potassium-bearing minerals [12], with solid soluble potassium resources in their natural state being the main form of existence, followed by salt lake brine or subsurface brine potassium resources. Potash rocks are mainly composed of potassium-bearing minerals-potassium rock salt (KCI), halloysite (MgCl2-KCl-6H2O), potash magnesium vanadium (KCl-MgSO4-3H2O) and anhydrous potassium magnesium vanadium (K2SO4-2MgSO4) [13]. Potassium salts in their natural state were discovered in 1856 in rock salt deposits near Magdeburg, Saxony-Anhalt, Germany, and the official mining in 1861 marked the beginning of global potassium development activities[14]. Potash resources are the foundation of the potash industry, which not only determines the geographical distribution and pattern of the industry, but also influences the scale and efficiency of potash enterprises. Therefore, the study of the spatial and temporal distribution of potash resources and their characteristics is important for the formulation of the development strategy and planning of potash industry and its production and trade.

Global spatial distribution of potash.

Global potassium resources are abundant and dominated by potash salts and halloysite, which are also the main types of potassium salts exploited today. However, the global distribution of potassium resources is very heterogeneous and highly concentrated [15]. Solid potash ores are mainly distributed in North America and Europe, with world-class salt belts such as the Saskatchewan-North Dakota ElkPoint Basin potash metallogenic area in Canada and the Nepa Basin potash metallogenic area in Eastern Siberia, Russia [16]. Potash lakes are mainly distributed in Asia and South America, with six major salt lakes in China, including Zabuye Salt Lake, and the world's largest salt lake, Uyuni Salt Lake, in Bolivia, with 10.2 million tons of reserves but low grade; Atacama Salt Lake in Chile has a high level of reserves and grade.

Global spatial distribution of potash.

China is rich in total potassium reserves, but there is a shortage of soluble potassium salts with economic value. Soluble potash resources in China mainly belong to the salt-lake type potash, and the current potash mining areas in China mainly include the Lop Nor potash mining area in Xinjiang (at the eastern end of the Qaidam Basin), the Tsar Khan potash mining area in Qinghai (within the Qaidam Basin), the Zabuye potash mining area in Tibet (north of the Qiangtang Plateau), the Sichuan Basin potash mining area, and the Mengyejing potash mining area in Yunnan (within the Simao Basin) [17-20]. At present, the identified mining areas with mining potential are still concentrated in the potassium salt mining area of Lop Nor in Xinjiang and the potassium salt mining area of Chalhan in Qinghai, and the scale of each potassium salt mineral reserve is divided according to the "Mineral Resource Reserve Scale Classification Standard" issued by the Ministry of Natural Resources of China, in which solid KCl content ≥10 million tons is large, KCl content 1-10 million tons is medium, KCl <1 million tons is small, liquid KCl content ≥50 million tons is large, KCl content 5-50 million tons is medium, and KCl <5 million tons is small. Small, liquid KCl content ≥50 million tons is large, KCl content 5-50 million tons is medium, and KCl <5 million tons is small. Soluble potash resources in China can be divided into three types: modern saline-lake type, underground brine type and sedimentary type according to the age of potash deposit formation, deposit genesis and deposit characteristics, and modern saline-lake type potash ore is the main type, with 97.74% of the proven reserves of modern saline-lake type potash ore.

2.3 Potassium Industry Development Status

Production of potash.

The uneven distribution of potassium resources also leads to a relatively concentrated potash production area. According to USGS data published in 2021, global potash production in 2020 will be about 43.19 million tons, an increase of 7% year-on-year. However, the distribution of production by country (region) shows that global potash production is highly concentrated, with the top five potash producing countries - Canada, Russia, Belarus, China and Germany - accounting for a combined production of 85.4%, with Canada and Russia accounting for about half of global production. Between 2010 and 2020, China's share of global potash production will remain in the range of 10%-15%.

Consumption of potash.

Global potash consumption is mainly concentrated in 3 regions, namely East Asia, Latin America and North America. According to IFA (International Fertilizer Association) data, from 2000-2018, global potash (discounted K2O) consumption increased from 22.095 million tons to 37.105 million tons, with the contribution of growth coming mainly from East Asia, Latin America, the Caribbean, and South Asia. Asia, with 60% of the global population, accounts for 29% of global potash consumption, followed by North America at 25%. China, Brazil, the U.S. and India are the world's major potash consumers, accounting for about 70% of total global potash consumption. The U.S. Geological Survey estimates that the consumption of fertilizer products related to potash will increase to 46.2 million tons by 2021[21]and that the major consumers of potash will be Asia and South America.

Potash industry chain.

Since the potash industry was first established in Germany in the mid-19th century and gradually took shape worldwide, it has gradually developed a complete technological system for mining water-soluble solid potash ores and potassium-rich liquid resources and processing them into industrial products such as potassium chloride, potassium sulfate, potassium magnesium sulfate, and potassium nitrate, which not only provide indispensable potash fertilizers for the agricultural sector, but also for industrial wastewater treatment, ceramic preparation, animal feed processing, and fire extinguisher and textile production as important auxiliary raw materials [22]. From the perspective of the potash chain (Fig.1), the upstream raw materials include potash salts and halloysite, which can produce a wide range of potash fertilizers and can be applied according to the needs of different crops. In addition to the agricultural sector, the downstream sector has a demand for potassium fertilizers in the pharmaceutical and landscape sectors.

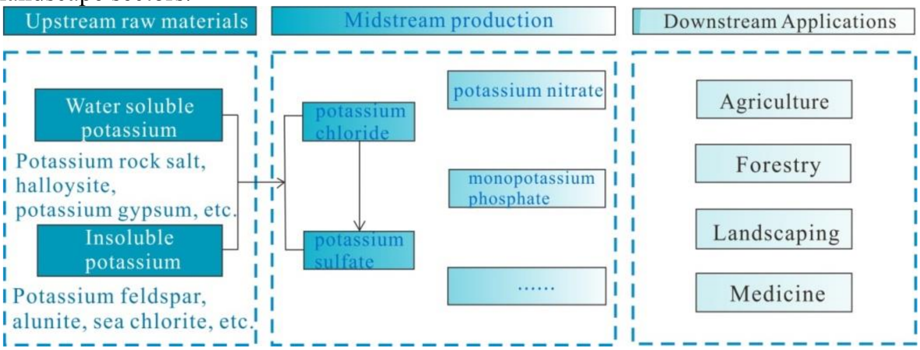

Fig. 1. Potash industry chain

Import and export trade of potash.

China's provable potash resource reserves have fluctuated between 1-1.1 billion tons since 2015, and the latest proven potash resource reserves in 2019 are 1.03 billion tons. Although China's potash reserves and production level are the fourth in the world, the immediate demand for potash due to food security makes China's potash reserves relatively scarce and its external dependence is still high. 2020 China's potash import dependence is still higher than 50%. Driven by the demand for potash, the three major global potash exporters, Canada, Russia and Belarus, show booming potash exports. According to TDM data, the potash export volume of Canada in Q1 and Q2 of 2021 is 4,941,200 tons and 6,223,100 tons respectively; the export volume of Russia is 2,296,100 tons and 3,322,700 tons respectively; the export volume of Belarus in Q1 is 2,029,800 tons. The global import and export trade volume of potash is at a relatively high level in history, reflecting the global level boom of potash.

3 Demand analysis of potash industry development

3.1 Analysis of potash market demand

Demographic factors.

According to the World Population Prospects projections released by the United Nations Department of Economic and Social Affairs in 2022[23] (Fig.2), the world population has reached 8 billion people as of November 15, 2022, with a global population

CAGR of about 1.1% for the period 2015-2020. Although the growth rate of the global population is declining year by year, the number of new population in the last decade is above 80 million, and the number of new population in 2020 will decline slightly due to the epidemic, which is about 78.25 million. 0.75%. Although the global population growth rate has slowed down, the overall population is still growing steadily. At the same time, the growth of the total population will also bring about an increase in total food consumption, while the current global arable land is relatively limited, corresponding to a continuous decline in per capita arable land, which also means that the unit area of arable land needs to produce more food to meet the huge population of food demand. As a result, higher quality seeds and more efficient fertilizers will be needed in the planting process, which will boost the demand for potash to a certain extent.

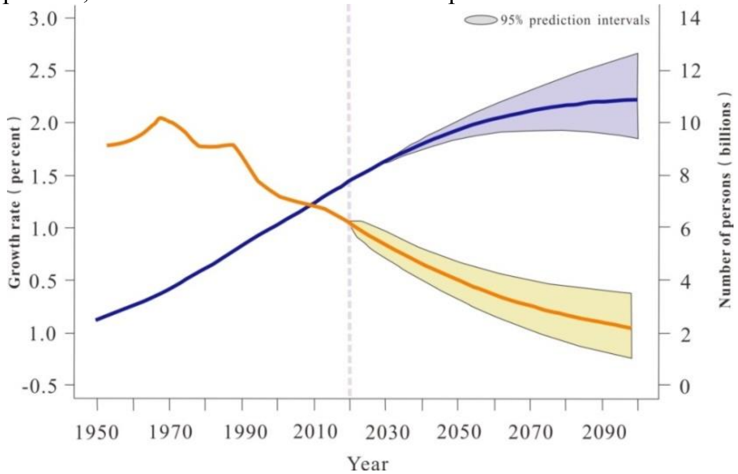

Fig. 2. Global population size and annual growth rate: estimates for 1950-2020, and projections and forecast intervals for 2020-2100 (data from UN)

In terms of per capita arable land area, the per capita arable land area in both China, India, and the United States has continued to decrease since the 21st century, with 0.09, 0.12, and 0.48 ha/person as of 2018, a decrease of 9.5%, 24.1%, and 22.3%, respectively, from 2000 (Fig.3). As per capita arable land decreases and to meet the growing population's demand for food, food production per hectare of arable land will inevitably need to increase. According to the National Bureau of Statistics (NBS), grain yield per hectare in China, India and the U.S. has continued to increase over the past few decades, which we believe is mainly due to the use of high-quality seeds and efficient fertilizers. As of 2018, grain yields per unit arable area in China, India, and the U.S. were 6,081, 3,248, and 8,692 kg/ha, respectively, an increase of 27.9%, 41.6%, and 48.5% per hectare, respectively, from 2000. We believe that there is a long-term demand to increase grain yield per unit arable area, which will drive up the application of efficient fertilizers, especially potash (either as a mono-quality fertilizer or as a compound fertilizer component).

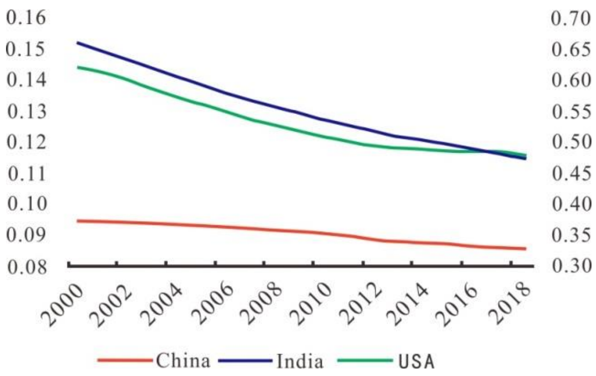

Fig. 3. Arable land per capita (ha/person) in China, India and the US, 2000-2018 (data source from iFinD)

Political factors.

Since the emergence of the new crown epidemic, the epidemic and the corresponding prevention and control measures have affected the food supply system in many ways, with the shutdown/reduction of production by the corresponding producers reducing the overall supply of food, and the restricted labor mobility increasing the delivery time of food. In this context, countries around the world are paying more and more attention to ensuring food self-sufficiency and enhancing their food security capacity. In China, for example, relevant authorities have frequently issued policies or guidance documents related to food security (Table1).

Table 1. Some of China's policies related to ensuring food security since 2020

Time	Release section	Policy name
January 2020	State Department	Opinions on Grasping the Key Work in the Field of "Three Rural Areas" to Ensure Achieving Comprehensive Prosperity on Time
January 2021	State Department	Opinions on Accelerating Agricultural and Rural Modernization by Comprehensively Promoting Rural Revitalization
September 2021	Ministry of Agriculture and Rural Affairs	National High Standard Farmland Construction Plan (2021-2030)
October 2021	Ministry of Agriculture and Rural Affairs	Opinions on Promoting Leading Agricultural Industrialized Enterprises to Grow and Strengthen
November 2021	State Department	The 14th Five-Year Plan to Promote Agricultural and Rural Modernization
January 2022	State Department	Opinions on the Key Efforts to Comprehensively Promote Rural Revitalization in 2022
March 2022	State Department	Government Work Report 2021
October 2022	Twentieth National Congress of the Communist Party of China	The Great Banner of Socialism with Chinese Characteristics and the Unity of Struggle for the Comprehensive Construction of a Modern Socialist

		Country
December 2022	Central Rural Work Conference	Xi Jinping's speech at the Central Rural Work Conference

In addition to the impact of the epidemic, the recent geopolitical conflict between Russia and Ukraine has also had a major impact on international food prices. According to USDA data, Russia and Ukraine will account for 28.5% and 49.8% of global exports of sunflower oil in 2021, respectively; Russia and Ukraine will account for 16.5% and 10.2% of global wheat exports in 2021, making Russia and Ukraine the world's top and fifth largest exporters of wheat, respectively (Fig.4).

Fig. 4. Global wheat exports and the share of Russia and Ukraine, 2011-2021 (data from iFinD)

The Russia-Ukraine conflict has caused significant uncertainty in the production of local food enterprises in Ukraine, and the cultivation and production of agricultural products represented by wheat and corn will be significantly affected. In addition, as the United States, the United Kingdom and the European Union have indicated that sanctions will be imposed on Russia, the subsequent Russian exports of commodities represented by agricultural products may face contraction, which will further push up international food prices. 24 February 2022, Russian President Vladimir Putin announced a special military operation against the Donbass region of Ukraine, and the settlement price of CBOT wheat futures rose by 5.7% on the same day, 24 February. Although recent grain futures prices have retreated from the end of February, they are still at historic highs. If high grain prices persist, global farmers' willingness to plant is expected to further strengthen, which will further push up the demand for fertilizer products such as potash.

Economic Factors.

The acreage of representative food crops and cash crops in China has changed considerably within the past nearly 20 years. According to data from the Chinese Ministry of Agriculture and Rural Affairs, for food crops, the acreage of wheat, rice, corn, beans and potatoes in China as of 2021 changed -1.4%, +2.5%, +75.9%, -19.3% and -25.8%, respectively, year-over-year from 2002, and the acreage of food crops other than corn remained relatively stable or declined. As for cash crops, the acreage of vegetables and fruits will increase by 23.8% and 39.0% respectively by 2020 compared with 2002, and the acreage of cotton will decrease by about 27.6% in 2021 compared with 2002. The continued high acreage of cash crops such as vegetables and fruits also represents the improvement of domestic residents' living standard and optimization of diet structure under the rapid development of domestic economy (Fig.5).

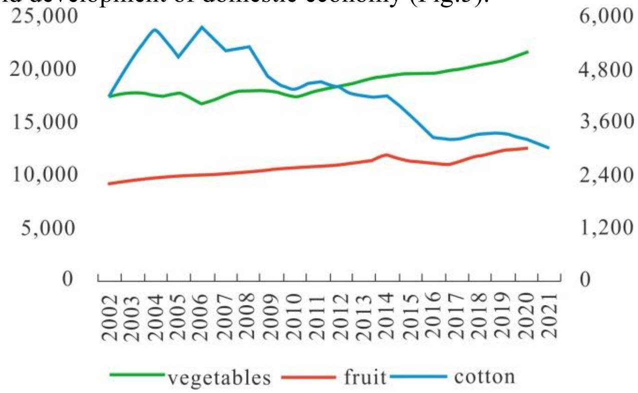

Fig. 5. Representative cash crop cultivation area in China (thousand hectares) (data from China Ministry of Agriculture and Rural Affairs)

At the same time, we also found that the amount of potassium fertilizer application per acre for cash crops such as vegetables, fruits, and cotton is significantly higher than that for food crops such as wheat, rice, and corn. According to iFinD data, the amount of potassium fertilizer applied per acre (discounted pure, same below) for cash crops such as sugarcane, vegetables, apples and cotton in 2020 is 6.51, 4.80, 1.14 and 1.17 kg, respectively, while the amount of potassium fertilizer applied per acre for food crops such as rice, soybeans, corn and wheat is 1.12, 0.48, 0.14 and 0.02 kg, respectively. The amount of potassium fertilizer for sugarcane and vegetables varies from several times to several hundred times that of food crops. Cash crops such as sugarcane have a higher sugar content and therefore have a greater demand for potassium fertilizer. At the same time, soils where cash crops are cultivated tend to have low levels of potassium availability, so a rise in demand for cash crops will drive a significant increase in potash demand. According to IFA data, fruits and vegetables account for about 19% of the potassium fertilizer application structure, ranking first. Combined with the continued increase in the area planted with fruits and vegetables mentioned above, the demand for domestic potash fertilizer will also increase rapidly.

3.2 Analysis of potash market demand

Potash industry is a typical resource-based industry. Therefore, resource security capacity is a key element that affects and restricts the sustainable development of potash industry, and it is of guiding significance to carry out research on resource security capacity for industrial development strategy.

For China, the nominal guarantee of potassium resources is only 30 years, which is close to that of the United States, and is a country with a weak guarantee of resources; in terms of the amount of potassium resources per capita, China's per capita level is only 0.16 tons, which is the last among 12 countries; not only that, the amount of potassium resources occupied by arable land in China is also at a low level. All these show that China, as a big country in terms of population and agriculture, has obvious shortage in potassium salt resource security capacity and the situation is rather severe. However, it is worth noting that the annual consumption rate of potassium resources in China is still at the middle level among 12 countries, despite its high level, indicating that the consumption level of potassium resources in China is still at a reasonable level. Based on the characteristics of potassium salt resources and the huge demand for potassium salt products in the agricultural field and the objective fact of insufficient potassium salt resource security capacity, although the Chinese government, scientific and technological workers and their enterprises have made useful attempts and practices in upgrading potassium salt reserves, intensive mining and processing, and developing non-water-soluble potassium salt resources, which have effectively improved China's potassium salt resource security capacity and guaranteed potassium salt supply and food security, etc. However, the situation that China's potassium salt resources are not enough to guarantee has not been significantly improved.

4 Strategic thinking on the sustainable development of potash

Based on the resource-based industrial attributes of the potash industry and its strategic position as a matter of national livelihood and agricultural security, this paper proposes suggestions for the development of China's potash industry, taking into account the current situation and characteristics of China's potash industry.

4.1 The government should increase its leading role

The development of potash industry in China should give full play to the leading role of the government in terms of policy leadership, financial support and resource allocation. First, it should introduce special policies for potash resource exploration to attract social capital, especially private capital, to enter the field of potash resource exploration; second, it should encourage potash enterprises to develop and produce new slow-release potash fertilizers and farmers to use slow-release potash fertilizers through policy guidance and financial support; third, the government should use its advantageous position in resource allocation to make reasonable allocation of potash resources and allocate more resources to major enterprises with advanced technology, resource utilization efficiency, product quality and social and economic benefits. Third, the government should use its advantageous position in resource allocation to make a rational allocation of potash resources, allocating more resources to major enterprises with advanced technology, high efficiency in resource utilization, and good product quality and socio-economic benefits, so as to improve the efficiency and benefits of comprehensive utilization of potassium and its associated resources.

4.2 Increase the comprehensive utilization of salt lake potash ore

Chinese potash mines are mainly salt-lake type resources. Modern salt lake type potash has many co-associated components and high value added for comprehensive utilization, often rich in useful minerals such as sodium, magnesium, lithium, iodine and bromine, which can be developed and utilized in a comprehensive manner. According to USGS data, the total global proven lithium resources is about 86 million tons, and China is 5.1 million tons, which is the sixth place in the world. In addition, China is one of the few countries in the world where all three types of resources, including lithium salt lake, lithium pyroxene and lithium mica, are distributed. Among them, salt lake lithium resource reserves account for 70% of the national total, and hard rock lithium represented by lithium pyroxene and lithium mica accounts for about 30%. In order to improve the utilization rate of resources, the comprehensive utilization of the associated mineral resources should be enhanced.

4.3 Enhancing research and utilization of insoluble potassium resources for manufacturing potash

The main potassium-rich minerals of non-water-soluble potassium ores are almost all microplagioclase feldspar. The abundant and high quality of non-water-soluble potassium ores in China provides good conditions for the development of potash (fertilizer) chemical industry. A lot of systematic practices have been carried out for the production of potash (potash fertilizer) from insoluble potassium resources. Among them, the medium temperature sintering method with sodium carbonate as ingredient and the hydrothermal decomposition method with soda lime as ingredient have the advantages of 100% utilization of potassium feldspar resources, minimal one-time resource and energy consumption, near-zero emission of "three wastes", reasonable product scheme and high added value, and have the technical conditions for large-scale engineering implementation. The development of potassium salt (fertilizer) processing industry by using non-water-soluble potassium resources on a large scale and with high efficiency is not only a realistic technical and economic feasibility and market demand at present, but also has the potential to have a profound impact on the sustainable development of China's economy, especially modern agriculture, in the long run.

4.4 Build a world-class salt lake industrial base

Chinese potash is mostly a salt lake type resource, which has high added value compared to overseas potash ore comprehensive utilization, but the external dependence of potash is still high. On August 25, 2021, China's Ministry of Industry and Information Technology proposed to incorporate the comprehensive development of salt lake resources into national planning, promote the comprehensive utilization of salt lake resources, and help the sustainable development of the salt lake industry. Recently, Salt Lake announced that it will build a pilot base for the development of salt lake resources. The company is pursuing the industrial chain to develop new added value beyond potassium and lithium with the policy and market dividend. At the same time, the overseas potassium search process of Chinese enterprises is gradually becoming clear, with the expansion of potassium in Laos becoming a successful case, and listed companies such as Asia Potash International and Orient Titan seeking new opportunities for overseas development. The future of China's potash industry will present a dual development of endogenous and external routes, gradually building a world-class salt lake industry base, which is also conducive to China's future mastery of potash, a globally important and scarce resource.

5 Conclusion

In the 21st century, with the rapid population growth and the impact of the conflict between Russia and Ukraine, food security is of great significance. The 20th National Congress of the Communist Party of China also made food security a major strategy. The role of potassium fertilizer in increasing food production and promoting agricultural development is becoming more and more important. . This article systematically analyzes the relationship between potassium and agricultural development, the status quo of potassium resources, and the status quo of potassium industry development. It conducts an in-depth analysis of the industrial development of potassium fertilizers from two aspects: market demand and guarantee demand, and finally puts forward some suggestions for the sustainable development of potassium resources. It is suggested to increase the leading role of the government and the comprehensive utilization of salt lake potash mines, strengthen the research and utilization of insoluble potassium resources to produce potash fertilizers, and continue to promote the construction of overseas potash fertilizer base industries in order to meet China's urgent demand for potash fertilizers in the future.

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