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Cross-Border Industrial Collaboration: Interactive Influences and Development Insights between European and Chinese Fertilizer Industries

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Abstract: This article traces the historical development of the fertilizer industry in major European countries, including Germany, the United Kingdom, and France, and examines its multifaceted influence on the formation of China's fertilizer industry. Specifically, it explores four key dimensions of this influence: the establishment of technical foundations, the construction of an industrial system, the shaping of international cooperation models, and the introduction of sustainable development concepts. The study finds that Europe-particularly Germany through the invention of the Haber-Bosch ammonia synthesis process-provided the crucial technological groundwork for China's fertilizer industry. Moreover, the evolution of Europe's fertilizer sector not only supplied the technical impetus for China's industrial modernization but also offered valuable experience and strategic guidance for building an independent, innovative, and sustainable fertilizer industry system.

Keywords: European fertilizer industry; technology transfer; Haber-Bosch process; China's fertilizer industry

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1. Introduction

Fertilizer, as a fundamental material basis for modern agriculture, plays an indispensable role in ensuring national food security and advancing agricultural modernization. Europe, recognized as the cradle of the global fertilizer industry, has accumulated profound experience in technological innovation, industrial organization, and policy system design since the late nineteenth and early twentieth centuries. This historical legacy has exerted a far-reaching influence on the evolution of the global fertilizer sector.

The establishment and development of China's fertilizer industry are closely intertwined with the European experience. From the early twentieth century, when the German company BASF established a trade office in China, to the large-scale introduction of European fertilizer production technologies and equipment following the founding of the People's Republic of China, and further to the implementation of the "43 Plan" during the reform and opening-up period, Europe has played a pivotal role in accelerating the modernization of China's fertilizer industry.

This article seeks to systematically review the developmental trajectory of the fertilizer industry in major European countries and to analyze the multidimensional impacts of Europe's fertilizer sector on the formation of China's fertilizer industry. By tracing these historical linkages, the study aims to extract valuable insights to support the high-quality development of China's fertilizer industry in the contemporary era. This research not only

deepens the understanding of the historical evolution of Sino-European cooperation in the fertilizer field but also provides historical perspectives and strategic implications for the transformation and upgrading of China's fertilizer industry in the context of sustainable development.

2. The Historical Development of the European Fertilizer Industry

The fertilizer industry originated in Europe as a direct product of the Industrial Revolution. In 1800, the United Kingdom pioneered the recovery of ammonium sulfate from industrial coke production, marking one of the earliest uses of chemical by-products as fertilizers. However, it was not until 1908, with Germany's invention of the modern synthetic ammonia process, that a stable and sufficient supply of fertilizers became possible.

The roots of Europe's fertilizer industry can be traced back to the late nineteenth century, when production primarily relied on natural ores and simple chemical raw materials. As the chemical industry advanced, fertilizer production gradually became industrialized, and countries such as Germany, France, and the United Kingdom emerged as the earliest centers of fertilizer manufacturing [1]. In its early stages, European fertilizer production mainly focused on nitrogen, phosphorus, and potassium fertilizers. Production methods were relatively rudimentary, relying on materials such as Chilean nitrate or ammonia by-products from coal coking. However, these early techniques could not fully meet the growing agricultural demands of European countries.

Before the 1980s, Western Europe remained the world's dominant fertilizer-producing region, accounting for nearly half of global fertilizer output. Therefore, the study of Europe's fertilizer industry holds significant representative value [2].

With the arrival of the twentieth century-particularly after World War II-the European fertilizer industry underwent rapid technological innovation. In 1904, German chemist Fritz Haber, at the Karlsruhe Institute of Technology, established the theoretical foundation for the synthetic ammonia industry. Two years later, in 1906, the Norwegian company Yara developed nitrate fertilizers. In 1908, BASF commissioned Carl Bosch to industrialize Haber's synthetic ammonia process. The world's first ammonia plant began operation in 1913 in Ludwigshafen, followed by the second in 1917 at the Leuna plant in Merseburg. The adoption of the Haber-Bosch process enabled large-scale nitrogen fertilizer production, greatly enhancing agricultural productivity and ushering in a new era of industrialized fertilizer manufacturing.

3. The Development of Fertilizer Industry in Major European Countries

3.1. Germany's Leading Position and Technological Innovation in the Fertilizer Industry

The invention and industrialization of Germany's synthetic ammonia process marked a major breakthrough in both the fertilizer and chemical industries, establishing Germany's leadership in global chemical innovation. In the early twentieth century, Germany faced a severe dependence on imported Chilean nitrate, which served as a key raw material for fertilizer and explosives production. As Chilean nitrate reserves gradually declined, the need to develop a domestic and sustainable source of nitrogen fertilizers became increasingly urgent.

Germany's early leadership in the fertilizer industry can be traced to crucial scientific discoveries and industrial advancements made during the nineteenth and early twentieth centuries. In 1840, German chemist Justus von Liebig identified nitrogen, phosphorus, and potassium as essential elements for crop growth, laying the theoretical foundation for modern fertilizer science. Although Liebig initially believed that plants could directly absorb nitrogen from the atmosphere-a hypothesis later proven incorrect-his work stimulated the systematic study of plant nutrition and spurred the development of nitrogen-based fertilizers.

At the dawn of the twentieth century, Fritz Haber began exploring methods to synthesize ammonia from atmospheric nitrogen and hydrogen. In 1909, assisted by his colleague Robert Le Rossignol, Haber successfully achieved ammonia synthesis using osmium compounds as catalysts under conditions of approximately 550°C and 175 atmospheres, yielding about 80 grams of liquid ammonia per hour [3]. This landmark achievement immediately drew the attention of Heinrich von Brunck, general manager of BASF, who dispatched engineer Carl Bosch to Haber's laboratory. After technical discussions, BASF decided to scale up Haber's experimental process for industrial production [4].

Originally a producer of chemical dyes, BASF gradually expanded into the field of nitrogen-based fertilizers. Under Carl Bosch's leadership, the company began developing the Haber-Bosch ammonia synthesis process for large-scale industrial application. In 1911, BASF successfully operated a pilot plant with a daily production capacity of 100 kilograms of ammonia [5]. Encouraged by this success, BASF expanded the facility, and by 1912, its daily output reached one ton. In 1913, the world's first commercial synthetic ammonia plant was completed in Ludwigshafen, Germany, marking the beginning of industrial-scale ammonia production. The plant commenced operation on September 9, 1913, equipped with three synthesis units, each capable of producing ten tons of ammonia per day, resulting in an annual capacity of 8,700 tons [6].

Germany's chemical industry continued to consolidate in the following years. In 1919, several nitrogen fertilizer producers merged with steel plants along the Ruhr River-where ammonia was a by-product of coke production-to form the Berlin Nitrogen Fertilizer Enterprises Union Ltd. Subsequently, in 1925, the merger of six major chemical companies led to the creation of I.G. Farben, which acquired 60% of the shares in the Berlin Nitrogen Fertilizer Union. I.G. Farben became not only the largest industrial conglomerate in Europe but also the world's leading chemical and pharmaceutical enterprise at the time [7,8].

As a result of these developments, Germany's annual synthetic ammonia production surged from 7,000 tons in 1913 to 2.5 million tons in 1939 [9]. This exponential growth not only ensured Germany's self-sufficiency in fertilizer production but also established a global model for the integration of scientific research, industrial application, and technological innovation in the chemical sector.

3.2. The Development and Global Layout of the UK Fertilizer Industry

Following World War I, Germany lost many of its key technological patents-including those related to synthetic ammonia-leading to a significant decline in its industrial dominance. During this period, the United Kingdom rose to prominence, assuming an increasingly important role in global fertilizer production and in the international transfer of fertilizer technologies, particularly to China.

In December 1926, Imperial Chemical Industries (ICI) was founded through the merger of four major British chemical corporations: Brunner Mond, Nobel Explosives, United Alkali Company, and British Dyestuffs Corporation [10]. With its strong engineering expertise and extensive global market network, ICI rapidly industrialized and commercialized fertilizer production technologies, achieving large-scale production and international expansion.

Driven by the rising food demand across the vast territories of the British Commonwealth, British fertilizer products quickly secured stable and extensive export markets. As one of the world's leading fertilizer producers of the time, ICI not only ensured an adequate fertilizer supply for the British Isles-supporting the continuous development of domestic agriculture-but also sustained agricultural output across the British Empire.

After World War II, the United Kingdom faced the urgent challenge of national reconstruction. To promote economic recovery and social stability, the Labour government launched a comprehensive nationalization program in 1945, designating the fertilizer industry as one of its strategic sectors. In 1947, the government acquired major fertilizer

production enterprises, including those at Billingham and Teesmouth, and established the National Fertilizer Company (NFU) to oversee production and distribution [11].

However, beginning in the 1960s, the British fertilizer industry faced increasing competition from the United States, whose large-scale ammonia and urea plants-based on petrochemical processes and low-cost oil feedstocks-greatly reduced global fertilizer prices. In contrast, the UK's fertilizer industry, which continued to rely on coal-based production methods, gradually lost its cost advantage. Although Britain retained technological strengths in specific areas such as nitrate fertilizers, ammonium phosphates, and high-concentration compound fertilizers, its overall competitiveness declined sharply.

The "Thatcher Revolution" of the 1970s brought about a second major transformation through privatization. The British Petrochemical and Fertilizer Company (BPCNFU), established in 1973, was privatized in 1977 and renamed the British Fertilizer Company, thereby ending nearly three decades of state control and introducing market-driven competition into the sector.

A particularly notable aspect of the UK's fertilizer strategy was its global approach to potash fertilizer production. Germany's monopoly on potash exports and its subsequent embargo created a serious supply crisis for Britain. In response, following General Allenby's capture of Jerusalem in 1917, the British government dispatched engineer Major John Talrock to investigate the mineral potential of the Dead Sea, recognizing it as a potential alternative source of potash. Although his initial application for a concession was rejected, Talrock later partnered with entrepreneur Moses Novomeysky, and in 1929, they jointly founded the Palestine Potash Company. After nearly nine years of negotiation, the company obtained the concession, with the strategic goal of breaking Germany's monopoly and securing fertilizer supplies for the British Empire.

During World War II, Dead Sea potash supplied approximately 50% of the United Kingdom's domestic demand and 80% of the Commonwealth's requirements. Following the war, the company expanded its export markets to include the United States, the United Kingdom, and China. By 1943, potash extracted from the Dead Sea accounted for 25% of global reserves, marking the beginning of a new era in the international potash industry. This strategic success effectively diversified global market supply and reduced Britain's dependence on German fertilizer resources [12].

3.3. The State Intervention Model of France's Fertilizer Industry

The development of France's fertilizer industry began relatively late compared with that of Germany and the United Kingdom. Before World War I, France had almost no nitrogen fertilizer industry of its own. Between 1850 and 1860, under the advocacy of Louis-Nicolas Grandeau (1834-1911), France established the first fertilizer regulatory institutions, including its earliest agricultural experiment stations. During this period, fertilizers used in France were largely derived from urban sewage, a type of artificial fertilizer commonly referred to as "Flemish fertilizer" [13].

Before the war, France could meet only 24.6% of its domestic nitrogen fertilizer demand, relying heavily on imports-primarily from Chile [14]. During wartime, large quantities of nitrogen were diverted to the production of explosives, resulting in an acute shortage of fertilizers for agricultural use. This crisis underscored the urgent need for France to establish an independent and controllable nitrogen fertilizer production system.

In the early years, France's nitrogen fertilizer market was coordinated through the French Ammonium Sulfate Sales Office (CFA), a semi-official organization responsible for the joint sale of nitrogen fertilizers. Following the Treaty of Versailles (1919), France obtained access to BASF's patents and the Haber-Bosch process, allowing for the industrial synthesis of nitrogen from atmospheric air and enabling large-scale nitrogen fertilizer production. However, private industrialists in France refused to purchase the patents, seeking instead to maintain their control over the nitrogen fertilizer market.

To counteract private monopolies, the French Parliament passed legislation on April 11, 1924, establishing the National Industrial Nitrogen Office (Office National Industriel de l'Azote, ONIA). As the first state-owned enterprise to compete directly in the fertilizer market, ONIA was tasked with supplying nitric acid to the military during wartime and providing fertilizers at low prices in peacetime to suppress monopolistic behavior among private industrial cartels [15].

During the 1930s, the global economic crisis led to overproduction, intensified market competition, and volatile prices in the nitrogen fertilizer industry. In 1937, ONIA reached an agreement with private manufacturers to divide the domestic nitrogen fertilizer market into two operational regions, thereby establishing a **shared monopoly system** [15].

After 1946, the French government launched the "Modernization and Equipment Plan" (Plan de Modernisation et d'Équipement), which aimed to standardize fertilizer production, encourage technological innovation, and strengthen the competitiveness of French fertilizer enterprises in the international market [16].

Throughout the 1950s and 1960s, France's fertilizer industry increasingly emphasized cooperation with large chemical engineering companies. Technological innovations such as granulation and bulk blending (BB) fertilizers became central to production modernization [17]. Moreover, new technologies-including the Spherodizer process and advanced methods for ammonium nitrate manufacturing-gradually gained international recognition and adoption [18].

The evolution of France's fertilizer industry played a crucial role in the modernization of French agriculture. Between 1850 and 2000, the average wheat yield in France increased dramatically from 1,000 kilograms per hectare to 7,104 kilograms per hectare [17]. This remarkable growth reflects the substantial improvement in fertilizer efficiency and illustrates how the fertilizer industry transformed France from a famine-prone agrarian nation into one of the world's leading agricultural powers.

4. The Impact of the European Fertilizer Industry on the Establishment of China's Fertilizer Industry

4.1. Laying the Technical Foundation for China's Fertilizer Industry

The most fundamental influence of the European fertilizer industry on China lies in its establishment of a solid technological foundation.

The invention and application of the German Haber-Bosch ammonia synthesis process revolutionized global fertilizer production and provided the core technological framework upon which China's fertilizer industry was built.

From the creation of China's unique small-scale nitrogen fertilizer system in 1958 to the large-scale introduction of nitrogen fertilizer technologies during the 1960s and 1970s, the essential technical foundation-ammonia synthesis-was predominantly based on the German Haber process.

This technological lineage represents the most significant and enduring impact of the European fertilizer industry on China's industrial modernization.

4.2. Provided a Reference Model for the Development of Industrial Organization

The industrial conglomerate model developed by I.G. Farben in Germany through strategic mergers and reorganizations highlighted the advantages of scale, synergy, and integrated production.

This model profoundly inspired China's approach to fostering large fertilizer enterprises and corporate groups, encouraging the integration and optimization of resources to enhance industrial efficiency.

Similarly, the multinational operational model of the British company Imperial Chemical Industries (ICI)-particularly its global technology transfer mechanisms and

market expansion strategies-provided valuable lessons for the internationalization of Chinese fertilizer enterprises after China's accession to the World Trade Organization.

These European organizational experiences collectively offered China a blueprint for developing efficient, globally competitive fertilizer enterprises.

4.3. Established Mechanisms for International Cooperation and Technology Transfer

The collaborative practices between the European fertilizer industry and China helped establish an effective framework for international cooperation and technology transfer, which became a crucial channel for China's fertilizer modernization.

This cooperation extended far beyond the importation of technology and equipment; it encompassed the comprehensive transfer of knowledge, including personnel training, managerial practices, quality control standards, and operational safety systems.

Through this multidimensional collaboration, a long-term mechanism emphasizing mutual benefit, innovation sharing, and sustainable partnership was formed.

The system of cooperation between European and Chinese fertilizer enterprises not only accelerated industrial upgrading but also laid the foundation for China's broader engagement in international technological exchange in subsequent decades.

4.4. Conveyed the Concept of Sustainable Industrial Development

The European fertilizer industry's evolving emphasis on environmental protection and sustainable development has had a profound and lasting influence on the strategic orientation of China's fertilizer industry.

Since the 1970s, Europe's efforts in technological upgrading, clean production, and the development of circular economy models have provided significant reference points for China's green transformation.

The precision fertilization practices pioneered in France-aimed at improving fertilizer use efficiency and minimizing environmental impact through technological innovation-offer critical insights for China's pursuit of "zero growth" in fertilizer application.

Likewise, Germany's rigorous environmental standards and its focus on clean production have shaped China's conceptual framework for sustainable fertilizer industry development.

Furthermore, the corporate social responsibility and sustainability philosophies embedded in the globalization of the UK's fertilizer enterprises-particularly through joint ventures and investment projects in China-have influenced Chinese enterprises' management concepts and strategic approaches to green growth.

5. Inspiration from the European Fertilizer Industry for China's Fertilizer Industry

5.1. Strengthen Technological Innovation Leadership and Build an Independent Technology System

Continuous technological innovation has been the core driving force behind the sustained development of the European fertilizer industry.

Drawing on this experience, China should increase its investment in basic fertilizer science and frontier technological research, focusing on the development of high-efficiency and environmentally friendly fertilizers, precision fertilization technologies, and technologies that enhance nutrient utilization efficiency.

It is essential to establish a comprehensive innovation ecosystem that deeply integrates industry, academia, and research institutions, forming an innovation chain that connects fundamental research, applied development, and industrial transformation.

At the same time, Chinese and European enterprises should be encouraged to pursue joint innovation in emerging fields such as intelligent fertilizer manufacturing, digital agriculture, and soil remediation technologies, thereby gradually forming a fertilizer technology system that is independent, globally competitive, and characterized by Chinese strengths.

5.2. Driving China's Fertilizer Industry Toward Green, Low-Carbon Development.

Drawing on Europe's experience in industrial structural adjustment, China's fertilizer industry should accelerate the phase-out of outdated production capacity characterized by high energy consumption and heavy pollution, and advance toward green, low-carbon, and circular development.

Priority should be given to the development of environmentally friendly fertilizers, including high-efficiency compound fertilizers, water-soluble fertilizers, and bio-based fertilizers.

China should establish a green evaluation and certification system for the fertilizer industry, adopting and aligning with European green certification standards to promote mutual recognition between Chinese and European green fertilizer labels.

Furthermore, inspired by Europe's circular economy model, China should promote the integration of the fertilizer industry with organic waste recycling, soil carbon sequestration, and related ecological industries, forming a closed-loop industrial ecosystem that harmonizes economic growth with environmental protection.

5.3. Deepen International Cooperation and Enhance Global Competitiveness

Building on Europe's successful experience in the internationalization of the fertilizer industry, China should actively participate in the global division of labor and value chain of fertilizer production.

At the multilateral level, China could promote the establishment of a China-Europe Fertilizer Industry Cooperation Mechanism, strengthening collaboration-particularly with Central and Eastern European countries-under the framework of the Belt and Road Initiative (BRI) to jointly build overseas fertilizer production bases and distribution networks.

At the bilateral level, Chinese fertilizer enterprises should be encouraged to form strategic partnerships with leading European companies through technology licensing, joint ventures, equity cooperation, and R&D alliances.

Meanwhile, China should deepen cooperation with international organizations such as the International Fertilizer Association (IFA) and the Fertilizers Europe, actively participating in global standard-setting processes to enhance China's international influence and voice in the fertilizer sector.

5.4. Improve the Policy Support System and Guide High-Quality Industry Development

Learning from the policy frameworks of European fertilizer industries, China should enhance its industrial policy support system, integrating fiscal, tax, and financial instruments to guide high-quality development.

A risk prevention and early-warning mechanism for the fertilizer industry should be established to ensure stability and sustainability.

In terms of international cooperation, China could set up a dedicated China-Europe Fertilizer Cooperation Fund to support enterprises on both sides in conducting joint R&D, market expansion, and capacity cooperation.

Furthermore, China should optimize its fertilizer import and export policies and improve measures that facilitate foreign investment and cross-border technology exchange.

Coordination with the European Union on fertilizer-related regulations and technical standards should be strengthened to promote policy alignment and foster a favorable international business environment for the multinational operations of Chinese fertilizer enterprises.

5.5. Promote Industry Integration and Innovation, Serve Agricultural Modernization

Drawing from Europe's experience in fostering synergistic development between agriculture and industry, China should promote the deep integration of the fertilizer industry with modern agriculture.

Fertilizer enterprises are encouraged to transform into comprehensive agricultural service providers, offering integrated solutions ranging from soil testing and customized fertilization to full-cycle crop management.

In terms of international collaboration, a China-Europe Smart Agriculture Cooperation Platform could be established to introduce European precision agriculture technologies and management experience, promoting the development of the "Internet+ Fertilizer Services" model.

China should also enhance collaboration with European agricultural cooperatives and agricultural machinery manufacturers to form a comprehensive industrial ecosystem that links fertilizers, machinery, and digital agricultural technologies.

By accelerating the application of digital tools and data-driven management in fertilizer production and agricultural operations, China can build a new international cooperation paradigm that simultaneously advances the modernization of both the fertilizer industry and agriculture.

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