Circular Economy Supporting Green Transition of Chemical Enterprises:

From key element utilization to industrial chain synergies[1]

Abstract: In response to growing resource and environmental pressures and the urgent need for carbon reduction, the chemical industry must identify viable pathways for green transformation. Fuhua Tongda Chemical Co., Ltd., has established a circular industrial chain centred on key elements, such as phosphorus, chlorine, and sodium. This approach has enhanced resource efficiency and promoted cleaner production. Phosphorus utilization efficiency has increased from 67.8% to 99.8%, while that of chlorine has risen from 87.7% to 92.4%. Meanwhile, some initiatives—such as the resource recovery from organic waste liquid, reinjection of dilute brine into salt mines, and comprehensive utilization of by-products—the company has significantly reduced both resource consumption and carbon emission intensity.

Keywords: Elemental economics; circular industrial chain; green transformation of the chemical industry

[1] Case provided by the Policy Research Group on "Promoting High-Quality Development through Circular Economy" of the China Council for International Cooperation on Environment and Development (CCICED)

I. Background

The chemical industry is a significant source of carbon emissions globally. As one of the world's largest producers and consumers of chemical products, China's chemical industry remains dominated by a development model characterized by high energy consumption and linear resource utilization, with sectoral emissions accounting for approximately 13% of the country's total carbon emissions[2]. Moreover, the industry also faces prominent issues of resource waste and by-product disposal. In response, China has designated the green and low-carbon development of the chemical industry, alongside resource recycling, as a priority area for national energy conservation and carbon reduction[3]. A specific target has been set: the petrochemical and chemical industry is to achieve a carbon reduction of 110 million tons by 2025[4]. Against this backdrop, how to simultaneously achieve green transformation and circular development has become a common challenge for the industry.

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[2] China National Petroleum & Chemical Planning Institute. Expert Opinions on Chemical Industry: Exploring the Pathways to Carbon Peaking and Carbon Neutrality in the Petrochemical and Chemical Industries [EB/OL]. [2022-08-25]. http://www.ciccc.com/Content/2022/08-25/1313567341.html

[3] State Council of the People's Republic of China. Action Plan for Carbon Peaking before 2030 [EB/OL]. [2021-10-26]. https://www.gov.cn/zhengce/content/2021-10/26/content_5644984.htm.

[4] State Council of the People's Republic of China. Notice on Issuing the 2024–2025 Action Plan for Energy Conservation and Carbon Reduction [EB/OL]. [2024-05-29]. https://www.gov.cn/zhengce/content/202405/content_6954322.htm

Fuhua Tongda Chemical Co., Ltd., (hereinafter referred to as Fuhua Chemical), a private chemical enterprise, has positioned circular economy design and ecological protection as key drivers of its competitiveness since 2004. The company introduced and developed the concept of “elemental economics,” and through continuous technological innovation, improved the resource utilization of by-products and the deep processing of intermediates. This has enabled the construction of an integrated industrial chain centred on key elements, such as phosphorus, chlorine, and sodium, thereby enhancing both product added value and resource efficiency. Meanwhile, through resource recycling design, Fuhua Chemical turns "waste" into "resources," effectively reducing the generation of waste.

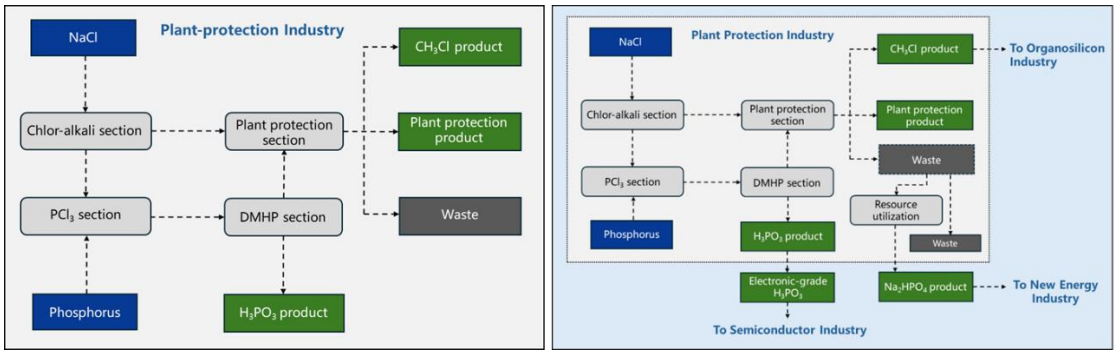

Figure 1. The development trajectory of Fuhua Chemical’s business segments.

II. Main Practices

(1) Extending the Industrial Chain Driven by Elemental Economics

To address the large volume of organic waste liquid generated during production, Fuhua Chemical has established a technological innovation incentive mechanism. Employees are encouraged to develop new approaches for by-product resource recovery and intermediate deep processing, guided by the objective of maximizing elemental value and minimizing waste generation. This has led to the application and deepening of the Elemental Economics concept, which has delivered notable results in enhancing the value-added utilization of key elements, such as phosphorus, chlorine, and sodium.

1. Phosphorus Utilization

Targeting higher conversion efficiency, reduced waste, and the elimination of phosphogypsum generation, the company has consistently pursued technological improvements and diversification in the production of phosphorus-based products. In addition, Fuhua Chemical actively explores resource recovery from organic phosphorus waste liquid. Through technological innovation, the company developed a thermal production process to convert organic phosphorus waste liquid into disodium hydrogen phosphate

dodecahydrate ($Na_2HPO_4 \cdot 12H_2O$), a high-value product for the new energy industry. This process not only eliminated phosphogypsum emissions—achieving zero organic-source phosphogypsum discharge since 2016—but also significantly reduced waste output and disposal costs. By 2024, the number of phosphorus-based products increased from two (in 2011) to four, with total revenue increasing 4.98 times compared to 2011. Meanwhile, phosphorus utilization improved substantially from 67.79% (Figure 2a) to 99.80% (Figure 2b).

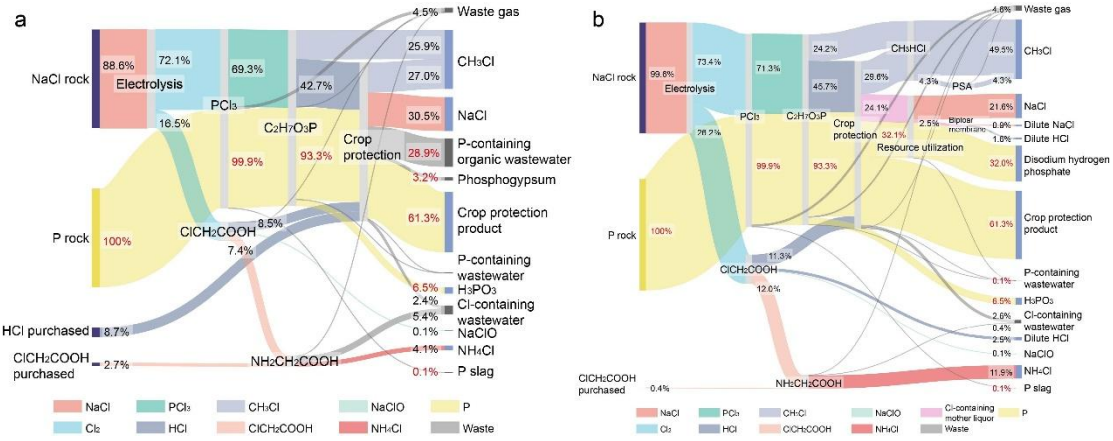

Figure 2. Elemental balance of phosphorus and chlorine in Fuhua Chemical. (a) Before recycling utilization; (b) After recycling utilization.

2. Chlorine Utilization

Chlorine is one of the key elements in crop protection product manufacturing. Before technological upgrades, a portion of chlorine was insufficiently utilized, mainly discharged as chlorine-containing wastewater or low-value by-products (Figure 2a), thereby increasing

treatment burdens and causing resource waste. In response, Fuhua Chemical implemented a bipolar membrane electrodialysis process to separate salts in organic phosphorus wastewater into dilute hydrochloric acid and brine. Consequently, chlorine contained in industrial salt decreased from about 30.51% before the upgrade to 21.58% of the total input. The company applied pressure swing adsorption (PSA) technology to enhance the recovery of volatile toxic methyl chloride (CH_3Cl), raising the recovery rate to 99% (Figure 2). Not only this method has reduced emissions of toxic gas, but it has also enhanced resource efficiency and product value while providing a more stable raw material supply for downstream industries. With CH_3Cl supplied to silicone producers in Southwest China, the associated economic benefits increased by about 7%. Overall, chlorine utilization efficiency increased from 87.66% (Figure 2a) to 92.41% (Figure 2b), achieving circular and higher-value use of chlorine resources along the industrial chain.

Figure 3. Chloromethane pressure swing adsorption unit and ball tank

Credit: Fuhua Tongda Chemical Co., Ltd.

3. Sodium Utilization

Although the organic wastewater resource recovery project did not significantly raise the overall utilization efficiency of sodium, which remained at about 96%, it successfully enabled high-value use of sodium. Specifically, sodium in low-value industrial salt was converted into high-value disodium hydrogen phosphate dodecahydrate products (Figure 3), resulting in an estimated 3,800-fold increase in economic value.

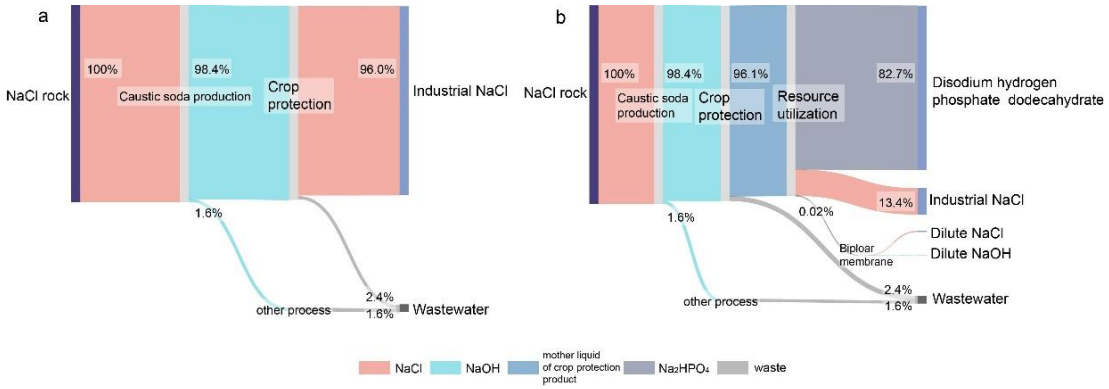

Figure 4. Sodium element balance before and after technical upgrades. (a) Before upgrade; (b) After upgrade.

(2) Synergistic Water and Carbon Savings Through Dilute Brine Recycling

In 2022, the Technical Upgrade Project on dilute brine recycling was put into official operation. By eliminating the triple-effect evaporation unit, dilute brine and condensate water from

the caustic soda evaporation process are directly reinjected into salt mines. This reduced both freshwater withdrawal and steam loss while also achieving significant energy savings. As a result of the upgrade, the freshwater consumption per ton of NaOH (100% equivalent) decreased from 5 tons (Figure 4a) to 1.04 tons (Figure 4b), with carbon emissions reduced by approximately 415.88 kg CO_2 eq.

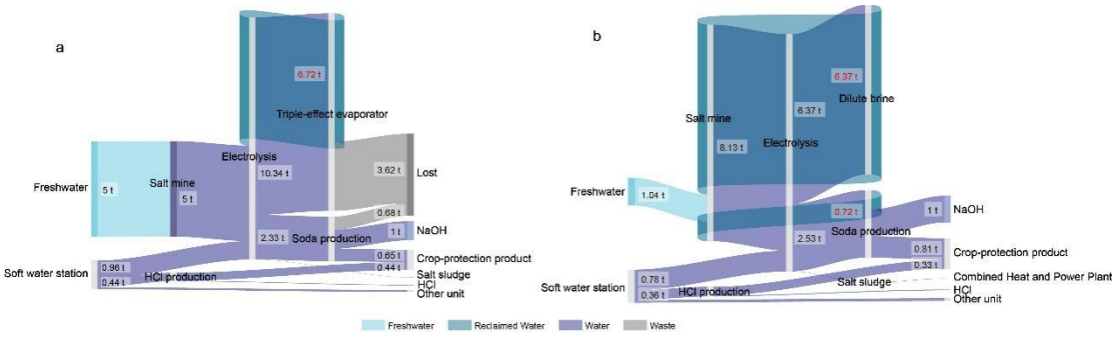

Figure 5. Water balance before and after the dilute brine recycling project implementation. (a) Before upgrade; (b) After upgrade.

Figure 6. Process for recycled use of fresh water

Credit: Fuhua Tongda Chemical Co., Ltd.

(3) Cross-Enterprise Resource Recovery of Brine Sludge

Brine sludge[5], a by-product of the chlor-alkali production process, was previously transported off-site together with wastewater sludge for centralized disposal before 2022, incurring annual costs of about RMB 4.98 million. A 2022 study found that brine sludge could substitute limestone for flue gas desulfurization of the on-site thermal power plant (Figure 4b). Since then, the company has reduced external limestone procurement by utilizing its own brine sludge, and has also accepted white mud sludge from a nearby paper mill at no cost for desulfurization. Through this cross-enterprise resource recycling chain, the company has avoided over 15,000 tons of CO_2 emissions annually, while saving approximately RMB 9 million in combined limestone procurement and sludge disposal costs.

Figure 7. Salt sludge waste

Credit: Fuhua Tongda Chemical Co., Ltd.

[5] Mainly composed of calcium carbonate and magnesium hydroxide.

III. Conclusions

Fuhua Chemical's practices show that optimizing production processes, extending industrial chains, and building resource recycling networks is an effective path for chemical enterprises to achieve green and low-carbon transformation.

First, optimizing production processes with key elements as the focus, and sustaining technological innovation to achieve the transformation from waste to resources. Focus on systematic and circular design for key elements, such as phosphorus, chlorine, and sodium; tap the resource recycling potential in the industrial chain; and promote the high-value utilization of by-products.

Second, extending internal industrial chains and fostering cross-enterprise resource circulation networks can drive coordinated regional progress in pollution reduction and carbon mitigation. Building an inter-enterprise resource recycling network and extending the enterprise's industrial chain not only effectively enhances the enterprise's level of coordinated pollution reduction and carbon reduction, but it also improves resource utilization efficiency within the region.

Third, integrated management of water, energy, and carbon represents an emerging trend for promoting economic development through resource circulation. On the basis of traditional water and energy conservation, chemical enterprises incorporate carbon emissions into their considerations. This is an inevitable trend against the backdrop of addressing climate change and lays the foundation for technological innovation and exploring more new growth opportunities.