

Vinnytsia National Technical University

Faculty of Construction, Civil and Environmental Engineering

Department of Ecology, Chemistry and Environmental Protection Technologies

MASTER THESIS

«Assessment of environmental pollution by chemical industry»

Student of 2Т3Д-21м group
specialty 183 “Environmental
protection technologies”

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«20» 06 2024

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«20» 06 2024

Accepted for defense
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«20» 06 2024

Vinnytsia – 2024

INDIVIDUAL TASK

Vinnitsia National Technical University

Faculty Construction, Civil and Environmental Engineering

Department Ecology, Chemistry and Environmental Protection Technologies

Level of study II (master)

Field of knowledge – 18 "Production and technologies"

Specialty – 183 "Environmental Protection Technologies"

Study program – "Environmental Protection Technologies"

APPROVED
Head of the Department ECEPT
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27.09. 2022

TASK

FOR MASTER THESIS

Li Li

1. Topic «Assessment of environmental pollution by chemical industry»
supervisor Vitalii Ishchenko
approved by the order of VNTU on « 14 » 09 2022 No. 103

2. Deadline for thesis submission – 10.00.2024

3. Input data: primary processing capacity of crude oil in China – 223.5 million tons per year

4. Content:

Introduction

1. Review of chemical industry in China
2. Environmental pollution caused by chemical industry
3. Assessment of environmental pollution by chemical industry
4. Environmental pollution prevention measures of coking plant
5. Economic effectiveness of environmental measures

Conclusions

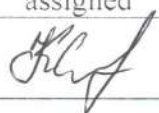

References

5. Illustrations

1. Ethylene capacity distribution
2. Main business income of enterprises above designated size in China's chemical industry from 2018 to 2020

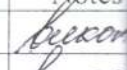
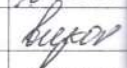
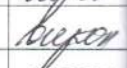
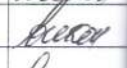
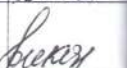

3. Flow diagram of sulfuric acid production from sulfur
4. Contact sulfuric acid process flow chart
5. Flow chart of cold drum section

6. Consultants

Chapter	Name and title of the consultant	Signature	
		task is assigned	task is accepted
5 Economical feasibility of environmental measures	Alla Kraevska		

7. Data of task acceptance "21" 09.10.22

CALENDAR PLAN

No.	Stages of master thesis	Deadline	Notes
1.	Technical task	30.09.2022	
2.	Literature review	08.10.2022	
3.	Review of chemical industry in China	15.10.2022	
4.	Environmental pollution caused by chemical industry	31.10.2022	
5.	Assessment of environmental pollution by chemical industry	15.11.2022	
6.	Environmental pollution prevention measures of coking plant	25.11.2022	
7.	Conclusions, literature list		

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ABSTRACT

UDC 504.054

Li Li «Assessment of environmental pollution by chemical industry». Master thesis, specialty 183 – “Environmental Protection Technologies”, study program – “Environmental Protection Technologies”. Vinnytsia: VNTU, 2024. 86 p.

English language. Bibliogr.: 16 references; 24 figures; 1 table.

Master thesis analyzes sources of environmental pollution from chemical industry. Chemical companies development in China are reviewed. Gaseous pollutants from technological processes in chemical industry are identified. Environmental pollution from coking process is assessed.

Keywords: environment, pollution, chemical industry, contaminant, emission.

SUPERVISOR'S REVIEW OF MASTER THESIS

Li Li «Assessment of environmental pollution by chemical industry»

The impact of chemical manufacturing on the environment is a complex issue that involves a range of environmental concerns, including air and water pollution, greenhouse gas emissions, soil contamination, and the depletion of natural resources. Chemical manufacturing is a significant contributor to these environmental issues, as the production and use of chemicals often involves the release of pollutants and other harmful substances into the environment. Therefore, study on environmental pollution by chemical industry is highly relevant.

Master thesis contains a thorough analysis of chemical industry processes, including those in China. Environmental pollution caused by chemical industry is analyzed (conditions, factors, etc.). Also, pollution from sulfuric acid production and coking process was assessed.

Besides, one should note that measures for environmental pollution prevention and control were prepared.

Master thesis are written at a high level and is of scientific and practical relevance. Master student Li Li has done all the tasks in time. Therefore, I recommend to accept the master thesis with "A" grade.

Scientific supervisor,

PhD, Head of the Department of Ecology,

Chemistry and Environmental Protection Technologies

 Vitalii ISHCENKO

MASTER THESIS REVIEWER'S REPORT

Student: Li Li

Thesis title: Assessment of environmental pollution by chemical industry

The aim of the thesis of Li Li was to analyze chemical industry in China and assess environmental impact of chemical companies.

The thesis meets the goal and results in a valuable theoretical study and successful practical implementation. The report itself is very well written, using an appropriate language and thesis structure, which makes the thesis easy to follow. Based on the state-of-the-art and state-of-the-practice investigation, it proposes measures for chemical industry pollution prevention.

The practical part is systematically discussed, including assessment of environmental pollution from chemical industry, as well as calculation of the financial profit of environmental measures and research on dust treatment.

The following shortcomings can be noted in the master thesis:

- the investigation of waste from chemical industry would be also valuable.

Overall the thesis is very interesting with very high practical value, and is hence in my opinion worth grade A.

Reviewer,
Ph.D., Associate Professor of the
Department of Ecology, chemistry and
environmental protection technologies



Taras TITOV

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INTRODUCTION

Relevance

The chemical industry plays an important role in the development of China's economy, indirectly affecting the speed of China's economic development. With the rapid development of the chemical industry, its role and status in the national economy is increasing, it plays an important role in promoting industrial and agricultural production, improving people's quality of life and consolidating national defense [1].

But in the development of chemical industry, environmental protection has become a very important topic. From the perspective of chemical environmental pollution, the scope of pollution by chemical enterprises is also very extensive, involving water bodies, soil, atmosphere, and other environments. At the same time, there will be a variety of forms, such as solid waste, noise, photothermal pollution and so on [2]. Due to the high energy consumption and high pollution of chemical industry, the pollution of the environment is relatively large, and with the implementation of environmental protection policies in China's provinces and cities, the environmental governance effect is better, but there are still various problems. Some large chemical companies choose to develop in desert areas to avoid urban settlements, but this often makes it more difficult to carry out environmental protection work, and if the environment causes pollution, more money to clean up the environment [3].

Based on this, this article around the chemical industry on the environmental pollution of related analysis. This work briefly introduces the present situation of environmental pollution caused by chemical industry in China, analyzes the prevention and control measures of environmental pollution with examples, and emphasizes the importance of chemical industry to environmental protection.

Connection of master thesis with scientific programs, plans, topics. The master thesis was prepared according to research area of the Department of Ecology,

Chemistry and Environmental Protection Technologies in Vinnytsia National Technical University.

The goal of master thesis is to analyze chemical industry in China and assess environmental impact of chemical companies.

Tasks of master thesis:

1. Review of chemical industry in China.
2. Assessment of environmental pollution caused by chemical industry.
3. Analyze pollutants emitted from chemical companies.
4. Prepare environmental pollution prevention measures.

Object of the research – environmental impact of chemical industry.

Subject of the research – parameters of environmental pollution from chemical industry.

Novelty of the results. Further development of scientific substantiation of environmental protection measures in chemical industry. This helps to reduce the environmental impact of chemical companies.

Practical value includes preparing the recommendations on reducing the negative impact of chemical industry on the environment.

Approbation of research results. Results of the master thesis were presented at LII Conference of Vinnytsia National Technical University.

Publications. The materials of this master thesis were published in:

Li Li, V. Ishchenko. Assessment of environmental pollution by chemical industry // Proceedings of LII Conference of Vinnytsia National Technical University, Vinnytsia, 21-23.06.2023. – 2023.

1 REVIEW OF CHEMICAL INDUSTRY IN CHINA

1.1 Chemical concept

In modern Chinese, chemical industry, chemical engineering and chemical technology are all referred to as chemical industry for short. They appeared in different historical periods with different meanings, but they are closely related and infiltrate each other [4]. In people's minds, the word "chemical engineering" has traditionally become a synonym for a general category of knowledge and cause. Its significance in the national economy and engineering technology has aroused widespread interest, attracted thousands of people, and contributed to it.

Broadly speaking, any chemical method used to change the composition or structure of substances or synthesize new substances belongs to chemical production technology, that is, chemical process. The products obtained are called chemicals or chemical products. In the early days, manual workshops were used to produce chemicals, which later evolved into factories and gradually formed a specific production sector, namely the chemical industry. With the development of productivity, some production departments, such as metallurgy, oil refining, paper making, leather making, have been divided from the chemical industry as independent production departments. After the large-scale petroleum refining industry and petrochemical industry developed vigorously, based on chemistry, physics and mathematics and combined with other engineering technologies, chemical engineering, a discipline that studies the common laws of industrial production process and solves many engineering and technical problems arising from the enlargement and large-scale production, was born and developed rapidly [5]. It has raised the production of chemical industry to a new level, and entered a new stage of theory and prediction from an empirical or semi empirical state. It has enabled the chemical industry to add a large amount of material wealth to mankind with its creativity in larger scale production, and accelerated the process of human social development.

1.2 Brief history of chemical industry

The chemical industry has a long history. It can be traced back to more than 2000 BC, and the earliest chemical processes include pottery making, smelting, brewing, bleaching and dyeing, leather kneading, etc. With natural resources and simple appliances, we can judge the chemical process by experience and get some daily necessities, which are small in scale, simple in technology and workshop production.

In the middle of the 18th century, the textile industry realized mechanization, which made the traditional bleaching and dyeing processes become the main contradiction. The sulfuric acid production method was magnified to become an industrial production device. The lead chamber method emerged under this background. The textile industry needs alkali, and so do glass, paper making, soap, gunpowder and other industries. Thus, the Lubrand process, which uses salt and sulfuric acid as raw materials to produce soda ash, emerged [8].

In the middle of the 19th century, Solvay's method of making alkali from ammonia alkali appeared. Subsequently, electrolytic caustic soda was introduced, providing more caustic soda than soda ash for papermaking, dye, explosives and other industries. Since then, the inorganic chemical industry, which is mainly composed of inorganic acids and bases, has been continuously developed. At the beginning of the 20th century, the advent of synthetic ammonia technology marked a new stage in the development of chemical industry. Modern organic chemical industry started from coal processing. In the 19th century, the development of the iron and steel industry promoted the coking industry. Aromatic compounds were extracted from the by-product coal tar to produce dyes, medicines, spices, explosives and other products [9].

1.3 Chemical industry categories

The category of chemical industry is complex, including industrial departments of multiple industries. Chemical industry includes petroleum refining and cracking

industry, coal coking and coal tar industry, basic organic synthesis industry, synthetic polymer industry, chlor alkali industry, acid making industry, fertilizer industry and fine chemical industry.

Chemical products can be divided into 25 categories. Class 1: ammonia, calcium carbide, sulfuric acid, chemical fertilizer; Category 2: alkali industrial products; Category 3: inorganic chemical products; Category 4: High pressure gas; Category 5: gunpowder; Category 6: aromatic and tar products; Category 7: Organic chemical products; Category 8: Petrochemical and petroleum refining products; Class 9: Plastics; Class 10: Plasticizers and stabilizers; Class 11: Synthetic rubber; Class 12: rubber additives and carbon black; Category 13: Artificial fibres and synthetic fibres; Category 14: pharmaceutical and dye intermediates; Class 15: Synthetic dyes; Category 16: Pigments (inorganic and organic); Class 17: grease and oil agent; Class 18: Coatings and adhesives; Class 19: Spices and food additives; Class 20: Household chemical products; Class 21: Catalysts; Category 22: Photographic drugs and discharge agents; Category 23: Pesticides; Category 24: Natural drugs and natural products; Class 25: Various medicaments for different purposes.

Chemical products are divided into two categories according to the intensity of production technology, the size of added value and profit, the type of varieties and output, the speed of renewal and the scope of application. The first category is general chemicals, which use coal, oil, natural gas, agricultural and sideline products and other natural resources as raw materials to obtain large tonnage products through simple and preliminary chemical processing, with low added value and profit, but wide application scope. Such as basic organic chemical raw materials such as ethylene, acetylene, methanol, ethanol and acetic acid, benzene, toluene, xylene, naphthalene and anthracene, and basic inorganic chemical products such as tri acid, bi alkali, synthetic ammonia and fertilizer. The other category is fine chemicals, or special chemicals. With general chemicals as raw materials, through deep processing, we can obtain small batches, multiple varieties and high purity chemical products with high technology intensity, large added value and profits, and some special properties. Such as pesticides, dyes, coatings, pigments, reagents and high-purity

materials, information chemicals, adhesives, catalysts and various auxiliaries, daily chemicals, functional polymer materials, etc.

1.4 Characteristics of chemical industry

1.4.1 Chemical industry as a unique and irreplaceable industrial sector

The chemical industry is dominated by chemical processing, which is an industry to create new substances. It covers a wide range of areas and has extremely strong permeability. It is almost impossible to find any industry department that has nothing to do with it.

1.4.2 A wide variety of chemical products and complex processes

Variety leads to diversity of production processes. The same raw material can be used to produce multiple products, and the same product can be produced with multiple raw materials, which is technically difficult. Reasonable resource allocation and raw material route, proper selection and combination of process technology, and optimization of product structure and industrial structure are the problems to be solved in chemical industry.

1.4.3 Chemical industry as a device industry with economies of scale

Most of the main equipment for chemical production are towers, tanks, tanks, vessels and pipes. The production capacity is proportional to the volume (i.e. the cubic of its linear dimension), and the manufacturing cost is proportional to the surface area of the container (i.e. the quadratic of its linear dimension). The investment cost of the plant is in direct proportion to the $2/3$ power of its production capacity (the so-called 0.6 power rule), that is, the larger the plant size is, the less investment per unit production capacity is, and the lower the cost is. The large-scale chemical industry can also greatly improve labor productivity, which is conducive to the development of by-products and the comprehensive utilization of energy sources.

1.4.4 Chemical industry as a capital intensive and technology intensive industrial sector

The process complexity and the large-scale device determine this feature. For example, a fertilizer plant with an annual output value of 300000 tons of synthetic ammonia and 450000 tons of urea has an investment of 4-5 billion yuan. For example, an ethylene plant with an annual output of 300000 tons needs to invest 6 billion to 8 billion yuan. The chemical technology is updated rapidly, and the service life of chemical plant equipment generally does not exceed 15 years. Technology intensive is shown in the long process flow, from raw materials to products, involving many fields such as chemistry, machinery, electronics, instruments, etc., with high knowledge intensity and strong technology comprehensiveness. For example, the technology intensity index of the machinery industry is 100, and that of the chemical industry is 2480.

The capital and technology intensity of the chemical industry is also reflected in the large investment in chemical research and development. Due to the accelerated development of industrial technology, the rapid upgrading of chemical products and the adjustment of the industrial structure of the chemical industry, R&D expenses account for 1/6 of the total industrial expenditure, second only to the electronics and communications industries. Taking new medicines and pesticides as an example, the success rate of development is one in ten thousand. It takes about 10 years in the United States to complete the development of a new variety, and costs 60 million dollars.

1.4.5 Chemical industry as a major energy consumer

The chemical industry takes coal, oil, natural gas and other energies as raw materials, as well as power and fuel for production. About 40% of the energy is used as raw materials for production and 60% as power and fuel. Raw material consumption accounts for 60% - 70% of the product cost.

1.4.6 Chemical industry as an industrial sector prone to pollution and heavy pollution

Most chemical products are flammable, explosive and toxic. In the process of production, storage, transportation and use, if leakage occurs, it will seriously endanger human health and pollute the environment. During production, waste gas, waste water and solid waste will be generated, which will bring harm to the atmosphere, water and soil. In 1999, dioxin pollution in Belgium and other countries led to high concentration of dioxin in livestock and poultry products and dairy products. The "three wastes" generated shall be recycled or comprehensively utilized in the production process; The "three wastes" finally discharged into the environment must be treated harmlessly.

Chemical process and operation are indispensable for pollution control and waste disposal and resource utilization.

1.5 Development status of China's chemical industry

After experiencing the impact of the financial crisis once in a century in 2008, the world economy gradually stabilized and recovered in 2009 as governments' stimulus policies became more effective. China's economy is the first to start. Under the strong stimulus policy and inventory adjustment cycle, China's macro-economy successfully walked out of the deep downturn since the third quarter of 2008, Realize "V "Reversal, the real economy rebounded more than expected. In 2009, China's petrochemical industry also recovered rapidly, the operating rate rebounded, the output value increased steadily, and the enterprise losses decreased. According to statistics, from January to November 2009, China's chemical industry's cumulative output value was 3531.57 billion yuan, a year-on-year increase of 7.4% compared with the cumulative output value of 3287.23 billion yuan in the same period last year. As of November 2009, China's chemical industry had realized a cumulative product sales revenue of 3458.8 billion yuan, a year-on-year increase 6.5%; The assets totaled 3248.6 billion yuan, up 12.9% year on year; The total profit was 171.8 billion yuan, up 13.5% year on year. The number of enterprises was 31966, and the number of loss

making enterprises was 4984, up 11.2% year on year. The loss of loss making enterprises was 34.047 billion yuan, down 16% year on year. The average number of employees was 4911400, up 3% over the same period of last year. The added value of the chemical industry increased by 15.1% year on year, 4.4 percentage points faster. Among the main products, the output of caustic soda was 17.63 million tons, up 6.8%. The output of soda ash was 18.37 million tons, up 7.2%. The output of chemical fertilizer was 60.51 million tons, up 14.3%; Among them, the output of nitrogen fertilizer, phosphorus fertilizer and potassium fertilizer increased by 12.8%, 18.4% and 18.5% respectively. The output of pesticides was 2.04 million tons, up 12%. The output of rubber tire casings was 597.34 million, up 15.6%. Calcium carbide output increased by 13.74 million tons (4.7%).

The following aspects are analyzed from petrochemical industry, coal chemical industry, natural gas liquefied gas chemical industry and saline alkali chemical industry.

1.5.1 Development status of petrochemical industry

After more than half a century of development, China's petrochemical industry has undergone tremendous changes and become an important force supporting the sustainable and healthy development of the national economy. By the end of 2009, China's primary crude oil processing capacity had reached 477 million tons/year, ranking second in the world. Sinopec and PetroChina, the two major state-owned oil companies, respectively ranked 9th and 13th among the world's top 500 enterprises in 2009. (In 2009, imported crude oil exceeded 200 million tons and reached 205 million tons.) The past decade has witnessed the largest and fastest growth in China's refining capacity, with an increase of 72.8% and an average annual growth rate of 6.3%. In 2009, Sinopec has become the world's third largest oil refiner after ExxonMobil and Shell, and PetroChina has also become the world's eighth largest oil refiner. Although the number of refineries under the jurisdiction of the two groups only accounts for 27.2% of the national total, the crude oil processing capacity has

accounted for 76.8% of the national total, leading the domestic market. CNOOC and local refineries also saw significant growth after 2008.

China has formed 1710 millions ton oil refining bases, and the primary processing capacity of refineries with a capacity of more than 10 million tons/year is close to half of the total processing capacity of the country. Among the 17 bases, the refining capacity of Dalian Petrochemical and Zhenhai Refining and Petrochemical reached 20 million tons/year. Another batch of ten million ton refining bases are under construction or planning.

Sinopec's refining capacity has grown rapidly in the past decade. The primary processing capacity of crude oil increased from 143 million tons in 2000 to 163.5 million tons in 2005, and reached 223.5 million tons in 2009, accounting for 46.9% of the national production capacity. The average scale of the refinery also increased from 4.32 million tons/year to 5.7 million tons/year. By the end of 2009, the company had 11 refineries with a capacity of more than 10 million tons/year, of which Zhenhai Refining and Petrochemical had a refining capacity of more than 20 million tons/year.

PetroChina's refining capacity has also grown rapidly in the past decade. From 2000 to 2009, China's crude oil processing capacity increased from 119 million tons in 2000 to 119.4 million tons in 2005, reaching 142.5 million tons in 2009, accounting for 29.9% of the national production capacity. The average scale of the refinery increased from 3.52 million tons/year to 5.4 million tons/year. By the end of 2009, the company had five refineries with a scale of more than 10 million tons/year, including Dalian Petrochemical with a refining scale of more than 20 million tons/year.

In May 2009, the 12 million ton/year Huizhou Refinery built by CNOOC was put into operation, marking CNOOC's formal large-scale entry into the refining industry. The refining capacity of CNOOC grew rapidly, from 7.5 million tons in 2005 to 19.5 million tons in 2009, accounting for 4.1% of the national capacity.

According to the situation of local refineries, by the end of 2008, including Shaanxi Yanchang Petroleum Group, which was originally a CNPC trusteeship

enterprise and was independent in September 2005 (its total capacity at the end of 2008 was 14 million tons), the total refining capacity of local refineries nationwide (hereinafter referred to as "local refineries") had reached 88.05 million tons/year. Except Yanchang, these refineries are mainly distributed in Shandong (37), Liaoning (15) and Guangdong (14). The main products include gasoline, diesel, lubricating oil, solvent oil, fuel oil, asphalt, ethylene, propylene, aromatics, liquefied petroleum gas, MTBE, etc. In 2009, except for the extension, the primary processing capacity of the top ten refineries reached 38.7 million tons, accounting for 42.7% of the total domestic refining capacity. However, the actual processing capacity of most refineries after the top ten refineries was less than 1 million tons/year. In terms of strength, Shandong's local refining ranks first in the country.

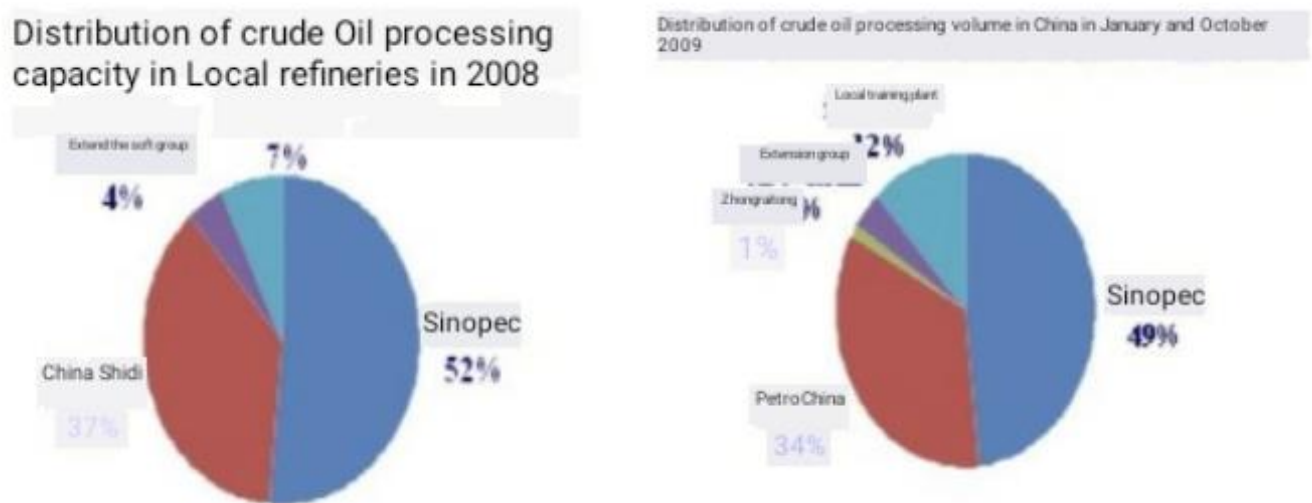


Figure 1.1 – Analysis of domestic refined oil market processing volume

The oil refining business of foreign companies in China has also made significant progress. Following Total's shareholding in Dalian Western Pacific in the mid-1990s, the Fujian Refining and Chemical Integration Project, which was built by ExxonMobil and Saudi Aramco, was officially put into operation in 2009. The equity refining capacity of foreign capital in China reached 10.5 million tons/year, accounting for 2.2% of China's total refining capacity. In addition, Sino Russian Tianjin Dongfang Petrochemical Refining Project, Venezuela PetroChina Joint Venture Guangdong Jieyang Refining Project, Qatar PetroChina Joint Venture

Project, Kuwait Sinopec Guangdong Zhanjiang Donghai Island Refining Project and other Sino foreign joint refining projects are also being promoted. China's oil refining industry presents a diversified market competition pattern dominated by two major groups.

China's oil refining layout follows the principle of being close to resources, markets and coastal and riverside construction, forming a cascade distribution with the east as the main part and the middle and west as the auxiliary part. The crude oil processing capacity is mainly concentrated in East China, Northeast China and South China, which respectively account for 32%, 21% and 15% of the national refining capacity. Liaoning is the province with the largest refining capacity in China, with a crude oil processing capacity of 76 million tons/year, followed by Shandong and Guangdong.

Limited by the distribution of domestic oil resources and the 1998 domestic petrochemical restructuring plan, PetroChina's refineries are mainly located in the northeast and northwest regions, but these regions are not the main consumption areas of product oil. In 2008, PetroChina's refined oil products transferred from northeast and northwest refineries to southeast coastal and southwest regions accounted for more than 50% of its total output. Sinopec refineries are mainly distributed in East China and Central South China, where oil consumption is highly concentrated, and the refined oil produced can be basically digested in their traditional sales regions. Local refining is mainly distributed in Shandong and Shaanxi. Except that some of the refined oil resources are sold by PetroChina and Sinopec, others are sold by themselves. Although PetroChina has focused on the strategic distribution of Guangdong, East China and Guangxi, and CNOOC has accelerated its construction, the overall main flow direction of China's oil products is roughly the pattern of "transporting oil from the north to the south" and "transferring oil from the west to the east".

According to the medium - and long-term oil refining plan released by the National Development and Reform Commission, by 2010, China will have formed about 20 10 million ton crude oil processing bases, with the total processing capacity

accounting for 65% of the total national capacity. The average size of enterprises will reach 5.7 million tons/year, and the overall level will be greatly improved. According to the newly issued national petrochemical revitalization plan, the ten new refining bases in China in the future will be: Ningbo, Shanghai, Nanjing and Dalian, which are large refining bases with a scale of more than 30 million tons per year, and Maoming, Guangzhou, Huizhou, Quanzhou, Tianjin and Caofeidian, which are large refining bases with a scale of more than 20 million tons per year.

At the end of 2007, Sinopec Zhenhai Refining and Petrochemical Co., Ltd. had a refining capacity of 20 million tons per year. In 2008, after the reconstruction and expansion of PetroChina Dalian Petrochemical Co., Ltd., the refining capacity reached 20.5 million tons per year, ranking among world-class refineries with a capacity of more than 20 million tons per year.

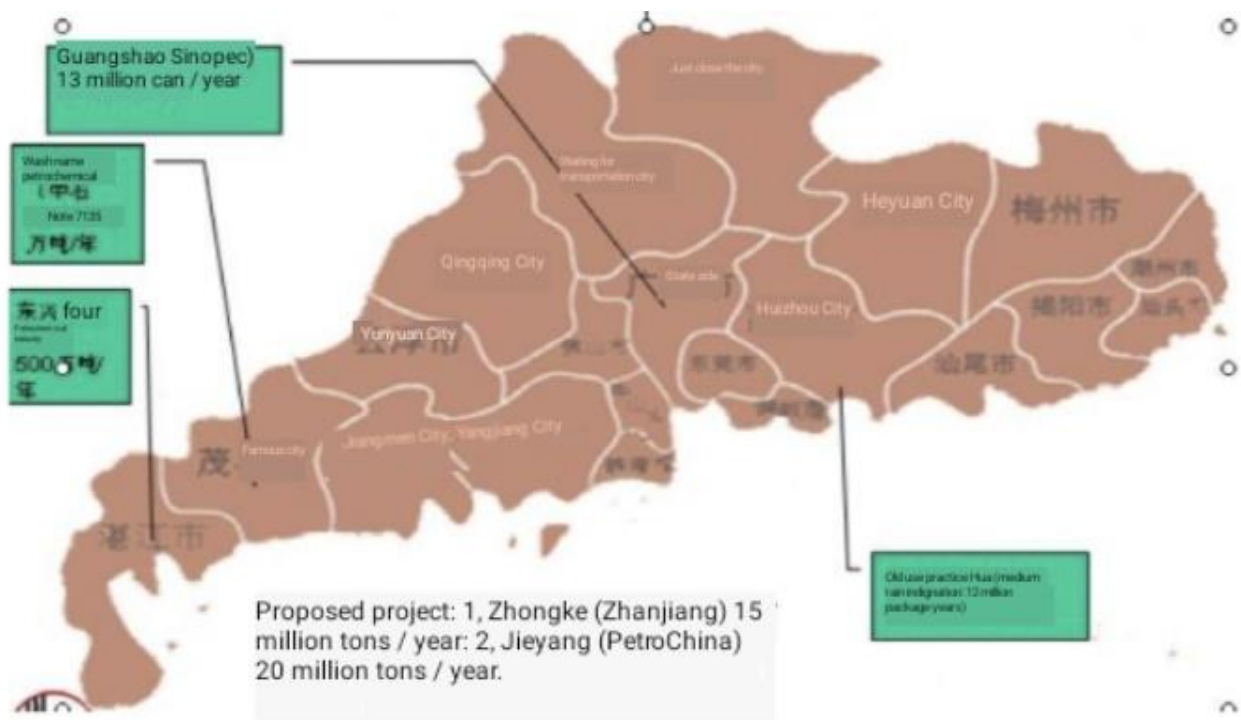


Figure 1.2 – Analysis of domestic refined oil market processing capacity Analysis of Guangdong's main refining capacity

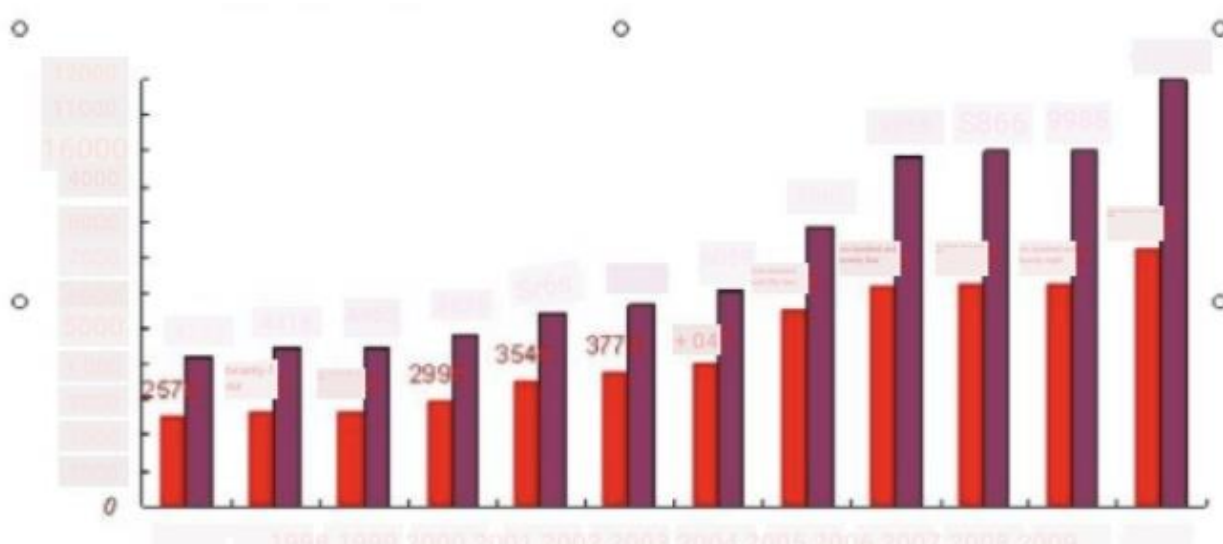


Figure 1.3 – China's ethylene production capacity

By the end of 2009, Sinopec had 12 ethylene production enterprises (including SECCO, Yangba and Fuling), with a total ethylene production capacity of 7.285 million tons/year (9.28 million tons/year in 2010), accounting for 61% of the total ethylene production capacity in mainland China of 11.975 million tons/year. The capacity of Maoming and Shanghai SECCO is 1 million tons/year and 1.09 million tons/year respectively, of which the ethylene output of Maoming reaches 1.06 million tons/year.

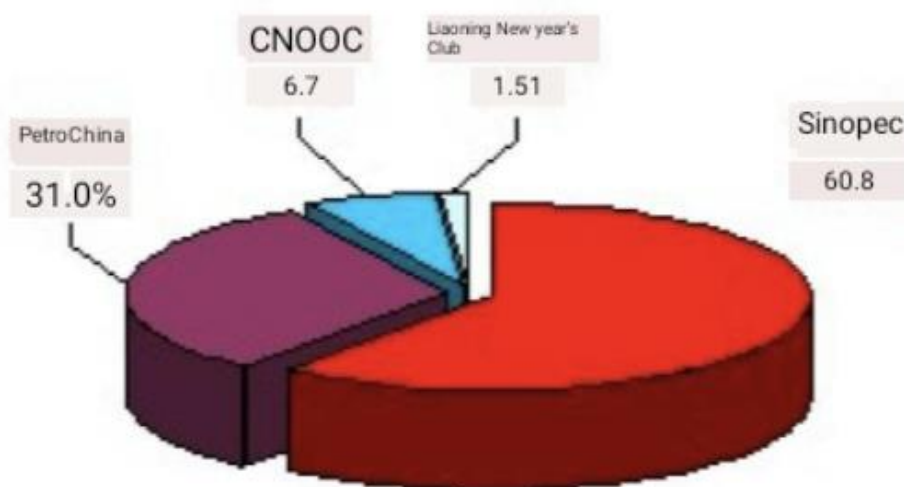


Figure 1.4 – Ethylene capacity distribution

1.5.2 Current situation of coal chemical industry

In the years before the global financial crisis in 2008, driven by the steady growth of the global economy, the global demand for primary energy showed a steady growth trend. From 2002 to 2008, the global primary energy demand grew by 3.0% annually, oil and natural gas by 1.4% and 3.0% respectively, and coal by 5.4% annually (see Figure 1). By the end of 2008, the global coal cost had become the fastest growing primary energy consumption for six consecutive years. The growth of coal demand has become the main driving force to promote the growth of primary energy demand. Compared with oil and natural gas resources, the world is rich in coal resources. According to statistics, the proven reserves of global crude oil in 2008 were about 170.8 billion tons, and the reserve production ratio was 42 years; The proven reserves of natural gas are about 185.02 trillion cubic meters, and the reserve production ratio is 60 years; The proven reserves of coal are about 826 billion tons, and the reserve production ratio is 122 years. According to the statistics of Division B, in the global primary energy consumption structure in 2008, oil accounted for 34.6%, coal accounted for 29.1%, natural gas accounted for 24.0%, and nuclear energy, hydropower, etc. accounted for about 12.3%. It can be seen that relatively rich coal resources provide resource conditions for the development of coal chemical industry. As far as China is concerned, the resource characteristics of oil shortage, gas shortage and coal enrichment are very significant. According to the national oil, gas and mineral reserves report in 2009, by the end of 2008, China's remaining economically recoverable crude oil reserves were about 2.090 billion tons, with a reserve production ratio of 11.8 years; The remaining economic recoverable reserves of natural gas are about 2651.1 billion cubic meters, with a reserve production ratio of 34 years; The coal reserves are about 114.5 billion tons, and the reserve production ratio is about 41 years.

In recent years, with the steady and rapid development of the national economy, China's energy consumption has maintained a rapid growth trend, especially the rapid growth of transportation fuels and the substantial growth of the demand for petrochemical products, making the contradiction between oil and gas

resources more prominent. From 2003 to 2009, China's primary energy consumption grew by 17.3% annually. In 2009, the primary energy consumption reached 3 billion tons of standard coal. Among them, coal accounts for about 70%, oil and natural gas accounts for about 20%, and nuclear power, wind power and hydropower account for about 10% (see Fig. 1.2). During this period, China's oil consumption grew at an average annual rate of 7.1%, while the output of crude oil grew at an average annual rate of only 1.8%. China's dependence on foreign crude oil has exceeded 50%. Developing alternative resources and reducing dependence on petroleum resources have objectively created opportunities for the development of China's coal chemical industry. The coal chemical industry in foreign countries started early. Since the 1940s, Germany, the United States, Japan and other advanced countries have successively built experimental devices and developed relevant process technologies in the fields of coal liquefaction, coal to olefin, coal to dimethyl ether, coal to ethylene glycol, and coal to natural gas. However, due to the impact of resources, technology, environment, oil prices, investment and other factors, few of them are truly industrialized. At present, only Sasol's coal indirect chemical plant in South Africa and Great Plains coal to natural gas plant in the United States are available. China's coal chemical industry has achieved rapid development in recent years.

The traditional coal chemical industry generally shows overcapacity. As early as the 1940s, China also began to have a traditional coal chemical industry, but the scale was small and the products were single. The products mainly included coke, synthetic ammonia, calcium carbide and methanol. In recent years, with the rapid development of China's local economy and the rise of resource rich regions, the capacity of traditional coal chemical industry and some products has grown rapidly. From the perspective of supply and demand of products, China's traditional coal chemical industry is generally characterized by overcapacity. In 2009, the consumption of coke in China was about 340 million tons, and the production capacity was about 380 million tons/year. The average operating rate of the unit was about 91%; The calcium carbide consumption is about 15 million tons, the total production capacity is about 22 million tons/year, and the average operating rate of

the device is less than 70%; The methanol consumption is about 16.6 million tons, the total production capacity is up to about 30 million tons/year, and the average operating rate of the unit is only 37.4%. It is worth noting that 70% of China's methanol production takes coal as raw material. As an important intermediate of new coal chemical industry, methanol has been favored by many investors in recent years. According to statistics, the capacity of methanol projects under construction and planned to be built at present is about 25 million tons/year. It is estimated that by 2012, the total capacity of methanol in China will reach more than 50 million tons/year. At that time, the most optimistic expectation is that the demand for methanol will only increase to about 31 million tons, and the overcapacity will further intensify.

New coal chemical industry shows a rapid development momentum. In recent years, driven by high oil prices, China's new coal chemical secondary industry has achieved rapid development, and has made breakthroughs in coal liquefaction synthetic oil, coal based methanol to olefins, coal based methanol to dimethyl ether, and coal to ethylene glycol.

1.5.3 Current situation of China's chemical industry

The number of enterprises above designated size decreases. In recent years, the petrochemical industry has been strengthened in supervision. In addition to the impact of the COVID-19, the number of enterprises above designated size in China's chemical industry will continue to decline in 2020. According to the 2020 Economic Operation Report of China's Petroleum and Chemical Industry released by the China Petroleum and Chemical Industry Federation in March 2021, by the end of 2020, there were 22973 enterprises above designated size in the chemical industry, a decrease of 362 compared with 2019.

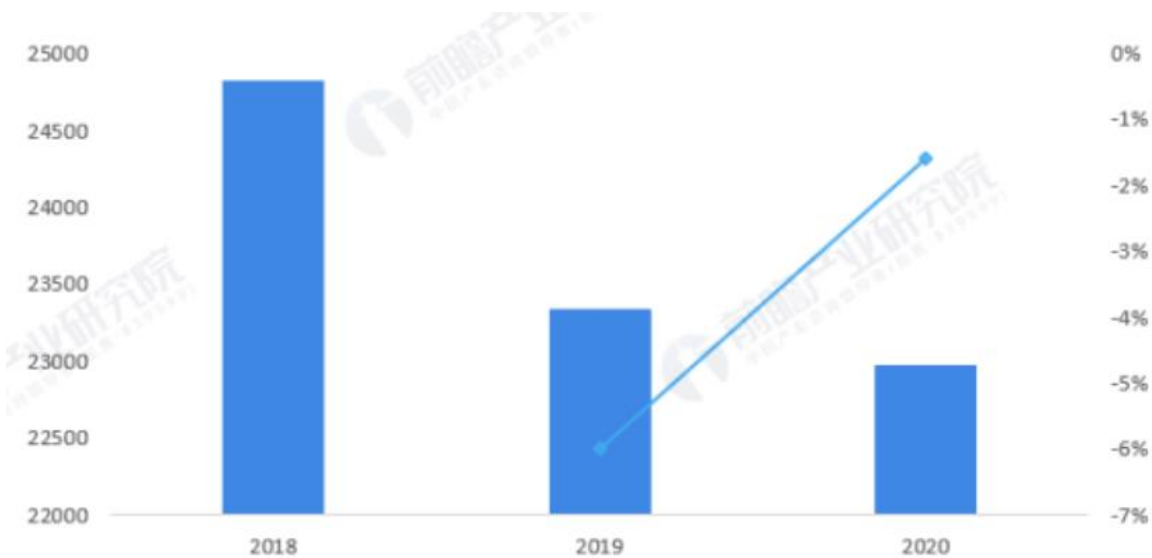


Figure 1.5 – Number of enterprises above designated size in China's chemical industry from 2018 to 2020

Counter trend growth of chemical industry benefits. The benefits of the chemical industry have been significantly improved. In 2020, enterprises above designated size in the chemical industry will achieve an accumulated operating revenue of 6.7 trillion yuan, up 12.7% year on year, and a decline of 19.8% in 2019, growing against the trend in the epidemic.

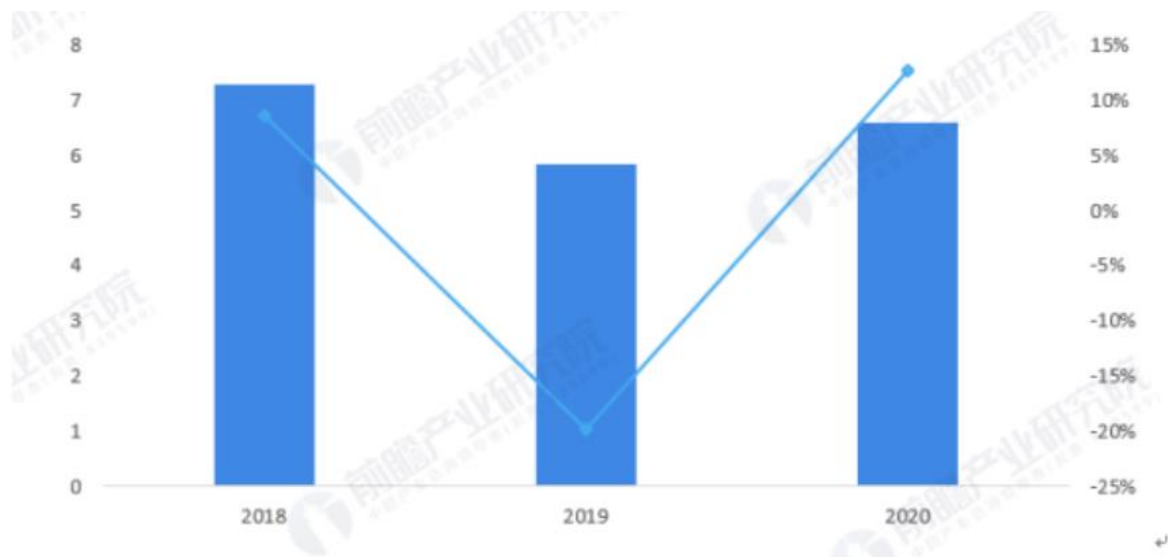


Figure 1.6 – Main business income of enterprises above designated size in China's chemical industry from 2018 to 2020

Increase in profits of enterprises above designated size in the chemical industry. Affected by the rise in the price of bulk commodities, the profits of enterprises above designated size in the chemical industry increased significantly. In 2020, the total accumulated profits for the whole year were 427.92 billion yuan, a year-on-year increase of 25.4%, and a decrease of 13.9% in 2019.

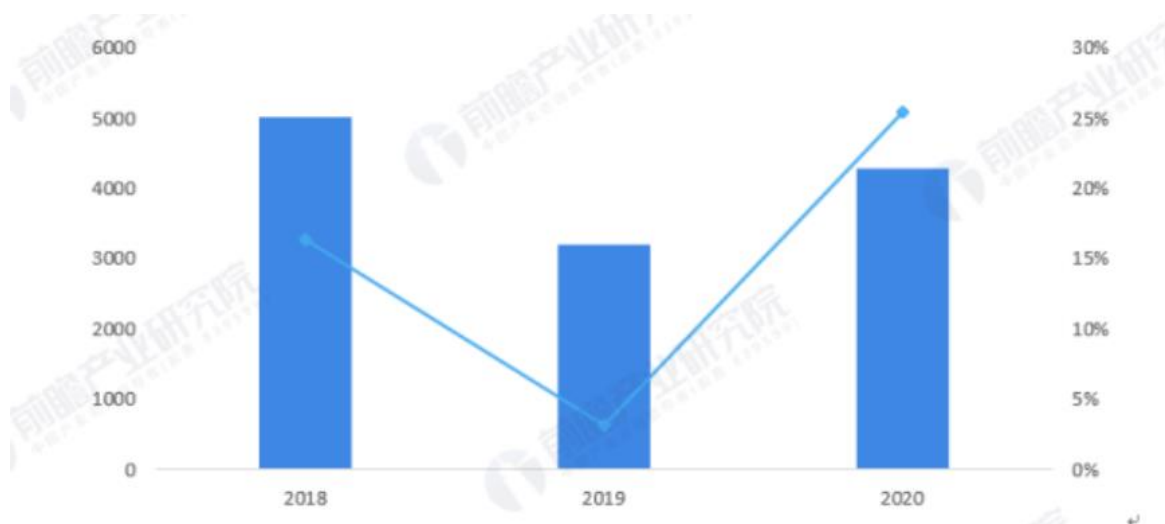


Figure 1.7 – Total profit of enterprises above designated size in China's chemical industry from 2018 to 2020

Overall increase in the output of key chemicals. In 2020, except for a slight decrease in the output of fertilizer and sulfuric acid, other major chemical products have increased, showing an overall upward trend. The national ethylene output is 21.6 million tons, an increase of 5.2% over 2019; The output of pure benzene was 10.42 million tons, up 8.6%; Methanol output was 49.84 million tons, up 4.7%; The output of sulfuric acid was 92.382 million tons, down 1.3%; The output of caustic soda was 36.739 million tons, up 6.2%; The total output of pure chemical fertilizer was 54.96 million tons, a decrease of 4.1% over 2019.

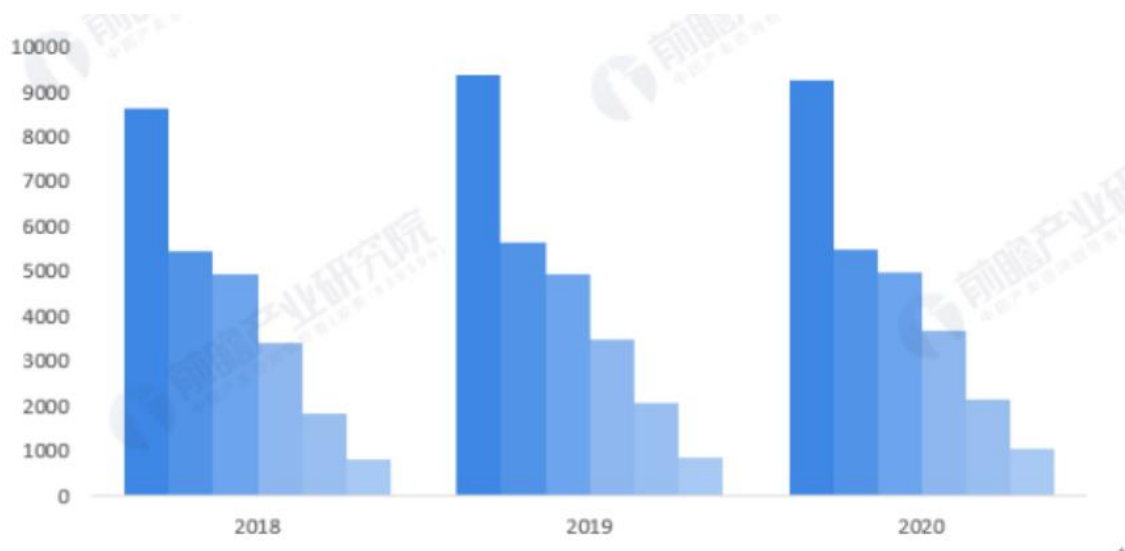


Figure 1.8 – Output of major chemical products of enterprises above designated size in China's chemical industry from 2018 to 2020

Increase in revenue and profit margin of chemical industry. In 2020, the operating income profit margin of enterprises above designated size in the chemical industry will be 6.51%, up 1.51 percentage points year on year. The benefits of the chemical industry increased significantly.

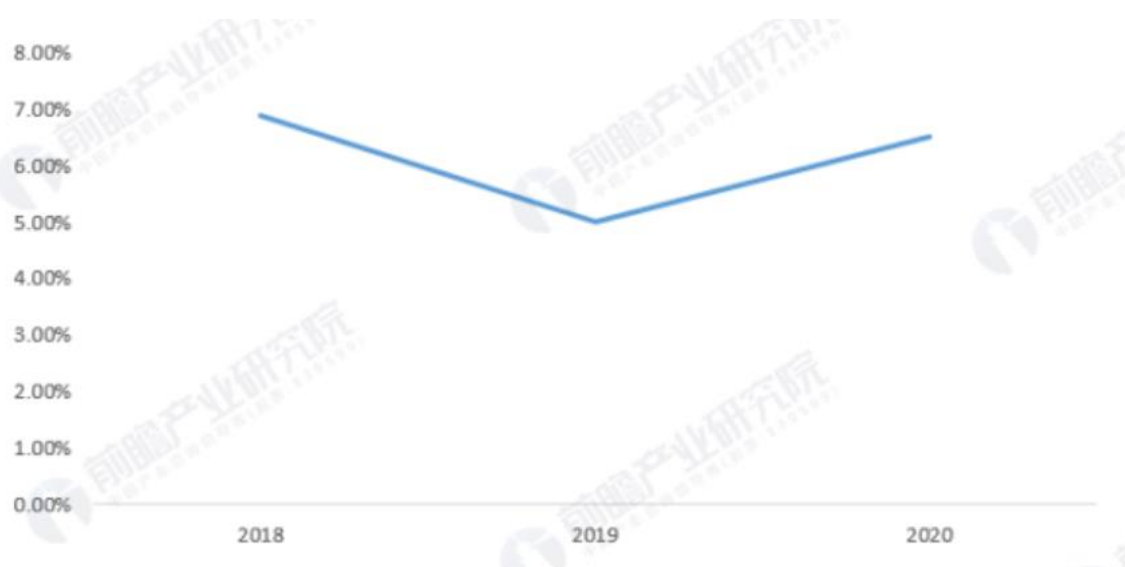


Figure 1.9 – Utilization rate of main business income of enterprises above designated size in China's chemical industry from 2018 to 2020

2 ENVIRONMENTAL POLLUTION CAUSED BY CHEMICAL INDUSTRY

2.1 Introduction

Chemical pollution refers to environmental pollution caused by chemical substances (chemicals) entering the environment. It refers to environmental pollution caused by chemical pollutants. These chemicals include organic and inorganic substances, most of which are products of human activities or artificial manufacture, as well as secondary pollutants.

10 million kinds of chemical substances have been synthesized in the world, and about 1000 kinds are newly registered and put on the market every year. These chemicals have played a huge role in promoting progress, improving productivity, eliminating pests, reducing diseases, and facilitating people's lives, but they inevitably enter the environment and cause pollution in the process of production, transportation, use, and abandonment. The hazards caused by environmental pollution are manifold, among which the environmental pollution to food is directly related to human health. The potential food borne hazards caused by the chronic long-term intake of chemical and organic pollutants have become the focus of attention, including pesticide residues, veterinary drug residues, mycotoxins, some carcinogens and mutagens (such as nitrosamines) formed during food processing, and industrial pollutants, such as dioxins [10].

2.2 Performance

During the growth and processing of food raw materials, toxic and harmful substances in the environment exceed the standard; Use pesticides; Polyethylene (PE) and polypropylene (PP) plastic products are used as food packaging bags; The food is added with preservatives, sweeteners, colorants, etc; Some factories (such as pesticide factories) discharge sewage unreasonably.

2.3 Reason

The causes of chemical pollution are as follows:

(1) The extensive use and improper use of agricultural chemicals.

(2) Use food additives that do not meet hygiene requirements.

(3) Packaging containers with unsanitary quality, such as lead in ceramics and vinyl chloride monomer in PVC plastics, may be transferred into food. For another example, the wax on wax paper may contain benzo (a) pyrene, and the color ink and printing paper may contain polychlorinated biphenyls, which are particularly easy to be dissolved in food rich in oil.

(4) The environmental pollution caused by unreasonable industrial emissions will also endanger human health through the food chain.

2.4 Hazards

It interferes with estrogen and androgen, affects the sex ratio of men and women, and damages lactating infants.

Hazards: For example, formaldehyde can induce nasal cancer, blood cancer (leukemia); Volatile organic compounds, such as benzene, toluene and xylene, can cause aplastic anemia and fetal malformation. Ammonia is colorless and has a strong irritating odor. It mainly comes from concrete antifreeze, which can cause pulmonary edema and respiratory symptoms in severe cases.

2.5 Defense

1. Toxic and harmful substances during crop growth can be realized by improving the overall environmental quality around.

2. Preventive measures for pesticide pollution:

(1) Develop efficient and low residue pesticides

(2) Rational use of pesticides

(3) Limit pesticide residues in food.

3. Preventive measures for toxic metal pollution:

(1) Eliminate pollution sources

(2) Formulate the maximum allowable level of toxic metal elements in various foods, and strengthen the inspection and supervision of food hygiene quality.

4. Preventive measures for food pollution: limit the content of additives in food.

5. Precautions for heterocyclic amine compounds:

(1) Change bad cooking methods and eating habits.

(2) Increase the intake of vegetables and fruits.

6. Hygiene of food packaging bags:

(1) Polyethylene and polypropylene can be made into films, woven bags and food turnover boxes.

(2) It is prohibited to use polystyrene as a fast food box to avoid white pollution.

(3) Use polycarbonate plastic to make food packaging, mold and milk bottle.

2.6 Pollutants

2.6.1 Gaseous pollutants

The chemical pollutants in the indoor environment mainly include formaldehyde, triphenyl (benzene, toluene, xylene), ammonia, sulfur dioxide, nitrogen dioxide, carbon monoxide, carbon dioxide, TVOC and inhalable particles. It mainly comes from decoration, furniture, toys, gas water heaters, insecticide sprays, cosmetics, smoking, cooking fume, etc., and also from factory emissions, waste water, medical waste, etc. [11].

1. Formaldehyde

Formaldehyde is a highly toxic gas, colorless, irritant and soluble in water. It has the function of coagulating proteins. Its 35%~40% aqueous solution is commonly called formalin, which is often used as the solution for dipping specimens. Formaldehyde ranks second on the priority control list of toxic chemicals in China, and its release period is generally 3 to 15 years. It has been identified by the World Health Organization as a carcinogenic and teratogenic substance. It is recognized as a source of allergy and one of the potential strong mutagens.

Outdoor air pollution: the formaldehyde content of industrial exhaust gas, automobile exhaust gas, photochemical smog and other gases is very low. This part of gas enters the room at some time, which is also a source of indoor formaldehyde pollution.

Indoor pollution: mainly refers to the indoor use of chemical products such as building materials, decoration items and household goods, as well as some secondary factors such as incomplete combustion of fuel and tobacco.

Formaldehyde can also come from, paint, chemical fiber carpet cleaner, insecticide, disinfectant, preservative, printing ink, paper, etc; Smoking indoors. Formaldehyde has strong adhesiveness, and it can also strengthen the hardness, insect prevention and corrosion resistance of the board. Generally, the formaldehyde content of newly decorated houses can exceed the standard by more than 6 times, and some may exceed the standard by more than 40 times.

2. Triphenyl

Benzene, toluene and xylene are commonly referred to as triphenyl in industry. Among the three substances, benzene is the most toxic.

(1) Benzene

Benzene in indoor environment mainly comes from smoke burning tobacco, solvent, paint, dye, fax machine, computer terminal and printer, adhesive, wallpaper, carpet, synthetic fiber and cleaner.

Benzene toxicity is caused by metabolites, which are metabolized in the liver and bone marrow (the formation site of red blood cells, white blood cells and platelets), so that hematopoietic tissues themselves can form hematotoxic metabolites. Long term exposure can cause bone marrow and genetic damage, leukopenia, thrombocytopenia, pancytopenia, aplastic anemia, and even leukemia.

When inhaled below 4000ppm, in addition to mucous membrane and lung irritation, the central nervous system also has inhibitory effect in a short time, accompanied by headache, nausea, gait instability, coma, convulsion and arrhythmia. Inhalation of more than 14000ppm will cause immediate death.

(2) Toluene

Toluene mainly comes from some solvents, perfume, detergents, wallpapers, adhesives, paints, etc. The amount of toluene produced by smoking in the indoor environment is also very considerable.

After entering the body, about 48% of toluene is metabolized in the body and finally discharged from the body through the liver, brain, lung and kidney, which is harmful to the nervous system. When the concentration of toluene in the blood reaches 1250mg/m³, the short-term memory ability, attention persistence and sensory motor speed of the contacts are significantly reduced.

(3) Xylene

Xylene comes from solvents, pesticides, polyester fibers, adhesive tapes, adhesives, wallpapers, paints, wet processing photocopiers, press plate products and carpets.

Xylene can be absorbed through the respiratory tract, skin and digestive tract. Its vapor enters the human body through the respiratory tract, and some of it is discharged through the respiratory tract. The most xylene absorbed is in adipose tissue and adrenal gland, followed by bone marrow, brain, blood, kidney and liver., Inhalation of high concentration of xylene can cause loss of appetite, nausea, vomiting and abdominal pain, and sometimes cause reversible damage to the liver and kidney. At the same time, xylene is also an anesthetic, and long-term exposure can cause nervous system dysfunction.

3. Ammonia

Ammonia is a colorless gas, belonging to low toxic compounds. When the ammonia in the ambient air is higher than 0.5~1.0 mg/m³, there is a strong pungent smell.

During building construction, to prevent concrete from being frozen and cracked during winter construction, artificially add expansive agent, antifreeze and other admixtures containing a large amount of ammonia in the concrete, which will be reduced into ammonia gas and slowly released from the wall with the change of humidity, temperature and other environmental factors, causing a large increase in the

concentration of ammonia in the indoor air. Also comes from interior decoration materials. Most of the additives and whitening agents used in furniture finishing are ammonia. For example, ammonia and the refrigerant CFC are also potential pollution sources in the process of perm.

Ammonia is an alkaline substance, which can absorb water in tissues after entering the human body. With high solubility, it can stimulate and corrode the upper respiratory tract of the human body and weaken the resistance of the human body to diseases. After entering the alveolus, it is easy to combine with hemoglobin to destroy the oxygen transport function. In a short time, inhalation of a large amount of ammonia may cause symptoms such as tears, sore throat, hoarseness, cough, dizziness, nausea, etc. In severe cases, pulmonary edema or respiratory distress syndrome may occur, and respiratory irritation symptoms may also occur.

4. Sulfur dioxide

Sulfur dioxide is a colorless gas with a strong pungent and pungent smell. The pollution of sulfur dioxide to the indoor environment is related to the family cooking mode, ventilation, indoor structure and fuel weight. The unreasonable structure of the stove, incomplete combustion of coal, and a large number of pollutants, mainly sulfur dioxide, are emitted. In addition, sulfur dioxide is also produced during smoking.

5. Nitrogen dioxide

Nitric oxide is the general name of nitric oxide and nitrogen dioxide. Nitric oxide is easily converted into nitrogen dioxide in the air. Nitrogen oxides in indoor environment are mainly due to the burning of fuel during cooking and heating. In addition, nitrogen oxides can also be produced when smoking. The generation of nitrogen oxides in indoor environment is not only related to the energy structure, but also different with the change of seasons. Summer is lower than winter.

6. Carbon monoxide

Carbon monoxide mainly comes from smoking, heating equipment and kitchen. A cigarette can usually produce about 13mg of carbon monoxide. The carbon monoxide produced by heating equipment and kitchen is mainly caused by incomplete combustion of fuel.

7. Carbon dioxide

Below 0.07%, it belongs to clean air, and the human body feels good; 0.07% – 0.1%, belongs to ordinary air, and some sensitive people will feel bad smell; At 0.1% – 0.15%, it belongs to critical air. Other symptoms of indoor air begin to deteriorate, and the human body begins to feel uncomfortable; 0.15% – 0.2%, belonging to cleanliness pollution; More than 0.2%, which is serious pollution; 0.3% – 0.4%, with deep breathing, headache, tinnitus, increased blood pressure and other symptoms; More than 0.8% will cause death.

8. Volatile organic pollutants (VOCs)

It is divided into four categories:

VVOCs – very volatile organic compounds.

VOCs – volatile organic compounds: organic pollutants represent the pollution status of organic compounds during the detection. In 1989, the United States Environmental Protection Agency detected more than 900 kinds of organic compounds.

It is mainly released from building materials, detergents, paints, water containing coatings, adhesives, cosmetics and detergents. In addition, it is also produced during smoking and cooking.

SVOCs – semi-volatile organic compounds.

POM – organic matter related to particulate matter or particulate organic matter.

9. Inhalable particles

Inhalable particles: refer to particles suspended in the air with aerodynamic equivalent diameter ≤ 10 microns.

Particulates in the air come from a wide range of sources. Dust, bacteria, hair, dandruff, ticks, dust, smoke and harmful substances in the air combine with inhalable particles to form an allergen with great harm.

2.6.2 Water pollution

Contaminated impurities are water pollution caused by chemicals. Chemical pollution can be divided into 6 categories according to specific impurities:

(1) Inorganic pollutants: The inorganic pollutants that pollute the water body include acid, alkali and some inorganic salts. Acid and alkali pollution changes the pH value of water body, hinders the self purification of water body, corrodes ships and underwater structures, and affects fishery.

(2) Inorganic toxic substances: The inorganic toxic substances that pollute water are mainly heavy metals and other substances with potential long-term impact, mainly including mercury, cadmium, lead, arsenic and other elements.

(3) Organic toxic substances: the organic toxic substances that pollute the water mainly include various organic pesticides, polycyclic aromatic hydrocarbons, aromatic hydrocarbons, etc. Most of them are synthetic substances, which are chemically stable and difficult to be decomposed by biology.

(4) Aerobic pollutants: Carbohydrate, protein, fat, phenol, alcohol and other organic substances contained in domestic sewage and some industrial wastewater can be decomposed by microorganisms. The decomposition process requires a lot of oxygen, so it is called aerobic pollutant.

(5) Plant nutrients: mainly nitrogen, phosphorus and other plant nutrients in domestic and industrial sewage, and residual nitrogen and phosphorus in farmland drainage.

(6) Oil pollutants: mainly refer to oil pollution to water bodies, especially marine oil production and oil tanker accidents.

2.6.3 Food contamination

Pesticide residue refers to the residues of its parent, derivative and metabolite in crops, water, soil and food after the use of pesticides. The reasons for pesticide residues are: ① direct pollution. Excessive dosage, too frequent use and too close to the harvest time of crops will lead to high residue of crops. ② environmental pollution. Some pesticides can float in the air and fall into water and soil to pollute

the environment. ③ Bioaccumulation. Through the predator-prey relationship in the food chain, pesticides can be accumulated to a high level in animals at the senior position of the food chain, which will cause harm to human health after human consumption. Therefore, we must strengthen the management of pesticides and learn to use pesticides scientifically.

What are the main pollution sources of vegetables and fruits, and how to prevent them?

The pollutants come from pesticides, human and animal manure, domestic sewage, polluted air and industrial wastewater, which contain a variety of chemical harmful substances, pathogenic microorganisms and parasites, which will pollute vegetables and fruits to varying degrees and endanger human health. The survey shows that the lead content of vegetables near the road is much higher than that far away from the road. Lead exists in the soil in a condensed state, so the amount of lead absorbed by vegetable roots is small. Vegetables mainly absorb lead from the atmosphere through leaves. Preventive measures: ① Human and livestock feces should be used after harmless treatment, and biogas digester treatment method can be promoted. ② We will promote the removal of residual leaves, rotten roots, cleaning and packaging of vegetables. ③ Fruits and raw vegetables should be thoroughly cleaned, and some should also be disinfected. ④ The pollution of vegetables is mainly in the growth period before picking. The regulations on safe use of pesticides and the residue standard for pesticide use should be strictly followed [12].

3 ASSESSMENT OF ENVIRONMENTAL POLLUTION BY CHEMICAL INDUSTRY

3.1 Sulfuric acid production and environmental pollution

3.1.1 Sulfuric acid production process

Sulfuric acid is an important basic chemical raw material, which is widely used in various industrial sectors. The output of sulfuric acid is often used as a measure of a country's industrial development level. Sulfuric acid is mainly used to produce phosphate fertilizer. Synthetic fibers, coatings, detergents, refrigerants, feed additives, petroleum refining, non-ferrous metal smelting, iron and steel, pharmaceutical and chemical industries, etc. Sulfuric acid is also indispensable.

China's sulfuric acid industry began in the 1870s, when the output was very small. After the founding of the People's Republic of China, especially after the 1980s, the sulfuric acid industry has developed rapidly. According to incomplete statistics at the end of 1999, China's existing sulfuric acid production plants "There are 632 households with a production capacity of 32500kt/a. After the 1950s, the contact method was gradually popularized to replace the lead chamber method and tower method. After the 1980s, the contact method was all used. The raw materials for production include pyrite, sulfur, smelting flue gas, phosphogypsum and hydrogen sulfide. In the production process of the contact sulfuric acid process, there are three basic chemical reactions and related processes: the production of SO_2 gas, the conversion of SO_2 , and the absorption of SO_3 .



Figure 3.1 – Sulfuric acid production process from pyrite

The pyrite raw material processed in the raw material section is sent to the roasting process for boiling roasting of pyrite. The gas is recycled by the waste heat boiler and then sent to the gas purification process through the cyclone and electric precipitator. The gas from the purification process enters the drying tower to dry the gas and then sent to the conversion section for catalytic oxidation of SO_2 . The SO_3 gas generated from the reaction is sent to the absorption tower to absorb and produce sulfuric acid.

(a) Baking process

The sulfur concentrate sent from the raw material process is mixed with the air from the air blower in the fluidized bed furnace and roasted at 800°C . The high temperature furnace gas with a concentration of 50: 13% and a temperature of about $800\text{-}950^\circ\text{C}$ generated by roasting is recycled by the waste heat boiler, and the temperature of some heat energy is reduced to 340°C . After that, it passes through the cyclone precipitator and the electric precipitator in turn, so that the dust content is less than or equal to 0.20 g/Nm^3 and the temperature is reduced to 320°C before entering the purification process.

(b) Purification process

The purification process adopts advanced power wave scrubbing technology. The flue gas is first adiabatic cooled and washed in the power wave scrubber to remove impurities. The gas-liquid separation is carried out through the power wave gas-liquid separation tank. The separated gas enters the gas cooling tower for further cooling and impurity removal. Most of the impurities such as dust, arsenic and fluorine in the flue gas from the gas cooling tower have been removed. At the same time, the temperature of the flue gas has dropped to about 40°C . Then the two-stage tubular electric demister is used to remove the acid mist, so that the acid mist content in the flue gas is reduced to $<5\text{mgNm}^3$. A small amount of arsenic, fluorine, dust and other impurities entrained in the flue gas have also been further removed. The purified flue gas is sent to the dry absorption section.

(c) Dry absorption and conversion process

The moisture in the purified flue gas is removed in the drying tower sprayed with 96% sulfuric acid. The flue gas with moisture content less than 0.1g/Nm^3 after drying is sent to the conversion section by SO_2 blower. The conversion section adopts the "3+1" four-stage double-contact process, and the total conversion rate is more than 99.75%. The drying and absorption system adopts a three-tower and two-tank process. 96% concentrated sulfuric acid is circulated in the drying tower and 98% concentrated sulfuric acid is circulated in the first and second absorption towers. The circulating acid in the first and second absorption towers share the circulating tank, circulating pump and acid cooler. The cooling of the circulating acid adopts the shell-and-tube acid cooler with anode protection. The circulating acid of the drying tower uses one acid cooler, and the circulating acid of the two absorption towers shares one acid cooler.

The finished acid is produced from the intermediate tank of the finished product, cooled by the finished acid cooler, and then sent to the acid storage tank of the acid storage tank, which is then put into the train tanker or car tanker and transported out of the factory.

2. Sulfur-based sulfuric acid production

Sulfur-based sulfuric acid production takes solid sulfur as raw material, and adopts rapid sulfur melting, liquid sulfur filtration, liquid sulfur combustion, waste heat recovery and "3+1" two-conversion and two-absorption production process. In order to make the best use of the high temperature level heat energy generated by liquid sulfur incineration and the medium temperature level heat energy generated by sulfur dioxide conversion, a medium-pressure fire tube waste heat boiler is set behind the sulfur incinerator, a high temperature superheater is set behind the first section of catalyst layer in the conversion process, a heat exchanger is set in the second section, a heat exchanger and an economizer are set in the third section, and a low temperature superheater and an economizer are set in the fourth section. The medium-pressure superheated steam generated by the system is incorporated into the steam pipe network and can be sent to the power generation device: the air fan of large device is driven by steam turbine.

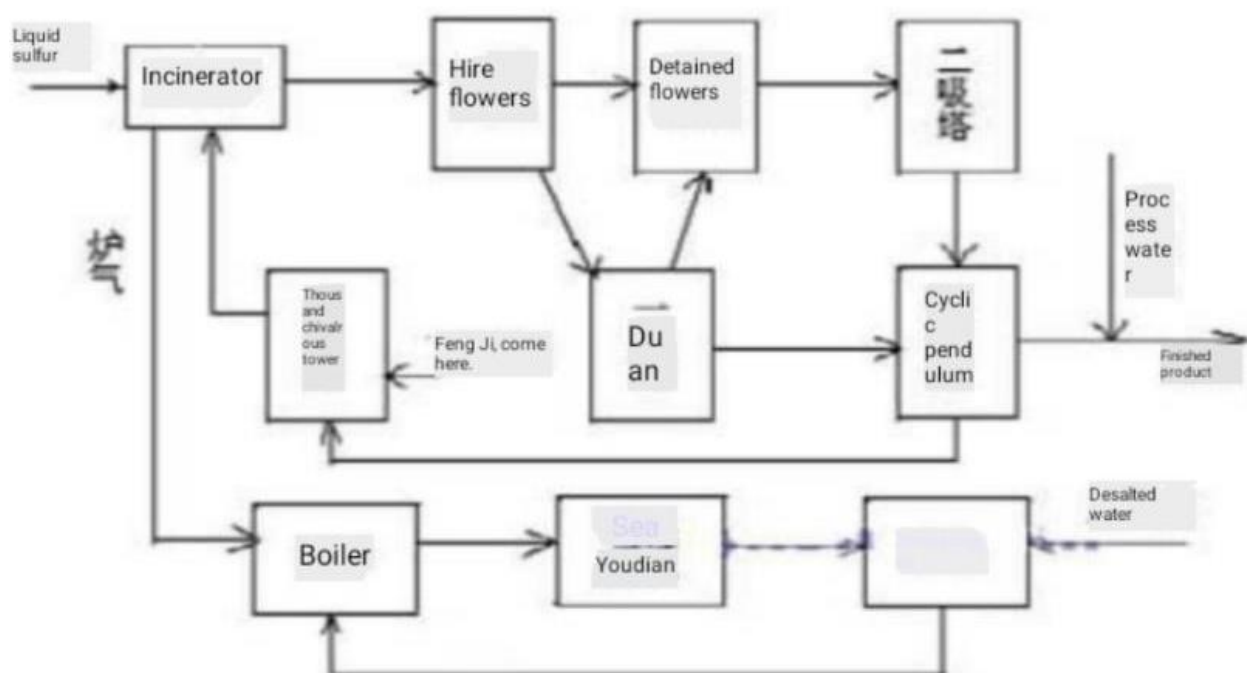


Figure 3.2 – Flow diagram of sulfuric acid production from sulfur

3. Acid production from smelting flue gas

There is a large amount of sulfur dioxide in nonferrous metal smelting flue gas. If sulfur dioxide is directly discharged, it will not only waste resources, but also cause great harm to the environment. With the acid production from smelting flue gas playing an increasingly important role in the field of chemical raw material production, the sulfuric acid industry adopts dilute acid washing purification process to reduce the sewage discharge, and a large number of valuable metals in the sewage are enriched after circulating washing, which has practical significance for comprehensive recovery. In order to make better use of smelting flue gas to produce acid, many effective smelting technologies and other measures have emerged at home and abroad in recent years, some of which are still in the experimental stage. The general process is as follows:



Figure 3.3 – General process of acid production

(a) The flue gas purification process (taking the newly-built 660kt/a copper smelting flue gas sulphuric acid system in Guixi Smelter of Jiangxi Copper Group as an example), in order to adapt to the characteristics of smelting flue gas gas volume, gas concentration, large periodic fluctuations, complex and volatile smoke and dust composition, effectively remove copper, arsenic, fluorine and other harmful impurities in the flue gas, ensure the flue gas purification index, strengthen the flue gas purification effect, and learn from the production experience of Guixi Smelter's sulphuric acid II series and sulphuric acid I series III project transformation, The purification of 660kt/a sulfuric acid plant adopts dilute acid washing and adiabatic evaporative cooling process. The purification process is the first stage power wave scrubber (single stage one reverse injection), the second stage power wave scrubber (single stage one reverse injection) and the second stage electric demister of the gas cooling tower (packing tower). The dilute acid produced in the purification process is sent to the waste acid treatment unit after the suspended solids are removed by Gore membrane filter and sulfur dioxide is desorbed.

(b) Dry cleaning process. The dry and suction process adopts the low efficient arrangement and the post-cooling process of circulating acid pump.

(c) Conversion process. The conversion process of the unit is designed to adopt the high concentration sulfur dioxide conversion technology similar to the second series of sulfuric acid. The air is added to the drying tower to control the inlet converter: the sulfur dioxide content is 12%. The conversion adopts 1-VII, "3+1" conversion heat exchange process, and the recycling of waste heat at low temperature is also considered.

4. Brief description of contact sulfuric acid process

The project adopts the contact sulfuric acid production process with pyrite as raw material. Its main processes include pyrite roasting, furnace gas purification, gas drying, sulfur dioxide.

And the absorption of sulfur trioxide. The basic process flow chart is as follows:

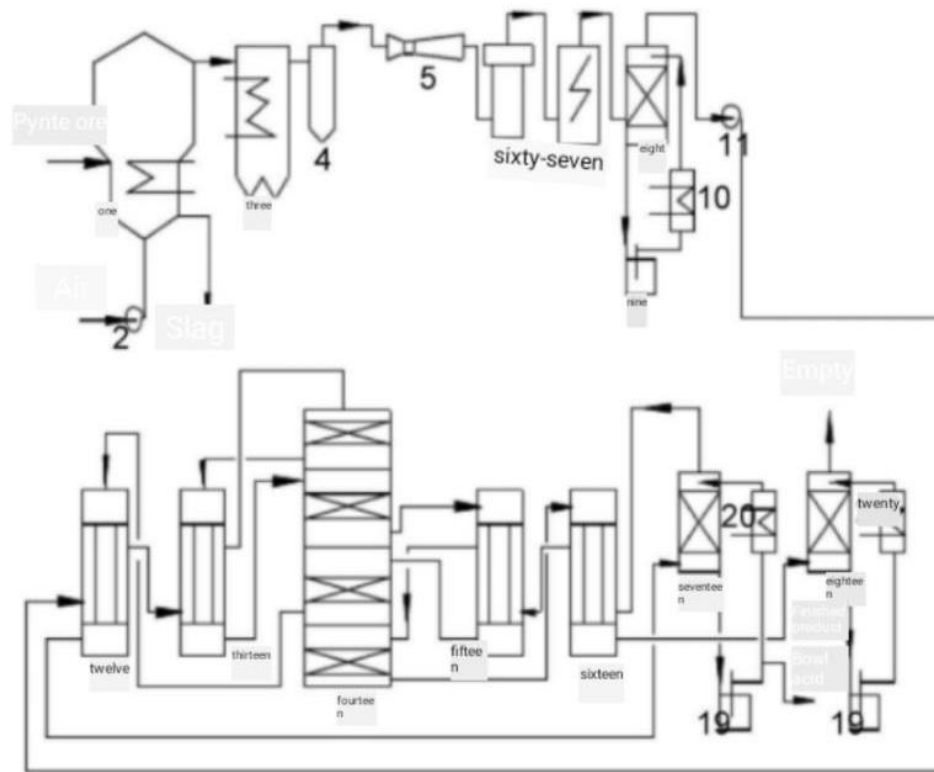


Figure 3.4 – Contact sulfuric acid process flow chart: 1 – fluidized bed roaster; 2 – air blower; 3 – waste heat boiler; 4 – Cyclone dust collector; 5 – Venturi tube; 6 – foam tower; 7 – electric demister; 8 – drying tower; 9 – circulating tank and acid pump; 10 – acid cooler; 11 – Sulfur dioxide blower; 12, 13, 15, 16 – gas heat exchanger; 14 – converter; 17 – intermediate absorption tower; 18 – final absorption tower; 19 – circulating tank and acid pump; 20 – acid cooler

The crushed and screened pyrites or dried pyrites are sent to the fluidized bed at the bottom of the fluidized bed roaster 1 for roasting reaction with the air sent from the bottom of the furnace through the air blower 2. The generated sulfur dioxide furnace gas is discharged from the boiling furnace and enters the waste heat boiler 3. Slag is discharged from the fluidized bed through the slag outlet at the lower part of the furnace.

The boiler gas is cooled to about 350°C in the waste heat boiler to produce 3.82Mpa, 450°C superheated steam. The main steam evaporation tube bundle is located in the waste heat boiler. The cooling pipe installed in the fluidized bed of the roasting furnace is also a part of the thermal system of the waste heat boiler, which is

connected with the steam drum of the boiler to recover part of the roasting reaction heat.

The furnace gas from the waste heat boiler also contains a considerable amount of mineral dust, which enters the purification system after preliminary dust removal by cyclone dust collector 4. The mineral dust removed by the waste heat boiler and cyclone dust collector and the slag discharged from the fluidized bed roaster are sent to the slag yard for further treatment or sale. The purification system includes venturi 5, foam tower 6 and electric mist eliminator 7. The Venturi tube is used to dust and cool the furnace gas. After the furnace gas passes through the Venturi tube, most of the mineral dust is removed. The foam tower further removes dust and cools the furnace gas. In venturi and foam tower, the trace sulfur trioxide contained in furnace gas changes from sulfuric acid vapor to acid mist; The oxides of steel, selenium and other metals become solid particles and are separated from the gas phase; Some of them and the trace mineral dust remaining in the furnace gas are washed and removed, and the other part enters the electric mist eliminator with the gas and is cleaned under the action of high voltage static electricity.

Generally, the furnace gas temperature of the purification system is controlled below 40°C to ensure the water balance of the dry-absorption system. The dilute acid with high dust content discharged from the purification system is sent to the sewage treatment system, and then pumped back to the system for recycling after being treated by the CN filter. The purified gas is dried in the drying tower 8 by circulating concentrated sulfuric acid. The concentration of dry acid is generally maintained at about 93%. Because a large amount of heat is released during the drying process of the gas by concentrated sulfuric acid, the acid cooler 10 is set in the sulfuric acid circulating system of the drying tower to remove the heat with cooling water. In order to reduce the corrosion of the equipment caused by the gas entrained with sulfuric acid mist, a wire mesh demister is usually installed at the top of the drying tower.

The dried gas enters the sulfur dioxide blower 11 and is sent to the conversion process after the pressure is raised. Except that the air delivered to the fluidized bed

roaster relies on the air blower to overcome the resistance of the fluidized bed, the gas delivery of the whole system depends on this sulfur dioxide blower.

The gas from the sulfur dioxide blower first passes through the heat exchanger 12 and 13, and then is heated by the sulfur trioxide gas from the third section and the third section of the converter 14, and enters the first section of the converter at a temperature of about 420°C. Under the catalysis of steel catalyst, part of sulfur dioxide in the gas reacts with oxygen in the gas to generate sulfur trioxide and release reaction heat, which increases the temperature of the gas after reaction. In order to further convert the unreacted part of sulfur dioxide, the gas from the first section is cooled in the heat exchanger 13 and then enters the second section. Continue the conversion reaction of sulfur dioxide. The gas from the second section is cooled in the heat exchanger 15, and then enters the third section for conversion. Most of the sulfur dioxide in the gas from the third section has been converted into sulfur trioxide. In order to achieve a higher final conversion rate, the gas from the third section is cooled in the heat exchanger 12 and the sulfur trioxide in the gas is absorbed and removed by concentrated sulfuric acid in the intermediate absorption tower 17.

The gas from the intermediate absorption tower has basically no sulfur trioxide and only contains a small amount of sulfur dioxide that has not been completely converted. In order to make the gas reach the temperature required for catalytic oxidation, the gas is heated by the gas from the fourth section and the gas from the second section through the heat exchanger 16 and 15, and then enters the fourth section of the converter for the final conversion of sulfur dioxide. After the fourth stage of conversion, the total conversion rate of sulfur dioxide can reach more than 99.7%. The gas from the fourth section of the converter is cooled in the heat exchanger 16, and then enters the final absorption tower 18 to absorb and remove all sulfur trioxide in the gas. In general, the gas from the final absorption tower can reach the emission standard specified by environmental protection and be discharged into the atmosphere through the chimney.

Both the intermediate absorption tower and the final absorption tower are equipped with an acid circulation system, which uses sulfuric acid with a

concentration of 98% for absorption. In the acid circulating system, an acid cooler 20 is set to remove the heat of absorption reaction. In order to remove the sulfuric acid mist entrained in the gas, fiber demister is usually installed on the top of the intermediate absorption tower and the final absorption tower. Between the acid circulating system of the absorption tower and the acid circulating system of the drying tower, an acid pipeline is set to continuously supplement the concentrated sulfuric acid from the absorption acid circulating system to the dry acid circulating system to keep the dry acid at the specified concentration. The surplus dry acid is transferred to the absorption acid circulation system. The water in the acid is used as part of the make-up water to react with sulfur trioxide to generate sulfuric acid, which can also be sold as finished products. In order to provide the water needed to produce sulfuric acid from sulfur trioxide, water must be continuously added to the absorption acid circulation system. As sulfur trioxide is continuously absorbed to form sulfuric acid, the amount of sulfuric acid in the absorption acid circulation system is increasing. The added part is exported to the production system as finished products.

3.1.2 Environmental pollution caused by sulfuric acid production

Main hazardous chemicals

(1) Sulfur

Sulfur is light yellow brittle crystalline flake, granular or powder, which may have a special odor due to a small amount of hydrogen sulfide. At 183.8° C, the vapor pressure is 0.13kPa, the flash point is 207° C, the melting point is 119° C, the boiling point is 444.6° C, the relative volume mass (water is 1.0) is 2.0, the spontaneous combustion temperature is 232° C, and the lower explosion limit is 2.3g/m³. Sulfur is a flammable solid, flammable in case of open fire and high heat, and can form explosion when mixed with oxidant. Explosive mixture. Sulfur powder and air can form explosive mixture. Sulfur is a poor conductor, which will generate static electricity due to mixing, transportation and injection in dry state. Sulfur can be partially converted into hydrogen sulfide in the intestine and absorbed, so a large

amount of oral administration can lead to hydrogen sulfide poisoning. Sulfur can cause eye conjunctivitis, skin eczema, and has weak irritation to the skin. Sulfur dust absorbed for a long time in the production process generally has no obvious toxic effect.

The toxicity of sulfur is relatively small, and the main hazard is dust explosion. When sulfur is disposed under dry climate and poor ventilation, dust will be enriched, and explosion will be caused under the action of external energy after reaching the explosion limit. Because the sulfur surface is easy to generate static electricity accumulation, the risk of explosion is increased.

(2) Hydrogen sulfide

Hydrogen sulfide is a flammable colorless gas with typical rotten egg smell. Its boiling point is 60.3, its relative volume mass (air is 1) is 1.19, and it is easily soluble in water and alcohol, carbon disulfide, petroleum solvent and crude oil. At 20° C, the vapor pressure is 1874.5kPa, the explosion limit (volume fraction) in the air is 4.3% - 45.5%, and the spontaneous combustion temperature is 260° C.

Hydrogen sulfide is a kind of nerve poison and also an asphyxiant and irritant gas. Hydrogen sulfide is absorbed quickly through mucous membrane and slowly through skin. Acute hydrogen sulfide poisoning generally occurs rapidly, with clinical manifestations mainly including brain and/or respiratory system damage, and also accompanied by organ dysfunction such as heart. The clinical manifestations vary significantly with the concentration of hydrogen sulfide and other factors. Damage to the central nervous system is the most common, ranging from headache, dizziness, fatigue, ataxia and mild disturbance of consciousness to blurred consciousness, coma, dyspnea or cardiac arrest after respiratory arrest. Contact with extremely high concentration (more than 1000mg/m³) of hydrogen sulfide can cause shock like death. The main hazard of hydrogen sulfide is poisoning. Because of the lower explosion limit, it is also easy to cause explosion accidents. The volume and mass of hydrogen sulfide is larger than that of air, and it will accumulate on the ground when leaking at low places and diffuse to the ground when leaking at high places, so it is easy to cause serious consequences.

(3) Intermediate products

The intermediate products of sulfuric acid production are sulfur dioxide and sulfur trioxide, which have certain safety risk factors.

1. Sulfur dioxide

Sulfur dioxide is a colorless, irritating odor, toxic gas, nonflammable, easy to liquefy, boiling point – 10°C, relative volume mass (air is 1) 2.26, and is a reducing agent.

Sulfur dioxide is easy to be absorbed by the moist mucous membrane surface to form sulfite and sulfuric acid, which has a strong irritant effect on the eyes and respiratory mucosa. A large amount of inhalation can cause pulmonary edema, laryngeal edema, vocal cord spasm and cause asphyxia. The acute effects are: lacrimation, photophobia, cough, sore throat, etc. occur in the case of mild poisoning, pulmonary edema can be caused in a few hours after severe poisoning, asphyxia can be caused by reflex glottis spasm when inhaled at extremely high concentration, and inflammation or burns will occur in the case of skin or eye contact. Chronic effects include: long-term low concentration exposure can cause general symptoms such as headache, dizziness, fatigue, and chronic rhinitis, pharyngitis, bronchitis, loss of smell and taste, and a few workers have tooth erosion. The main danger of sulfur dioxide is poisoning.

2. Sulfur trioxide

Under normal conditions, sulfur trioxide is a volatile colorless liquid or colorless to white crystal, nonflammable, with smoke and moisture absorption characteristics, boiling point of 45°C, relative volume mass (air is 1) 2.8, and is a strong oxidant.

Sulfur trioxide reacts violently with combustible substances, reducing substances and organic compounds, causing fire and explosion hazards; React violently with water and moist air to produce sulfuric acid; The aqueous solution is a strong acid; Strong reaction with alkali; Corrosive metal, forming explosive gas hydrogen. Sulfur trioxide has a strong stimulation and corrosion effect on skin, mucosa and other tissues, which can cause conjunctivitis, edema, corneal opacity and

blindness; Irritating to respiratory tract, causing dyspnea and pulmonary edema in severe cases; High concentration exposure may cause laryngeal spasm or glottis edema to death; After taking orally, it will burn the digestive tract and form ulcers. In severe cases, it can cause gastric perforation, peritonitis, laryngeal spasm, glottis edema, kidney damage, shock, etc; Chronic effects include tooth erosion, chronic bronchitis, emphysema and liver cirrhosis. The main danger of sulfur trioxide is poisoning.

3. Vanadium pentoxide catalyst

Vanadium pentoxide is an orange or brick red solid, odorless, tasteless, toxic, insoluble in water, soluble in hot water, insoluble in ethanol ether ammonium chloride. Melting point 690°C, density 3.357 g/cm³.

Vanadium pentoxide is an amphoteric oxide, which is more acidic than alkaline. It is dissolved in strong alkali to form vanadate, and dissolved in strong acid to form vanadium oxide ion VO or VO₃⁺. Vanadium pentoxide can be prepared by thermal decomposition of ammonium metavanadate or the reaction of vanadium oxychloride with water.

Vanadium pentoxide dust can stimulate the respiratory system, cause chest tightness, cough, dark green tongue, and stimulate the eyes, causing conjunctivitis. According to animal experiments, vanadium pentoxide is more toxic than vanadium trioxide and vanadium trichloride, and more toxic than vanadate, metal vanadium, iron vanadium, vanadium carbide, etc. Vanadium pentoxide belongs to the category 6.1 poison, so the main hazard characteristic is poisoning.

1.4 Sulfuric acid product

sulfuric acid is a transparent viscous oily corrosive liquid, odorless, with colors ranging from five colors, yellow to yellow brown, and a relative volume mass (water is 1) of 1.84, which is easily soluble in water and emits a large amount of heat. Concentrated sulfuric acid has obvious dehydration, oxidation and corrosivity. Although sulfuric acid itself does not burn, because of its active chemical properties, it will react violently with water and many combustible substances, such as wood chips, rice straw, paper, calcium carbide, perchlorate, fulminate, nitrate, picrate, etc., releasing high heat and may cause combustion; The dilute sulfuric acid will react

with metal and release hydrogen, causing explosion. Sulfuric acid is highly corrosive, can seriously burn the eyes and cause the risk of blindness. It is irritating to the skin and can cause dermatitis or burns. Like sulfur trioxide, sulfuric acid can cause upper respiratory tract inflammation and lung damage, and its toxicity is shown in the "sulfur trioxide" section above.

The main hazard source of sulfuric acid is its chemical activity and strong corrosivity, which may cause combustion, explosion and serious injury to human body.

Environmental pollution caused by sulfuric acid production

(1) Hazards of chemical corrosion

In this production process, because the main process materials such as sulfur dioxide, sulfur trioxide, sulfuric acid and other acidic substances are corrosive, they will cause corrosive damage to buildings, equipment, pipelines, instruments, electrical facilities, floors, equipment foundations, operating platforms, etc., affecting production safety.

(2) Hazards of chemical burns

The human body is exposed to the diluted sulfuric acid or concentrated sulfuric acid leaked and splashed during the production process. The diluted sulfuric acid or concentrated sulfuric acid will cause corrosion to the human body and form chemical burns.

(3) Hazards of chemical poisoning

Toxic gases such as sulfur dioxide, sulfur trioxide and carbon monoxide produced in the production process will cause human poisoning or death once leaked and inhaled.

(4) Dust hazard

The dust is mainly generated from the raw material dust in the raw material section and the slag ash in the slag removal post of the fluidized bed furnace. Workers exposed to these dust environments for a long time will cause pneumoconiosis and other hazards due to inhalation of dust.

3.2 Coking process and its environmental pollution

3.2.1 Overview

The preparation of coking coal stock, referred to as coal preparation, is the preparation of various clean coals (or low-ash raw coal) transported from coal mines into coal stocks with accurate proportions, appropriate particle size, uniform quality, and meeting the requirements of coking. Generally include: unloading coal, storing and mixing, blending, crushing and mixing, and sending the prepared coal to the coke oven coal storage tower. In severe cold areas, there should also be thawing warehouses and thawing block equipment. To make high-quality coke, sufficient attention must be paid to coal preparation operations. Mix the coal well, improve the accuracy of coal blending, minimize the fluctuation of coal quality, and ensure the stability of the chemical composition and physical and mechanical properties of the coke to stabilize the quality of the coke. Therefore, the coal blending equipment must accurately blend the coal according to the given value; the coal blending trough must uniformly and continuously discharge the coal. The sundries in the coal should be removed, and the moisture should not be too high. Reasonable pulverization of coal can effectively improve the mechanical strength of coke. The most suitable crushing particle size must be determined for different coal materials according to specific conditions.

Improving the coal preparation process is the way to expand the source of coking coal and improve the quality of coke. At present, most of the coking plants in China adopt the mixing and crushing process that is first matched in accordance with the specified ratio. This process cannot be processed separately according to the hardness difference of various coals, so it is only suitable for coking coal materials with better cohesiveness and uniform coal quality. There are three newer coal preparation processes [12]: ①Single pulverization process, which is to pulverize various coals separately, and then match them according to the specified ratio, and then mix; ②The group pulverization process is to first comminute various coal types with similar hardness. According to the proportion, each group is sent to the

respective crusher to be crushed to the required particle size, and then mixed; ③The crushing process is selected, which is to sieve the crushed coal to a certain degree, and then the coarse-grained components are screened out. Re-pulverization is carried out so that coarse-grained components with poor cohesiveness and high inert content can be pulverized finer, and excessive pulverization of lithofacies components with good cohesiveness can be avoided.

The prepared coal material is put into the coal charging truck from the coal tower and sent to each carbonization chamber for charging. The coal gas produced by dry distillation is sent to the chemical product recovery workshop for processing through the gas gathering system. After a coking cycle (that is, the time required from loading the furnace to pushing the coke, generally 14 to 18 hours, depending on the width of the coking chamber), the coke pushing machine is used to push the mature coke through the coking machine into the quenching machine. After quenching the coke, unload the coke into the cold coke station; then sieving and storing.

The coking workshop generally consists of two coke ovens forming one group. The two coke ovens are arranged on the same centerline with a coal tower in the middle. A furnace group is equipped with corresponding coke oven machinery — coal loader, coke pusher, coke blocker, coke quenching car and electric locomotive; it is also equipped with a set of coke quenching facilities, including coke quenching tower, coke quenching pump room, powder The coke sedimentation tank and the powder coke grab are arranged at the end of the furnace group. The distance between the center of the quenching tower and the center of the furnace end carbonization chamber is generally not less than 40 meters. If dry quenching is used, a dry quenching station is required. The coking workshop is also equipped with necessary piping and reversing systems.

Coke treatment: High-temperature coke from the coke oven needs to undergo a series of treatments such as coke quenching, coke cooling, coke screening, and coke storage. In order to meet the requirements of ironmaking, some also need to be granulated.

Quenching: There are two methods: wet quenching and dry quenching. The former is to use the quenching car to carry the red coke out of the furnace to the quenching tower and spray it with water. In the latter, inert gas at about 180°C is used countercurrently to pass through the red coke layer for heat exchange. The coke is cooled to about 200°C, and the inert gas is heated to about 800°C and sent to the waste heat boiler to produce steam. The amount of steam generated per ton of coke is about 400-500 kg. Dry quenching can eliminate the environmental pollution caused by wet quenching, improve the quality of coke, and recover a large amount of heat energy. However, the capital investment is large, the equipment is complicated, and the maintenance cost is high.

Cool coke: The coke after wet quenching is discharged onto the inclined cold coke table for cooling. The residence time of the coke on the cold coke table is generally about 30 minutes to evaporate the water and quench the few unquenched red coke.

Sieve coke: According to user requirements, the mixed coke is screened and classified in the coke sieve building. The coking plant of the Chinese steel complex generally divides the coke into four levels, that is, the particle size is larger than 40 mm for large coke, 40-25 mm for medium coke, 25 to 10 mm for small coke, and less than 10 mm for fine coke. . Usually large and medium coke is used for metallurgy, small coke is used for chemical industry, and fine coke is used as fuel for sintering plant.

Coke storage: After screening, all levels of coke are stored in coke storage tanks, and then loaded into trucks for transportation, or directly delivered to users by belt conveyors. Whole grain The coke larger than 80 (or 75) mm is sieved out in advance, crushed by a coke cutter, and then sieved to obtain coke with a particle size of 80-25 (or 75-25) mm for ironmaking. This can improve the uniformity of the coke particle size and prevent large pieces of coke from breaking along the inherent cracks in the blast furnace, thereby improving the mechanical strength of the coke, which is conducive to ironmaking production.

3.2.2 Coking production process

The so-called high-temperature coking means that coal is heated to 950-1050°C in isolation from air, and then coke is finally obtained through processes such as drying, pyrolysis, melting, bonding, solidification, and shrinking [13].

1. Coking production process

The combined coal sent from the coal preparation workshop is loaded into the coal tower, and the coal loading truck takes the coal from the coal tower according to the operation plan, and loads it into the carbonization chamber after being measured. The coal material undergoes a high-temperature carbonization cycle in the carbonization chamber to produce coke and produce raw gas.

After the coke in the carbonization chamber is mature, it is pushed out by a coke pushing car, and guided into the quenching car by the coke blocking car, and the coke quenching car is pulled by the electric locomotive to the coke quenching tower for water spray quenching. The quenched coke is unloaded on the coke cooling table, cooled for a certain period of time, and then sent to the coke screening section, where it is sieved and stored according to grades for transportation.

The raw gas generated during the carbonization chamber dry distillation process is collected in the top space of the carbonization chamber, and enters the gas collecting pipe through the riser pipe and the bridge pipe. The raw gas at about 700°C is sprayed with ammonia water in the bridge pipe and cooled to about 90°C. The tar in the wild gas is condensed at the same time. The gas and the condensed tar are sent to the gas purification workshop through the gas suction pipe together with the ammonia water.

The coke oven gas used for heating the coke oven is introduced overhead from an external pipeline. After being preheated, the coke oven gas is sent to the basement of the coke oven, and the gas is sent to the bottom of the combustion chamber through the lower nozzle to merge and burn with the air entered by the exhaust gas exchange switch. After combustion, the exhaust gas passes through the top of the vertical fire channel and crosses the hole into the downflow vertical fire channel, and then passes through the regenerator and the grid earns part of the sensible heat of the

exhaust gas, and then passes through the small flue, the exhaust gas exchange switch, and the smoke distribution The tunnel, the main flue, and the chimney are discharged into the atmosphere.

2. Coke oven structure analysis

The change and development of the coke oven structure are mainly to better solve the heating uniformity of the coke cake in the high and long directions, save energy and reduce consumption, reduce investment costs, and improve economic benefits. In order to ensure the quality and output of coke and coal gas, it is necessary not only to have a suitable coal blending ratio, but also to have good external conditions. A reasonable coke oven structure is a means to ensure external conditions. For this reason, it is necessary to analyze from various parts of the coke oven structure. Handan Iron and Steel Coking Plant uses JN43-58-II coke oven and JN43-80 coke oven.

The uppermost part of the modern coke oven body is the furnace roof. Below the furnace roof are the alternately arranged combustion chambers and carbonization chambers. The lower part of the furnace body has a regenerator and a chute area connecting the regenerator and the combustion chamber. Each regenerator The small flue at the lower part is connected with the flue through an exchange switch. The flue is arranged in the coke oven foundation or on both sides of the foundation, and the end of the flue leads to the chimney. Therefore, the coke oven is composed of three chambers and two zones, namely, the coking chamber, the combustion chamber, the regenerator, the chute zone, the furnace top zone and the foundation part. Because the JN43-80 type coke oven is based on the JN43-58-II type coke oven, through years of production practice, further improvement and improvement, so the following is the example of the JN43-58-II type coke oven. The above part of the analysis.

1) Carbonization room

The carbonization chamber is a furnace chamber that accepts coal and isolates the air from the charged coal to dry the coke. It is generally made of siliceous refractory materials. The carbonization chamber is located between the combustion chambers on both sides, with 3-4 coal filling holes on the top, and 1-2 rising pipes

leading out the dry distillation gas. The two ends of it are cast iron furnace doors lined with refractory materials. The size of the carbonization chamber of the JN43-58-II coke oven is divided into two widths, that is, the average width is 407mm and 450mm. The total height of the carbonization chamber is 4300mm, the overall length is 14080mm, and the effective length is 13350mm. The effective area of the carbonization chamber is 21.7m³, and the heating level is 800mm.

2) Combustion chamber

The combustion chamber is located on both sides of the carbonization chamber, where the gas burns. The gas and air are mixed and burned. The heat generated is transferred to the furnace wall to indirectly heat the coal in the carbonization chamber and perform high-temperature dry distillation. The combustion chamber is generally built with silica bricks. The width of the combustion chamber of the JN43-58-II coke oven is 736mm and 693mm (including the furnace wall), and the furnace wall is made of silica bricks with tongue and groove with a thickness of 100mm. The combustion chamber is a dual-fire channel with exhaust gas circulation structure. It is composed of 28 vertical fire channels. The center distance of adjacent fire channels is 480mm, and the thickness of the vertical fire channel partition wall is 130 mm. Among them, the upper part of the pair of partition walls has spanning holes, and the lower part cancels the circulation holes of the side fire channel to prevent short circuits. The exits of the two chute areas at the bottom of the standing fire channel are set on both sides of the center line of the combustion chamber. On the basis of the JN43-58-II coke oven, the cross-sectional area of the side chute opening is enlarged to ensure the gas supply to the burners at both ends.

3) Regenerator

The function of the regenerator is to use the heat of the accumulated exhaust gas to preheat the air and lean gas required for combustion. There are two regenerators at the bottom of each coking chamber of JN43-58-II coke oven, one is a gas regenerator and the other is an air regenerator. They are connected to the two combustion chambers placed on their sides at the same time. The main wall is

directly below the combustion chamber, and there is a vertical brick gas duct in the main wall. The coke oven gas is sent from the basement gas and the main pipe to the bottom of the vertical fire duct and mixed with air through this duct. Because the airflow is oriented on both sides of the main wall and there is a brick gas duct in the middle, the pressure difference is large and it is easy to cross leakage. Therefore, the brick gas pipe system uses pipe bricks with an inner diameter of 50mm, and outside the pipe bricks, special-shaped bricks with tongues and grooves are used to form a main wall with a thickness of 270mm. The width of the regenerator hole is 321.5mm, and 17 layers of nine-hole thin-walled checker bricks are placed inside. In order to evenly distribute the airflow in the longitudinal direction of the regenerator, diffuse grate bricks are used, with diffusing or shrinking hole types with different apertures. The partition walls of the regenerator are all built with silica bricks, and the inner surface of the regenerator is lined with clay bricks.

4) Ramp area

The channel connecting the regenerator and the combustion chamber is a chute area, which is located between the top of the regenerator and the bottom of the combustion chamber, used to introduce air and gas, and distribute them to each vertical fire channel, while excluding exhaust gas. Each vertical fire channel of the combustion chamber is connected with its corresponding chute. When the coke oven gas is used for heating, air is fed in and exhaust gas is discharged from the two chute, and the coke oven gas enters from the vertical brick gas channel. When the lean gas is used for heating, one chute sends in gas, the other chute sends in air, and both chutes lead out exhaust gas after reversing. Adjusting bricks are arranged at the ramp opening. When determining the cross section size of the ramp, the resistance at the ramp opening should generally account for 2/3 to 3/4 of the total resistance of the updraft ramp; in order to maintain the furnace head temperature, the exit section of the furnace head ramp should be made It is 50%-60% larger than the middle part; the inclination angle of the ramp opening should generally not be less than 30°, and the gradually reduced angle of the ramp section is generally less than 7° and so on.

5) Basic platform

The base platform is located at the bottom of the furnace body, it supports the entire furnace body, the quality of the furnace body facilities and machinery, and transmits it to the foundation. The foundation of the JN43-58-II coke oven is a downward spraying type, and it is composed of a bottom plate, a top plate and a pillar, and is made of reinforced concrete. In order to reduce the influence of temperature on the foundation, there are 4-6 layers of red bricks between the lower part of the coke oven masonry and the foundation platform.

6) Furnace top area

The roof area of the JN43-58-II coke oven is equipped with coal charging holes, rising pipe holes, fire viewing holes, furnace holes and bracing hooks. The solid part of the furnace roof is built with waste refractory bricks in the process of building the furnace, and the surface of the furnace roof is built with clinker bricks with good wear resistance and resistance to rain erosion.

In a word, the structural characteristics of JN43-58-II coke oven are: double flue with exhaust gas circulation, coke oven gas down spray, two-cell regenerator reheating coke oven, with a tight structure, the burner is not easy to crack. It has the advantages of uniform heating in high direction, high thermal efficiency, fewer bricks, and low volatility [14].

3.2.3 Coking plant production process

Coking chemical industry is an important part of coal chemical industry. The main processing methods of coal include high temperature coking (950~1050°C), medium temperature coking and low temperature coking. The metallurgical industry generally uses high temperature coking to obtain coke and recover chemical products. The product coke can be used as fuel for blast furnace smelting, casting, non-ferrous metal smelting, and water gas production; it can be used to produce producer gas for producing synthetic ammonia, and it can also be used to produce calcium carbide to obtain raw materials for organic synthesis industry. The chemical products produced in the coking process are recovered and processed to extract tar, ammonia,

naphthalene, hydrogen sulfide, crude benzene and other products, and obtain clean coke oven gas, coal tar, crude benzene refining and deep processing, and then benzene can be produced, toluene, xylene, carbon disulfide, etc. These products are widely used in chemical industry, pharmaceutical industry, refractory industry and national defense industry. Net coke oven gas is available for domestic use and as an industrial fuel. Ammonia in coal gas can be used to make ammonium sulfate, concentrated ammonia water, anhydrous ammonia, etc. The coking chemical industry has produced hundreds of products, and China's coking chemical industry has been able to produce more than 100 chemical products from coke oven gas, tar and crude benzene, which is of great significance to the development of China's national economy [15].

Raw material: coal

Coal is the main raw material for coking. According to different coal-forming conditions, natural coal can be divided into three categories, namely humic coal, residual coal and sapropelic coal. Humic coal is the most widely distributed in nature and has the largest reserves, and occupies a major position in coal utilization and chemical processing.

Coal preparation process – the operation of the coal preparation operation area is completed.

①Coal preparation: The cleaned coal entering the plant is processed to meet the coking requirements. Usually, the process of raw coal before coking is called the coal preparation process. After meeting the coking requirements, it is transported to the coal tower through the belt for use in the coking operation area.

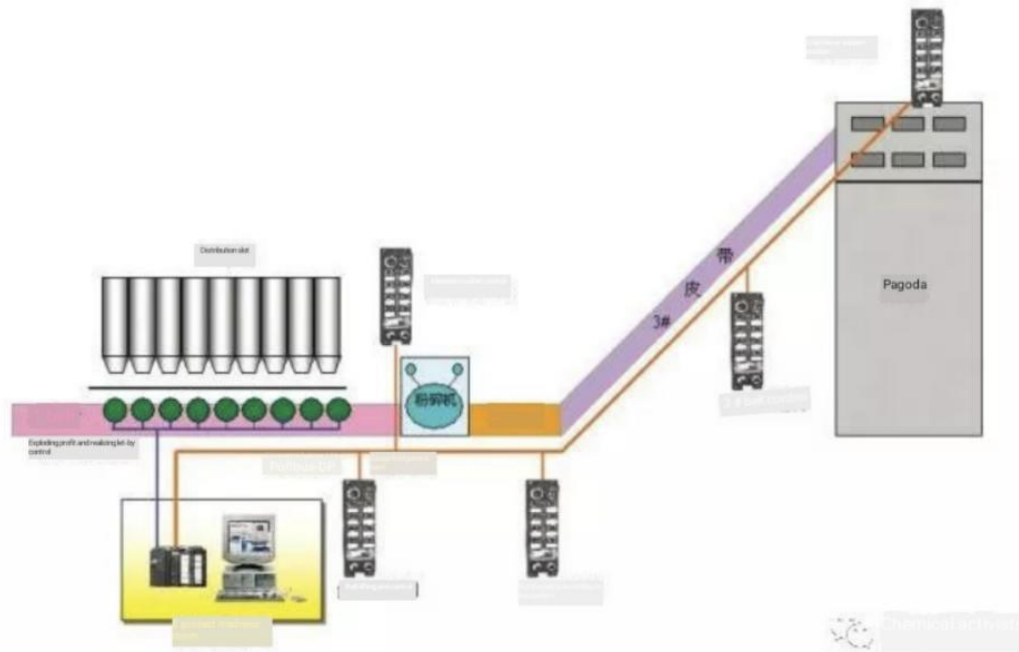


Figure 3.5 – Coal preparation process

②Process: Cleaned coal (<80mm) is transported by car(reserved for train unloading system) → unloaded by screw unloader into the coal unloading chute → different coal belt conveyors according to the type of coal → stacking and reclaiming Main belt of machine → stockpiling operation → coal loading → stacker-reclaimer takes coal through belt conveyor → coal blending bin → electronic automatic batching scale → according to the corresponding proportion to the belt under the bin and the iron remover → reversible impact hammer The type pulverizer is pulverized to <3mm accounting for more than 85% → the coke oven coal tower is used for coking.

Equipment diagram

①Unloading: The coal dump truck from the car directly enters the coal unloading tank, and the non-dump truck is unloaded by a bridge screw unloader, which can unload about 800 tons/hour.

②Clean coal storage yard: The coal storage area of the coal yard is ~34,000m², and the storage capacity of 74,000 tons of clean coal is about the coal consumption for 17 days of coking; 600t/h, reclaiming capacity 300t/h, bulldozer hangar is set up in coal yard to assist stacker-reclaimer operation. The clean coal yard

is equipped with spraying water and spraying covering agent devices, which can prevent the pollution of the surrounding environment caused by the flying of coal dust.



Figure 3.6 – Screw unloader



Figure 3.7 – Coal yards and stackers and reclaimers

③Coal blending: mix different types of coal in proportion to make the blended coal meet the requirements of coking coal. The coal blending bins are 7 hyperbolic bucket bins with a diameter of 8 meters. The reserve of each warehouse is about 500t. The hyperbolic steel funnel of the coal bunker is lined with ultra-high polymer plastic

plates to prevent shedding. The coal blending equipment under the warehouse adopts an electronic automatic batching scale with stable batching, accurate proportioning and high degree of automation, and the system control is PLC control.



Figure 3.8 – Coal blending bunker



Figure 3.9 – Coal tower

④ Crushing: Two sets of reversible impact hammer mills PFCK are selected, and the crushing capacity of a single set is 250t/h, one is open and the other is ready. The pulverizer is developed by absorbing the advanced technology of similar equipment in Germany and Japan. It has the advantages of large crushing ratio, large capacity, low speed, less dust, and strong adaptability to the moisture of coal. It adopts hydraulic coupling, which can effectively protect Overload and soft start; the opening and closing of the body shell and the adjustment of the counterattack plate are all hydraulic devices, which is convenient for maintenance and replacement of the hammer head; the use of a combined hammer head has long service life, low maintenance and repair costs, and saves production costs.

Coal blending process and coal blending index

① Coal blending and coking: It is to combine several different brands of single coal in a certain proportion for coking.

Why blend coal? The main reasons are as follows:

- a. Save high-quality coking coal and expand the source of coking coal;
- b. Make full use of the coking characteristics of various coals to learn from each other to improve the quality of metallurgical coke;
- c. Coal resources can also be used reasonably, and the yield of coking chemical products and the generation of coking gas can be increased on the premise of ensuring the quality of coke;
- d. Make full use of local resources and develop coking enterprises according to local conditions.

② Coal blending process: two processes: first powder and then blend and first blend and then powder, most of the coking plants use the latter.

③ Basic principles of coal blending:

- a. The coke quality reaches the specified index and meets the requirements of the user department;
- b. It will not generate expansion pressure that is harmful to the furnace wall and cause difficulty in pushing coke;

c. On the premise of satisfying the quality of coke, mix as much gas coal as possible to increase the yield of chemical products, mix less high-quality coal and more low-quality coal;

d. Reduce the ash and sulfur content in coal blending as much as possible;

e. Make full use of local resources, achieve reasonable transportation, reduce costs, and maximize regional coal blending;

f. Strive to achieve stable coal blending quality, which is beneficial to production and operation.

④Quality requirements for blended coal: moisture 9-12%; ash content $\leq 10\%$; sulfur content $\leq 0.9\%$; volatilization 24-30%; The percentage of total coal weight is called coal blending fineness) is about 90%; G value ≥ 68 ; Y value 12-20.

Coking process

The blended coal that meets the coking requirements is sent to the coking section for coking.



Figure 3.10 – Coke oven structure diagram

Coking principle

Combined with high temperature dry distillation of coal. That is, after the coking and blending coal is loaded into the coking chamber at normal temperature, the coal is heated by the heat flow from the furnace wall and furnace bottom

(1000°C–1100°C) under the condition of isolating air. The coal material goes through the process of drying, preheating, decomposing, producing colloid, solidifying the colloid, shrinking semi-coke and converting it into coke layer by layer from the wall of the carbonization chamber to the center of the carbonization chamber.



Figure 3.11 – Coke oven roof

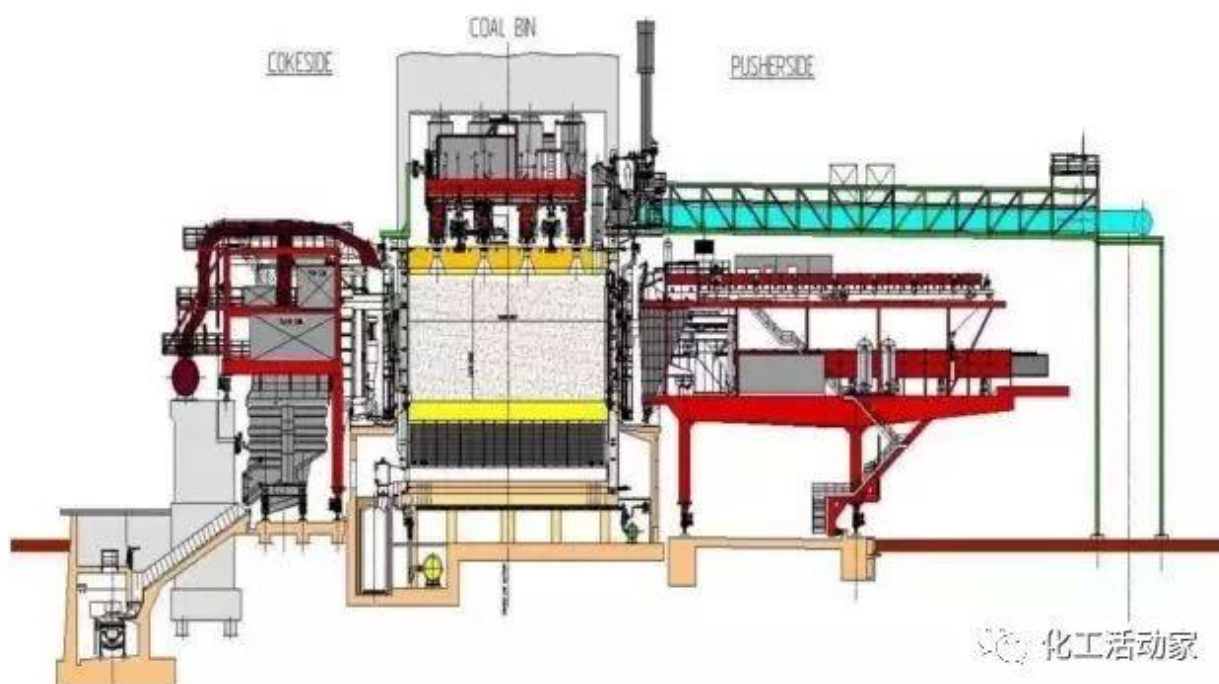


Figure 3.12 – Coke oven side

Cleaned coal from the coal preparation workshop → transported into the coal tower by the coal transport trestle → the coal loading truck moves to the bottom of the coal tower → shakes the feeder to feed material layer by layer evenly → 21 hammer fixed tamping machine for layer-by-layer tamping → tamped Coal cake → Load into the carbonization chamber from the machine side → High temperature dry distillation at the temperature of $950\sim 1050\text{ }^{\circ}\text{C}$ → After 22.5 hours → mature coke is pushed by the coke car and passed through the coke guide grid of the coke trap car → pushed out and falls into the coke quenching car → sent Spray coke quenching with water in the coke quenching tower → send it to the coke cooling table by the coke quenching car → after supplementing the coke quenching and cooling coke, it is sent to the coke feeding field by the scraper. A photoelectric automatic controller is installed at the coke quenching tower, and the spraying time is adjusted through the time relay in the controller to ensure that the red coke is extinguished.

The waste gas produced in the dry distillation process enters the gas collecting pipe through the top of the carbonization chamber, the riser pipe, and the bridge pipe. At the bridge pipe and the gas collecting pipe, the circulating ammonia water with a pressure of $\sim 0.3\text{MPa}$ and a temperature of $\sim 78^{\circ}\text{C}$ is sprayed and cooled, so that the raw gas of $\sim 700^{\circ}\text{C}$ is cooled to about 84°C , and then sucked through the suction elbow and suction pipe to the cold drum section. The tar and ammonia water condensed in the gas collecting pipe are sent to the cold drum section through the tar box and the suction main pipe [16].

Cold drum, electric capture process

The mixture of tar ammonia water and gas from the coking section is about 80°C → gas-liquid separator to separate gas and tar ammonia water → crude gas enters the horizontal tube type primary cooler, the primary cooler is divided into upper and lower sections, in the upper section, use $23\text{ }^{\circ}\text{C}$ The chemical circulating water cools the gas to 45°C , and the chemical circulating water warms up to 40°C → Then the gas enters the lower section of the primary cooler to exchange heat with the 16°C refrigeration water, the gas is cooled to 22°C , and the refrigeration water warms to 23°C → Cooling The last gas enters the gas blower for pressurization → after the

pressurization, the gas enters the electric tar catcher, and the gas after tar mist is captured → sent to the desulfurization and sulfur recovery section.



Figure 3.13 – Primary cooler

The gas condensate of the primary cooler flows out from the upper and lower sections of the primary cooler—respectively enters the respective condensate circulation tanks, and the condensate is circulated and pumped to the upper and lower sections of the primary cooler for spraying. Pumped to the mechanized ammonia clarifier.

The tar ammonia water and tar residue separated from the gas-liquid separator go to the mechanized ammonia water clarifier. After clarification, it is separated into three layers, the upper layer is ammonia water, the middle layer is tar, and the lower layer is tar residue.



Figure 3.14 – Electric tar catcher

Ammonia water – circulating ammonia water tank, and then pumping it to the coking workshop to cool the waste gas and the upper section of the primary cooler

and the electric tar catcher for intermittent purging and spraying. The excess ammonia water goes to the remaining ammonia water tank, and the remaining ammonia water is pumped to the desulfurization section for ammonia distillation.

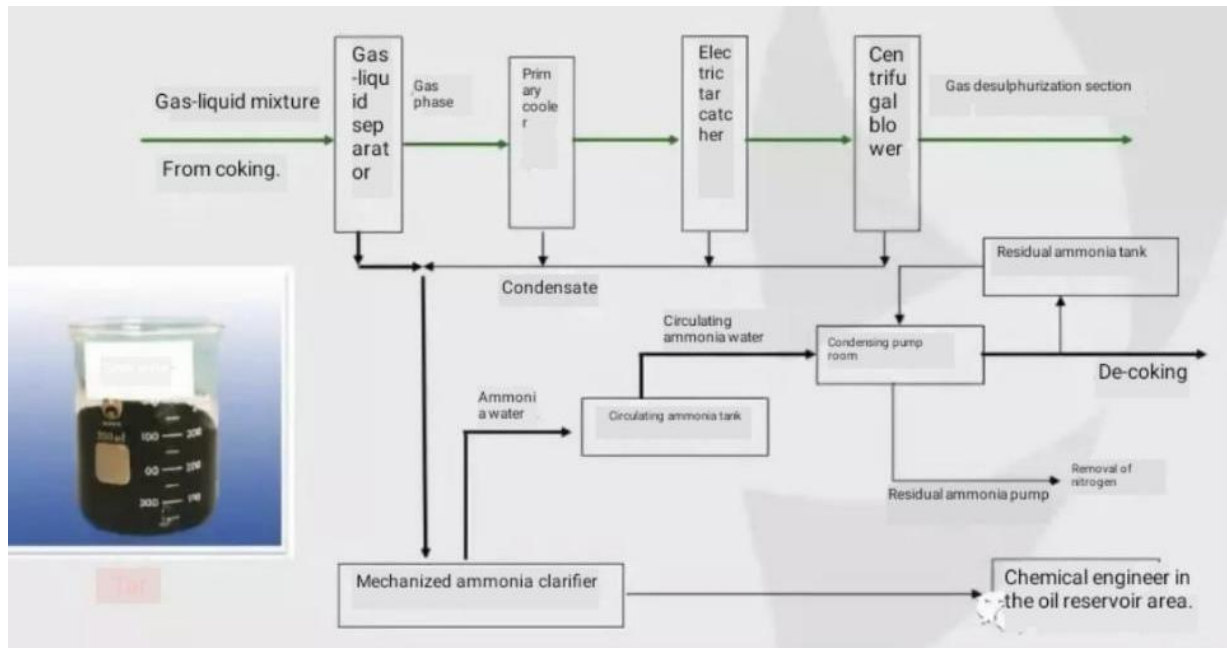


Figure 3.15 – Flow chart of cold drum section

Tar – the tar is stored in the middle tank. When the liquid level reaches a certain level, it is sent to the tar tank with a tar pump. When the tar needs to be sold out, it is sent to the tar tank truck for sale with a tar pump.

3.2.4 Environmental pollution of coking plant

1. Environmental pollution classification of coking plant

(1) Dust pollution

In the actual production process of coking plant, the main pollution factor is dust. For coking plants, the main raw material for production is coal. However, a large amount of coal dust will appear during the process of coal transportation, stacking and top coal loading. The size of coal dust produced by the coking plant is directly related to many aspects, such as the production location of the plant, external climate factors, production technology and management. Through actual investigation, it is found that the dust in the coking plant will generally appear in the

form of logarithmic curve due to its own weight and physical characteristics, and will also be arranged at a distance of 15~20m. The coal dust in coking plant has many characteristics, such as hygroscopicity, dispersion and cohesiveness. No matter what kind of characteristics, they will not only cause great pollution to the environment, but also threaten people's lives in serious cases. The main hazards of coal dust in coking plants can be summarized as follows. First, people working in the coking plant, because of long-term contact with a large amount of dust, will cause lung damage in the human body, lead to silicosis, pulmonary disease and other diseases, and ultimately seriously threaten the health of the human body. In addition, residents living around the coking plant will also be affected by different levels of dust pollution from the coking plant for a long time. Second, when the dust in the coking plant forms a certain concentration, if it encounters an open fire in a certain space, it will easily cause an explosion. In a serious case, it will also cause a fire, which will cause great losses to people's life and property safety, and also reduce the economic benefits of the enterprise. Third, in the normal production process of the coking plant, a large number of production equipment will be used, and the existence of dust will lead to the belt slipping or short circuit of the production equipment, which will not only affect the production work, but also require the enterprise to invest a large amount of money for maintenance or purchase of new production equipment.

(2) Sewage pollution

As the main raw material used in the production of coking plants, coal will produce solid coke, liquid coal tar and gaseous coke gas during the operation of the retorting process. In the process of source coal washing ->coking ->gas coking -coking product recovery, there is no doubt that there will be "three wastes" problems, among which the pollutants generated by coking wastewater are the most. However, the coking waste water generated most in the production process of ammonia distillation, benzene removal, tar processing, etc., contains many polycyclic aromatic compound pollutants such as phenol, benzene, naphthalene, pyridine, indole, etc., and the content of benzene ring organic compounds is also high. These substances are difficult to be effectively treated. Therefore, the benzene ring substances are the most

typical of the sewage pollutants in the production process of coking plants, It is also the most difficult waste water substance to be treated.

4 ENVIRONMENTAL POLLUTION PREVENTION MEASURES OF COKING PLANT

4.1 Dust pollution prevention measures

In order to solve the dust pollution problem existing in the shoveling process of coking plant, the main prevention measures can be carried out around the following points. First, do a good job in the prevention and control of coal transportation. In the actual transportation process, the staff should cover the coal with a tarpaulin, and unload the coal after arriving at the transportation site to avoid dust spreading everywhere. In addition, for some open-air coal storage methods, it is very easy to raise dust. From the perspective of prevention and control, a fully enclosed stockyard or coal storage silo can be established to provide protection against environmental pollution. No_ E. Prevention and control of dust pollution caused by coal loading at the top of the furnace. Because the positive pressure in the furnace top carbonization room is the main reason for the spread of dust everywhere, in order to prevent the dust problem, the dust removal equipment can be installed on the coal truck, or the riser monotone system can be adopted, and the smokeless coal loading can be realized by high-pressure ammonia spray. At the same time, the innovation of coal loading operation enables the staff to master the standard work skills and effectively prevent dust pollution. Third, prevent and control dust pollution during coking. In the process of product production, there will be a lot of dust pollutants in the first sequence of coke discharge from the coking plant. In order to prevent dust pollution, the installation of dust removal station on the ground can remove a large amount of dust. At the same time, for the rest of the dust, advanced dust removal equipment can be used to further improve the dust removal rate when coke is discharged. Fourth, the dust pollutants in the coking plant run through the whole production process of the coking plant. Therefore, in order to prevent the physical injury caused by dust to the

workers, the workers must be required to wear dust-proof tools, such as masks, in the actual production process.

4.2 Sewage pollution prevention measures

Industrial wastewater is the most typical pollution factor in the coking plant environment. In order to do a good job in sewage prevention, we can focus on the following aspects. First of all, control the generation of waste water in coking product smelting process. In the past, the most common way for coking plants to treat coking polluted water was to use activated sludge treatment method. Through actual investigation, it was found that this treatment method had poor effect. With the progress of science and technology, a new sewage and wastewater treatment process, A/O technology, was produced. Using this technology can achieve the best effect of sewage treatment. The so-called A/O treatment process is simply to set the denitrification tank at the front of the carbonitration process, so that the denitrification tank can directly use the organic carbon source in the influent water on the one hand; finally, control the reflux ratio of the mixed liquid in the nitrification tank. Through the control of the reflux ratio of the mixed liquid in the nitrification tank, NO_3 ions can be denitrified in the denitrification tank. Therefore, in the A/O treatment process, although there is only one sludge reflux system, a series of decontamination treatments have been achieved, which greatly improves the treatment efficiency of coking wastewater.

5 ECONOMIC EFFECTIVENESS OF ENVIRONMENTAL MEASURES

5.1 Economics and environmental protection

Economic effectiveness is a means of measuring the efficacy and purposefulness of a given business activity given by the comparison (ratio) of the value of the obtained effects to the factors invested in order to achieve them [17].

Economics explains how people survive. It concerns the ways in which individuals and groups act to attain what they want in terms of income, subsistence and other goods and services which they feel will provide them with an adequate quality of life. Economics basically addresses the problem of scarcity – how to fulfil people's unlimited needs and aspirations from a scarce resource base in a way which is both equitable and efficient.

Incorporating environmental concerns into economics involves introducing concepts of sustainability into scarcity. It deals with the issue of how to meet people's current needs in a way which is both equitable and efficient and does not diminish the supply or quality of environmental goods and services available for future generations.

If the environmental resource base is conserved it will continue to provide these economic benefits and support human production and consumption in the future. If it is destroyed or environmental quality declines, such goods and services will decrease and human economies will suffer as a result, at global, national and local levels.

Economics is also linked to the environment because economic forces contribute to environmental degradation. While environmental resources support economic production and consumption opportunities, the same economic activities impact back on the environment through using up non-renewable environmental goods and services, by converting environmental resources to other uses and by adding waste and effluent to the environment. A decline in environmental quality and resources impacts on economic activities by diminishing the amount of goods and services available for future production and consumption, and by progressively

precluding economic activities. Economic opportunities spiral downwards as the environment becomes more and more degraded.

This downward spiral has implications for both economic efficiency – the sound use and management of scarce resources to generate output, and equity – the access of different groups and individuals to secure livelihoods and economic opportunities. The people who bear the costs of environmental degradation are not necessarily those who are causing degradation, spatially or temporally. For example, many of the indirect or knock-on effects of environmental degradation such as bad health, loss of productive opportunities and ecological disaster are felt by poorer people who lack the resources to cope with these costs, or will be felt by future generations as a result of activities carried out today. Environmental degradation also incurs substantial costs to governments, who bear the overall responsibility for maintaining the basic quality of life in a country [18].

It is clear that production and consumption activities can lead to a downward spiral of environmental degradation, economic costs and loss of productive opportunities. Conversely, environmental conservation can lead to an upward spiral of economic growth and benefits. A major challenge is to ensure that sound environmental management systems are set in place which will enhance current opportunities for production and consumption at the same time as sustaining economic growth in the future.

A range of policy factors, as well as broader socio-economic conditions such as poverty and land pressure, put people in a situation where it makes more economic sense to them to degrade the environment in the course of their day-to-day economic activities than to conserve it. There is often little immediate or tangible economic gain to conserving the environment, and many gains and profits from mining, depleting, polluting or converting it. People are often unwilling – or economically unable – to conserve the environment, because there is no personal benefit to them in doing so.

Economic analysis provides a useful set of tools understanding the forces which lead to environmental degradation. Economic measures can encourage people

to conserve the environment by setting in place the conditions which result in their being economically better off by doing so. They aim to make sure that producers and consumers take into account the real value of the environment and the real cost of environmental damage when they make decisions.

Basic tools for the use of economics for environmental planning and management are as follows [19]:

Identifying environmental economic benefits and costs: ensures that the economic impacts of environmental activities, and the environmental impact of economic activities, are understood and made explicit in both conservation and development planning and management.

Valuing environmental economic benefits and costs: provides important information which can be integrated into both development and conservation planning and management. Making monetary estimates of environmental values means that they can be considered, and given equal weight, alongside other sectors of the economy, benefits and costs.

Analysing the profitability of economic activities in terms of their environmental effects: provides a framework within which to use information about environmental costs and benefits and their values for decision-making. It provides basic measures of whether a policy, programme or activity can be judged desirable in environmental and economic terms.

Highlighting the economic causes of environmental degradation and the need for economic measures for environmental conservation: points to areas and groups where there is a need for the use of economic measures to provide incentives and finance for environmental conservation. It forms the basis of identifying and planning conservation activities.

Setting in place economic incentives for environmental conservation: forms a cross-cutting component of environmental planning and management. Unless people are provided with positive incentives to conserve the environment in the course of their economic activities, and the perverse incentives which encourage environmental

degradation are overcome, environmental programmes and projects are unlikely to succeed.

Financing mechanisms for environmental conservation: form an important part of environmental planning and management because they provide the basic funding which enables environmental projects, programmes and activities to be carried out.

Ensuring that economic measures for conservation are appropriate and sustainable: means that they are practically implementable in different social, cultural, institutional and ecological situations.

5.2 Calculation of the financial profit of resource saving

Net financial result due to the implementation of resource-saving measures in company is calculated by the equation:

$$FP = t \cdot (C_f + p_e + p_h) - I_t \quad (5.1)$$

where:

t is time of implementation of resource saving measures, years;

C_f is the cost of fuel saved, USD/year;

p_e is the payment for emissions of pollutants into the environment, USD/year;

p_h is the payment for damage to public health, USD/year. We accept equal to 0 USD;

I_t is the investment in resource-saving measures, USD.

Cost of fuel saved:

$$C_f = Pr \cdot N_f \quad (5.2)$$

where:

Pr is the price for fuel (1 m³ of natural gas - 0.38 USD, 1 ton of coal – 125 USD);

N_f is the amount of fuel saved or the amount of fuel that would need to be burned to obtain energy produced by alternative sources. In fact, N_f is the total amount of fuel used by company (then we suggest that we completely replace it with alternative energy).

Payment for emissions of pollutants into the environment:

$$p_e = (M_1 \cdot r_1) + (M_2 \cdot r_2) + \dots + (M_n \cdot r_n) \quad (5.3)$$

where M is the amount of pollutant emission, ton:

$$M = q \cdot N_f \quad (5.4)$$

where q is specific emission of pollutant:

for coal: $\text{SO}_2 - 30 \text{ kg/t}$, $\text{NO}_x - 9 \text{ kg/t}$, $\text{CO} - 55 \text{ kg/t}$

for natural gas: $\text{SO}_2 - 0.0037 \text{ kg/m}^3$, $\text{NO}_x - 0.0031 \text{ kg/m}^3$, $\text{CO} - 0.0051 \text{ kg/m}^3$.

r is fee rate per ton of pollutant, USD/t (see Table 5.1).

Table 5.1. Fee rate for pollutants [20]

Pollutant	rate, USD/t
Nitrogen oxides	75
Ammonia	15
Sulfur dioxide	75
Carbon monoxide	3
Hydrocarbons	5

Investments (e.g., in wind or solar energy) are calculated as follows:

$$I_t = k \cdot N_f \cdot T / 8760 \quad (5.5)$$

where:

k is the specific investment in the production of 1 kWh of energy (for wind turbines $k = 500$ USD/kWh, for solar panels $k = 900$ USD/kWh);

T is the heat capacity of the fuel to be replaced (7.5 kW/t for coal and 8.8 kW/m³ for natural gas).

Calculate the net result from the implementation of resource saving measures in chemical company. The company consumes 2000 ton of coal per year and is going to replace it with wind turbines). The project implementation period is 5 years.

1. Time of implementation: $t = 5$ years
2. Amount of fuel used (= amount of fuel saved): $N_f = 2000$ t/year
3. Cost of fuel saved: $C_f = P_r \cdot N_f$ (Eq. 5.2).

The price for coal $P_r = 125$ USD/t.

Then, $C_f = 125$ USD/t \cdot 2000 t/year = 250000 USD/year

4. To calculate the payment for emissions of pollutants (p_e), we need to know amount of pollutant emission (M) for each pollutant (see Eq. 5.4):

Pollutant 1. Nitrogen oxides. $q_1 = 9$ kg/t (see specific emission of NO_x for coal). Then, $M_1 = q_1 \cdot N_f = 9$ kg/t \cdot 2000 t/year = 18000 kg/year = 18 t/year.

Pollutant 2. Sulfur dioxide. $q_2 = 30$ kg/t (see specific emission of SO₂ for coal). Then, $M_2 = q_2 \cdot N_f = 30$ kg/t \cdot 2000 t/year = 60000 kg/year = 60 t/year.

Pollutant 3. Carbon monoxide. $q_3 = 55$ kg/t (see specific emission of CO for coal). Then, $M_3 = q_3 \cdot N_f = 55$ kg/t \cdot 2000 t/year = 110000 kg/year = 110 t/year.

5. From Table 5.1:

for NO_x $r_1 = 75$ USD/t

for SO₂ $r_2 = 75$ USD/t

for CO $r_3 = 3$ USD/t

According to Eq. 5.3:

$p_e = (M_1 \cdot r_1) + (M_2 \cdot r_2) + (M_3 \cdot r_3) = (18 \text{ t/y} \cdot 75 \text{ USD/t}) + (60 \text{ t/y} \cdot 75 \text{ USD/t}) + (110 \text{ t/y} \cdot 3 \text{ USD/t}) = 6180 \text{ USD/year}$

6. Specific investments for wind turbines $k = 500$ USD/kWh, heat capacity for coal $T = 7.5$ kW/t.

Then investments:

$$I_t = k \cdot N_f \cdot T / 8760 = 500 \text{ USD/kWh} \cdot 2000 \text{ t/year} \cdot 7.5 \text{ kW/t} / 8760 \text{ h/year} = 856 \text{ USD}$$

7. Financial result (Eq. 5.1):

$$FP = t (C_f + p_e + p_h) - I_t = 5 \text{ y} \cdot (250000 \text{ USD/y} + 6180 \text{ USD/y} + 0) - 856 \text{ USD} = 1280000 \text{ USD}.$$

Therefore, implementation of resource-saving measures in company (use of wind turbines for energy production) would lead to income 1.28 million USD during 10 years.

CONCLUSIONS

In the process of production and development, chemical enterprises should pay attention to the protection of the environment. Based on the characteristics of the analytical chemistry industry and the environmental pollution caused by the chemical industry, this work enumerates the production processes and environmental pollution of the sulphuric acid production plants and coking plants, and puts forward the prevention and control measures.

A comprehensive review of chemical industry development in China shows significant economy potential. In the same time, this results in big environment pollution from chemical companies. Main industries highly polluting the environment are sulfuric acid production and coking process. There are such contaminants as sulfur, hydrogen sulfide, sulfur oxides, vanadium pentoxide catalyst, etc. Besides, measures for decreasing the environmental pollution from chemical industry are analysed.

Now the society has higher and higher demands on the environment, so the demands on the chemical industry are higher, more energy-saving and environmental protection. Only when we truly realize clean energy and circular economy can we minimize the pollution to the environment as much as possible.

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APPENDIX A

Technical task

Ministry of education and science of Ukraine
 Vinnytsia National Technical University
 Faculty of Construction, Civil and Environmental Engineering

APPROVED
 Head of the Department
 ECEPT
 Prof. V. Petruk
27.09.2022

TECHNICAL TASK

for master thesis

“Assessment of environmental pollution by chemical industry”
 specialty 183 – Environmental protection technologies
 08-12.MKP.102.01.01 T3

Supervisor: PhD, Dr.
(signature) V. Ishchenko
 « 27.09. » 2022

Student: group 2T3Д-21М
(signature) Li Li
 « 27.09. » 2022

Vinnytsia VNTU 2022

1. Basis.

The basis for master thesis preparing is the order of VNTU No. 105 on "14" 09 2022, and individual task approved by protocol of Department ECEPT No. 3 on "21" 09 2022.

2. Goal.

The goal is to analyze chemical industry in China and assess environmental impact of chemical companies.

3. Input data.

The primary processing capacity of crude oil in China – 223.5 million tons per year

4. Research methods

Analysis, mathematical modelling, environmental impact assessment, statistical methods.

5. Stages and deadlines

No	Stages of master thesis	Deadline
1.	Technical task	
2.	Literature review	
3.	Review of chemical industry in China	
4.	Environmental pollution caused by chemical industry	
5.	Assessment of environmental pollution by chemical industry	
6.	Environmental pollution prevention measures of coking plant	
7.	Conclusions, literature list	

6. Area of use

The results can be used by chemical companies to reduce environmental impact.

7. Requirements

Main part and illustrative part.

8. Procedures

Public defense «27» 06.2024
Beginning of writing «27» 06.2024

Finish due to «27» 06.2024

Student Li Li Li

APPENDIX B**PROTOCOL
OF CHECK FOR PLAGIARISM**

Title of work: Assessment of environmental pollution by chemical industry

Type of work: master thesis

Department Ecology, Chemistry and Environmental Protection Technologies

Similarity report by Unicheck

Originality 81,8% Similarity 18,2%

Analysis of similarity report (mark the relevant)

1. Similarities found in the work are correctly formatted and may not be considered as plagiarism.
2. Similarities found in the work may not be considered as plagiarism, but their large amount results in doubts about the value of the work and the lack of independence of the author during writing. The work has to be assessed by expert committee of the Department.
3. Similarities found in the work may be considered as plagiarism.

Person responsible for the check  M. Matusiak

Acquainted with the similarity report generated by Unicheck:

Author  Li Li

Supervisor  V. Ishchenko

APPENDIX C

ILLUSTRATIVE PART

ASSESSMENT OF ENVIRONMENTAL POLLUTION BY CHEMICAL INDUSTRY

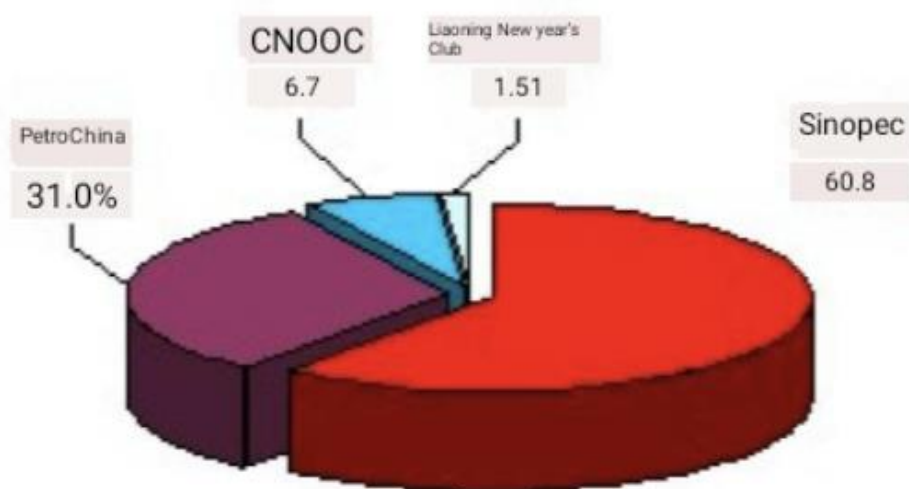


Figure C.1 – Ethylene capacity distribution

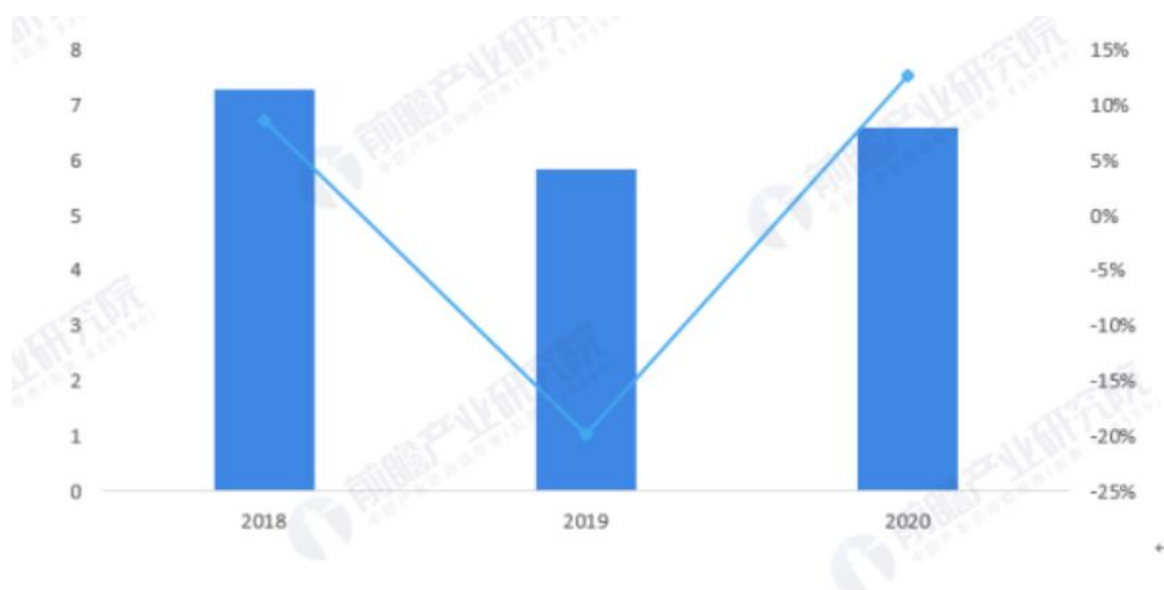


Figure C.2 – Main business income of enterprises above designated size in China's chemical industry from 2018 to 2020

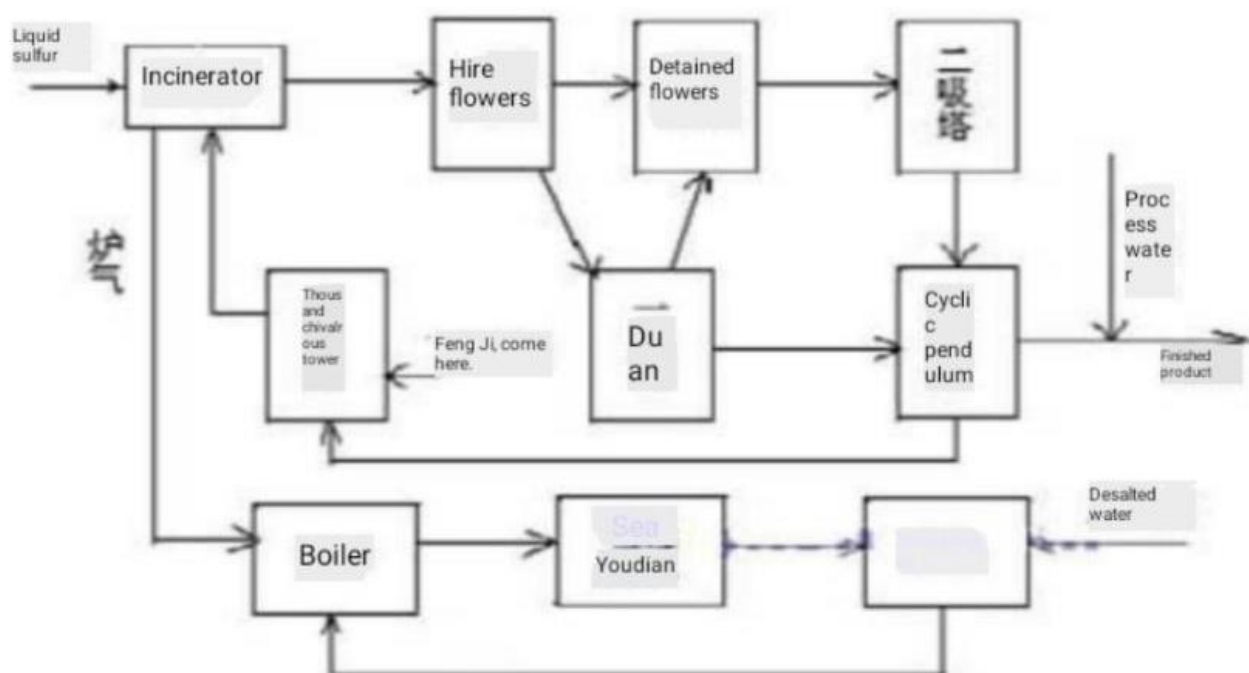


Figure C.3 – Flow diagram of sulfuric acid production from sulfur

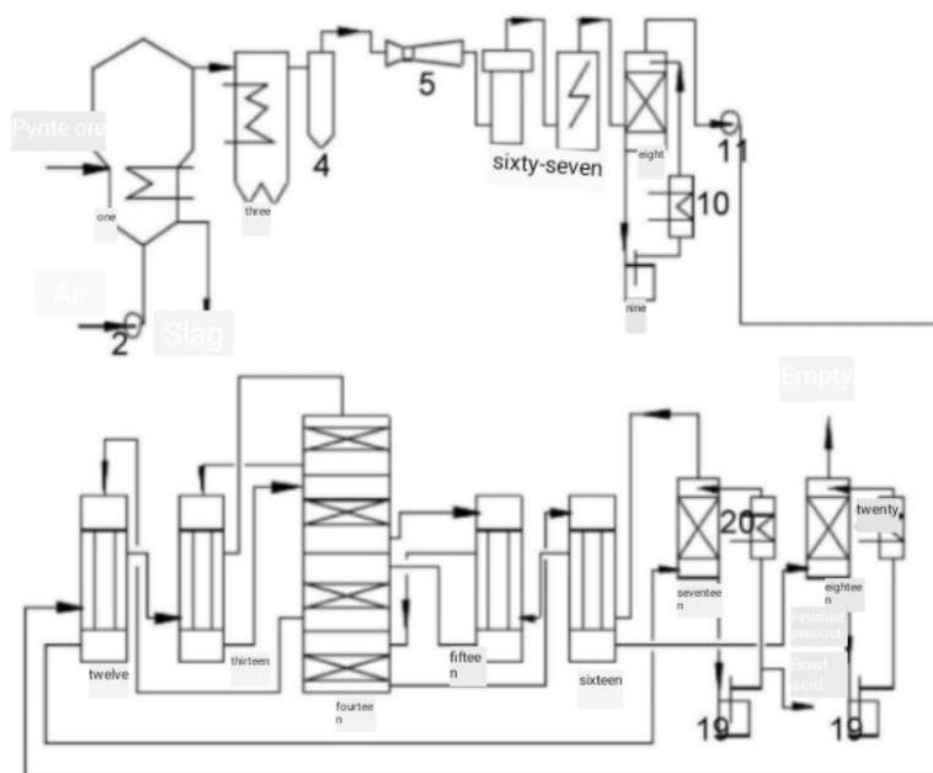


Figure C.4 – Contact sulfuric acid process flow chart: 1 – fluidized bed roaster; 2 – air blower; 3 – waste heat boiler; 4 – Cyclone dust collector; 5 – Venturi tube; 6 – foam tower; 7 – electric demister; 8 – drying tower; 9 – circulating tank and acid pump; 10 – acid cooler; 11 – Sulfur dioxide blower; 12, 13, 15, 16 – gas heat exchanger; 14 – converter; 17 – intermediate absorption tower; 18 – final absorption tower; 19 – circulating tank and acid pump; 20 – acid cooler

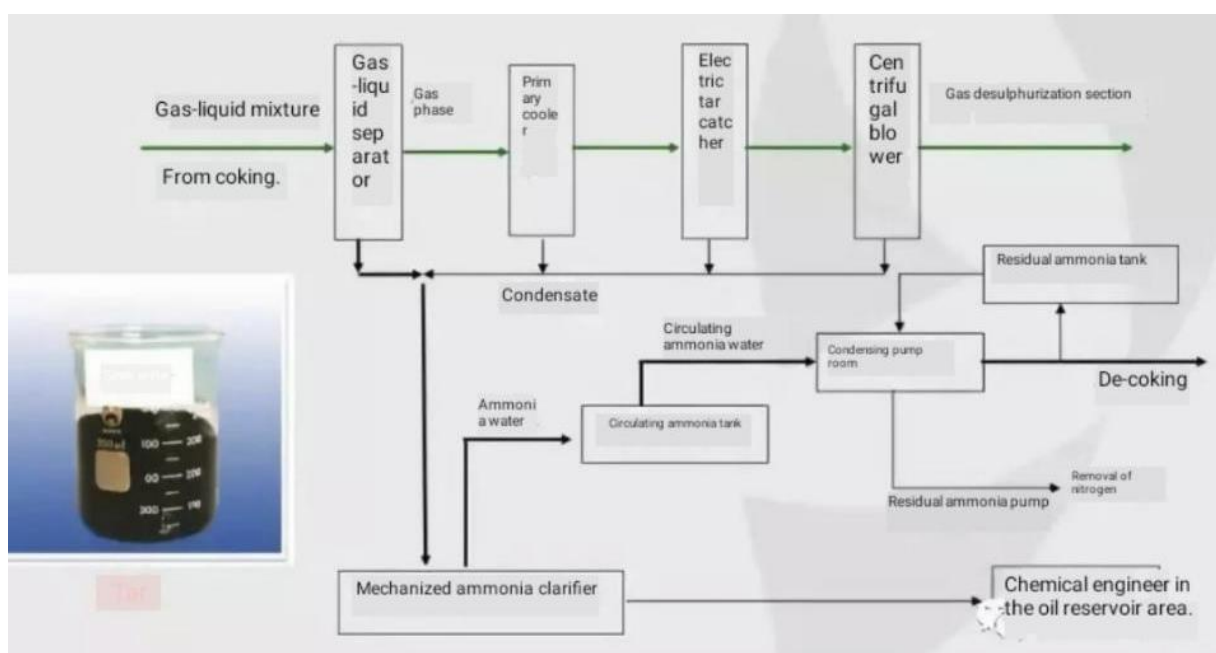


Figure C.5 – Flow chart of cold drum section