Global Environment Facility (GEF) 9771: Global best practices on emerging chemicals policy issues of concern under the Strategic Approach to International Chemicals Management (SAICM)

Component 1: Promoting regulatory and voluntary action by government and industry to phase out lead in paint

Market Analysis of the Coatings Industry in China

Reported by

Li Zixiu, Fang Gang, Lin Yuchen, Zhou Changbo

Chinese Research Academy of Environmental Sciences

(CRAES)/NCPC China

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Content

1 Background

A number of additional ‘Emerging Policy Issues’ (EPIs) have been nominated for voluntary cooperative risk reduction actions by countries through the Strategic Approach for International Chemicals Management (SAICM). In 2002, Governments agreed that “by 2020, chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment.”

One of the Emerging Policy Issues is focused on Lead in Paint. Lead paint is a major source of childhood lead exposure, for example via contaminated dust in homes that can be inhaled or ingested (UNEP 2010). There is no safe level of lead exposure known, and even relatively low levels of exposure to lead can cause serious and irreversible neurological damages, such as loss of IQ points. The Institute for Health Metrics and Evaluation (IHME) has estimated that in 2017 lead exposure accounted for 1.05 million deaths due to long-term effects on health, with the highest burden in low and middle-income countries. Lead in paints has raised the concern of the international community as an emerging policy issue. Over the past few years, the international community has called for global actions on law-making to reduce or eliminate the risk of lead exposure and they are actively taking actions to address the acute problem of lead in paints, in order to prevent and mitigate the harm to the human health and environment by exposure to lead.

In 2010, the Global Alliance to Eliminate Lead Paint, a voluntary partnership with secretariats by the United Nations Environment Programme (UN Environment) the World Health Organization (WHO) convened its first meeting in Geneva and was finally founded in 2011 upon the conclusion of the work at the operational level. The primary goal of the Lead Paint Alliance is to prevent children’s exposure to paints containing lead and to minimize occupational exposure to lead paint. The Lead Paint Alliance is working to phase-out the manufacture, import and sale of all paints containing lead. To achieve this global goal, countries must eliminate the use of lead additives in new paints by establishing and enforcing lead paint laws. The strategic target of the Alliance is for all countries to have effective lead paint laws in place by the year 2020.

China is a major producer of paints which supplies a considerable share of paints in the world. Key paint production hot spots were identified as Guangdong, Shanghai, Jiangsu, Hunan and Shandong provinces and cities. The cost of removing existing decorative lead paint from surfaces in homes, schools, and other buildings is significant. By comparison, the cost for eliminating the use of lead compounds in new decorative paints is low and alternatives to lead additives are available for all types of paints. Many manufacturers have successfully reformulated their paint products to avoid the intentional addition of lead. However, the continued use of lead paint around the country remains a significant source of human exposure. In this context, China has formulated and promulgated a range of policies and regulations on the elimination of lead paint, and the total lead limit shall apply to most of the paints from 2020.

China National Cleaner Production Center (NCPC China) is a unit of the Chinese Research Academy of Environmental Sciences (CREAS), one of the national government's research institutes with a particular mandate for undertaking policy relevant research in environmental sciences, engineering and management. NCPC China has been selected as a project executing partner in Lead in Paint Component output 1.1 of the Strategic Approach to International Chemicals Management (SAICM) Global Environment Facility (GEF), to promote regulatory and voluntary action by government and industry to phase out lead in paint.

2 Development status of major upstream and downstream of coatings industries of China

2.1 Downstream of the coatings industrial chain

2.1.1 Real estate industry

In 2018, the development of China's real estate industry showed a trend of regionalization, with rapid growth of policy housing, and slow commercial growth. The government is more inclined to develop western regions and second-tier and third-tier cities in terms of policy, land, and credit support. It has developed rapidly in shantytown renovation and policy-based housing, and investment in commercial residential and office buildings has been decelerated.

Table 2-1 Real estate development and investment in different regions of China in 2018

Region	**Investment Amount(billion)**		**Increase over 2017 (%)**	
	Total	Residential	Total	Residential
National Total	12026.4	8519.2	9.5	13.4
Eastern	6435.5	4535.2	10.9	14.0
Central	2518.0	1880.5	5.4	10.6
Western	2600.9	1760.3	8.9	13.5
North-east	472.0	343.3	17.5	20.0

2.1.2 Furniture industry

According to the National Bureau of Statistics, the annual main business income of the furniture manufacturing industry reached 701.19 billion RMB in 2018, with an increase of 4.3% over 2017, and the total annual profit reached 42.59 billion RMB. In the whole year, the export value of furniture and parts was 354.4 billion RMB, with an increase of 4.8% over the same period last year. The operating cost of furniture manufacturing was 594.0 billion RMB, with a year-on-year increase of 3.8%.

2.1.3 Automobile industry

In 2018, the production and sales of automobiles were 27.809 million and 28.81 million respectively, with the decrease of 4.2% and 2.8% over the same period of the previous year. The growth rate of the main economic indicators of the auto industry slowed down. On the one hand, it was affected by the full withdrawal of the purchase tax preferential policy; on the other hand, it was affected by factors such as the slowdown in macroeconomic growth, loss of consumer confidence.

2.1.4 Petrochemical industry

According to data from the National Bureau of Statistics, as of the end of 2018, there were 24,821 enterprises above designated size in the chemical industry in the petroleum and chemical industries, with a cumulative increase of 3.6%. The chemical industry maintained a momentum of improvement and its revenue growth was generally stable. The growth structure continued to be optimized and the manufacturing of basic chemical raw materials, synthetic materials and specialty chemicals contributed to a relatively high rate of revenue growth.

2.2 Upstream of the industrial chain--Inorganic pigment industry

2.2.1 Overview of iron oxide industry

In 2018, the overall economic operation of the iron oxide industry was at a low speed. With increasing pressure on environmental protection and safety regulations and the continuous increase in raw material prices, the iron oxide industry faces increased difficulty of market development. The United States is China's largest exporter of iron oxide pigments, with approximately 80,000-100,000 tons per year, accounting for more than 30% of total sales. Due to the stricter environmental protection requirements, many domestic pigment companies have been restricted or even suspended of production. Therefore the market supply has been reduced, and the export volume becomes relatively small.

Table 2-2 China's Exports of Iron Oxide

2018		**2017**		**Average export price**	
Export Volume	Sales USD	Export Volume	Sales USD	2018	2017
307700 tons	315 million	319220 tons	313.14 million	1023.72 USD/ton	980.5 USD/ton

Table 2-3 China's Imports of Iron Oxide

2018		**2017**		**Average import price**	
Import Volume	Incomes USD	Import Volume	Incomes USD	2018	2017
172570 tons	88.7 million	217400 tons	107.6 million	510.78 USD/ton	495.12 USD/ton

2.2.2 Overview of titanium dioxide industry

In 2018, there were 39 full-process enterprises of titanium dioxide industry with normal production conditions in China, with a decrease of 2 enterprises from the previous year. The reason for the decrease was the impact of corporate restructuring or capital chain. According to the statistics, in 2018, China's total production capacity of titanium dioxide was 3.4 million tons, and the actual output was 2,954,300 tons, with an increase of 2.95%. The national import of titanium dioxide was 209,200 tons, with a year-on-year decrease of 2.70%; while the export volume of national titanium dioxide was

908,300 tons, with an increase of 9.30%. The consumption of titanium dioxide in the country was 2.255 million tons. As the environmental protection policy further strictly controls pollutant discharge, the companies with heavy pollution and small production capacity will be further reduced and even shut down. Enterprises with energy-saving, emission-reduction, cleaner production, and the production of new products will become the mainstreams of titanium dioxide industry in China.

2.2.3 Overview of lead chromium industry

Since the 1990s, lead chromium pigments have developed rapidly and reached a peak in 2010. There were more than 20 companies by then, and the number has gradually decreased during the past 10 years. In 2020, there are only 7 companies that supply some special (such as military equipment and facilities) and heavy-duty industries, such as ocean engineering, large-scale infrastructure projects, etc. The existing producers are namely Shuangle Pigment, Xinxiang Hailun, Chongqing Jiangnan, Ningxia Junma, Qingyuan Shuangjiang, Hebei Jiacai, Shijiazhuang Youyi in China.

In 2016, the output of lead pigments is nearly 60,000 tons, while the output of lead-chromium pigment alternatives have not reached its full capacity yet, with 500 tons of bismuth yellow, 5000 of MMO pigments and 1000 tons of others. The capacity and output of alternatives are shown in Table 2-4.

Table 2-4 Output of lead-chromium pigment and alternatives in 2016

Items	**Pigments (tons)**			
	Lead-containing pigments (lead chrome yellow)	**Bismuth Yellow**	**MMO pigment**	**Others**
Global demand	--	10000	50000	100000
China demand	--	5000	15000	80000
Global production capacity	--	2000	20000	10000
China's production capacity	--	500	5000	2000
China’s output	60000	500	5000	1000

Calculations based on pigment output of top enterprises as reference

The output of lead chromium pigments for the existing seven supplier of 2017 and 2018 are shown in Table 2-5.

Table 2-5 Output and export of lead-chromium pigment in 2017 and 2018

2018		**2017**	
Output /tons	Export Volume /tons	Output /tons	Export Volume /tons
54000	2500	51000	3200

Source:CNCIA

3 Overview of coatings market of China

3.1 Coatings classification

According to the classification of coatings' function, domestic commercial coatings can be categorized into architectural coatings, general coatings, industrial coatings and auxiliary materials. Architectural coatings include interior and exterior wall coatings, waterproof coatings, floor coatings and functional architectural coatings. Industrial coatings include automotive coatings, railways and road coatings, marine coatings, wood coatings, light-industrial coatings, anticorrosive coatings and other special coatings. General coatings and auxiliary materials include blending paint, varnishes, enamels, primers, putties, thinners, moisture barriers, drier, paint remover, curing agents and others

In terms of classification of coating's properties, coating products can be categorized into solvent-based coatings and water-based coatings. Solvent-based coatings refer to the coatings produced by using organic solvents as dispersion medium, including epoxy coatings, acrylic polyurethane coatings, fluorocarbon coatings, alkyd coatings, chlorinated polyolefin coatings, silicone coatings and other types of coatings. Water-based paints refer to the use of water as a dispersion medium, mainly including water-soluble paints, water-dilutable paints, and water-dispersible paints.

3.2 Market analysis of China's national coatings industry

According to China National Coating Industry Association (CNCIA) statistics, coating output was 24.388 million tons in 2019, with a year-on-year increase of 2.6%. The national paint sales volume was 24.161 million tons, compared with 17.468 million tons, with a year-on-year increase of 38.32%

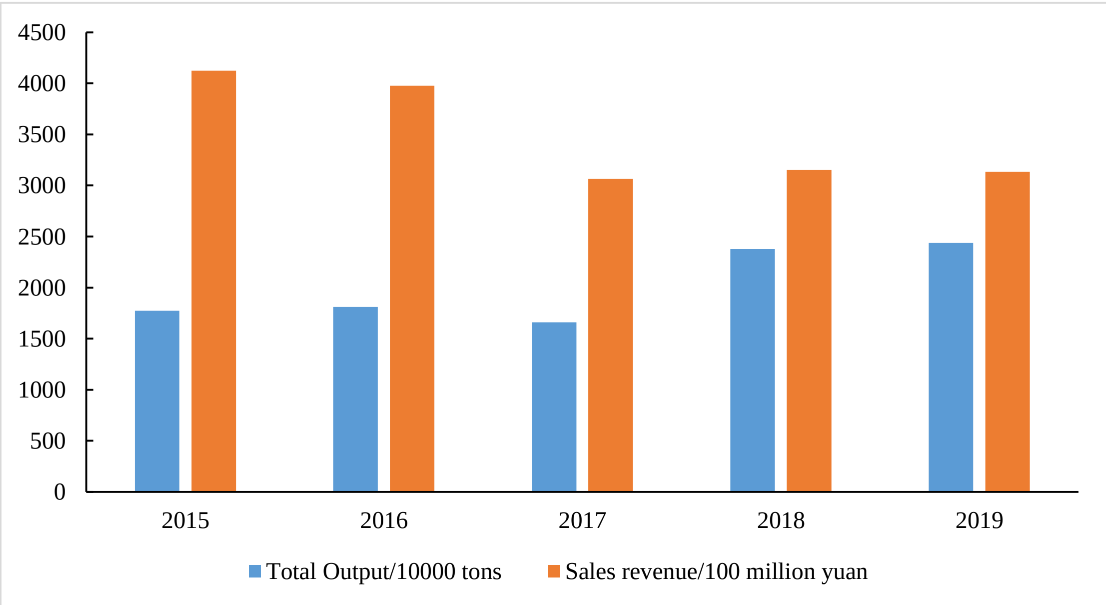


Figure 3-1 Output and Sales of China's Coatings Industry from 2015 to 2019

In the four quarters of 2019, the cumulative output of the coatings was 3.86 million, 9.64 million, 18.53 million and 24.93 million tons respectively, increased by 7.3%, 4.8%, 9.2% and 2.6% (Figure 3-2). The rapid production growth is mainly concentrated in the third quarter.

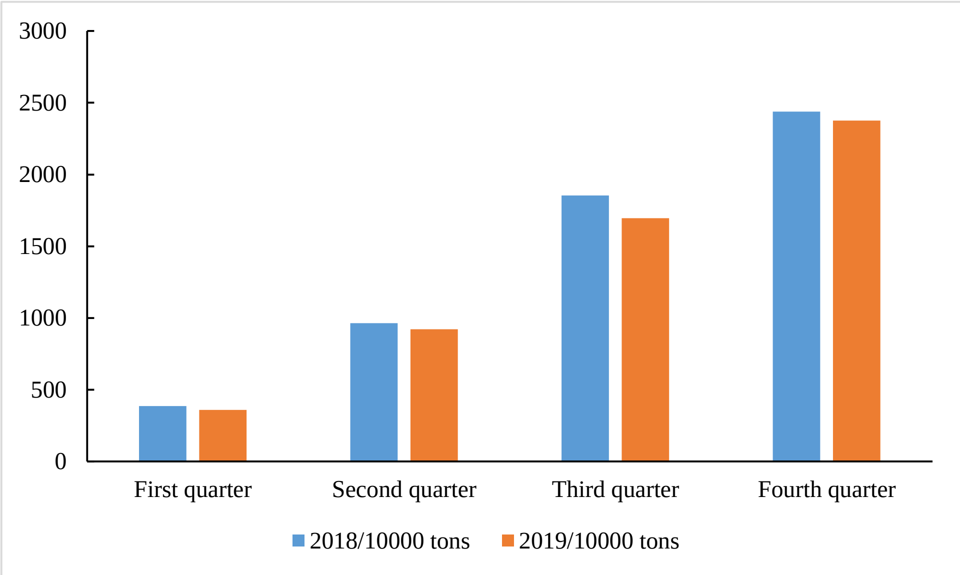


Figure 3-2 Quarterly Cumulative Output Distribution of China's Coatings Industry from 2018 to 2019

In the four quarters of 2019, the cumulative income column was 69.3 billion RMB, 148.9 billion RMB, 228.9 billion RMB, and 313.2 billion RMB, rose by 2.7%, -1.0%, -0.3%, -0.6% year-on-year (Figure 3-3). The main business growth rate was only positive in the first quarter, and negative growth in the second, third and fourth quarters. The main reason for the drop is closely related to the industry development in 2019. On the one hand, import and export trade was blocked and declined; on the other hand, the downward pressure on the domestic industry's economy resulting in the low consumption and demand of downstream.

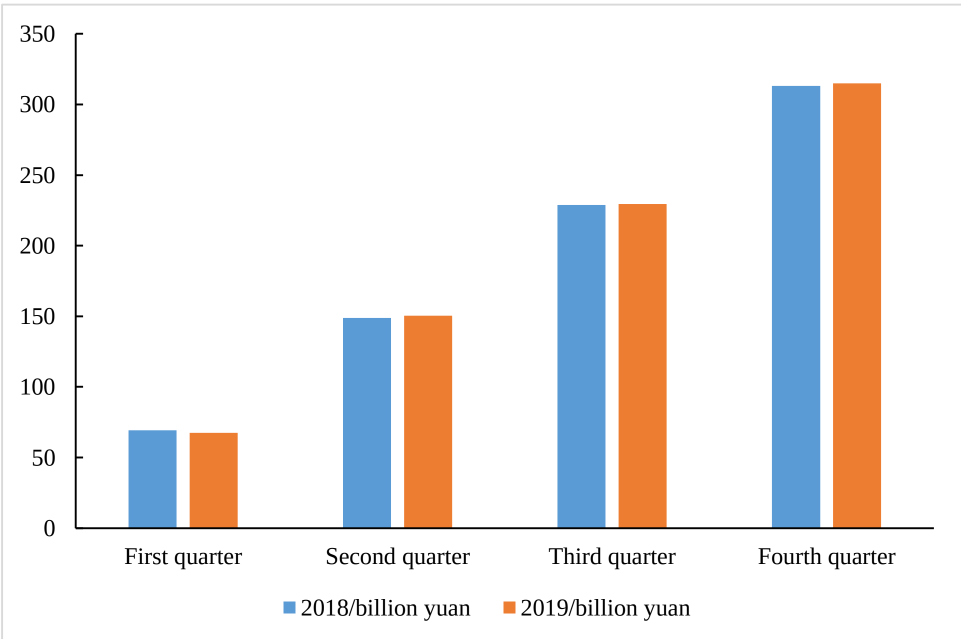


Figure 3-3 Quarterly Cumulative Income Distribution of China's Coatings Industry from 2018 to 2019

3.3 Market analysis of the coatings industry in provincial level of China

The provinces with annual output of more than 500,000 tons of China's coatings industry and a year-on-year growth rate of more than 10% in 2019 include: Zhejiang (32.3%), Fujian (15.8%), Henan (23.1%), Chongqing (54.4%) and Sichuan provinces (13.9%). The provinces with annual output of more than 1 million tons and a year-on-year growth rate of more than 5% include: Zhejiang, Fujian, Hunan provinces (7.5%), Guangdong (9.3%), Sichuan (13.9%), and the above-mentioned provinces and cities have played a positive role in driving the growth of China's coatings industry.

Provinces and cities with annual production volume of 1 million tons and above but a year-on-year decrease of more than 5% include: Shandong (-22.6%), Hubei (-22.1%) and Jiangsu (-7.5%), and the rapid decline is closely related to the environmental protection and safety regulations in 2019. For example, some industrial parks in regions are closed and some companies are required to withdraw from local operations, but it is difficult to find a suitable chemical park to rebuild in a short time. In addition, for some cities belonged to special control areas of air pollution, enterprises are hard to achieve normal production under new environmental protection policies.

According to Figure 3, China's coatings industry has an annual output of more than 100,000 tons in 2018. The provinces and cities have increased by more than 20% in Guizhou (67.4%), Yunnan (44.12%), Hebei (42.64%), Hunan (26.11%), Chongqing (24.28%), Hubei (21.64%) and Guangxi (21.04%), which are mainly concentrated in the central and southwestern regions. The provinces and cities have increased by 10% and above include Shandong (14.5%), Anhui (14.2%) and Fujian (13.4%), and those are all located in East China. Within China's "13th Five-Year Plan" period, the coatings industry is rapidly concentrated in east, central south and southwest China. With the further deepening of the industrial structure adjustment, production of Anhui will be assumed to transfer in Jiangsu, Zhejiang and Shanghai.

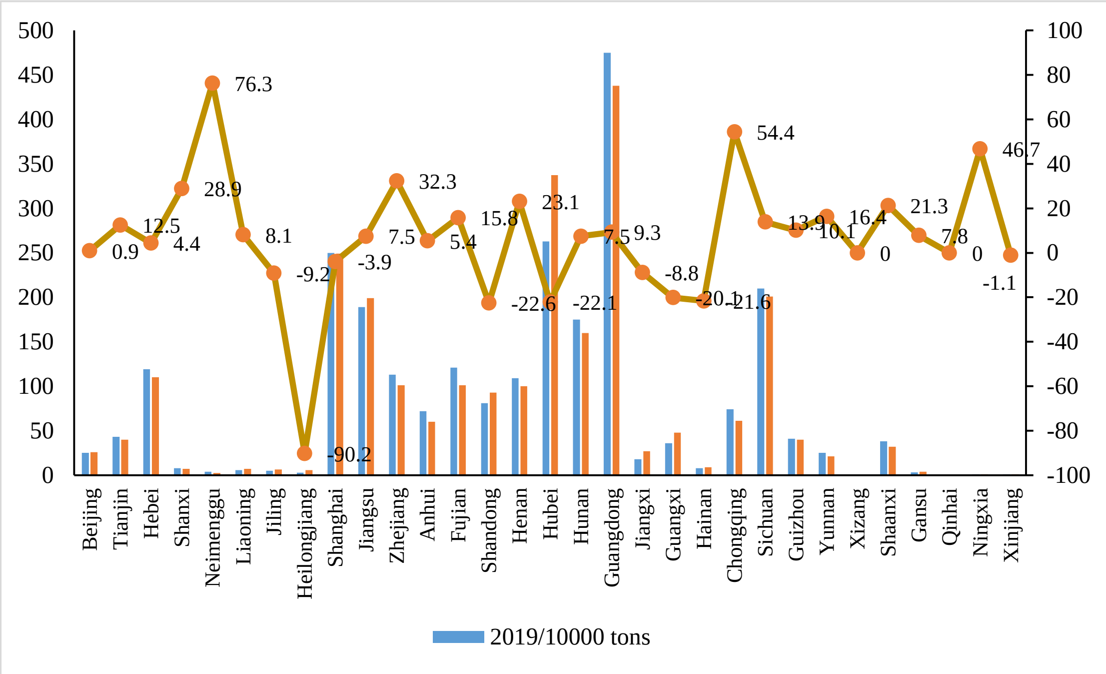


Figure 3-4 Coatings Output Distribution of Provinces and Municipalities of China in 2019

3.4 Analysis of the total revenue of the China's coatings industry

The distribution of the total revenue of China's coatings industry in 2019 shows that the main the revenue of Top 100 companies accounted for 42% of the total of the entire industry, the Top 101-200 companies accounted for 15%; 201-500 ranked companies accounted for 21%, 501-1,000 ranked companies accounted for 14%; the enterprises listed after 1,000 accounted for 8%. Compared with those date of 2018, the proportion of the Top 100 companies decreased by 6.91%, and the proportion of companies ranked 101-200, 201-500, 501-1,000, and 1,000 companies increased by 1.5%, 2.4%, 1.89% and 1.11% respectively, which fully demonstrates that the central government and local governments' support policies for small and medium-sized enterprises have been effective realized this year, and the balanced development of the industry is more conducive to the healthy development of the industry.

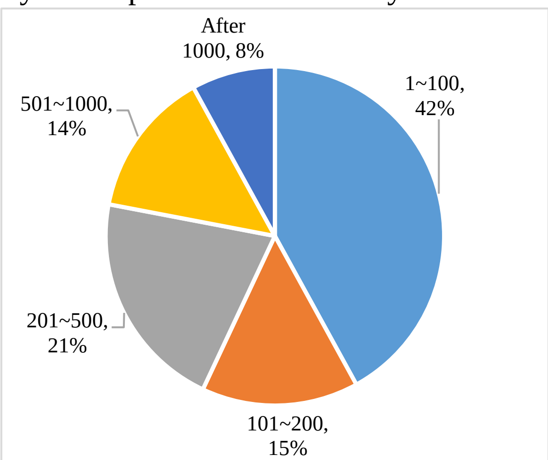


Figure 3-5 Total Revenue Distribution of Ranked Coatings Enterprises in 2019

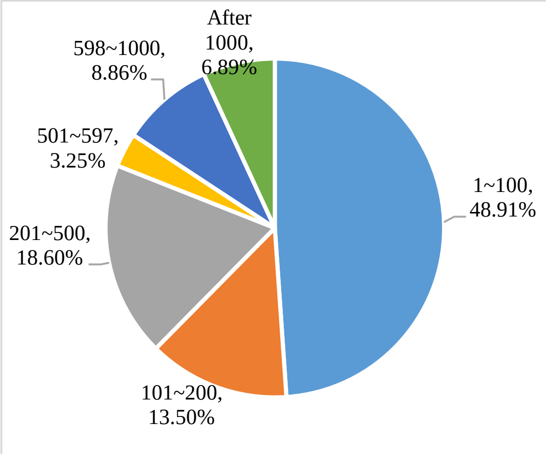


Figure 3-6 Total Revenue Distribution of Ranked Coatings Enterprises in 2018

3.5 Analysis of Top 100 coatings enterprises of China coatings industry

The output of the top 100 coatings enterprises in 2019 is about 9.43 million tons, a year-on-year increase of 5.7%. The business revenue was 120 billion RMB, with an increase of 0.3% year-on-year. The average profit rate was 8.6%, slightly higher than the industry average of 7.3%.

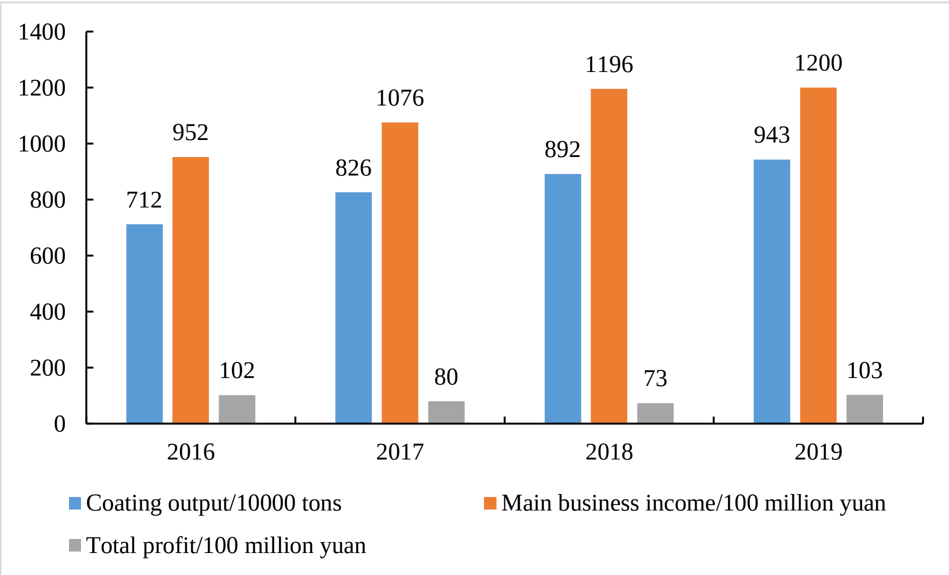


Figure 3-7 Output and Revenue of Top 100 Enterprises of China's Coatings Industry from 2016 to 2019

For the Top 100 companies in 2019, Chinese capital accounted for 42.6% and number was 42.2% in 2018, while foreign/joint ventures accounted for 57.4% and it was 57.8% in 2018, as shown in Figure 3-8 and Figure 3-9. The proportion of Chinese capital increased slightly compared to 2018.

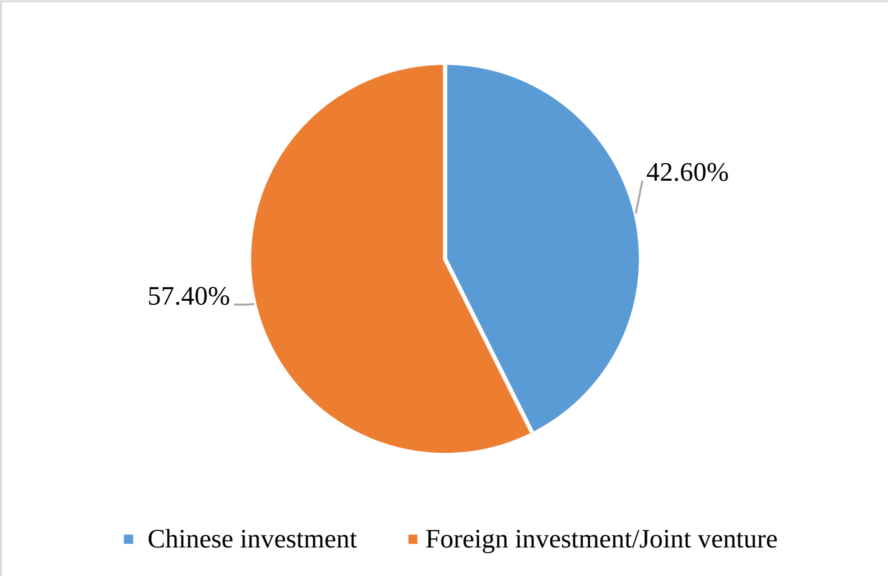


Figure 3-8 Comparison of business income of Chinese-funded and foreign-funded of China Coatings Industry Top 100 enterprises in 2019

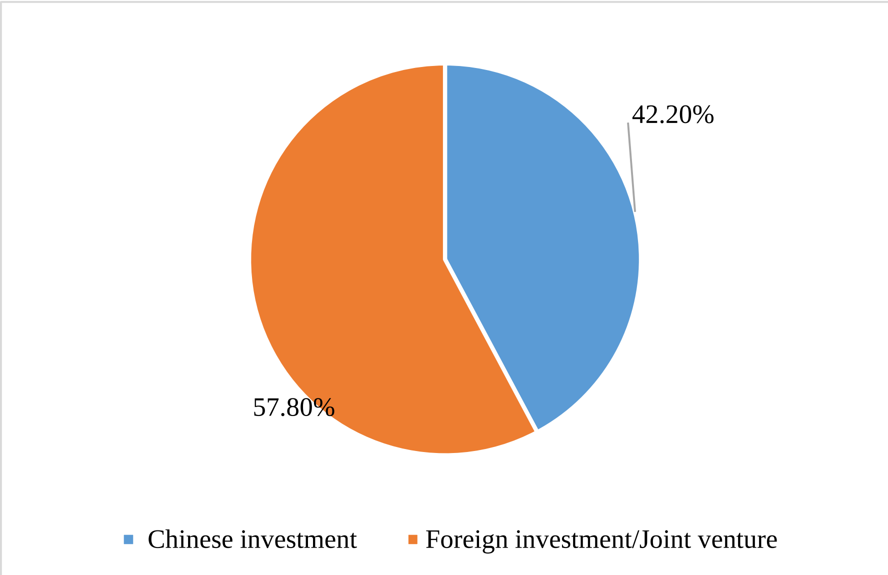


Figure 3-9 Comparison of business income of Chinese-funded and foreign-funded of China Coatings Industry Top 100 enterprises in 2018

As shown in Figure 3-10, the output of industrial coatings was about 4.22 million tons, and the output of architectural coatings was around 5.22 million tons in 2019. The total revenue of industrial coatings was 76.3 billion RMB, and the revenue of architectural coatings was 45.3 billion RMB. Although the output of architectural coatings is higher than that of industrial coatings, but the main income is much lower than that of industrial coatings. The main reason for the analysis is that the market pricing of architectural coatings is still low. In this regard, architectural coatings companies also need to increase the added value of their products through high-quality development.

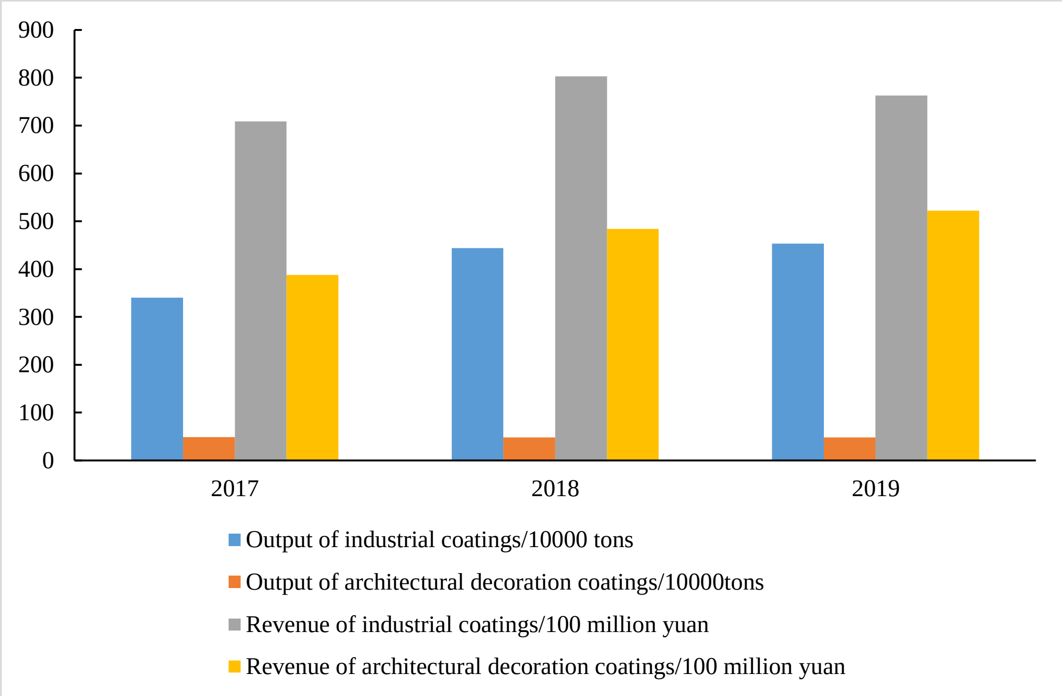


Figure 3-10 Data of Top 100 enterprises of industrial and architectural decoration from 2017 to 2019

The size of a paint producer shall be stipulated by the *Circular of the National Bureau of Statistics on Printing and Distributing the Measures for the Classification of Large-, Medium-, Small-, and Micro-Enterprises in Statistical Term*. The classification standards is shown in Table 3-1. An enterprise has to be equal to or above the minimum limit of each indicator to be classified as a large-, medium-, or small-sized enterprise; otherwise, it shall be classified into a smaller size. A micro-sized enterprise only has to meet the requirement of either indicator.

Table 3-1 Classification of large-, medium-, small-, and micro-sized enterprises

Sector	Indicator	Unit	Large	Medium	Small	Micro
Industrial Sector	Payroll (X)	Person	X≥1000	300≤X<1000	20≤X<300	X<20
	Business revenue (Y)	10,000 yuan	Y≥40000	2000≤Y<40000	300≤Y<2000	Y<300

3.6 Output of different categories of coatings products in China

In 2018, architectural coatings production accounted for 35% of the total, while industrial coatings production accounted for 65%, of which industrial protective coatings accounted for 37% in China, automotive coatings accounted for 9%, wood coatings accounted for 6%, and powder coatings accounted for 8%, marine coatings accounted for 3%, and other coatings accounted for 2%, as shown in Figure 3-11.

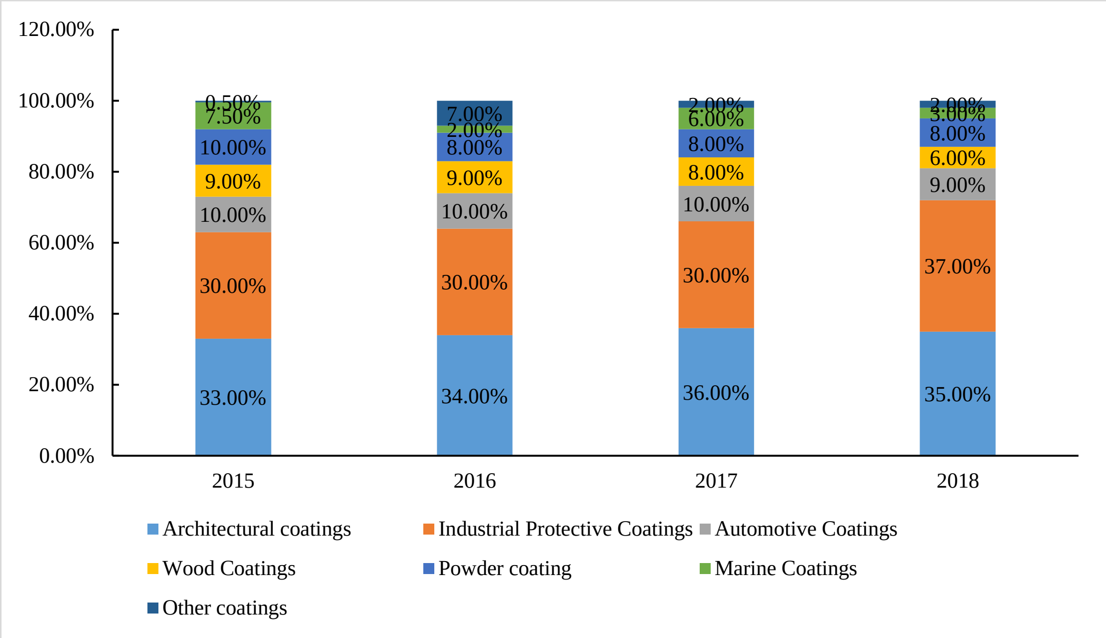


Figure 3-11 Proportion of Different Categories of Coatings in the Industry from 2015 to 2018

3.6.1 Architectural coatings market

The architectural coatings industry slowed down under strict environmental protection pressure. In 2019, the output growth rate of architectural coatings companies was about 7%, reaching 6.94 million tons. If calculated based on 1% of real estate investment, the sales revenue would be 132.2 billion RMB. The output national architectural coatings and the proportion of architectural coatings in coatings from 2012 to 2019 are shown in the following Table 3-2.

Table 3-2 China's Output of Architectural Coatings

Year	Coatings		Architectural Coatings		
	Output(10000-ton)	Growth rate(%)	Output(10000-ton)	Growth rate(%)	Proportion of architectural coatings(%)
2012	1272	17.8	416	20.4	32.7
2013	1303	2.4	478	14.9	36.7
2014	1648	26.5	516	7.9	31.3
2015	1718	4.2	538	4.2	31.1
2016	1900	10.6	577	7.2	30.4
2017	2036	7.2	630	9	30.9
2018	1760	-13.6	649	3	36.9
2019	2439	38.6	694	7	28.5

Statistics in Figure 3-12 shows that the total output of China's architectural coatings in 2011 was about 3.4 million tons, the output in 2019 was about 6.9 million tons, accounting for about 30% of the total output of coatings in China. The proportion of traditional Chinese solvent-based coatings is gradually decreasing, and the development of water-based coatings is rapid. Compared with other categories of coatings products, architectural coatings account for the highest share.

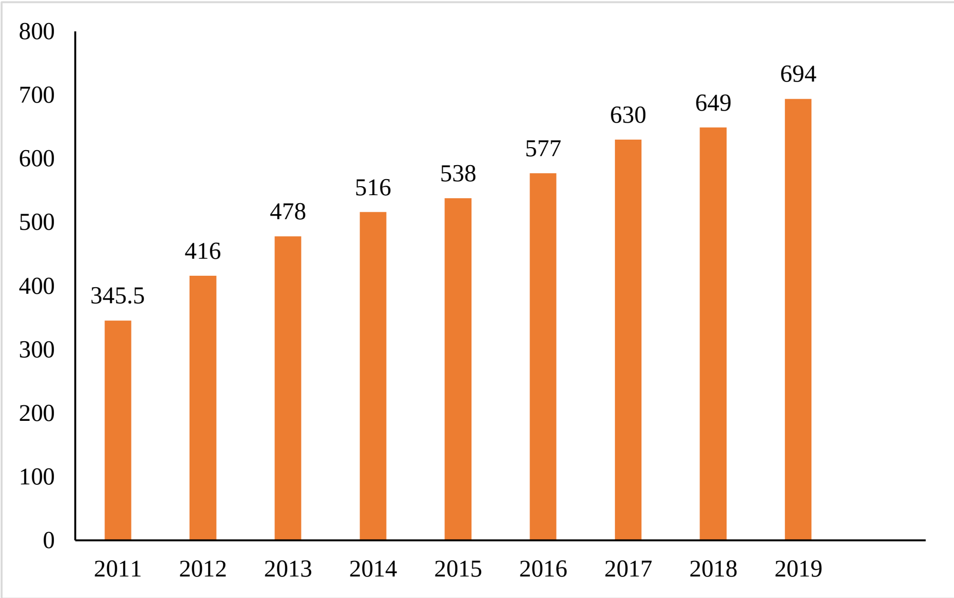


Figure 3-12 Output of Architectural Coatings in China from 2011 to 2019(10000 tons)

The architectural coatings product is improved with the highlights as following:

(1) Bio-based architectural coatings. It can reduce oil dependence, low carbon emissions, reduce the greenhouse effect, and promote the sustainable development of the coating industry. Some companies introduced bio-based architectural coatings, especially bio-based interior wall coatings. However, bio-based architectural coatings still need to solve some problems, such as insufficient supply in the medium and long term, competition with food and overall utilization of arable land, cost-effective issues, etc.

(2) Inorganic architectural coatings. Inorganic architectural coatings have become a hot spot for recent development in China because it has good fire resistance and belongs to Class A. The advantages of inorganic architectural coatings include fire resistance, good durability and air permeability, but the disadvantages are that they are inferior to organic architectural coatings in terms of decoration, construction and water absorption.

(3) Flexible ceramic coatings/liquid granite coatings. According to "Organic Coatings Science and Technology" (2017), it includes alkyd bright ceramic coatings and latex bright ceramic coatings, and domestic inorganic flexible ceramic coatings.

(4) Sand-containing colorful paint and reflective and heat-insulating colorful paint are much applied in engineering.

3.6.2 Automotive coatings market

According to data released by the China Automobile Association, automobile production and sales have experienced negative growth since May 2018. The total output for 2018 was 27,809,200 vehicles, with a drop of 4.16%; the total sales were 28,080,600 vehicles, with a drop of 2.76%. According to statistics from the Ministry of Public Security, the number of car ownership reached 240 million. China’s car ownership is about 170 per 1,000 people, this number much lower than the US’s 800.

Automotive coatings are one of the fastest-growing varieties in the coatings industry, as well as those with the highest performance requirements in China. It is estimated that by 2022, the production scale is to exceed 3 million tons. The output of automotive coatings from 2011 to 2018 is shown in Figure 3-13.

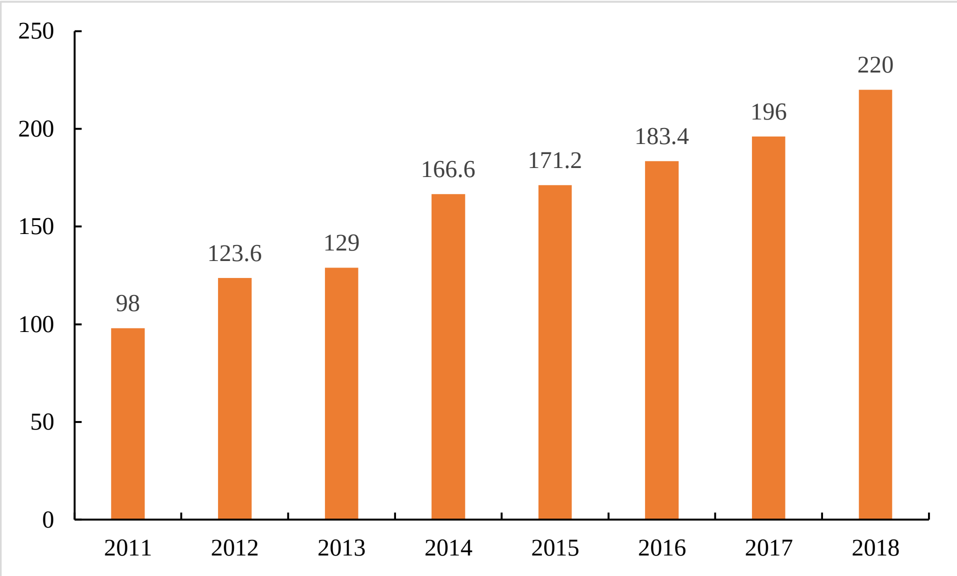


Figure 3-13 Output of Automotive coatings in China from 2011 to 2018(10000 tons)

Cars coatings accounted for the largest proportion with 49% of the total, followed by SUV accounting for 20.7%, MPV accounting for 9.2%, microbuses accounting for 3.3%, truck coatings for 13%, and passenger car coatings for 5.2% (Figure 3-14).

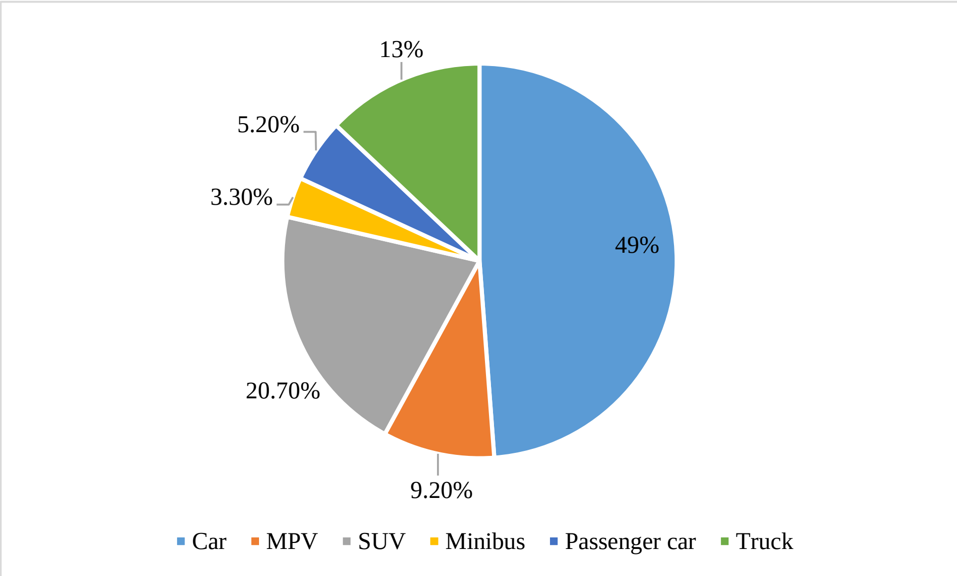


Figure 3-14 Coatings Proportions of Varying Vehicles in 2018

Automotive coatings mainly keep long-term protection and appearance for automobiles. They can be divided into three categories: original equipment manufacturer (OEM) coatings, automotive refinish paints, and automotive interior and exterior parts coatings. From the perspective of the global market, the development trend tends to be stable.

The market shares of OEM coatings and automotive refinishes are occupied by a few well-known companies worldwide. Table 3-3 lists the basic situation of the world's top ten automotive coatings companies in 2018.

Table 3-3 Top 10 Automotive Coatings Companies in 2018

No.	Company	Headquarter	Automotive paint sales(100 million US dollars)	Market share
1	PPG	USA	46.122	19.22%
2	BAFS	Germany	35.774	14.91%
3	AXALTA	USA	33.982	14.17%
4	Nippon	Japan	18.112	7.55%
5	AkzoNobel	Netherlands	15.941	6.64%
6	Sherwin-Williams	USA	14.00	5.83%
7	Kansai	Japan	13.137	5.47%
8	KCC	Korea	11.072	4.61%
9	Xiangjiang	Sino-Japan	4.961	2.07%
10	Worwag	Germany	2.251	0.94%

(1) Automotive Coatings (OEM) Market

Automotive OEM coatings are mainly used in new car assembly lines, so they have a high correlation with new car sales.

For the global automotive OEM coatings, foreign brands occupy a dominant position and the competitiveness of Chinese brands is very weak. Foreign shareholders of joint venture auto companies have always occupied a leading position in terms of car components technology and supplier certification access.

According to data from Sohu.com, in the first half of 2019, a number of paint companies experienced a slight negative sales growth. BASF dropped 1%, of which OEM coatings dropped significantly; AkzoNobel automotive coatings and specialty coatings fell 1%; Axalta fell 4.72%, and OEM coatings were the main decline factor.

(2)Automotive interior and exterior coatings market

Automotive interior and exterior trim coatings are used for interior and exterior trim coatings for new cars, as well as replacement parts for automotive aftermarket. The exterior large-part coatings and OEM coatings have similar market patterns, with European, American, Japanese and Korean monopolists occupying most of the market. For small and medium-sized exterior and interior coatings, due to the messy characteristics of mixed colors, small and multiple batches, coupled with long-term historical cooperation under country restrictions, these companies in Europe, America and Japan have occupied their professional territories. The market concentration of automotive interior and exterior trim coatings also shows an accelerated upward trend, but the relative monopoly of OEM coatings has eased.

Comprehensive analysis based on the official website of each company and media reports and other information, it is listed relevant information about China's automotive interior and exterior coatings industry in 2019 (Table 3-4).

Table 3-4 2019 China's Automotive Interior and Exterior Coatings Industry Information

No.	Company	Headquarter	Product	Major clients
1	PPG	USA	Exterior	GM, Volkswagen, Ford, Great Wall, Geely, SAIC, GAC, BYD, Changan, SAIC-GM-Wuling
2	AkzoNobel	Netherlands	Interior and exterior	Audi, Volkswagen, GM, Hyundai, Great Wall, BYD
3	Kansai	Japan	Exterior	Nissan, Toyota, Changan, SAIC-GM-Wuling
4	AXALTA	USA	Interior and exterior	GM, Ford, Volkswagen, SAIC, Geely, Mercedes-Benz, Volvo
5	BAFS	Germany	Exterior	Volkswagen, Nissan, Honda, Toyota, SAIC, Geely, BMW
6	Nippon	Japan	Exterior	Nissan, Honda, Great Wall
7	Nippon Bee	Japan	Interior and exterior	Toyota, Honda, Nissan, Mazda, GAC, BYD
8	Donglai	China	Interior and exterior	Nissan, Audi, Honda, Toyota, GM, Volkswagen, Hyundai, SAIC, Geely, Great Wall, GAC, SAIC-GM-Wuling, Changan, Peugeot Citroen, FAW, Jaguar Land Rover, Volvo
9	KCC	Korea	Exterior	Hyundai, Great Wall, BAIC, Kia
10	Musashi	Japan	Interior	Toyota, Honda, Nissan
11	Peter-Lacke	Germany	Interior	GM, Ford, SAIC, Volkswagen
12	Worwag	Germany	Interior and exterior	Volkswagen, GM, SAIC, Audi, Mercedes-Benz, BMW, Great Wall
13	Mankiewicz	Germany	Interior	Volkswagen, Audi, Mercedes-Benz, SAIC, Peugeot Citroen, Borgward
14	Fujikura Kasei	Japan	Interior	Toyota, Nissan, Honda, Mazda
15	Origin	Japan	Interior	Toyota, Honda, Nissan, Geely

(3) Automotive refinish coatings market

Automobile refinishing paints are mainly used for after-sales maintenance of passenger cars and painting of new passenger cars. Car ownership is the main influencing factor for the market, secondary factors include that economic expectations affect the actual mileage of car owners, insurance rate policies affect the frequency of small sheet spray maintenance, and technical progress in traffic laws and regulations affect the vehicle accident rate.

Unlike the automotive OEM coatings industry defined as high-tech advanced manufacturing, the automotive refinish industry is essentially a modern service industry based on high-tech manufacturing, with the following characteristics: (1) customers are extremely scattered. There are 29,000 brand 4S stores and 500,000 auto repair shops in China; (2) on-site color matching. 80~100 semi-finished masterbatch systems, high-level color technicians deployed on site to 100,000 repair colors without color difference and restoration of primary colors; (3) complex combination of various primers, color paints, varnishes and water-based and oily products that requires on-site professional technical training and guidance.

The best performing companies in China's automotive refinish market in 2019 are PPG, Donglai Coatings, Axalta, AkzoNobel and BASF. Table 3-5 lists the relevant situation of the brands in the Chinese market for automotive refinish in 2019.

Table 3-5 Market brands of automotive refinish coatings in China (2019)

No.	Company	Headquarter	First-tier(1) high-end brands	Second-tier(2) mid-range brands	Third-tier(3) economic brands
1	PPG	USA	Autocolor 2K Deltron Aquabase PLUS Envirobase	ACS Haocai EmaXX Quickline	V-pro Bonny NPIT AIERF PROGRESS DOLLA KJL
2	Donglai	China	Onwings Onwaves Fixs	YESKY	
3	AXALTA	USA	Spies Hecker Permahyd Cromax Cromax Pro	Duxone Syrox	Lucite ANVANC Nason
4	AkzoNobel	Netherlands	Sikkens Autowave	Lesonal Wanda	Miluz PRIME FREYA CLONE PEILIDE SHITEMEI
5	BAFS	Germany	Glasurit R-M	Baslac	Norbin
6	Sherwin-Williams	USA	Ultra7000 AWXP	ATX FINISH1 Quantum	OCTORAL PLANET DFL

				DE BEER	RUNNING CONELY
7	Nippon	Japan	NAX E3WB	LACS Uni-best	Light

(1)First-tier high-end brands refer to the global quality certification of mainstream auto brands, which are mainly for car 4S shops and mid to high-end car customers;

(2)Second-tier mid-range brands refer large and medium-sized repair shops and low-end brands 4S shops;

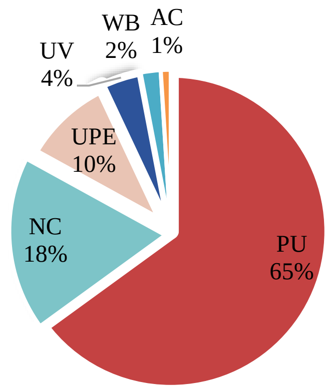
(3)Third-tier economic brands refer to small and medium repair shops.

3.6.3 Woodware coatings market

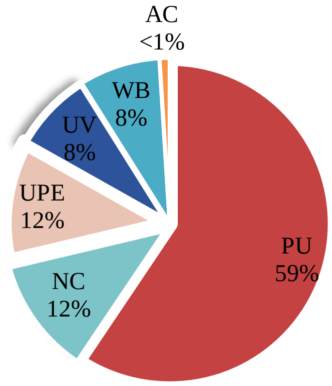
The woodware coatings manufacturers were mainly concentrated in the Pearl River Delta region in early to mid-1990s, and then gradually developed into the Yangtze River Delta and North China. By the end of the 1990s, it began to spread across the country. In recent years, as national policies and regulations, the enterprises are concentrated to industrial parks. The woodware coatings manufacturers exceeds 600 in China. The output of the top 10 companies accounts for 49% of the total, and the output of the top 30 companies accounts for more than 73% of the total. Although foreign-funded enterprises also occupy a certain market share, private enterprises have been the absolute main force in China's woodware coatings industry. As a major manufacturing country in the global furniture industry, China's annual furniture main business revenue reached 701.19 billion yuan, with an increase of 4.3% over 2017, and its total annual profit reached 42.59 billion r.

According to data from American Coatings Industry Association: woodware coatings accounted for about 7% of the market in 2018, and the growth rate of global coatings is expected to be about 5% in 2020. In China, woodware coatings market is dominated by polyurethane (PU) coatings, and the proportion of nitro (NC) coatings has declined. Large-scale American furniture manufacturers began to use water-based wood coatings, such as water-based acrylic (PA) coatings, whose performance is similar with that of nitro (NC) coatings. The proportion of unsaturated polyester (UPE) coatings has declined, and they are mainly used as fully enclosed primer and in conjunction with polyurethane (PU) topcoat. UV coatings are mainly used in furniture such as wooden doors and cabinets with regular shapes. The proportion of water-based woodware coatings has increased, mainly in IKEA, children's furniture, toys, doors and windows, and simple furniture, etc.

So far, woodware coatings have developed six categories, including nitro (NC), solvent polyurethane (PU), unsaturated polyester (UPE), acid curing (AC), light curing (UV), and water-based (WB) coatings. NC, PU and UPE woodware coatings have been widely used in the past 40 years. UV woodware coatings have developed rapidly from 2000 to 2010. After 2010, especially from 2015 to the present, water-based woodware coatings have emerged and showed strong trend. The two-component and UV-based water-based woodware coatings are gradually leading the coatings market with a very high annual growth rate. As of 2012, the market share of PU coatings is about 65%, NC coatings accounts for 18%, UPE coatings is about 10%, UV coatings takes a proportion of 4%, and water-based coatings shares 2%. AC coatings have gradually faded out of the market due to their hazards, and NC coatings have gradually declined. PU coatings are still in a dominant position, and UV and water-based wood coatings are still in their infancy. As of 2017, China's total output of wood coatings is about 2.6 million tons. The market share of PU coatings is about 60%, NC coatings makes up for 12%, UPE occupies 12%, UV coatings is about 8%, and water-based coatings accounts for 8%; PU coatings is still in the As the leading position, the production of NC coatings is gradually shifting to Southeast Asia, UPE coatings have little room for improvement, and UV coatings are gradually improving. Water-based wood coatings will gradually increase their market share with a rapid development trend. China's total output of wood coatings is about 2.6 million tons in 2017. The market share of various domestic wood coatings products: PU coatings about 60%, NC coatings about 12%, UPE coatings about 12%, UV coatings about 8%, and water-based coatings about 8%. PU coatings are still in a dominant position, and the production of NC coatings is gradually shifting to Southeast Asia. There is no much room for improvement of UPE coatings. UV coatings are gradually improving, and water-based wood coatings increase their share with a rapid development trend. The woodware coatings market in 2012 and 2017 are shown in Figure 3-15.



(a) Sales Distribution of China's Woodware Coatings in 2012



(b) Sales Distribution of China's Woodware Coatings in 2017

Figure 3-15 Profile of the China's Industrial Woodware Coatings Market

The United States of America (USA) is a major country in the use of nitro coatings. Water-based woodware coatings have already been used in the United States, such as in furniture, flooring, etc.; Europe has stricter VOCs emission standards for coatings (VOCs≤300 g/L), and Germany and some Nordic countries have a relatively high water-based ratio of wood coatings production, reaching more than 60%. The situation in China is similar to the United States that solvent-based coatings are dominated by PU. With the improvement of technology, the growth of national policies and consumers' awareness raising, the market share of water-based woodware coatings will continue to grow. The overview of the global woodware coatings market is shown in Figure 3-16.

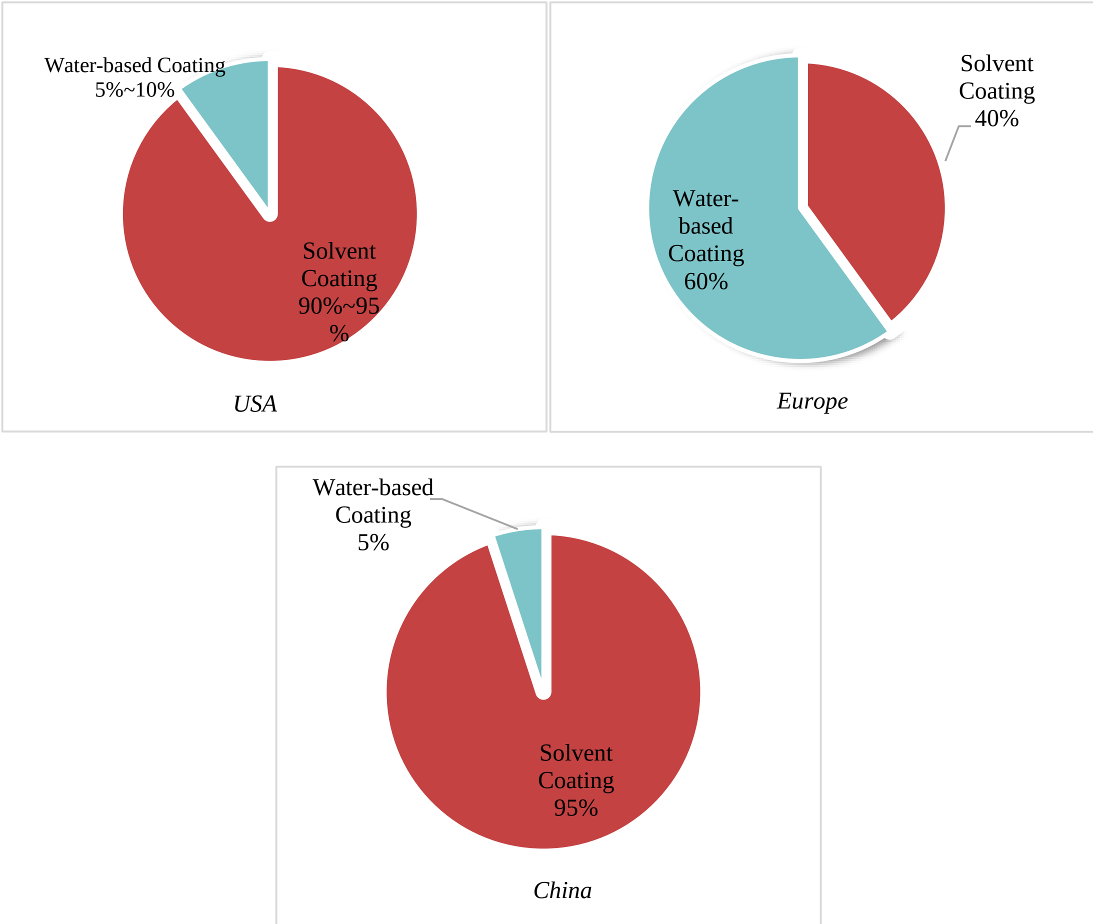


Figure 3-16 Profile of the Global Woodware Coatings Market

The sales volume of water-based wood coatings in China is dominated by single-component waterborne acrylic coatings, with a share of 60%-65%; followed by water-based polyurethane coatings, of which single-component coatings and two-component coatings take a proportion of about 10%-15%; UV coatings and other coatings account for 8%-11%, as shown in Figure 3-17.

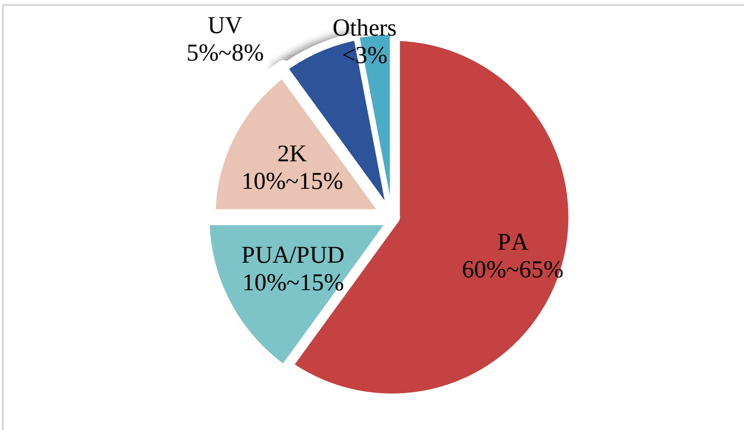


Figure 3-17 Distribution of Water-based Woodware Coatings Products in China

3.6.4 Power coatings market

In 2018, the sales volume of thermosetting powder coatings in China was about 1.76 million tons, with an increase of 9.7% over the previous year. According to data released by the National Bureau of Statistics, the cumulative output of paints nationwide was 17.598 million tons in 2018, and 16.619 million tons in 2017 (revised), with a year-on-year increase of 5.9%. Driven by the national environmental protection and other related policies, the powder coatings maintain a rapid growth.

Statistics show that for the thermosetting powder coatings, pure epoxy powder coatings accounted for 20.3%, epoxy/polyester hybrid powder coatings accounted for 32.9%, polyester/TGIC powder coatings accounted for 27.0%, polyester/HAA powder coatings accounted for 19.1%, and other types of powder coatings accounted for 0.7% in 2018. Generally, the proportions between the various systems is significantly affected by cost and technology, and the pure polyester powder products have obvious substitutions for other systems.

Table 3-6 Major powder coatings manufacturers in China

NO.	Company	Sales Volume(t)
1	AkzoNobel	67000
2	Huangshan Huajia Surface Technology Co., Ltd	32026
3	Fujian Wanan	26713
4	Jiangsu Huaguang Power Coatings	26160
5	Guangdong Ruizhi	21519
6	Anhui Meijia new materials Co., Ltd.	18579
7	Zhejiang Huacai	18025
8	Tiger Coatings	17060
9	NipponPaint	16983
10	Sunroad Group	15900
11	Defu Sheng Powder Coatings Co.,Ltd	14500
12	Guangzhou Kinte Materials Science and Technology Co.,Ltd	13905
13	Zhaoqing Qianjiang	13500
14	Beijing Hansbond Science & technology Co. Ltd	13000
15	Wenzhou Libang plastic powder Co., Ltd	12675

From the perspective of global powder coatings development, many of the advanced spraying technologies and equipment are firstly used in China and most foreign-funded enterprises' latest powder products were first put on the market in China. In 2018, Wuhu Ruijiang’s powder tank powder coatings line was successfully put into operation, which provided a successful experience in conversion to powder. After that, Henan's first "dry mixed mortar storage tank" powder spray system was put into production, which is currently the world's largest electrostatic powder spray booth system. In addition, China has built a number of new high-speed coil powder coatings lines, and the line speed reaches up to 120 m/min. Many of these have become best cases in the global powder coatings industry.

3.7 Import and export of China’s coatings industry

In 2019, the export volume of coatings was 211,378 tons, with a year-on-year increase of 10.9%, while the export value was 679.94 million dollars with a year-on-year increase of 8.2%. The import volume of coatings in 2019 was 180,840 tons, and the import value was 137.38 million dollars with a year-on-year increase of 32.5%. Detail data of import and export coatings products from 2015 to 2019 are shown in Table 3-7. In 2019, the trade surplus of China's coatings import and export volume was 30,538 tons, and the trade deficit was 627.45 million dollars. On the whole, unfavorable balance of coatings trade has been in a deficit for a long time, reflecting that the price of domestic exports is lower than those imports, and the China's coatings product structure still needs to be further improved.

Table 3-7 2015-2019 import/export data of coatings products

Year	Import quantity /t	Import amount / thousand dollars	Export quantity /t	Export amount / thousand dollars
2015	158382	800710	197724	716410
2016	154521	820790	158865	547020
2017	168760	866890	183236	591660
2018	164555	986560	190544	628260
2019	180840	1307380	211378	679940

The import of coatings is mainly high-end and high value-added coatings, and the export is mid-end coatings in China. According to statistics, the average import price of China's coatings was 7,229 dollars/ton, the average export price was 3,217 dollars/ton in 2019(Figure 3-18). The average import price was 2.2 times as that of the export, widening the gap between the import and export prices.

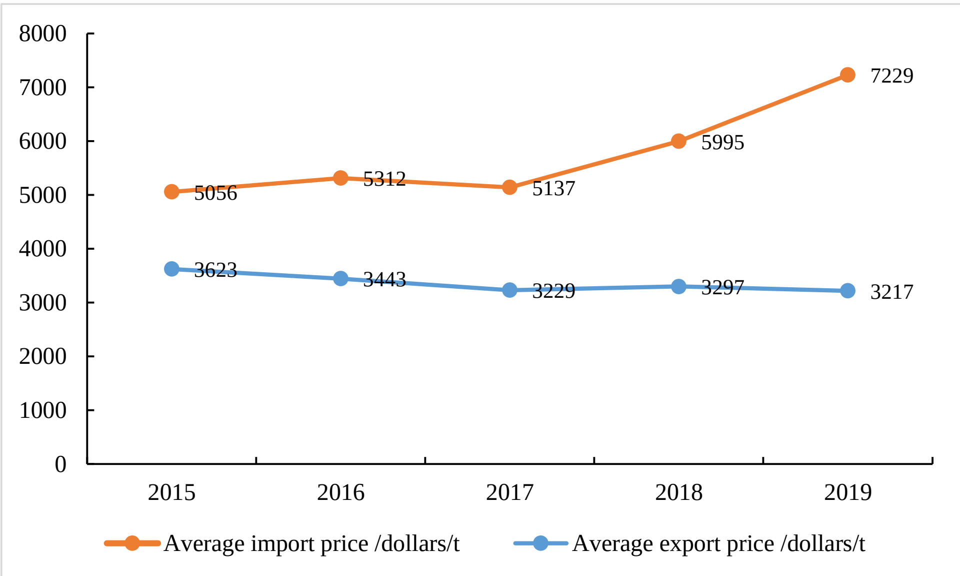


Figure 3-18 Coatings price comparison between import and export from 2015 to 2019

In 2019, coatings exports destinations are mainly in Hong Kong (China), Vietnam, and Panama, accounting for 16.9%, 8.9% and 6.2% respectively, as shown in Figure 3-19. Coatings imports from Germany, South Korea, and Japan accounted for 19.8%, 19.5%

and 14.4% of China's coatings imports in Figure 3-20.

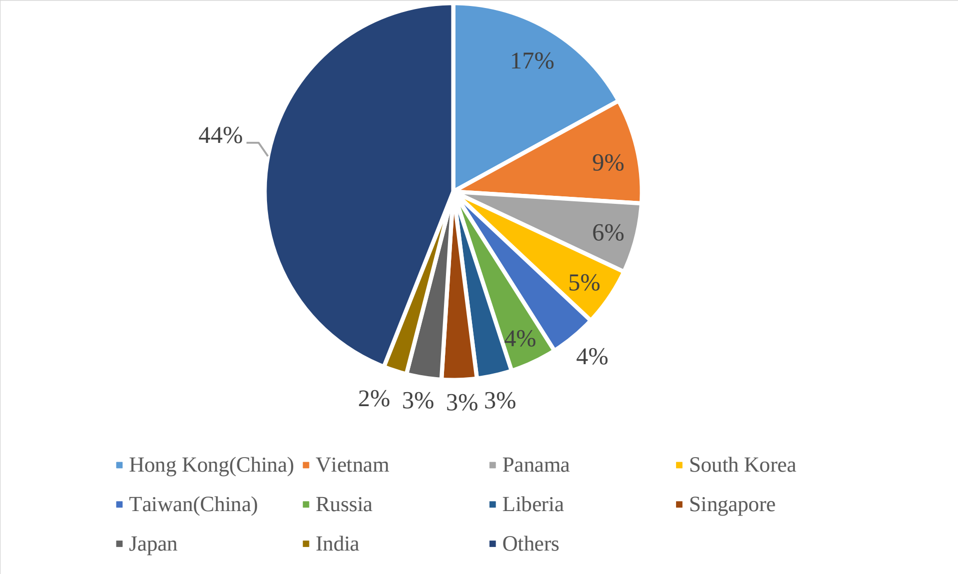


Figure 3-19 China's Coatings export regions in 2019

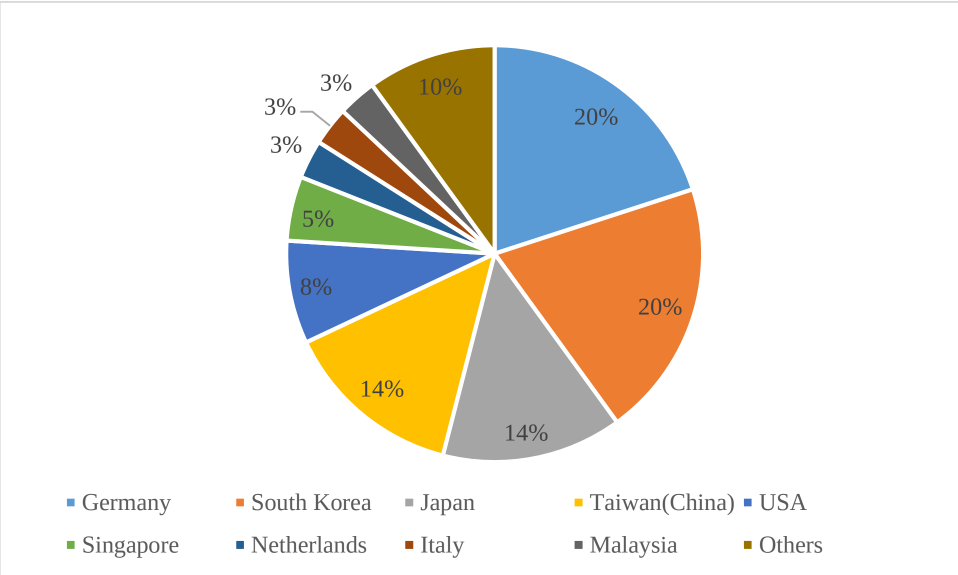


Figure 3-20 China's Coatings import regions in 2019

(Chapter 3 Source: China Coatings)

4 Lead in paint

4.1 The source of lead in paint

Lead-containing paint is the paint with one or more lead compounds added. Lead is mainly used in pigments, such as red lead, chrome yellow, white lead, etc. It is also used in additives to improve the specific properties of paints, like driers and catalysts.

4.1.1 Pigment

Pigment is one of the important sources of lead in paint. The function of the pigment is to give the coatings film various colors and special properties. Commonly used lead-containing pigments include red lead, lead chromium pigments and so on. Red lead, namely lead tetroxide, is a stable anti-rust pigment. The coatings with red lead has good permeability and wettability, strong adhesion and water resistance, fast drying and good stability. It is often used as a primer on the surface of steel structures such as bridges, ships, machinery and pipelines. China has already banned red lead.

Lead chromium pigments are inorganic color pigments with lead chromate as the main component, including lemon yellow, medium chrome yellow, molybdenum chrome red, etc. Lead-chromium pigments have the characteristics of bright color, good tinting power, strong hiding power, etc., easy to disperse, good light resistance, heat resistance and stability. It is used in the fields of construction, industry, woodware and anti-corrosion. Lead chromium pigments currently in use are lead chromium yellow, molybdenum chromium red, lead chromium green, and basic lead silicate chromate.

4.1.2 Drier

Drier can promote the curing of the coatings film and shorten the drying time. It is used the most in additives and is a major source of lead in paint. Commonly used lead-containing driers include lead acetate, lead naphthenate, lead isooctanoate, etc. Rare earth driers are developed to replace them.

4.1.3 Catalyst

The alcoholysis catalyst can speed up the alcoholysis process and make the synthesized resin clear and transparent. The commonly used lead-containing catalyst is Huang Dan, or lead oxide, which is widely used in the production process of alkyd resins. Lithium hydroxide or zinc isooctanoate are used instead of Huang Dan catalyst.

4.2 Lead in paint analysis

Paint products of the coatings industry are classified based on their uses, such as for construction, woodware, automobiles, coils, ships, containers, and other industries. Except for architectural coatings, other coatings belong to the category of industrial coatings, and the lead concentration is also different accordingly. The production of architectural are basically lead free, while other types of paints contain lead to some extent. At present, China's lead paint is mainly used in road marking, construction machinery, field oil and gas pipelines, offshore operation platforms and military equipment. The analysis focuses on the architectural wall coatings and construction steel structure coatings as examples.

4.2.1 Architectural wall coatings

Compared with other paints, the use of paints for interior and exterior walls of buildings is the largest and it has the most frequent contact with the human body. Therefore, the harm it produces is more serious than paints for other purposes. Numerous hazards have aroused the attention of the international community, among which paints for interior and exterior walls have become the main object of concern.

In March 2020, China has released national standard of “Limit of Harmful Substances of Architectural Wall Coatings” (GB 18582-2020), in which the limit of total lead concentration is 90 mg/kg. Under the new national standard of GB 18582-2020, architectural wall coatings in China follows the total lead limit of 90 ppm, for both architectural wall coatings and decorative panel coatings. According to relevant test results, the current paints sold in the Chinese market could meet the total lead concentration of 90ppm, and these coating products that are frequently exposed to human bodies are basically free of lead in China.

Also, the government's strict regulatory on VOCs emission contributes to the control of the coatings industry's environmental impacts and pollution. Since solvent-based architectural wall coatings will emit a large amount of VOCs into the atmosphere, which causes great pollution to the air, the governments enact strict restrictions of various environmental protection regulations and standards in recent years to regulate the use of solvent-based coatings. In comparison, water-based architectural wall coatings have great environmental advantages so its use for interior wall coatings has reached nearly 100% on the market. There has been no technical problem in the water-based coatings of building interior and exterior wall coatings in China.

Moreover, the medium of water-based coatings is water, and its cost is much lower than the organic solvents in solvent-based coatings. This directly reduces the production cost of wall coatings and directly eliminates cost of security precautions for production, storage and transportation. In addition, the paint consumption tax was levied on February 1, 2015 in China. If VOCs emissions exceed 420 g/L, a 4% consumption tax must be paid for the tax. The paint tax is mainly for solvent-based coatings companies, while water-based architectural wall coatings ones do not need to pay additional taxes, which also forces companies to transform to produce and use water-based paints.

With the improvement of people's living standards, the public has higher requirements for the environment, especially the living environment. Therefore, the solvent-based coatings used in the past are gradually abandoned by consumers. On the contrary, water-based and lead-free wall coatings could meet the requirements of non-toxic, environmental friendly and other technical requirements, so it is more favored by consumers.

4.2.2 Construction steel structure coatings

Construction steel structure coatings is one of the major industrial coatings. 46% of China's construction steel structure products are used in factory buildings, commercial buildings taking up 30%, venue buildings and public buildings accounting for 10%, transportation hubs accounting for 10%, and residential building steel structures occupying 4%. Generally, the commonly used coatings for construction steel structures are alkyd and phenolic, and most used for heavy anti-corrosion coatings. Traditional alkyd and phenolic coatings are sometimes used in large quantities in some factories and civil buildings. Due to its good anti-corrosion function, these lead paints for construction steel structures are still used.

According to statistics, in 2018, the market volume of water-based construction steel structure coatings is 21,000 tons, accounting for 3.5% of construction steel structure coatings. It is mainly used in commercial buildings, public buildings, residential buildings and other steel structure buildings protection with an anti-corrosion grade of C3 (usually not higher than C4). In recent years, the construction of landmark buildings (such as the Expo China Pavilion, Shanghai Center, Shanghai Disney, etc.) has used water-based paints, leading the trend of construction design institutes using water-based paints. In addition, various provinces in China have also put forward clear requirements for hazardous substance such as VOCs emissions during the coating process of steel structures. Because the lead content in water-based coatings is very few and negligible, the heavy metal lead mainly comes from the anticorrosive paint for architectural steel structure. The governments have made development plans to actively promote the application of water-based architectural steel structure coatings. It is estimated that water-based architectural steel structure coatings are likely to maintain a rapid growth of more than 20%.

The main source of lead in architectural steel structure coatings： Many commonly used pigments and additives are produced with lead as raw materials, and inorganic pigments are the main source of lead in lead-containing coatings, such as lead chrome yellow (chrome yellow), molybdenum chrome red, lead chrome green, red lead, etc.

Lead Chrome Yellow: It is a yellow pigment and its chemical composition is lead chromate, lead sulfate, and basic lead chromate series. It usually contains 53~64% lead. With the different concentration of lead chromate, its color ranges from yellow to orange, and it has good light resistance, heat resistance, water resistance, solvent resistance, and acid and alkali resistance.
Molybdate Red: Its main components are lead chromate, lead molybdate, and lead sulfate. The color ranges from orange to red with the different proportions. It can be combined with white anti-rust pigment to make anti-rust pigments similar as red lead.
Lead Chrome Green: Chrome yellow and iron blue or phthalocyanine blue mixed color matching pigments.
Red Lead: used as an anti-rust pigment.

Barriers: Construction steel structure coatings is one of the main varieties of coatings used on metal surfaces. With the development of economy, structural adjustment and technological advancement of the construction industry, construction steel structures have entered a period of rapid development. However, there are still many environmental protection problems in the production and application of coatings for building steel structures in China. Some anti-rust pigments containing heavy metal elements such as lead and chromium occupy a certain market due to its good rust resistance and low price.

At present, "Limit of Hazardous Substances of Anticorrosive Coatings for Construction Steel Structure" is the national standard for architectural steel structure coatings in China, the limit of lead in which is 1000 ppm (total lead) as recommendatory. With the development of China's construction steel structure, lead in the anti-corrosion coatings and lead-free substitution has become more and more concerned.

5 Substitution of lead pigments

Lead chromate pigments are still used in various coatings, plastics and inks and other products, and are ultimately used in many fields such as transportation, construction, vehicles, toys, ships and construction machinery that are in close contact with people. As the hazardous of lead-chromium pigments is gradually recognized by the public, laws and regulations are being formulated to restrict or prohibit their use in China. Many manufacturers have abandoned lead-based chromium pigments in many ways and seek to switch to the best alternatives. Some of the large-scale plastics and paint companies have used lead-free pigments, but most small and medium-sized enterprises are still using lead-containing pigments due to cost considerations.

5.1 Possible alternatives

At present, the main ways to replace lead chromate pigments includes: (1) appropriate organic pigments; (2) mix inorganic pigments with high hiding power with appropriate organic pigments; (3) new inorganic pigments R&D; (4) organic-inorganic composite pigments.

5.1.1 Organic pigments

Organic pigments are one of the important ways to replace lead-chromium pigments. Since lead-chromium pigments are in the chromatogram range of yellow, orange and red, alternative organic pigments should be also screened according to product usage within this range. Table 5-1 shows the types of organic alternatives that can substitute lead chromate pigments in different applications.

Table 5-1 Organic alternatives

Yellow	**Orange**	**Red**
Diaryl	Benzidine	Azo Red 2B
Benzimidazolone	Dianisidine	Toluidine
Isoindoline	Azo condensation	Azo condensation
Tetrachloroisoindolinone	Benzimidazolone	Naphthol
Azo condensation	Pyrazolinone	Perylene
	Dinitroaniline	Quinacridone
	Diketopyrrolopyrrole	Diketopyrrolopyrrole

Compared with lead chromate pigments, organic pigment has more colorful varieties, higher color strength, more vivid colors, but poor covering ability and dispersibility. These disadvantages can be improved by changing the particle size distribution of organic pigments, or mixing with inorganic pigments with strong hiding ability (such as rutile titanium dioxide, titanium nickel yellow, titanium chrome yellow, etc.).

5.1.2 Inorganic pigments

Existing lead-free inorganic pigments could not substitute lead chromate pigments alone because of poor color brightness and insufficient color variety. Although the iron oxide series of pigments do not contain lead and they are low in price, their colors are in dark and can only be used to assist color matching in the form of fillers. The newly introduced varieties have a few market supply and output due to incomplete chromatogram or expensive price. The chromatograms of several major lead-free and environmental-friendly colored mixed phase inorganic pigments are shown in Figure 5-1.

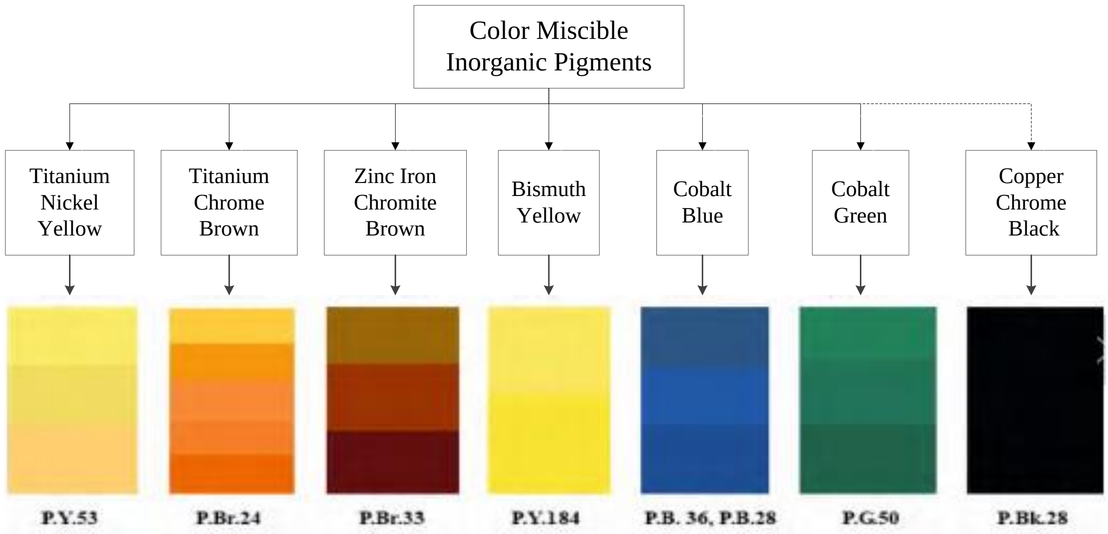


Figure 5-1 Chromatograms of major lead-free mixed inorganic pigments

5.1.2.1 Rutile mixed pigment

Rutile mixed pigment is an important crystal series of mixed metal oxide pigments (MMO pigments). It takes rutile titanium dioxide as the main raw material, and are formed of nickel and chromium plasma infiltrating into the crystal lattice to replace titanium ions. Titanium nickel yellow and titanium chrome brown (also known as titanium chrome yellow) are the two most important rutile mixed pigment products, and these two pigments are referred to as titanium yellow in China. Since they do not contain toxic heavy metal such as lead and hexavalent chromium, and with good resistance, including heat resistance, light and weather resistance, solvent resistance, acid and alkali resistance, with supplement by organic yellow to improve color saturation, it could substitute lead-containing lead chromate pigments for outdoor construction machinery, road signs, bridges, taxis and other end-uses. For safety reasons, a striking yellow is used as the logo color. In many countries, this yellow pigment is called "taxi yellow", or "school bus yellow". Table 5-2 and Table 5-3 indicates the formulations of lead-free pigments for taxi yellow and school bus yellow as reference. The technical performance of titanium yellow MMO pigment is shown in Table 5-4.

Table 5-2 Formulation of lead-free pigment for taxi yellow

Pigment	Brand and Manufacturer	W/%
Titanium Chrome Brown （Pigment Brown 24）	JF-B2406(Ju Fa)	40
Titanium nickel yellow （Pigment Yellow 53）	JF-B5303(Ju Fa)	40
Organic Yellow	Hostaperm Yellow 6GL(Clariant)	20

Total		100

Table 5-3 Formulation of lead-free pigment for school bus yellow

Pigment	**Brand and Manufacturer**	***W*/%**
Titanium Chrome Brown （Pigment Brown 24）	JF-A2405(Ju Fa)	66
Pigment Yellow 151	Benzimidazolone Green Yellow	23
Pigment Orange 36	Benzimidazolone Orange	11
Copper Chrome Black （Pigment Black 28）	JF-B2852(Ju Fa)	0.1
Total		100.1

Table 5-4 Main technical performance of titanium yellow MMO pigment

Item	**Performance**
Temperature Resistance	the average is 1000, the highest is above 1250
Acid and alkali Resistance	Level 5 (the highest level)
Migration Resistance	Level 5 (the highest level)
Weather Resistance	Level 5 (the highest level)
Light Fastness	Level 8 (the highest level)
Salt Spray Resistance	Excellent
Dispersion	Excellent
Hygienic Performance	environmental-friendly and non-toxic, in line with limit requirements of ROHS EN71-3 and other standards
Other Features	excellent infrared reflection function

The price of titanium nickel yellow and titanium chrome brown (titanium chrome yellow), which are all called titanium yellow, is higher than that of lead chrome yellow pigments, and their coloring power is relatively low and their saturation is not high enough. Therefore, to completely replace a certain lead-containing lead chrome yellow pigment, it is necessary to blend in suitable organic pigments. It can be seen from Table 5-4 that the technical performance such as temperature resistance and light resistance of titanium yellow are very excellent, while the resistance of organic pigments are generally lower than or equivalent to titanium yellow. So the selection of organic pigments is particularly important, and if it is blended with organic pigments of poor performance that will inevitably reduce the overall performance of the blended pigments.

5.1.2.2 Bismuth vanadate yellow pigment (bismuth yellow)

Bismuth vanadate pigment (bismuth yellow) is a relatively new environmental-friendly inorganic pigment with a bright greenish lemon yellow appearance and high saturation. It was first developed and marketed by BASF in Germany in the mid-1980s. Its basic color component is bismuth vanadate ($BiVO_4$). The light reflectivity of visible light in the yellow region with a wavelength in the range of 550 to 600 nm, which is higher than that of lead chromium. It can directly substitute lead chrome yellow without mixing with organic pigments. Bismuth yellow pigment has excellent weather resistance, light resistance, heat resistance and chemical resistance, and it is non-toxic, and its hiding power is very strong, which is better than lead chrome yellow pigment. The disadvantage of this pigment is that it is quite expensive and the color is relatively single. In terms of coloring ability, there is still a certain gap compared with organic pigments. Therefore, in addition to being used alone in the natural color system, this pigment is also used in combination with organic pigments. However, due to the relatively high density of bismuth yellow pigments, the incomplete formulation may cause delamination of coatings, and it is only suitable for high-end applications, such as high-end industrial coatings, automotive topcoats, engineering plastics, etc.

International companies such as BASF, DCC, Cappelle and other companies have commodity supplies of this pigment. In China, many universities and enterprises have been conducting research and development in the past 20 years. At present, there is bismuth yellow pigments produced by Ju Fa that can match DCC, BASF and other companies in terms of chromaticity, reaching the leading level in heat resistance, but in small batches on the market due to small demand and price issue.

5.1.2.3 Rare earth pigments

Rare earth pigments are pure in color, with high color strength, strong hiding power, excellent light resistance, heat resistance, good dispersibility, and they are environmental-friendly and non-toxic. Therefore, although the price is expensive compared to lead chromate pigments, they are still popular with industries such as coatings and plastics as a substitution for orange and red toxic pigments.

Internationally, there are a few of rare earth pigment manufacturers. In China, Baotou Hongbot Technology Co., Ltd. acquired the technology of French Solvay rare earth sulfide, making it one of the few manufacturer in the world that has realized industrialization of rare earth pigment production. It has built a production line with an annual output of 100 tons, with 5 brand product models include PR-001, PR-002, PR-003, PO-001, and PO-002, and 4 international brand of Neolor models include PR265, PR275, PO75, PO78.

5.1.3 Blending of organic and inorganic pigments

A simple blending method can be used to substitute lead and chromium pigments. Although the method is simple, it is much difficult to operate due to the difference in the density of the two pigments itself, and the blended color tends to be unstable because of weak combination of the pigments. Table 5-5 shows a formula for replacing the lead-containing molybdenum chrome red pigment as a reference, mixing high-grade macromolecular organic red with iron oxide red, titanium chrome brown, titanium dioxide, cobalt blue, and iron chrome black.

Table 5-5 Blending formulation of organic and inorganic red pigments

Pigment	Formula A（W/%）	Formula B（W/%）
Red 122	16.90	-
Red 188	-	17.29

Iron oxide red	70.3	79.00
Iron chrome black	2.60	1.88
Cobalt blue	-	1.83
Titanium yellow	10.20	-

The high-grade red organic pigments, such as Pigment Red 122 Dimethylquinacridone are very expensive. There is a need to find a more cost-effective pigment to substitute, or change part of the properties of organic pigments through post-processing, or develop organic pigments with new chemical structures to ensure the key performance required.

5.1.4 Organic/inorganic composite pigments

It is been studied to use colorful organic pigments combined with inorganic pigments with good durability and high hiding power to produce composite lead-free pigments. As early as the 1990s, a Lide powder factory in Guangdong of China cooperated with a company of the United States to try to develop a yellow composite pigment with an inorganic composition of lithopone and used in sign paints to replace lead chrome yellow pigments, and this pigment is called safety yellow and road marking yellow. This core-coated pigment has better overall performance than lead chrome yellow, but due to the poor grade of the basic pigment lithopone yellow and high price, it has not been widely promoted in China.

In recent years, a company of Hunan in China patented its composite pigment technology, which owns higher heat resistance, light resistance, weather resistance, acid and alkali resistance, than that of lead chromate pigments, and it can completely substitute lead-containing pigments. This series of pigments mainly include composite titanium yellow and composite titanium red. The inorganic components are titanium nickel yellow or titanium chrome brown (also known as titanium chrome yellow), while organic pigments are high-grade organic yellows with shades ranging from green to red, and high-grade organic red with shade from yellow to blue. Table 5-6 presents formula of organic and inorganic yellow pigments.

Table 5-6 Formulation of organic and inorganic yellow pigments

Pigment	**Formula A（W/%）**	**Formula B（W/%）**
Yellow 83	15	-
Yellow 180	35	50
Titanium nickel yellow JF-B5302	50	38
Titanium Chrome Brown JF-A2407	-	12

5.2 Performance and cost of alternatives

Substitutes are better than lead-chromium pigments in terms of environmental protection, temperature resistance, light and weather resistance, acid and alkali resistance, etc. Although they are in lack of color vividness and tinting strength. Cost and price becomes the biggest obstacle to substitute lead pigment. Table 5-7 presents the comparison of performance and cost of alternatives.

Among those alternatives, the simply mixture of "appropriate organic pigments" and "inorganic pigments with high hiding power and suitable organic pigments" are not recommended for anti-corrosion primers and it has not been collected for data that they can be used as primers. Moreover, "using some newly developed inorganic pigments" such as titanium yellow pigment, due to its high inertness, various outstanding resistances, including acid and alkali resistance, solvent resistance and salt spray resistance, it is verified that it could be used as a primer. For composite titanium yellow, "using organic-inorganic composite and organic pigments" allows the inorganic and organic be firmly combined, and the performance is also excellent with both advantages of the two types of pigments. It can be used as anti-corrosion primers after passing relevant application tests and reaching relevant technical performance indicators.

With the increasing attention of environmental protection and lead elimination, the introduction of lead paint regulations and standards, lead substitution is an inevitable trend of paint development.

Table 5-7 Comparison of performance and cost of lead-chromium pigment substitutes

Function	**Lead chromium pigment**	**MMO pigment**	**Bismuth Yellow**	**Cerium sulfide red**	**Organic/inorganic blended pigments**	**Organic/inorganic composite pigment**
Heat Resistance	Poor	Excellent	Good	Good	Moderate	Good
Light Fastness	Poor	Excellent	Excellent	Excellent	Moderate	Excellent
Weather Resistance	Poor	Excellent	Excellent	Excellent	Moderate	Excellent
Acid Resistance	Poor	Excellent	Excellent	Excellent	Moderate	Excellent
Alkali Resistance	Poor	Excellent	Excellent	Excellent	Moderate	Excellent
Salt Spray Resistance		Excellent	/	/	/	Excellent
Coloring Performance	Bright colors and strong coloring power	The color is not bright enough and the tinting strength is average	Bright colors and strong coloring power	Bright colors and strong coloring power	Bright colors and strong coloring power	Bright colors and strong coloring power
Environmental Performance	Poor (toxic)	Non-toxic and environmental-friendly	Non-toxic and environmental-friendly	Non-toxic and environmental-friendly	Non-toxic and environmental-friendly	Non-toxic and environmental-friendly
Cost	Excellent	Moderate	Poor	Poor	Moderate	Moderate
Remarks	Low price	Fair	Expensive	Expensive	Dust pollution; moderate price	Fair

6 Control and Regulation of Lead Paint

6.1 Global progress on lead paint elimination

In 2011, UN Environment and WHO published the Lead Paint Alliance operational framework to promote the elimination of lead paint. It aims to phasing out the manufacture, import and sale of paints containing lead and eventually to eliminate the risks from such paint. The goal of the Lead Paint Alliance is for all countries to have lead paint laws in place by 2020.

As of 30th September 2019, there 73 countries worldwide having legally binding controls to limit the production, import and sale of lead paints, which is 38% of all countries. The Figure 6-1 shows the percentage of with lead paint laws in UN Environment Region.

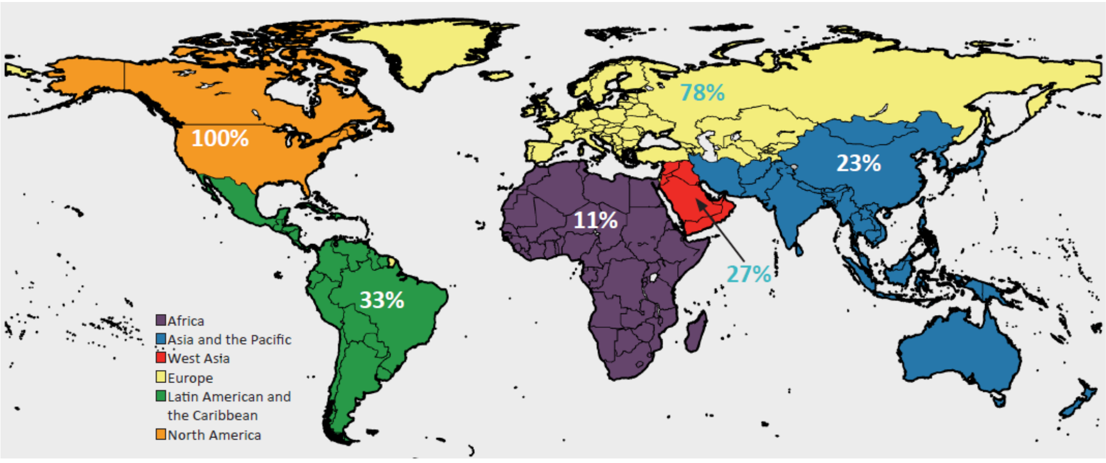


Figure 6-1 Percentage of countries with lead paint laws in each UN Environment Region

Concentration limit of 90 ppm total lead is most protective regulatory limit for lead paints that has been set in countries. Of the 73 countries with lead paint laws, 35 countries have established a single regulatory limit on the total lead concentration in paint. These existing lead limits range from 90 ppm to 1,000 ppm or higher. 13 countries have a limit of 90ppm, 3 countries of 100 ppm and 14 countries of 600 ppm, which are all relatively low levels and indicate that lead compounds maybe have not been added to the paint. Table 6-1 presents the countries with limits on lead concentration.

Table 6-1 Limits on lead concentration in countries

90ppm	100ppm	600ppm	1000ppm
Bangladesh	Switzerland	Argentina	Algeria
Canada	Thailand	Brazil	Armenia
Cameroon	United Republic	Chile	Australia
China	of Tanzania	Costa Rica	Belarus
Ethiopia		Dominica	Cuba
India		Guyana	New Zealand

Iraq Israel Jordan Kenya Nepal Philippines United States of America		Mexico Oman Panama South Africa Sri Lanka Trinidad and Tobago Uruguay	

(Source: UN Environment 2019 Update on the Global Status of Legal Limits on Lead in Paint)

6.2 Lead paint control in China

6.2.1 Policies

China government has formulated and issued a series of policies and regulations to limit the production and use of lead paint in recent years, including:

(1) **National Development and Reform Commission** issued "Industrial Structure Adjustment Guidance Catalog (2019 Edition)" and it was came into force on January 1, 2020. The previous catalog of 2011 Edition was repealed. Rules related to coatings industry includes:

- Encouraging category: water-based woodware, industrial and marine coatings, high solids, solvent-free, radiation curing coatings, environmental- friendly and resource-saving coatings with low VOCs concentration, are encouraged to be used in the production of high-performance anticorrosive coatings in key areas such as large aircraft and high-speed rail; The production of chlorinated titanium dioxide with a single line capacity of 30,000 tons/year and above.
- Restricting categories: newly-built sulfuric acid method titanium dioxide, lead chrome yellow, iron oxide pigments with an annual output of less than 10,000 tons, solvent-based paints (except for encouraged paint varieties and production processes), triglycidyl isocyanurate (TGIC) contained powder coatings production equipment
- Eliminating categories: modified starch, modified fiber, colorful interior wall (the resin is mainly nitrocellulose, while the solvent is mainly xylene O/W type coatings), vinyl chloride-vinylidene chloride copolymer emulsion exterior wall, tar type Polyurethane waterproofing, water-based polyvinyl chloride tar waterproofing, polyvinyl alcohol and its acetals for interior and exterior walls (106, 107 coatings, etc.), polyvinyl acetate emulsion (including ethylene/vinyl acetate copolymer emulsion) exterior wall coatings; hazardous substances exceed standards of interior wall, solvent-based woodware, toys, automobiles, exterior wall coatings, coatings contains hazardous substances of bis-p-chlorophenyl trichloroethane, tributyl tin, perfluorooctanoic acid and its salts, perfluorooctane sulfonic acid, red lead,etc.

(2) **The National Development and Reform Commission and the Ministry of Commerce** issued "Plan of Market Access Negative List (Pilot Version)" with 328 items, including 96 prohibited items and 232 restricted items. It is pointed out that it is forbidden to produce, sell and use construction and decoration materials with toxic and hazardous substances exceeding national standards. It is forbidden to build new

production facilities for powder coatings such as sulfuric acid titanium dioxide, lead chrome yellow, iron oxide pigments under 10,000 tons, solvent-based paints. It is prohibited to invest in DDT containing coatings projects and others.

(3) **Ministry of Industry and Information Technology, Ministry of Science and Technology, Ministry of Environmental Protection** jointly issued "Catalog of Substitutes for Toxic and Hazardous Materials (Products) Encouraged by China (2016 Edition)", to guide enterprises to develop and use low-toxic, low-hazardous and non-toxic and harmless raw materials, reduce the concentration of toxic substances in products, and avoid pollutants generation from the source. It is encouraged to use calcium sulfite anti-rust pigments to replace lead-containing anti-rust pigments in this regulation.

(4) **Ministry of Environmental Protection (MEP)** issued "High Pollution, High Environmental Risk (double high) Product Catalog (2017 Edition)". "Double high" products include more than 50 products that produce large amounts of pollutants (such as sulfur dioxide, nitrogen oxides, chemical oxygen demand, ammonia nitrogen) during the production process, and 40 products with large amounts of volatile organic pollutants (VOCs), 200 products involving heavy metal pollution and 570 kinds of high environmental risk products. For coatings and pigment industry, lead-containing paint materials such as lead and chromium-containing cathodic electrophoretic paint, lead-containing road marking paint, rosin lead soap, lead chrome yellow, basic lead carbonate white and other lead-containing paint materials are listed as of high pollution or high environmental risk. Several "double-high" products have been cancelled for export tax rebates and processing for production is prohibited. Enterprises should be more proactive in fulfilling their main responsibility for environmental protection, and reduce or even avoid the purchase, production and use of "double-high" products.

(5) **Ministry of Environmental Protection issued** "Catalogue of Environmental Protection Technologies Encouraged by the State for Development"(2013). The production and application technology of composite iron-titanium powder anti-corrosive paint is listed to substitute lead and chromium pigments. This paint can partially replace lead chromium paints. The price is about 70 RMB/kg, which is much lower than other coatings with equivalent performance (20-50 US dollars/kg). It could be used for anti-rust primer of industrial coatings (military and civil).

(6) **Ministry of Environmental Protection issued** "National Advanced Pollution Prevention Demonstration Technology List"(2013). The production technology of rare earth sulfide pigment is listed. The lead concentration of earth sulfide pigment is less than 10mg/kg, cadmium concentration is less than 10mg/kg, mercury concentration is less than 10mg/kg, and hexavalent chromium concentration is less than 10mg/kg. The paint could be used for the technological cleaner production upgrade in the pigment industry.

(7) **Ministry of Ecology and Environment and the National Health Commission** have formulated the List of Toxic and Harmful Large Gas Pollutants (2018), which was issued on January 25, 2019. 11 types of pollutants are listed, including 6 types of VOCs

and 5 types of heavy metals and metalloids and their compounds. Formaldehyde, lead and its compounds, mercury and its compounds and other toxic and hazardous substances that the paint industry focuses on are included in the list. In accordance with the requirements of the Ministry of Ecology and Environment, the list will be updated in due course based on the results of risk assessment, the need to improve environmental quality and the actual environmental management capabilities.

Table 6-2 List of Toxic and Harmful Air Pollutants

No.	Pollutants
1	Methylene chloride
2	Formaldehyde
3	Chloroform
4	Trichloroethylene
5	Tetrachloroethylene
6	Acetaldehyde
7	Cadmium and its compounds
8	Chromium and its Compounds
9	Mercury and its compounds
10	**Lead and its Compounds**
11	Arsenic and its Compounds

(8) **National Development and Reform Commission, Ministry of Environmental Protection and Ministry of Industry and Information Technology** jointly issued "Clean Production Index System for Painting Industry" (2016). It stipulates that lead-free electrophoretic paint should be used as the primer in the first-level benchmark. This index system is applicable to the orderly coatings production of automobiles, electromechanical, iron furniture, machinery engineering and other industries.

(9) **Ministry of Ecology and Environment** issued the "Comprehensive Treatment Plan for Volatile Organic Compounds in Key Industries" on June 26, 2019. The Plan requires to promote source substitution. Using water-based, powder, high-solid, solvent-free, radiation-curable coatings with low VOCs, to substitute solvent-based coatings. Industries such as industrial coatings, packaging and printing should increase the intensity of source substitution; companies should promote the use of low-VOCs concentration wood coatings, vehicle coatings, mechanical equipment coatings, container coatings and protective coatings for buildings and structures.

(The name of Ministry of Environmental Protection was official changed to the Ministry of Ecology and Environment in 2018)

(10) "Thirteenth Five-Year Plan" for the coatings industry (2016)

The Plan sets goals and directions for the development of China's coatings industry. It is pointed to have substitution of lead and heavy metals for environmental sustainable development of coatings industry. For raw materials containing lead impurities and lead-containing additives, it is aim to improve the relevant policies and standards of paint limits on lead and heavy metals. By strict supervision, these paint could meet the standards of lead paint. For lead pigments, it faces challenging to substitute lead chrome yellow due to certain technical and economic obstacles. It is recommended to introduce incentives to encourage the lead substitution.

6.2.2 Standards

In China, the national standards are divided into mandatory national standards and recommended national standards. GB code-named national standards refer to mandatory provisions. GB mandatory provisions are national standards enforced by laws and administrative regulations to protect human health, personal, and property safety. China has established series of regulatory standards and limits on the total or soluble lead concentration in paint. In 2020, China issued 4 national standards on the control of lead paint with total lead rather than soluble lead. Table 6-3 shows the mandatory national standards on lead concentration of paint in China.

Table 6-3: Regulatory limits on lead concentration of paints in China

No.	Standard No.	Name	Lead limit (mg / kg)
1	GB 18581—2020 (GB 18581—2009,GB 24410—2009 were replaced)	Limit of harmful substances of woodware coatings	90
2	GB 18582—2020 (GB 18582-2008,GB 24408—2009 were replaced)	Limit of harmful substances of architectural wall coatings	90
3	GB 24409—2020 (GB 24409—2009 was replaced)	Limit of harmful substances of vehicle coatings	1000
4	GB 30981—2020 (GB 30981—2014 was replaced)	Limit of harmful substances of industrial protective coatings	1000
5	GB 38469—2019	Limit of harmful substances in marine coatings	1000
6	GB 30981—2014	Limit of harmful substances anti-corrosion coatings for construction steel structure	1000
7	GB 24613—2009	Limit of harmful substances of coatings for toys	600 90(soluble)
8	GB18585—2001	Indoor decorating and refurbishing materials--Limit of harmful substances in wallpapers	90
9	GB 38468—2019	Limit of harmful substances of interior floor coatings	90(soluble)
10	GB 8771—2007	Maximum limits for soluble elements content of pencil coating	90(soluble)
11	GB 18584—2001	Indoor decorating and refurbishing materials--Limit of harmful substances of wood based furniture	90(soluble)

(1) GB18581-2020 Limit of harmful substances of woodware coatings

Significant changes of the standard include, the indicators and limit of lead has been changed from "soluble lead" into the total lead of 90 ppm. VOCs limits have also be slightly reduced compared with the old standard.

Table 6-4: The limit of hazardous heavy metals of paint in GB18581-2020

<table>
<tr><th colspan="2" rowspan="3">Item</th><th colspan="9">Limit</th></tr>
<tr><th colspan="4">Solvent-based coatings</th><th colspan="2">Water-based coatings</th><th colspan="2">Radiation curing coatings</th><th rowspan="2">Powder coatings</th></tr>
<tr><th>Polyurethan e</th><th>Nitros</th><th>Alkyd</th><th>Unsaturated Polyester</th><th>Paint</th><th>Varnish</th><th>Water-based</th><th>Non-aqueous</th></tr>
<tr><td colspan="2">Total Lead / (mg/kg) （color paint, putty and alkyd varnish)</td><td colspan="9">≤90</td></tr>
<tr><td rowspan="3">Others (soluble) (color paint, putty and alkyd varnish)</td><td>Cd</td><td colspan="9">≤75</td></tr>
<tr><td>Cr</td><td colspan="9">≤60</td></tr>
<tr><td>Hg</td><td colspan="9">≤60</td></tr>
</table>

(2) GB 18582-2020 Limit of harmful substances of architectural wall coatings

Significant changes of the standard include, the indicators and limit of lead has been changed from "soluble lead" into the total lead of 90 ppm.

Table 6-5: The limit of hazardous heavy metals of paint in GB 18582-2020

<table>
<tr><th colspan="2" rowspan="3">Item</th><th colspan="4">Limit</th></tr>
<tr><th rowspan="2">Interior Wall Paint</th><th colspan="2">Exterior Paint</th><th rowspan="2">Putty</th></tr>
<tr><th>Special effect pigments contained</th><th>Others</th></tr>
<tr><td colspan="2">Total Lead / (mg/kg) (color paint and putty)</td><td colspan="4">≤90</td></tr>
<tr><td rowspan="3">Other heavy metals (soluble) (color paint and putty)</td><td>Cd</td><td colspan="4">≤75</td></tr>
<tr><td>Cr</td><td colspan="4">≤60</td></tr>
<tr><td>Hg</td><td colspan="4">≤60</td></tr>
</table>

(3) GB 24409-2020 Limit of harmful substances of vehicle coatings

The total lead concentration is 1000 ppm in this mandatory national standard. The limit of VOCs emission has increased from 560 g/L to 480 g/L for vanish, and increased from 420 g/L to 380 g/L for water-based paint.

Table 6-6: The limit of hazardous heavy metals of paint in GB 24409-2020

<table>
<tr><th colspan="2" rowspan="3">Item</th><th colspan="5">Limit</th></tr>
<tr><th rowspan="2">Water-based coatings</th><th rowspan="2">Solvent-based coatings</th><th colspan="2">Radiation curing coatings</th><th rowspan="2">Powder coatings</th></tr>
<tr><th>Water</th><th>Non-aqueous</th></tr>
<tr><td rowspan="4">Total heavy metal concentration / (mg/kg) (color paint)</td><td>Pb</td><td colspan="5">≤1000</td></tr>
<tr><td>Cd</td><td colspan="5">≤100</td></tr>
<tr><td>Cr</td><td colspan="5">≤1000</td></tr>
<tr><td>Hg</td><td colspan="5">≤1000</td></tr>
</table>

(4) GB 30981-2020 Limit of harmful substances of industrial protective coatings

The concentration of lead is 1000 ppm of total lead as a mandatory limit, so as for other heavy metals. This standard applies to the types of industrial protective coatings that protect surfaces such as metal, concrete, plastic,etc,(marine paint as an exception).

Table 6-7: he limit of hazardous heavy metals of paint in GB 30981-2020

<table>
<tr><th colspan="2">Item</th><th>Limit</th></tr>
<tr><td rowspan="4">Total heavy metal concentration / (mg/kg) (color paint, powder coating, alkyd varnish)</td><td>Pb</td><td>≤1000</td></tr>
<tr><td>Cd</td><td>≤100</td></tr>
<tr><td>Cr</td><td>≤1000</td></tr>
<tr><td>Hg</td><td>≤1000</td></tr>
</table>

Annex 1 List of Top 100 Manufacturers

No.	Company Name	Company Address	Tel.	Province or municipality
1	Nippon	No. 287, Chuangye Road, Jinqiao Export Processing Zone, Pudong New Area, Shanghai	400-885-1687	Shanghai
2	AkzoNobel	22F, No.1788, West Nanjing Road, Jing'an District, Shanghai 200040	8621-22205000	Shanghai
3	PPG	25th Floor, Longzhimeng Building, 1118 West Yan'an Road, Changning District, Shanghai	400-880-1717	Shanghai
4	BASF	333 Jiangxinsha Road, Pudong, Shanghai	86-21-2039 1000	Shanghai
5	Jotun	Floor 20, Jiu Shi Mansions, No. 28, Zhongshan Road (South), Shanghai	86-21-6333-0800	Shanghai
6	3trees	No. 518, Liyuan North Avenue, Putian City, Fujian Province	0594-2889766	Fujian
7	Hunan Xiangjiang Paint Group Co.,LTD	China ·No. 279, Section 2, Maqiaohe Road, Wangcheng District, Changsha, Hunan	0731-84218088	Hunan
8	Jiabaoli Chemical Group Co., Ltd.	Jinxi Industrial Zone, Tangxia Town, Pengjiang District, Jiangmen City	400-883-1800	Guangdong
9	Axalta	Lane 2290, Zuchong Road, Pudong New Area, Shanghai	021 60203666	Shanghai
10	King Kong Chemical Co., Ltd.	3703, Building B, Zhongtai International Plaza, 161 Linhe West Road, Guangzhou City, Guangdong Province	(020)32221111	Guangdong
11	Sherwin-Williams	Jiaoyun Building, 176 Qiutao North Road, Jianggan District, Hangzhou	400-9057197	Hangzhou
12	Hebei Chenyang Industry and Trade Group Co., Ltd.	No. 1, Chenyang Street, Xushui District, Baoding City	0312-8584888	Hebei
13	HEMPEL	Lane 299, Jiangchang West Road, Jing'an District, Shanghai, China Railway Central Times Square, 10th Floor, Building 1 (Begonia Building)	86(21)3588 6788	Shanghai

14	COSCO Kansai Paint Chemical Co., Ltd.	Room 1706, No. 355 Guangzhong West Road, Jing'an District, Shanghai	02131833979	Shanghai
15	Zhanchen Paint Group Co., Ltd.	8555, Xinze Avenue, Qingpu Industrial Park, Qingpu District, Shanghai	0755-29089112	Shanghai
16	Chugoku marine Paints Co., Ltd.	No. 4677, Jiasong North Road, Jiading District, Shanghai	021-59591000	Shanghai
17	Maydos	11 Zhenxing Road, Sanzhou, Lunjiao, Shunde District, Foshan City, Guangdong	0757-27332286	Guangdong
18	Cuanon	28 Xintao Road, Qingpu Industrial Park, Shanghai	021-59705888	Shanghai
19	Oriental Yuhong	Building 4, Kangjiayuan, Gaobeidian North Road, Chaoyang District, Beijing	400-779-1975	Beijing
20	Shijiazhuang Paint Factory	433 Zhongshan West Road, Shijiazhuang, Hebei Province	0311-85233806	Hebei
21	Dongguan Taiho Paint Products Co., Ltd.	Lakeside Industrial Park, Datanglang Village, Dalingshan Town, Dongguan City, Guangdong Province	86-769-85786789	Guangdong
22	Bardez Chemical New Materials Co., Ltd.	108 Zhengxing Road, Nantou Town, Zhongshan City, Guangdong Province, China	076089733207	Guangdong
23	Jiangsu Dewei Advanced Materials Co., Ltd	99 Shanan East Road, Shaxi Town, Taicang City, Jiangsu Province	0512-53229395	Jiangsu
24	Fusi Special Paint (Beijing) Co., Ltd.	No. 4 Anding South Street, Anding Town, Daxing District, Beijing	400-666-5100	Beijing
25	Zhejiang Brother Guidepost Paint Co., Ltd.	Hongxingqiao Industrial Park, Changxing County, Zhejiang Province	0572-6901555	Zhejiang
26	Kansai Paint (China) Investment Co., Ltd.	Room 215, No. 220 Linghe Road, Pudong New Area, Shanghai	021-50939636	Shanghai

27	Gook Paint Group Co., Ltd.	16A, International Bank Building, 8 Lujiang Road, Xiamen City, Fujian Province	0592-5896666	Fujian
28	Swan Paint Group	World Financial City, Xiangyang City, Hubei Province	0710-3041598	Hubei
29	Shanghai International Paint Co., Ltd.	1515, Xinjinqiao Road, Pudong New Area, Shanghai	021-38570219	Shanghai
30	Shanghai Jinlitai Chemical Co., Ltd.	No. 34, Lane 419, Yuyuan Road, Shanghai	021-31156999	Shanghai
31	Guangzhou Kinte Material Technology Co.,Ltd	Guangzhou Kinte Material Technology Co., Ltd.	020-86985856	Guangdong
32	Guangdong Hongchang Chemical Co., Ltd.	Jun'an Town, Shunde District, Foshan City, Guangdong Province	86-0757-25392369	Guangdong
33	Bauhinia Paint (Shanghai) Co., Ltd.	1288 Huatong Road, Jinshan District, Shanghai	021-37917777	Shanghai
34	Aekyung (Foshan) Coating Co., Ltd.	Dongcheng Road, Hecheng Street (Fuwan Industrial Zone), Gaoming District, Foshan City	0757-88911000	Guangdong
35	Changzhou Wujin Chenguang Metal Coating Co., Ltd.	54 Ronghu Road, Hengshanqiao Town, Wujin District, Changzhou City, Jiangsu Province	0519-88761265	Jiangsu
36	China Paint (Shenzhen) Co., Ltd.	Yabian Industrial Zone, Shajing Town, Baoan District, Shenzhen, Guangdong, China	0755-33658888	Guangdong
37	Shanghai Clivia New Material Co., Ltd.	1689 Huilian Road, Qingpu District, Shanghai	086-021-31167666	Shanghai
38	Jiangsu Jiunuo Building Material Technology Co., Ltd.	No. 168, Zhidong Road, Zhixi Town, Jintan District, Changzhou City, Jiangsu Province	0519-68085555	Jiangsu

39	Zhejiang Tiannu Group Paint Co.,ltd.	No. 150, Gaoxin West 2nd Road, Tongxiang Economic Development Zone, Zhejiang Province	0573-88361737	Zhejiang
40	Foshan Shunde Hongchang Coating Industrial Co., Ltd.	Lingxi Taiping Industrial Zone, Jun'an Town, Shunde District, Foshan City, Guangdong Province	0757-25381779	Guangdong
41	Shandong Qilu Paint Industry Co., Ltd.	No. 1, Yansi Industrial Zone, Dongchangfu District, Liaocheng City, Shandong Province	0635-8721110	Shandong
42	TIGER New Surface Materials (Suzhou) Co.,Ltd.	No.28 Qingdao Road(E), Taicang, Jiangsu, China	0512 5373 7999	Jiangsu
43	Chongqing Southern Paint Co., Ltd.	Chongqing Jiangjin Degan Industrial Park	023-47852638	Chongqing
44	Musashi Paint	Room 04A, 11th Floor, Financial Plaza, 333 Jiujiang Road, Huangpu District, Shanghai	0512-6299 8314	Shanghai
45	Shaanxi Baotashan Paint Co., Ltd.	56 Xingyu Road, Xingping City, Shaanxi Province	029-38811111	Shanxi
46	Jiangsu Lanling Chemical Group Co., Ltd.	Hengshanqiao Town, Eastern Suburb, Changzhou City, Jiangsu Province, China	0519-88604883	Jiangsu
47	Shanghai Coatings Co.,Ltd.	18th Floor, 560 Xujiahui Road, Shanghai	021-23536668	Shanghai
48	Donglai Paint Technology (Shanghai) Co., Ltd.	1221 Xinhe Road, Jiading Industrial Zone, Shanghai	021-59968290	Shanghai
49	Chongqing Three Gorges Paint Co., Ltd.	Degan Industrial Park, Jiangjin District, Chongqing	010-84871154	Chongqing
50	Zhongshan Bridge Chemical	Sunwen Road, Zhongshan City, Guangdong Province	15976081608	Guangdong

	Group Co., Ltd.			
51	Fujian Wanan Industrial Group Co., Ltd.	Nanshan Scenic Area Industrial Park, Shiting Town, Xiangcheng District, Zhangzhou City, Fujian Province	0596-2573745	Fujian
52	ACTO Advanced Materials Co., Ltd.	Sanlian Industrial Area 2, Gulao Heshan, Guangdong, China	750 8773826	Guangdong
53	CNOOC Changzhou Environmental Coating Co., Ltd.	2 Yulong Middle Road, Changzhou, Jiangsu, China	0519-83282371	Jiangsu
54	Guangdong Baichuan Chemical Co., Ltd.	North of Xiaodong Industrial Park, Genghe Town, Gaoming District, Foshan City, Guangdong Province	0757-23883333	Guangdong
55	Chongqing Tiling paints Inc., Ltd	No. 6, Chuangye Avenue, Shuangfu Industrial Park, Jiangjin District, Chongqing	023-47261111	Chongqing
56	Wuxi Huhuang Paint Industry Co., Ltd.	No.888 Huhuang Road, Fangqiao Town Industrial Park, Yixing City	0510-87542658	Jiangsu
57	Sifang Weikai Paint Co., Ltd.	Paint Factory in Wanfeng Industrial Park, Xinchang County, Shaoxing City, Zhejiang Province	0575-86295281	Zhejiang
58	Zhuzhou Feilu Advanced Materials Technology Co., Ltd.	No. 98, Xiangxie Road, Jinshan Industrial Park, Hetang District, Zhuzhou City, Hunan Province	0731-22778601	Hunan
59	Beko Industrial Coatings Shanghai Co., Ltd.	100 Jiangtian East Road, Songjiang District, Shanghai	021-57743788	Shanghai
60	Huabao (Tianjin) Paint Co., Ltd.	No. 2, Xingtong Road, Cuihuangkou Town, Wuqing District, Tianjin	0316-2392230	Tianjin

61	Jiangmen Paint Factory Co., Ltd.	No. 18, North Second Road, Duruan Town, Jiangmen City	0750-3657143	Guangdong
62	Hexion Special Coating (Shanghai) Co., Ltd.	Building 12, No. 1, Kangqiao East Road, China (Shanghai) Pilot Free Trade Zone	021-41629222	Shanghai
63	Shanghai Shendeou Co., Ltd.	288 Qingda Road, Pudong, Shanghai	021-58972295	Shanghai
64	Yongji Paint Industry (Kunshan) Co., Ltd.	No. 1, Yongji Road, Zhangpu Town, Kunshan City, Jiangsu Province	0512-57449865	Jiangsu
65	Yejian New Material Co., Ltd.	No. 189, Dongsheng Road, Licheng Town, Liyang City	0519-83109608	Jiangsu
66	Zhejiang Daqiao Paint Co., Ltd.	No. 3, Hedong Road, Xinshi Town Industrial Park, Deqing County, Huzhou City, Zhejiang Province	0572-8186718	Zhejiang
67	AVIC Bermuda New Material Technology Engineering Co., Ltd.	China Aviation Development Building, Building 2, Area A, No.9 Yard, Yongxiang North Road, Haidian District, Beijing	010-62497081	Beijing
68	Wuxi Kaxiubaohui Paint Co., Ltd.	No. 99, Tongyuan Avenue, Ehu Town, Xishan District, Wuxi City, Jiangsu Province, China	0510-88746888-8706	Jiangsu
69	Guangdong Zhujiang Chemical Coating Co., Ltd.	No. 3001, Petrochemical Sixth Road, Gaolan Port, Zhuhai City, Guangdong Province	0756-6327128	Guangdong
70	Northwest Yongxin Paint Co., Ltd.	Yongxin Chemical Park, Beilongkou, Chengguan District, Lanzhou City, Gansu Province, China	0931-8654972	Gansu
71	Suzhou Jiren High-tech Materials Co., Ltd.	Chunwang Road, Panyang Industrial Park, Xiangcheng District, Suzhou City	0512-65085359	Jiangsu

72	Guangdong Shuangrui Investment Group Co., Ltd.	Room 1002, Block B, Zhonghai Fuhuali, West of Jiuzhou Avenue, Xiangzhou District, Zhuhai City	0756-2253783	Guangdong
73	Shandong Saideli Paint Industry Group	Chemical Industry Park, Jinxiang County, Jining City, Shandong	1516-6770091	Shandong
74	Hebei Chenhong Paint Co., Ltd.	Qianzhuang Industrial Zone, Nanwu Village, Jizhou District, Hengshui City, Hebei Province	3188735405	Hebei
75	Shanghai Zhenhua Heavy Industry Co., Ltd.	3261 Dongfang Road, Pudong New Area, Shanghai, China	021-58396666	Shanghai
76	Wuhan Shuanghu Paint Co., Ltd.	No. 1, 2nd Road, Wuhan Chemical Industry Zone	400-811-1357	Hubei
77	Guangdong Huilong Paint Co., Ltd.	No. 8, District 8, Sanlian Industrial Zone, Gulao Town, Heshan City, Guangdong Province	0750-8392090	Guangdong
78	Sino New Material Co., Ltd.	Tangxi Industrial Zone, Wanhong Road, Luojiang District, Quanzhou City, Fujian Province, China	595-68861777	Fujian
79	Changzhou Guanghui Chemical Co., Ltd.	No.678, Yulong North Road, Chunjiang Town, Xinbei District, Changzhou City, Jiangsu Province	0519-86892061	Jiangsu
80	Zhejiang Transchem Coating Co., Ltd.	125 Hongda Road, Economic and Technological Development Zone, Xiaoshan District, Hangzhou	0571-82693776	Zhejiang
81	Anhui Linghu Paint Co., Ltd.	Jixian Industrial Park, Daguan Private Economic Development Zone, Anqing City, Anhui Province	0556-5912779	Anhui
82	Chongqing Huahui Paint Co., Ltd.	No. 20 Yuma Road, Chayuan Industrial Park, Nan'an District, Chongqing	023-68836888	Chongqing
83	Marine Chemical Research Institute	No.4, Jinhu Road, Qingdao City	532-85845913	Shandong

84	Beijing Lions New Material Technology Co., Ltd.	11 Xingguang 5th Street, Optical Mechatronics Industrial Base, Tongzhou District	010-57190739	Beijing
85	Shanghai Hilong Saineng New Material Co., Ltd.	1825 Luodong Road, Baoshan Industrial Park, Shanghai	021-33851886	Shanghai
86	Nanyang Wolong Paint Industry Co., Ltd.	2760 Chezhan South Road, Nanyang City, Henan Province	0377-63327788	Henan
87	Zhejiang Zhiqiang Paint Co., Ltd.	Lion Mountain Industrial Park, Dongcheng Town, Linhai City, Zhejiang Province	4001010055	Zhejiang
88	Zhejiang Mandeli Paint Co., Ltd.	No. 60, Tiancai Road, Tudian Industrial Park, Tongxiang City, Jiaxing	57388862777	Zhejiang
89	Guangdong Chiba Pine Chemical Co., Ltd.	Qianye Song Chemical Co., Ltd., Huangshi Industrial Park, Huiyang District, Huizhou City, Guangdong Province	0752-3535960	Guangdong
90	Shaanxi Dongfang Paint Co., Ltd.	Dongfang Road, Economic and Technological Development Zone, Weinan City, Shaanxi Province	0913-2092073	Shanxi
91	Tianjin Lighthouse Coating Co., Ltd.	East of Chaoyang Road, Nancang Road, Beichen District, Tianjin	022-26340236	Tianjin
92	Crocodile Paint (Shanghai) Co., Ltd.	Room 513, 5th Floor, North Half Building, No. 500 Caoyang Road, Putuo District, Shanghai	021-59758650	Shanghai
93	Zhejiang Global Paint Group Co., Ltd.	2788 South Second Ring West Road, Wucheng District, Jinhua City, Zhejiang, China	0579 82116888	Zhejiang
94	Jiangsu Chenguang Paint Co., Ltd.	Huangli Industrial Park, Wujin District, Changzhou City, Jiangsu Province	0519-83761288	Jiangsu
95	Liaoning Baoshan	No. 95, Qinghua Street West, Yingkou City, Liaoning Province	0417 4892762	Liaoning

	Ecological Paint Co., Ltd.			
96	Anhui Jindun Paint Co., Ltd.	Guanqiao Industrial Park, Qinlan Town, Tianchang City, Anhui Province	0550-7933477	Anhui
97	Xi'an Economic Construction Paint Co., Ltd.	Industrial Avenue, Weibei Coal Chemical Industry Park, Pucheng County, Weinan City, Shaanxi Province	029-84241221	Shanxi
98	Shanghai Zhongnan Building Materials Co., Ltd.	No. 3001 Kaixuan Road, Xuhui District, Shanghai	021-64867722	Shanghai
99	Maanshan Caishiji Paint Co., Ltd.	Gua Industrial Concentration Zone, Dangtu County, Ma'anshan City, Anhui Province	0555-6862721	Anhui
100	Zhejiang Yutong New Material Co., Ltd.	No. 11, Shengyang Road, Shangma Industrial Park, Economic Development Zone, Wenling City, Zhejiang Province, China	0576-86628888	Zhejiang
101	Zhejiang Feijing New Material Technology Co., Ltd.	Zone B, Zhanmao Industrial Zone, Putuo District, Zhoushan City, Zhejiang Province	0580-6629666	Zhejiang
102	Anhui Phoenix Paint Technology Co., Ltd.	11th Floor, Guoxin Building, No.188 Xiangzhang Avenue, High-tech Zone, Hefei	0551-65300044	Anhui
103	Anhui Haosjia Paint Co., Ltd.	199 Kaiyuan Avenue, Mohekou Industrial Park, Huaishang District, Bengbu City, Anhui Province	0552-3755200	Anhui
104	Jiangsu Baihe Paint Co., Ltd.	No. 32, Airport South Road, Luoxi Town, Xinbei District, Changzhou City, Jiangsu Province	0519-83405577	Jiangsu
105	Xinjiang Hongshan Paint Co., Ltd.	Xinjiang Uygur Autonomous Region Shuimogou District, Urumqi City, Xinjiang Urumqi City, Hetan North Road 30	0991 4529820	Xinjiang
106	Guangxi Wuzhou Dragon Fish	57 Tangyuan Road, Wuzhou City	4008-608-398	Guangxi

	Paint Industry Co., Ltd.			
107	Kunming Zhonghua Paint Co., Ltd.	Wangjiaying, Luoyang Sub-district Office, Kunming Economic Development Zone	0871-67413618	Yunnan
108	Jiangsu Champion Technology Group Co., Ltd.	No.777, Pingan West Road, Honglan Town, Lishui District, Nanjing City, Jiangsu Province	400-110-3777	Jiangsu
109	Guangdong Qiansehua Chemical Co., Ltd.	45 Jinzhou Road, Xinhui Economic Development Zone, Jiangmen City, Guangdong Province	0750-7362638	Guangdong
110	Guangzhou Wuyang Paint (Wengyuan) Co., Ltd.	Room 520, No.135 (Building 3), Huangyuan Road, Baiyun District, Guangzhou City, Guangdong Province	020-86297777	Guangdong
111	Jiangsu Changjiang Paint Co., Ltd.	157 West Road, Nanjing Chemical Industry Park	025-58394999	Jiangsu
112	Shandong Lehua Group Co., Ltd.	No. 6705 Fangshan Road, Changle County, Shandong Province	0536-6681127	Shandong

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