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Environmental production: Use of waste materials in cement kilns in China



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Abstract:

This report mainly talks about utilizing the cement kiln to dispose wastes. In China, there are huge amounts of wastes can be produced every year. China government pays more attention to the environmental protection. The government wants to dispose the wastes securely. The cement kiln is a good 'place' to take the wastes. The cement kiln has a high temperature, long remaining time, and can solidify the heavy metals, dispose the solid, semi-solid or liquid wastes. To dispose the wastes in cement kiln will not cause the new emissions. In addition, it is cheaper than building the new incinerator plants. So utilizing the cement kiln is good way to dispose wastes in environment and economy. Now China has more than 600 NSP cement kilns. If each kiln can dispose 100 000 tons wastes, China cement industry would dispose about 60 million tons wastes per year.



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FMH606 Master Thesis

Title: Environmental production: Use of waste materials in cement kilns in China

TUC supervisor: Assoc. Professor Lars-André Tokheim

External partner: China Cement Association, Zhuang Chunlai

Student: Ning Wang

Task background:

The cement industry consumes a significant amount of natural resources and energy. Improved environmental performance, in terms of optimized use of fuels and other materials as well as reduced energy consumption, is a goal for the cement industry.

In China the annual cement production in 2006 amounted to 1.2 billion tons, close to half of the cement output in the world.

The use of alternative fuels and raw materials can decrease the environmental impact of wastes, decrease CO₂ emissions, reduce waste handling costs and save money for the cement industry.



Task description:

The goal of the task is to investigate the potential of increased use of waste materials in the Chinese cement industry. The following points should be included in the thesis:

- Overview of the waste hierarchy
- Current and potential pre-treatment of waste
- Annual volumes of different types of waste
- Evaluation of what waste types that can be utilized in cement kilns and what types that can not be used
- Chemical and physical characteristics of the various waste types
- Overview of the Chinese cement industry (output, technology status, number of kilns/plants etc)
- Overview of Chinese emission standards applicable to (different types of) cement kilns (a comparison with Norway/Europe could be included)
- Technical solution for waste utilization in different kiln types
- Expected impact on emissions from the cement production process
- Overview of equipment required for utilizing waste in Chinese cement kilns (including equipment for storage, feeding, metering, emissions control, gas cleaning etc)
- Technical and practical potential (perhaps in selected regions)
- Economy analysis with a view to the environment as well as the cement industry
- China government policy regarding the development of the Chinese cement industry

Practical arrangements:

The work will mainly be carried out in Beijing, partly at China Cement Association, partly at Beijing Cement Plant.

Formal acceptance by student (with ultimate task description as stated above):

Student's signature and date:

Ning Wang

11.01.2008

Supervisor's signature and date:

Lars-André Tokheim

11.01.2008

Contents

1	Introduction	11
1.1	Background	11
1.2	Task definition	12
2	Overview of China cement industry	13
2.1	History of China cement industry	13
2.1.1	Old China	13
2.1.2	New China	14
2.2	Status	15
2.2.1	Output	15
2.2.2	Numbers of plants	17
2.2.3	Achievement	17
3	Overview of waste materials in China	19
3.1	Overview of waste hierarchy	19
3.1.1	Waste source	19
3.1.2	Waste hierarchy	20
3.1.3	Why do we implement the waste hierarchy	20
3.1.4	Annual volumes of different types of waste	21
3.2	Pre-treatment of waste	22
3.2.1	Current	22
3.2.2	Potential	22
3.3	Evaluation of waste types	22
3.3.1	Chemical characteristics	22
3.3.2	Physical characteristics	23
3.3.3	What can be utilized in cement kiln	23
3.3.4	What can not be utilized in cement kiln	24
4	Compare of emission standards	25
4.1	China cement industry emission standard	25
4.2	Europe cement industry emission standard	27
4.3	Compare of emission standards between Europe and China	28
4.4	Possible impacts on emission caused by the wastes	29
5	Economy analysis	31
5.1	Economy analysis to the environment	31
5.1.1	Cycling economy	31
5.1.2	The potential of CO ₂ emission reduced	32
5.2	Economy analysis to the cement industry	33
5.3	Economy analysis to the investment	34
6	China government policy regarding the development of the China cement industry	35

6.1	Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste	36
6.2	Law of the People's Republic of China on Regenerable Energies	37
6.3	Law of the People's Republic of China on Energy	38
7	Case study: Equipment required for utilizing waste at Beijing cement plant	39
7.1	Introduction of Beijing cement plant	39
7.2	The range of hazardous waste	42
7.3	The systems of waste disposal in Beijing cement plant	43
7.3.1	Mud and crust preparation system	43
7.3.2	Liquid disposal system	45
7.3.3	Substituting fuel preparation and manufacturing system	46
7.3.4	Industrial sludge processing system	48
7.3.5	Burned crust processing system	50
7.3.6	Fly ash processing system	52
7.4	The process of waste disposal	54
7.4.1	Collect the samples	54
7.4.2	Elements analysis	54
7.4.3	Contract with the company which has the waste	54
7.4.4	Transportation	54
7.4.5	Storage	55
7.4.6	Scheme	56
7.4.7	Disposal	57
7.4.8	Monitoring	57
7.4.9	Impacts on the clinker quality	57
7.5	Cement testing	58
7.5.1	Compressive strength and breaking strength	58
7.5.2	Heavy metal extraction ratio	62
7.5.3	Setting time	63
7.5.4	Soundness	63
7.6	Emissions	63
7.7	Economy analysis in Beijing cement plant	64
7.7.1	For Beijing cement plant	64
7.7.2	For the environment	64
8	Discussion and Conclusion	65
8.1	Discussion	65
8.2	Conclusion	65
	Reference	67
	Appendix A	71
	Law of the People's Republic of China on Prevention of Environmental Pollution Caused by Solid Waste	71

Appendix B	86
Certification of quality management system ISO9001:2000	86
Perfecting the system of inspection measurement and test ISO10012:2003	87
Environment management system ISO14001:1996	88
Appendix C	89
National Catalogue of Hazardous Wastes	89
Acknowledgment	101

Index of tables

Table 1	The capacity and output before the founding of new China	13
Table 2	Cement plants distribution before the founding of new China	14
Table 3	Main industrial waste source	19
Table 4	Main hazardous waste source	19
Table 5	Waste chemical characteristics	23
Table 6	Waste physical characteristics	23
Table 7	Emission limits for cement plants which were built before 2005	26
Table 8	Emission limits for cement plants which were built after 2005	26
Table 9	Emission limit values for cement kilns co-incinerating waste	27
Table 10	Norcem Brevik emission limits in 2005	28
Table 11	Compare of emission standards between China and Europe	29
Table 12	Possible impacts on emission caused by the wastes	30
Table 13	The gate fee of main waste	33
Table 14	The investment analysis between cement kiln and incinerator	34
Table 15	National catalogue of hazardous wastes	42
Table 16	The waste states in mud and crust preparation system	44
Table 17	The waste states in liquid disposal system	45
Table 18	The waste states in substituting fuel preparation and manufacturing system	47
Table 19	The waste states in industrial sludge processing system	48
Table 20	The waste states in burned crust processing system	50
Table 21	The waste states in fly ash processing system	52
Table 22	The result of elements analysis	54
Table 23	The scheme of waste disposal	56
Table 24	The standard of compressive strength and breaking strength	62
Table 25	The result of compressive strength and breaking strength	62
Table 26	The result of heavy metal extraction ratio	62
Table 27	The result of setting time	63
Table 28	The result of emissions	63

Index of figures

Figure 1	The rotary kiln of Qi Xin Yang Hui Plant in 1906	13
Figure 2	The shaft kiln	14
Figure 3	The first 2000 tpd kiln with NSP in Jiangxi Cement Plant	15
Figure 4	The tendency of cement output, 1985~2007	15
Figure 5	The proportion of shaft kiln and NSP kiln	15
Figure 6	The survey of cement output in China	16
Figure 7	Conch Zongyang 10 000 tpd cement production line	17
Figure 8	5 000 tpd cement production line in Saudi Arabia made by Sinoma	17
Figure 9	Tibet Gaozheng cement plant with 3 730m	18
Figure 10	China industrial waste production	21
Figure 11	China municipal waste production	22
Figure 12	The front page of Emission Standard of Air Pollutants for Cement Industry	22
Figure 13	Previous model of waste treatment	31
Figure 14	Current model of waste treatment	31
Figure 15	The front page of Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste	36
Figure 16	The front page of Law of the People's Republic of China on Regenerable Energies	36
Figure 17	The location of Beijing cement plant in Beijing	39
Figure 18	The gate of Beijing Cement Plant	40
Figure 19	The kiln of Beijing cement plant with precalciner	41
Figure 20	The process of mud and crust preparation system	43
Figure 21	The feed point of mud and crust preparation system	44
Figure 22	The real mud and crust preparation system	44
Figure 23	The process of liquid disposal system	45
Figure 24	The feed point of liquid disposal system	45
Figure 25	The real liquid disposal system	46
Figure 26	The process of substituting fuel preparation and manufacturing system	46
Figure 27	The feed point of substituting fuel preparation and manufacturing system	47
Figure 28	The real substituting fuel preparation and manufacturing system	48
Figure 29	The process of industrial sludge processing system	48
Figure 30	The feed point of industrial sludge processing system	49
Figure 31	The real industrial sludge processing system	49
Figure 32	The process of burned crust processing system	50
Figure 33	The feed point of burned crust processing system	51
Figure 34	The real burned crust processing system	51
Figure 35	The process of fly ash processing system	52
Figure 36	The feed point of fly ash processing system	53

Figure 37	The real fly ash processing system	53
Figure 38	Vehicles in Beijing cement plant	55
Figure 39	The wastes storage in Beijing cement plant (sludge)	56
Figure 40	Cement mortar mixer	58
Figure 41	Cement mold	59
Figure 42	Cement platform vibrator (before)	59
Figure 43	Cement platform vibrator (after)	60
Figure 44	Constant temperature and humidity box	60
Figure 45	Breaking strength testing machine	61
Figure 46	Compressive strength testing machine	61
Figure 47	The status of waste treatment process	65
Figure 48	The amelioration of waste treatment process	65

1. Introduction

1.1 Background

The cement industry consumes a significant amount of natural resources and energy. It also contributes worldwide to the development and modernization of cities and infrastructure. The cement industry and its associations continuously try to improve environmental performance by optimizing the use of natural resources and reducing its overall energy consumption.

Especially in China, the output of cement is 1.35 billion tons in 2007, which is more than half of cement output in the world. But more cement plant consumes more natural resources and energy. The use of alternative fuels and raw materials can decrease the environmental impacts of wastes, safely dispose of hazardous wastes, decrease CO₂ emissions, decrease waste handling costs, and save money in the cement industry.

Beijing cement plant equipped 6 different systems which include Mud and crust preparation system, Liquid disposal system, Substituting fuel preparation and manufacturing system, Industrial sludge processing system, Burned crust processing system, Fly ash processing system. Based on these systems, Beijing cement plant can dispose different kinds of wastes. The capacity of wastes disposal is 100 000 tons per year.

Beijing cement plant is located in the northwest of Beijing city. It is about 55 kilometers from Beijing city. Beijing cement plant was built in 1992. Beijing cement plant has two cement kilns, one is 2 500 tpd and another is 3 500 tpd. The capacity of limestone mine is 120 million tons. At the end of 2007, the number of staff in Beijing cement plant is 733. Beijing cement plant has passed certification of quality management system ISO9001:2000, perfecting the system of inspection measurement and test ISO10012:2003 and environment management system ISO14001:1996.

Beijing cement plant which products the low-alkali cement, is situated in Machikou Town, Changping District. The annual product of Beijing cement plant is 2 million tons. The products have become the first selection products used in the enlarging construction of Capital Airport, Badaling Thruway, National Grand Theater, Beijing Metro, Beijing Oriental Plaza, The National Stadium, and other big projects in Beijing.

Now China has more than 600 cement kilns with NSP. If all of them have these wastes disposal systems, the China cement industry will save lots of energy and reduce the pollution.

1.2 Task definition

The goal of the task is to investigate the potential of increased use of waste materials in the China cement industry.

2. Overview of China cement industry

2.1 History of China cement industry

2.1.1 Old China

China cement industry has a long history. In 1889, the first cement plant was built in Tangshan City which is 200 km from Beijing. So Tangshan City is the cradle land of cement production in China. The old name of cement is ‘Yang Hui’ which means gray powder from abroad. The name was not changed until the early of 1930s [1].

In 1906, Qi Xin Yang Hui Plant installed two rotary kilns with $\Phi 2.1\text{m} \times 30\text{m}$. Both rotary kilns were produced by F.L Smidth. The photo of rotary kiln is represented in Figure 1. That was the first time to use a rotary kiln in China, but it was 20 years later than in the western countries. During 1889~1937, parts of Chinese cities, for instance, Shanghai, Guangzhou, Dalian, Daye, Longtan, Taiyuan and Chongqing, had built some cement plants. In the period of War of Resistance Against Japan, 13 cement plants were built in the northeast of China. But when the war was finished, most of these plants had been destroyed by the Japanese. China cement industry has also been severely damaged by the war [2].



Figure 1: The rotary kiln of Qi Xin Yang Hui Plant in 1906 [3].

From 1900 to the founding of New China (1949), the capacity of China cement industry developed from 10 000 tons to 3.15 million tons. The capacity and output before founding of new China are given in Table 1. And cement plants distribution before founding of new China are given in Table 2.

In 1949, the cement consumption was just 1.5 kg per person, which is 155 times lower than Americans [1]. China cement industry fell behind at that time.

Table 1: The capacity and output before the founding of new China [2].

Year	Capacity (million tons)	Output (million tons)
1908	0.20	0.01
1918	0.32	—
1931	1.26	0.79
1937	2.57	1.01
1945	4.05	—
1949	3.15	0.66

Table 2: Cement plants distribution before the founding of new China [2].

Regions	1937			1949		
	Capacity (million tons)	Percentage in Capacity (%)	Numbers of Plants	Capacity (million tons)	Percentage in Capacity (%)	Numbers of Plants
Total	2.57	100.0	17	3.15	100.0	38
Northeast	1.20	47.0	8	1.29	40.9	14
North	0.37	14.4	2	0.55	17.6	5
East	0.38	14.4	3	0.44	13.9	8
Mid-South	0.19	7.4	2	0.11	3.5	3
Southwest	0.05	1.8	1	0.07	2.4	4
Northwest	0.00	0.0	0	0.00	0.1	1
Taiwan	0.39	15.0	1	0.68	21.6	3

2.1.2 New China

After the founding of New China, the cement industry entered a new period of development. From 1950~1952, most of cement plants have been repaired and restarted to produce cement. In the end of 1952, the output of cement reached 2.86 million tons [4]. In other words, it was 4 more times than it was in 1949.

In 1953, the first cement institute was founded in Shenyang, which was part of Ministry of Heavy Industry. At that time, it was impossible to design a new cement plant, because China did not have enough experience on cement industry. So China had to import complete plant from West Germany, Democratic Germany, Denmark, Romania and Czech. 9 cement plants were built in different areas from 1957 to 1960, for instance, Datong, Yongdeng, Kunming, Jiangyou, Yaoxian, Chaohu, Jiangshan, Guizhou and Lushan. In 1960, the total capacity of the cement industry had reached 11 million tons [1].

It was amazing that China could export cement equipments with types of $\Phi 2.5\text{m} \times 78\text{m}$ and $\Phi 3.5\text{m} \times 145\text{m}$ wet kilns to Cambodia and Albania in 1970s.



Figure 2: The shaft kiln [6].

From 1953 to 1980, about 5 000 shaft kiln cement plants had been built because of economy [5]. It was cheaper to install shaft kiln than other types of kilns. The photo of shaft kiln is represented in Figure 2.

In 1980s, Tianjin Cement Industry Design & Research Institute could design a 2 000 tpd kiln with NSP (New Suspension Preheater). On November 1986, the first

complete domestic plant with a 2 000 tpd kiln was built in Jiangxi Cement Plant [7]. This marked an important milestone in the China cement industry development. The photo of first 2 000 tpd kiln with NSP is represented in Figure 3.



Figure 3: The first 2 000 tpd kiln with NSP in Jiangxi Cement Plant [8].

2.2 Status

2.2.1 Output

In 2007, the annual cement production was 1.35 billion tons, increased 13.48% [9]. It was 10 times than in 1985. The tendency of cement output is represented in Figure 4.

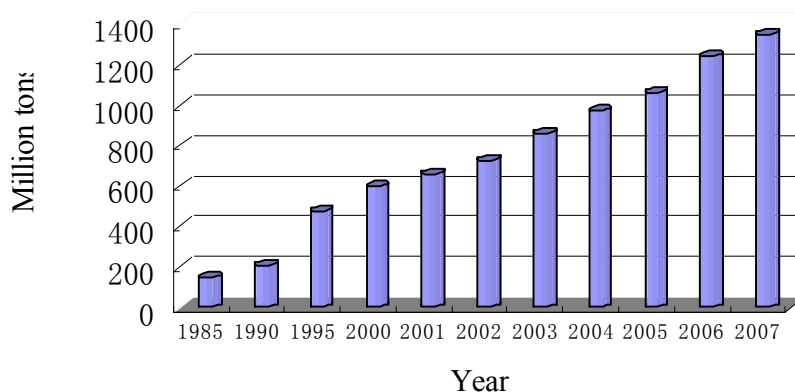


Figure 4: The tendency of cement output, 1985~2007.

A pleasing piece of news is that the cement production from shaft kiln has decreased. Now there is 53% of the cement production has been produced by advanced NSP kiln [10].The proportion of shaft kiln and NSP kiln is represented in Figure 5.

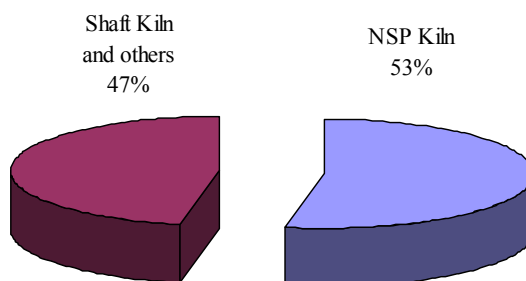


Figure5: The proportion of shaft kiln and NSP kiln.

China is very big country (9.6 million square kilometer), so the cement output is not balance. In the east part of China, the cement output is higher than other parts. The survey of cement output in China is represented in Figure 6.

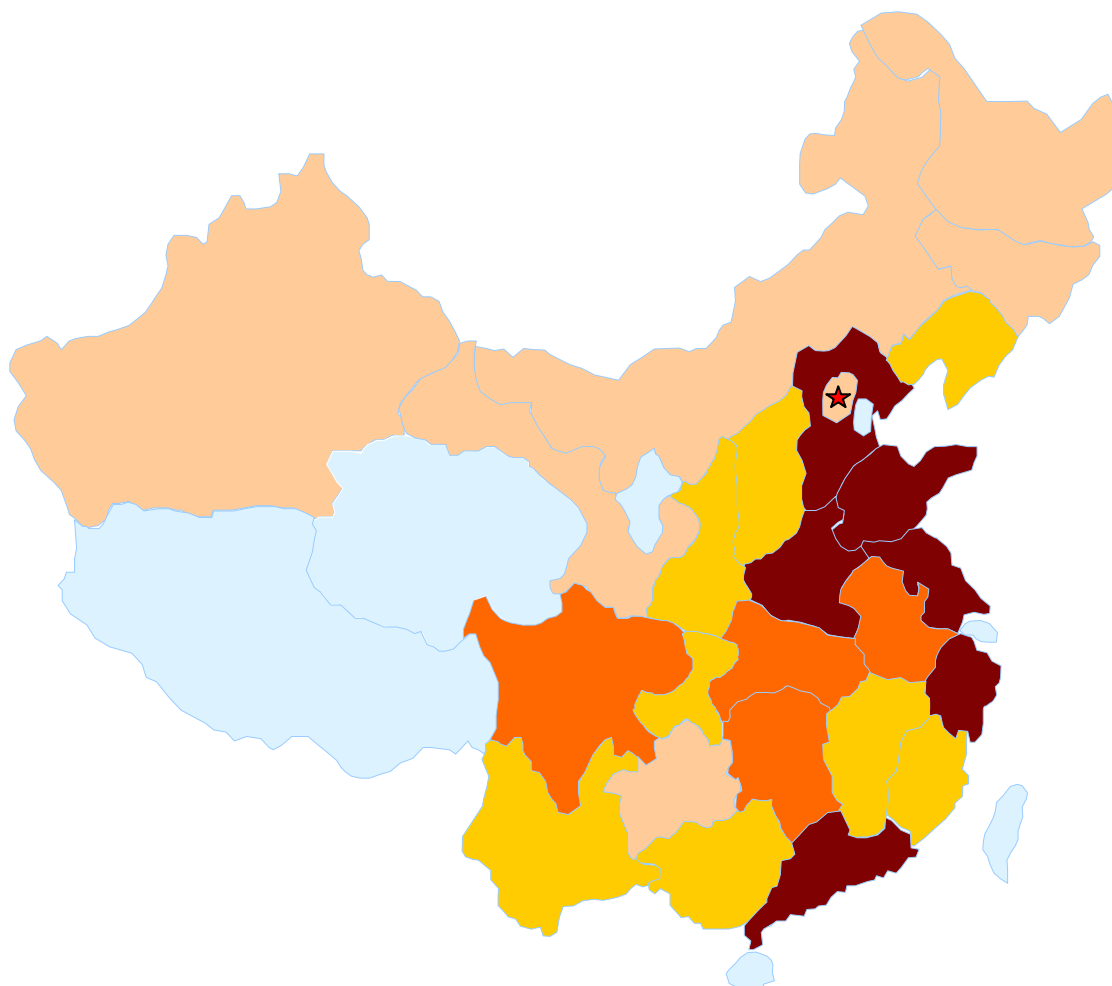
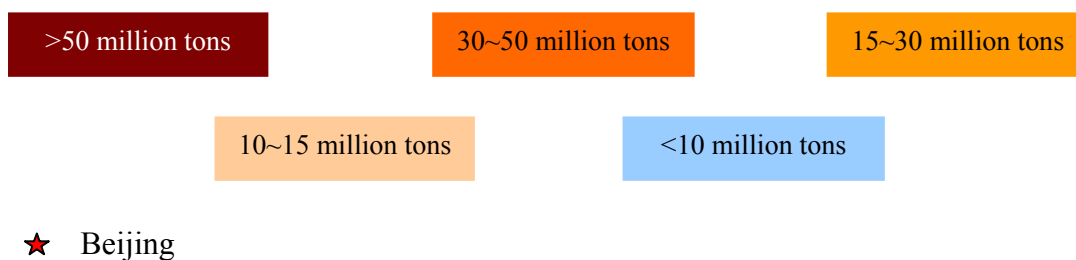


Figure6: The survey of cement output in China.



2.2.2 Numbers of plants

There are more than 5 000 cement plants in China but only one-tenth of cement plants have NSP kilns. China government plans to close more than 2 000 shaft kiln plants. In other words, there will be about 2 000 cement plants left in 2020.

2.2.3 Achievement

Over the past 40-odd post-liberation years and particularly in the past decade and more since the adoption of the policy of reform and opening to the outside world, China cement industry gain great achievements.

From 1985, the output of China cement industry has become a leader in the world till now. In 2007, the output of China cement is more than half of world cement output. Now China government encourages cement enterprises to become large-scale group. Like Conch Group, China National Building Material Group Corporation, Huaxin, Shandong, Sanshi , each of them can produce 20 million tons cement per year.

Cement industry institutes can design a set of the cement production lines from 2 000 tpd to 10 000 tpd. China has 4 cement production lines with 10 000 tpd. And more than 80% of equipments, which include mill, kiln, burner, conveyer etc., can be made in China. Conch Zhongyang 10 000 tpd cement production line is represented in Figure 7.



Figure7: Conch Zongyang 10 000 tpd cement production line [11].

China also exports the cement production lines to Africa, Middle East and some Europe countries. Sinoma is a famous turn-key supplier in cement plant construction. 5 000 tpd cement production line in Saudi Arabia made by Sinoma is represented in Figure 8.



Figure8: 5 000 tpd cement production line in Saudi Arabia made by Sinoma [12].

In order to protect environment and save energy, now some cement industry institutes are studying in areas of wastes disposal in cement kilns and power generation by the heat from cement production.

Tibet is an inalienable part of China. In 2005, a 2 000 tpd cement production line was built in Tibet. It is the highest elevation cement plant with 3 730 m in the world [13]. It is difficult to build a cement plant in a high elevation place. Tibet Gaozheng cement plant is represented in Figure 9.



Figure9: Tibet Gaozheng cement plant with 3 730m [14].

That shows China cement industry has a strong achievement.

3. Overview of waste materials in China

3.1 Overview of waste hierarchy

3.1.1 Waste source

The waste mainly comes from three parts: industry waste, municipal waste and agricultural waste.

3.1.1.1 Industrial Waste

Industrial waste is the residual substance of industry production. Most of the industrial waste comes from coal mining, power plant, steel plant, electrolytic aluminum plant, waste water treatment plant and so on. Main industrial waste source is given in Table 3. If the industrial waste contains Hg, As, Cr, Pb, Cd, C₆H₆ or radioactivity, it can be called hazardous waste [15]. Many serious diseases can be caused by the hazardous waste. The industrial wastes also pollute the water, soil and biology. Main hazardous waste source is given in Table 4.

Table 3: Main industrial waste source.

Industrial waste	Main Source
Coal gangue	Coal mining
Fly ash	Power plant
Slag	Steel plant
Red mud	Electrolytic aluminum plant
Sludge	Waste water treatment plant

Table 4: Main hazardous waste source.

Element	Main Source
Hg	Mercury mining (HgS) [16]
	Lamp
	Barometer
	Thermometer
As	Arsenical pyrite (FeAsS) [17]
	Pesticide
Cr	Chromite (FeCr ₂ O ₄) [18]
	Electroplating effluent
Pb	Galena (PbS) [19]
	Storage battery
Cd	Ore of cadmium (CdS) [20]
	Storage battery
	Pesticide
	Electroplating effluent
C ₆ H ₆ (Benzene)	Organic material

3.1.1.2 Municipal Waste

Municipal waste is a type of waste produced by resident's activities. Municipal waste contains household waste, hospital waste, commercial waste, construction waste and so on. But the component of municipal waste is unstable.

3.1.1.3 Agricultural Waste

Agricultural waste mainly comes from agriculture activities. Agricultural waste is mainly composed of the organic matter. The organic matter can be converted to the fertilizer. But some parts of agricultural waste are toxic. The pesticide can be disposed in cement kiln.

3.1.2 Waste hierarchy

Different countries have different waste hierarchy. In Australia, the waste can be divided into compost waste, recycling waste and non- recycling waste. In Japan, they have combustible waste and incombustible waste.

In China, the wastes usually can be divided into three parts: recycling waste, non-recycling waste and hazardous waste.

3.1.2.1 Recycling waste

Recycling waste contains waste paper, waste metal, waste plastic, waste glass and so on. One ton of waste paper can reproduce 0.85 ton of new paper [21]. One ton of waste steel can reproduce 0.9 ton of new steel [21]. Based on recycling, we can reduce pollution and save resource.

3.1.2.2 Non- recycling waste

Non- recycling waste includes waste building materials and some household waste. We usually use the way of landfill to dispose non- recycling waste.

3.1.2.3 Hazardous waste

Hazardous waste contains some heavy metal, battery waste, hospital waste. Hazardous waste can cause some pollution to water or soil or air, so we must treat them carefully.

3.1.3 Why do we implement the waste hierarchy?

The advantages of waste hierarchy are:

3.1.3.1 Save land

Several years ago, we usually use the way of landfill to treat waste. At that time, we have

to use some land to keep the waste. But now, when we implement hierarchy, we do not send recycling waste to landfill. So we can save some land for living.

3.1.3.2 Reduce pollution

Some pollution can be caused by the waste. When we implement the waste hierarchy, we can treat different wastes by different ways. In that case, we can reduce the pollution and save our environment.

3.1.3.3 Change the waste into the valuables

Waste is a kind of special source. We can produce the new things by some waste. For example, make new paper, steel and so on.

3.1.4 Annual volumes of different types of waste

China is a developing country, so there are many factories/plants here. From 1999 to 2004, the industrial waste increased nearly two times. The volumes of waste should increase in the future. China industrial waste production is represented in Figure 10.

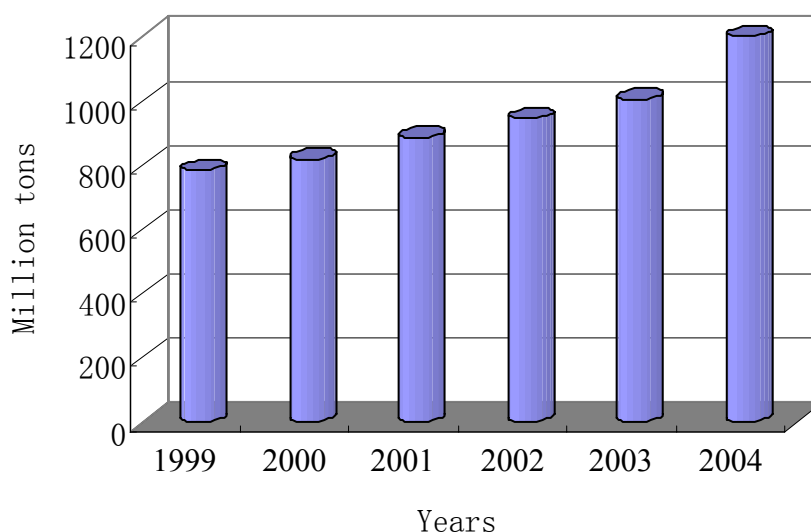


Figure 10: China industrial waste production [22].

China has the largest population on earth. More people have more municipal waste. China municipal waste production is represented in Figure 11.

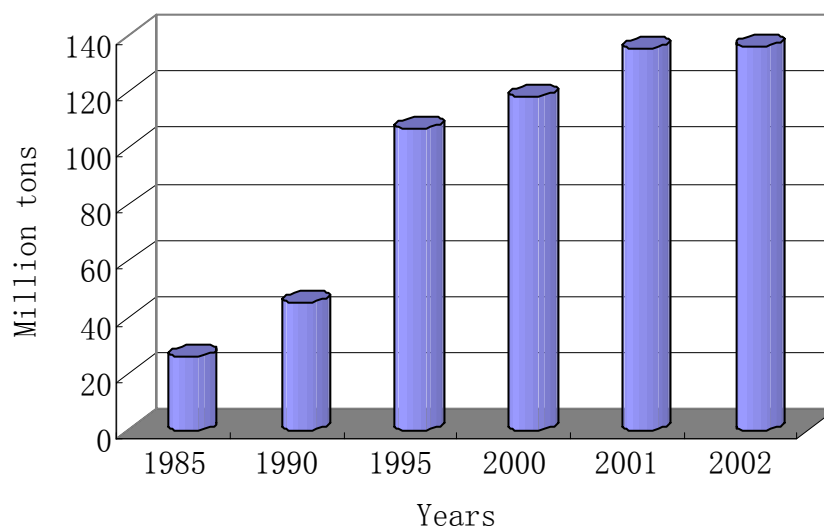


Figure 11: China municipal waste production [23].

3.2 Pre-treatment of waste

3.2.1 Current

There are three ways which includes incineration, compost and landfill to treat waste. Before we treat the waste, we usually have some processes to pre-treat the waste.

The main process are selecting, crashing, storing, weighing and transporting.

3.2.2 Potential

Unfortunately, in China, not all of wastes have a pre-treatment process. Some wastes go to the water or land without any pre-treatment. We need set up more pre-treatment plant to solve these problems.

3.3 Evaluation of waste types

3.3.1 Chemical characteristics

Chemical characteristics are related to combustibility, acidity, alkalescence and so on. Waste chemical characteristics are given in Table 5.

Table 5: Waste chemical characteristics.

Chemical characteristics	Main Source
Combustibility	Plastic
	Rubber
Acidity	Storage battery
	Waste acid
	SO ₂
Alkalescence	Paper mill
	Printing and dyeing
	NH ₃

3.3.2 Physical characteristics

Usually, waste physical characteristic exists in three states: solid, liquid and gas. Waste physical characteristics are given in Table 6.

Table 6: Waste physical characteristics.

State	Main Source
Solid	Coal gangue
	Fly ash
	Slag
	Red mud
	Sludge
Liquid	Waste acid
	Waste alkali
	Waste solution
Gas	SO ₂
	NO _x

3.3.3 What can be utilized in cement kiln?

Not all of waste can be utilized in cement production. Usually we use waste as raw materials and fuels in cement production. Some industrial waste, for example, fly ash, slag, sludge can be used as raw materials. And animal meal, refuse derived fuel, residual oil can be used as fuels.

Now we are trying to use cement kiln to dispose the pesticide. In China, more than 300 000 tons of pesticide can be produced per year. It is a new study field for China cement

industry [24].

3.3.4 What can not be utilized in cement kiln?

Most of municipal waste can not be utilized in cement kiln, because municipal waste contains lots of water and the component of municipal waste is unstable. It is hard to control them in cement production.

In addition, high concentration of K, Na, Cl, S will cause block in the preheater and kiln. So the waste must be pre-treated before disposal.

4. Compare of emission standards

4.1 China cement industry emission standard

In China, the latest ‘Emission Standard of Air Pollutants for Cement Industry’ (GB 4915—2004) was issued by Ministry of Environmental Protection of the People’s Republic of China and General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China in 2005. The front page of Emission Standard of Air Pollutants for Cement Industry is represented in Figure 12.

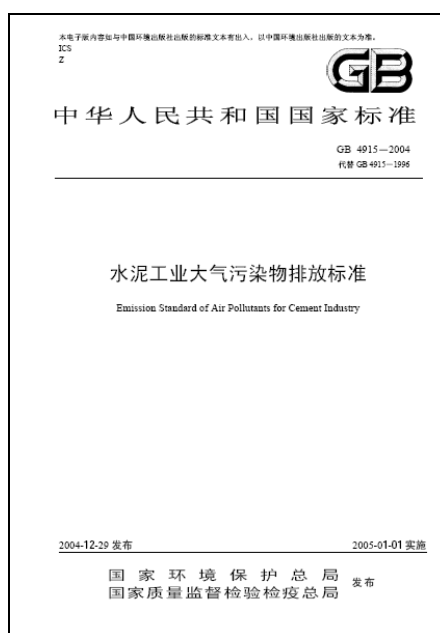


Figure 12: The front page of Emission Standard of Air Pollutants for Cement Industry.

In this emission standard, there are two conditions. Whatever shaft kilns or rotary kilns, if the cement plants were built before 1 January 2005, they will follow the old standard. Emission limits for cement plants which were built before 2005 are given in Table 7. If the cement plants were built after 1 January 2005, they will follow the new standard. Emission limits for cement plants which were built after 2005 are given in Table 8. But all of cement plants in China will follow the standard on 1 January 2010.

Table 7: Emission limits for cement plants which were built before 2005 [25].

Process	Dust		SO ₂		NO ₂		F	
	Concentration (mg / Nm ³)	Unit Emission (kg / t)	Concentration (mg / Nm ³)	Unit Emission (kg / t)	Concentration (mg / Nm ³)	Unit Emission (kg / t)	Concentration (mg / Nm ³)	Unit Emission (kg / t)
Kiln*	100	0.30	400	1.20	800	2.40	10	0.03
Dryer, Mill, Coal Mill and Cooler	100	0.30	-	-	-	-	-	-
Crusher, Packer	50	0.04	-	-	-	-	-	-

* Concentration values given at 10% O₂

Table 8: Emission limits for cement plants which were built after 2005 [25].

Process	Dust		SO ₂		NO ₂		F	
	Concentration (mg / Nm ³)	Unit Emission (kg / t)	Concentration (mg / Nm ³)	Unit Emission (kg / t)	Concentration (mg / Nm ³)	Unit Emission (kg / t)	Concentration (mg / Nm ³)	Unit Emission (kg / t)
Kiln*	50	0.15	200	0.60	800	2.40	5	0.015
Dryer, Mill, Coal Mill and Cooler	50	0.15	-	-	-	-	-	-
Crusher, Packer	30	0.024	-	-	-	-	-	-

* Concentration values given at 10% O₂

In order to protect the environment, China government made the new emission standard in 2005. The previous dust emission standard was 150 mg/Nm³. But now the emission standard is 100 mg/Nm³ for the old and 50 mg/Nm³ for the new. In other words, based on new emission standard, China cement industry reduce at least 1/3 dust emission.

4.2 Europe cement industry emission standard

The European Parliament and the Council of the European Union made Directive 2007/76/EC on the incineration of waste on 4 December 2000. Emission limit values for cement kilns co-incinerating waste are given in Table 9.

Table 9: Emission limit values for cement kilns co-incinerating waste [26].

Pollutant ^a	Concentration (mg / Nm ³)
Total dust	30
HCl	10
HF	1
NO _x for existing plants	800
NO _x for new plants	500
Cd+Tl	0.05
Hg	0.05
Sb+As+Pb+Cr+Co+Cu+Mn+Ni+N	0.5
Dioxins and furans ^b	0.1
SO ₂	50
TOC	10
CO	can be set by the competent authority

a) Conditions: Temperature 273 K, Pressure 101.3 kPa, 10 % O₂, Dry gas.

b) All concentration values given as mg/Nm³ except Dioxins and furans, given as ng/Nm³

In Norway, Norcem, Brevik is the leading cement producer. Norcem AS is member of the Heidelberg Cement group, and the sole producer of cement in Norway. Norcem operates two modern and energy efficient cement plants in Norway. The Brevik plant has an annual production capacity of about 1.35 mill tons of clinker and cement [27].

Norcem is an environment friendly cement plant. In order to reduce CO₂ emissions and save fossil fuels, Norcem utilizes alternative fuels extensively. In the Brevik plant more than 50% of the fuel used in clinker production is comprised by alternative fuels to reduce the greenhouse gases and conserving energy and resources [27]. Norcem Brevik emission limits in 2005 are given in Table 10.

Table 10: Norcem Brevik emission limits in 2005 [28].

Pollutant	Europe Standard Concentration (mg / Nm ³)	Norcem Brevik Concentration in 2005 ^b
Total dust	30	30
HCl	10	10
HF	1	1
NO _x	800(old)/500(new)	800
Cd+Tl	0.05	0.05
Hg	0.05	0.05
Sb+As+Pb+Cr+Co+Cu+Mn+Ni+N	0.5	0.5
Dioxins and furans ^b	0.1	0.1
SO ₂	50	500
TOC	10	10
CO	can be set by the competent authority	–

a) All concentration values given as mg/Nm³ except Dioxins and furans, given as ng/Nm³

b) Concentration values 2005 given at 10 % O₂

It seems that the pollutant emissions of Norcem Brevik cement plant match the Europe standard except SO₂. The concentration of SO₂ is ten times than the Europe standard.

4.3 Compare of emission standards between Europe and China

Actually, China does not have emission standards especially for cement kilns co-incinerating waste. The Emission Standard of Air Pollutants for Cement Industry is for all of the cement kilns, whatever they use the waste or not.

On the other hand, there are some differences between China and Europe in emission standards. Europe has a perfect emission standards system for cement kilns co-incinerating waste. But China does not have the emission standards for pollutants in HCl, Cd+Tl, Hg, Sb+As+Pb+Cr+Co+Cu+Mn+Ni+N, dioxins and furans and TOC. China should enhance the emission standards. Compare of emission standards between China and Europe are given in Table 11.

Table 11: Compare of emission standards between China and Europe.

Pollutant	Europe	China		
	kiln	Kiln	Dryer, Mill, Coal Mill and Cooler	Crusher, Packer
	Concentration (mg / Nm ³)			
Total dust	30	100(old)/50(new)	100(old)/50(new)	50(old)/30(new)
HCl	10	-	-	-
HF	1	-	-	-
NOx	800(old)/500(new)	800	-	-
Cd+Tl	0.05	-	-	-
Hg	0.05	-	-	-
Sb+As+Pb+Cr+ Co+Cu+Mn+Ni+ N	0.5	-	-	-
Dioxins and furans	0.1	-	-	-
SO ₂	50	400(old)/200(new)	-	-
TOC	10	-	-	-
F	-	10(old)/5(new)	-	-
CO	can be set by the competent authority	-	-	-

4.4 Possible impacts on emission caused by the wastes

Industrial waste, municipal waste and agricultural waste are the main resources of wastes. These wastes can cause the possible impacts on emission.

The possible impacts on emission caused by the wastes are given in Table 12.

Table 12: Possible impacts on emission caused by the wastes.

Wastes	Possible impacts					
Industrial	Dust	CO	SO ₂	HF	HCl	NO _x [30]
Municipal	Dust	Hg	Cd	Pb	[31]	
Agricultural	Dust	As	[32]			

5. Economy analysis

5.1 Economy analysis to the environment

5.1.1 Cycling economy

The aim of cement industry is not only for production but also have responsibility for protecting the environment.

Cycling economy is the best way to study the relationship between economy and environment. Cycling economy shows a model on the basis of constant and circulatory use of resources. There are three important parts in the cycling economy which includes reduce, reuse and recycle. Europe, America and Japanese have more experience on management between economy and environment. In China, we just start to research this field.

Several years ago, China usually uses landfill way to treat the waste without any pre-treatment. Previous model of waste treatment is represented in Figure 13. In that way, the waste can cause lots of pollution in air, water and soil. It is harmful to our health.



Figure 13: Previous model of waste treatment.

Now China has changed the model to dispose the waste. Current model of waste treatment is represented in Figure 14.

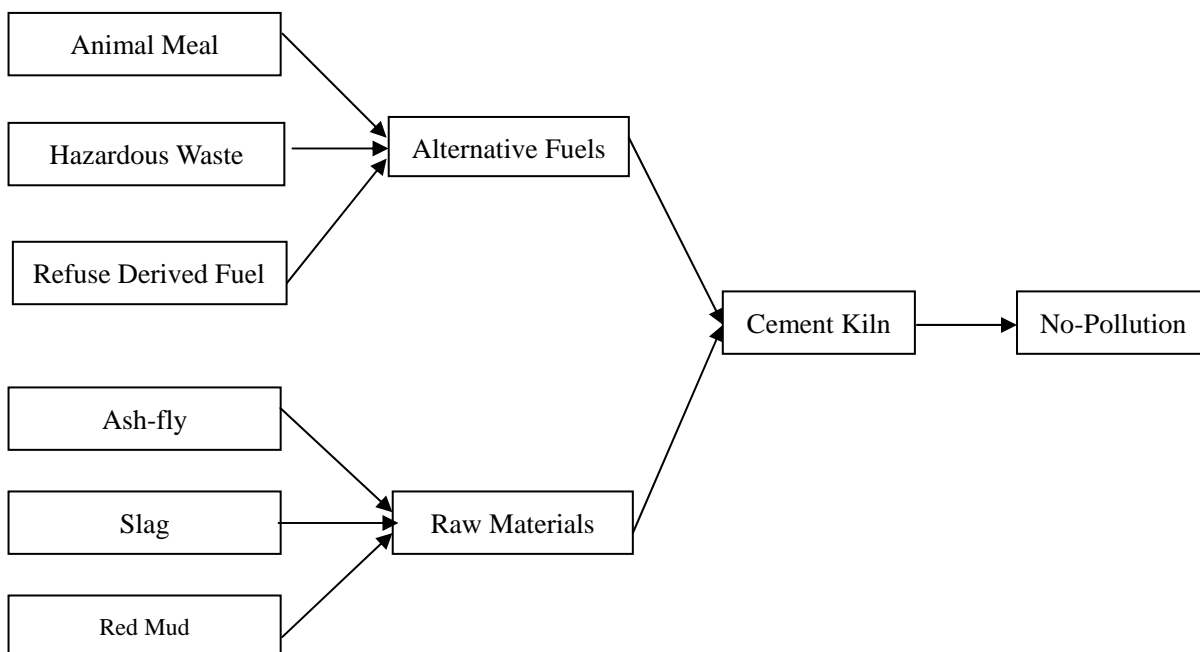


Figure 14: Current model of waste treatment.

In this process, we reuse and recycle the waste, reduce the emission. We can save the native resource and protect environment. On the other hand, some wastes contain the hazardous things which we can utilize as the fuels. In that way, we can save both native resources and fossil fuels and there will be 'zero hazardous emission'. This is a typical model for the cycling economy.

5.1.2 The potential of CO₂ emission reduced

CO₂ mainly comes from two parts in cement production. One is from raw materials, another is from fuels.

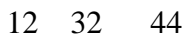
For the raw materials, if we assume the output of cement is 1 billion tons per year, China cement industry will consume nearly 1 billion tons limestone and 80% of them are CaCO₃. Based on the Equation 1, we can find raw materials will produce about 352 million tons of CO₂ per year.



$$m_{CO_2-RawMaterials} = \frac{1,000,000,000 * 0.8 * 44}{100} = 352,000,000t$$

$$m_{CO_2-RawMaterials} \quad \text{Mass of } CO_2 \text{ from raw materials in cement production (t)}$$

For the fuels, if we assume 1 ton of cement will consume 0.18 ton of coal and 1 ton of coal contains 65% of carbon (C). Based on Based on the Equation 2, we can find fuels will produce about 429 million tons of CO₂ per year



$$m_{CO_2-Fuels} = \frac{1,000,000,000 * 0.18 * 0.65 * 44}{12} = 429,000,000t$$

$$m_{CO_2-Fuels} \quad \text{Mass of } CO_2 \text{ from fuels in cement production (t)}$$

The main CO₂ emission in cement production is about 781 million tons per year.

$$m_{CO_2-Main} = m_{CO_2-RawMaterials} + m_{CO_2-Fuels} = 781,000,000t$$

If 1% of raw materials and fuels can be saved, China cement industry will reduce 7.81 million tons of CO₂. That is an enormous number.

5.2 Economy analysis to the cement industry

Do you believe that the cement plant can earn money from the waste? That is true. In China, for the cement plant, there are several ways to get payment from the waste.

The company who product the waste will pay the cement plant. For example, slug from waste water treatment plant, plastic from mobile phone. The gate fee of main waste is given in Table 13.

Table 13: The gate fee of main waste.

	Municipal waste	Sludge with organic	Hazardous waste
H ₂ O (%) [33]	60~80	<70	>60
NHV (kJ/kg) [33]	5040~6300	5880~8400	Based on waste
Harmful elements	Cl, Na, S	S, Na, K	S, Na, K, Cl
Heavy metal	Low	Low	Based on waste
Stability	Medium	High	Low
Gate fee (\$/t) [34]	<21	28~42	>114

The equation 3, 4 and 5 will show the income of cement plant from the waste.

$$I_m = G_m * M_m \quad (3)$$

I_m *Income from municipal waste (\$)*

G_m *Gate fee of municipal waste (\$/t)*

M_m *Mass of municipal waste (t)*

$$I_s = G_s * M_s \quad (4)$$

I_s *Income from sludge with organic (\$)*

G_s *Gate fee of sludge with organic (\$/t)*

M_s *Mass of sludge with organic (t)*

$$I_h = G_h * M_h \quad (5)$$

I_h *Income from hazardous waste (\$)*

G_h *Gate fee of hazardous waste (\$/t)*

M_h *Mass of hazardous waste (t)*

Another way is the local government will drawback the value added tax to the cement plant, if the cement plant can use more than 30% waste to instead of raw materials.

More details will be given in the model of Beijing cement plant.

In Norway, the hazardous waste is strictly forbidden to landfill. The plants that landfill such waste will be punished by the law. For the organic waste, the plants have to pay “landfill fee” to the Norwegian state. That promotes alternative use of waste in cement kilns. The cement plant will be paid by the waste handling companies. [35]

5.3 Economy analysis to the investment

Use cement kiln to dispose waste is better than incinerator. Temperature, remaining time and rotate speed of cement kiln are higher than incinerator. The key thing is the investment is lower than building a new incinerator. And it is no need to use new land. The investment analysis between cement kiln and incinerator are given in Table 14.

Table 14: The investment analysis between cement kiln and incinerator.

	Incinerator [36]	Cement kiln
Temperature (°C)	1100	1750
Gas Remaining Time (s)	2	>4
Solid Remaining Time (min)	Based on waste	20~30
Rotate speed (r/min)	0.2~0.3	2.8~3.2
Capacity (t/y)	250 000	150 000
Land (m ²)	80 000~150 000	No new place
Investment (\$)	65 000 000	24 000 000

6. China government policy regarding the development of the China cement industry

China consumes lots of energy and brings some pollution because of the most population in the world annually. During the period of the 10th Five-Year Plan (2001~2005), the average growth rate of gross domestic product (GDP) is 9.5% [37], but the average growth rate of the energy consumption also reaches 9.9% [38]. The growth rate of the energy consumption is even higher than the GDP. More energy consumption can cause more pollution, so our government plans to reduce 20% of energy consumption at the end of the 11th Five-Year Plan (2006~2010) [39].

In order to reduce the energy consumption and protect the environment, the China cement industry began to study how to treat the waste materials in cement kilns at the end of the last century. The cement industry tries to find the suitable way to solve these problems.

Before the period of the 10th Five-Year Plan, China cement industry mainly uses the waste as raw materials. Some waste, for example slag, ash-fly, coal gangue, red mud can be used as raw materials. Based on this way, the cement plants reduce a little bit production cost and pollution.

But China cement industry does not have more experience on alternative fuel. In other words, we have more than 5 000 cement plants, but less than 10 plants can utilize the alternative fuel. Most of the cement plants still use the coal as the fuel.

Because of the successful application of using waste in cement kilns in Europe, America and Japanese, China government decide to encourage cement plants to study waste treatment in cement kilns.

Now China government put lots of money into cement institutes to support scientists to study the technology in field of waste treatment every year. The government is very interested on waste treatment in cement kiln, because it is no need to build extra incinerators. The price of a new incinerator is two times much than the cement kilns. The government does not need spend more money on the project of waste treatment in cement kilns.

For the future, the government needs to give due consideration to the cement plants. The companies, who produce the waste, will assume responsibility in economy. They must pay the money to the cement plants for the waste treatment.

The government needs to establish the new emission standard, because of some hazardous waste will be used in cement kiln. And the government also needs to establish the standard about collection, storage and transportation of the waste.

China government has promulgated a series of laws for energy and environment. Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste (effective April 1, 2005) and Law of the People's Republic of China on Regenerable Energies (effective January 1, 2006) will be implemented. And Law of the People's Republic of China on Energy will be effective in 2009.

6.1 Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste

To prevent the pollution of the environment by solid waste, ensure the good health of the public, and promote the development of socialist modernization, the law is hereby established. The front page of Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste is represented in Figure 15.



Figure 15: The front page of Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste [40].

- The abandonment or spread of solid waste during transportation is forbidden.
- It is forbidden to close, disuse, or dismantle without authorization the facilities and sites for preventing environmental pollution caused by industrial solid waste.
- Within the territory of the People's Republic of China, it is forbidden to dump, pile, or

dispose of solid waste from outside the People's Republic of China.

- Mixed storage of dangerous waste with non-dangerous waste is forbidden.
- Transport of dangerous waste in a passenger vehicle is forbidden.
- Throwing or piling rubbish outside these designated places is forbidden.
- Unauthorized closure, disuse, or dismantling of the facilities or sites for the disposal of urban residential refuse is forbidden.
- Transit of dangerous waste passing through the territory of the People's Republic of China is forbidden.

Any unit will be punished by 1 500\$ ~ 150 000\$, if they break the law above. That would be described in Appendix A.

6.2 Law of the People's Republic of China on Regenerable Energies

To encourage using regenerable energy and saving energy, the law is hereby established. The front page of the front page of Law of the People's Republic of China on Regenerable Energies is represented in Figure 16.



Figure 16: The front page of Law of the People's Republic of China on Regenerable Energies [41].

This law encourages using non- fossil substance to produce electricity or heating. For the cement industry, the waste can be used as fuels to produce heating. China government encourages cement industry to research waste disposal in cement kiln.

6.3 Law of the People's Republic of China on Energy

Law of the People's Republic of China on Energy is being discussed and will be effective in 2009.

The law and policy will promote the development of waste disposal in cement kiln. Any unit or person must throw the waste in regular. Fortunately, cement kiln is a good 'place' to take the waste.

7. Case study: Equipment required for utilizing waste at Beijing cement plant

7.1 Introduction of Beijing cement plant

Beijing cement plant is a branch of Beijing Building Materials Group (BBMG) which is the biggest building materials company in Beijing. BBMG is a large-scale enterprise, combining industrial products manufacturing, design and building construction and trading. The manufacturing includes five series such as: cement, wood-based panel, sanitary ceramics, furniture, indoor and outdoor wall coating. It also produces over 20 kinds of new-type building materials such as steel radiator, mineral wool sound absorbing ceiling board, glass fiber, color steel plate, autoclaved concrete etc. The BBMG has research institute and takes the leading in the building materials industry of China.

BBMG have three cement plants in Beijing which are Beijing cement plant, Beijing Liulihe cement plant and Beijing Yanshan cement plant. The cement capacity of these three plants is 5.2 million tons per year. Some big construction projects use the cement from BBMG in Beijing. More than 90% of cement supply for the Olympic Games buildings come from BBMG [42].

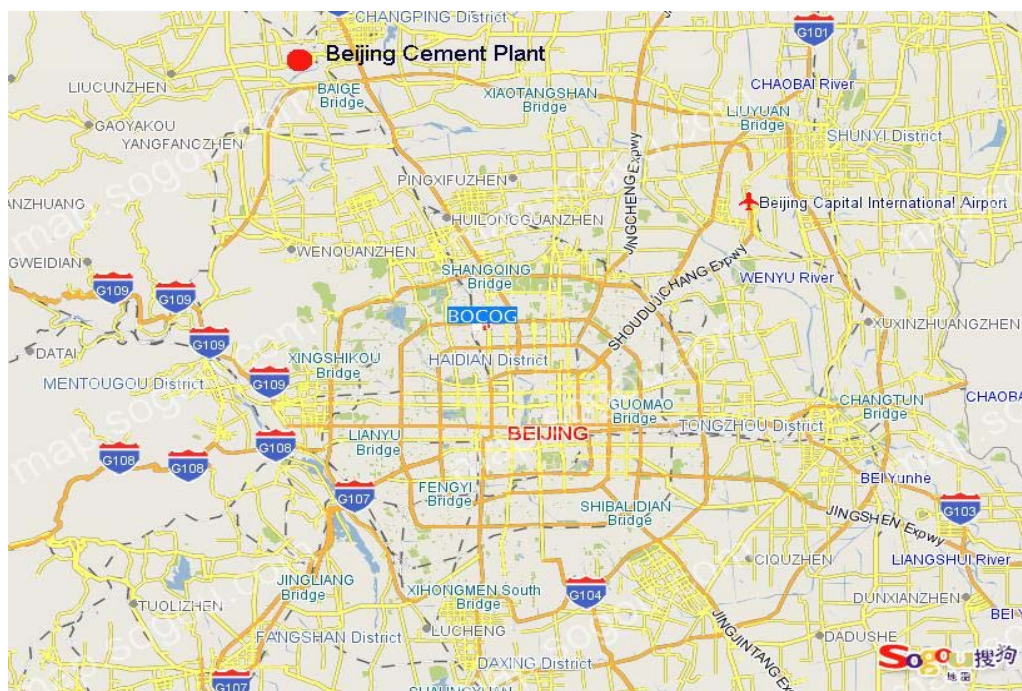


Figure 17: The location of Beijing cement plant in Beijing [43].

Beijing cement plant is located in the northwest of Beijing city. It is about 55 kilometers from Beijing city. Beijing cement plant was built in 1992. Beijing cement plant has two cement kilns, one is 2500 tpd and another is 3500 tpd. Both of them are precalciner kilns. And most of the equipments, for example, Kiln, Mill, Electric collector, Filter bag, Motor, Cooler and Burner can be made by Chinese suppliers. CITIC Heavy Industries is a leading company in cement equipments. The capacity of limestone mine is 120 million tons. At the end of 2007, the number of staff in Beijing cement plant is 733 [44]. Beijing cement plant has passed certification of quality management system ISO9001:2000, perfecting the system of inspection measurement and test ISO10012:2003 and environment management system ISO14001:1996. That would be described in Appendix B.

Beijing cement plant which products the low- alkali cement, is situated in Machikou Town, Changping District. The annual product of Beijing cement plant is 2 million tons. The products have become the first selection products used in the enlarging construction of Capital Airport, Badaling Thruway, National Grand Theater, Beijing Metro, Beijing Oriental Plaza, The National Stadium, and other big projects in Beijing [45].

Beijing cement plant pays highly attention to the environmental protection and the responsibility to the society. In 2005, Beijing cement plant was determined as one of the trial units of circular economy of the first batch by the National Development and Reformation Committee which is very important ministry in China.

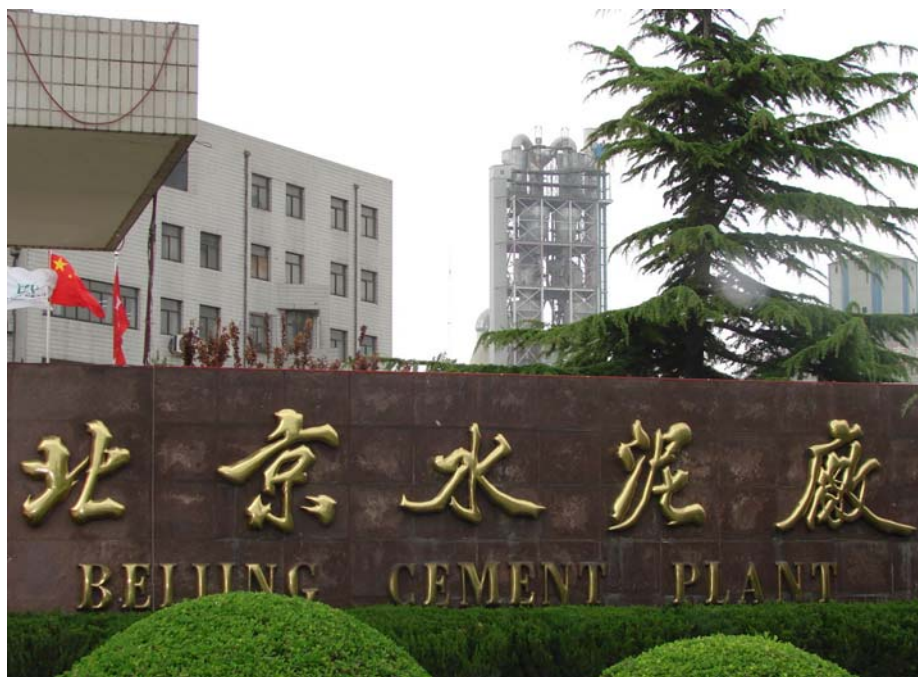


Figure 18: The gate of Beijing Cement Plant.

Beijing cement plant created a new method for the cement plants to realize the sustainable development combining with the features of the capital economy. It has realized the harmonized unification of the economical, environmental and social benefits.

In 2002, Beijing cement plant was elected the famous brand by Beijing Government. In 2003, Beijing cement plant was granted the National Examination-free Certification on the quality.

Beijing cement plant owns the first specialized environment protective kiln dealing with the industrial wastes in China. Beijing cement plant has the waste inspection equipment and online supervision equipment. Beijing cement plant regards executing the social responsibility as its own duty.

Beijing cement plant is converting the industry structure by the cement production, develop the environment protection industry and cultivate the core technology. By the year of 2010, the operation income of the cooperation will exceed 140 million \$ and the profit will be 21 million \$. Beijing cement plant will become the best in the industry and construct the harmonious and first-ranked environment protective enterprise [45].



Figure 19: The kiln of Beijing cement plant with precalciner. (3 500 tpd)

7.2 The range of hazardous waste

In 1998, the National Environmental Protection Agency, the State of Economy & Trade Committee, the Ministry of Foreign Trade & Economic Cooperation, the Ministry of Public Security promulgated National Catalogue of Hazardous Wastes. There are 47 species of hazardous wastes which are permitted to treat.

In Beijing cement plant, there are 28 species of hazardous wastes can be treated. National catalogue of hazardous wastes are given in Table 15. That would be described in Appendix C.

Table 15: National catalogue of hazardous wastes.

Permission	Code	Categories of the Waste	
	HW01	Clinical wastes	
01	●	HW02	Pharmaceutical wastes
02	●	HW03	Waste pharmaceuticals, drugs and medicines
03	●	HW04	Pesticide wastes
04	●	HW05	Wastes containing wood preserving chemicals
05	●	HW06	Organic solvent wastes
06	●	HW07	Cyanides wastes
07	●	HW08	Waste mineral oils
08	●	HW09	Waste emulsion
		HW10	Polychlorobiphenyl wastes
09	●	HW11	Residues of refinery or distillation
10	●	HW12	Waste dyes and paints
11	●	HW13	Organic resins wastes
12	●	HW14	New chemical wastes
		HW15	Explosive wastes
13	●	HW16	Photographic chemical wastes
14	●	HW17	Wastes from surface treatment
15	●	HW18	Residues of incinerating disposal
16	●	HW19	Metal carbonyl compound wastes
		HW20	Beryllium wastes
		HW21	Chromium wastes
		HW22	Copper wastes
		HW23	Zinc wastes
17	●	HW24	Arsenic wastes
		HW25	Selenium
		HW26	Cadmium wastes
		HW27	Antimony wastes
		HW28	Tellurium wastes
		HW29	Mercury wastes

		HW30	Thallium wastes
		HW31	Lead wastes
18	•	HW32	Inorganic fluoride wastes
19	•	HW33	Inorganic cyanide wastes
20	•	HW34	Waste acid
21	•	HW35	Waste alkali
		HW36	Asbestic wastes
22	•	HW37	Organic phosphorus wastes
23	•	HW38	Organic cyanide wastes
24	•	HW39	Phenols wastes
25	•	HW40	Ethers wastes
		HW41	Waste halogenated organic solvent
26	•	HW42	Waste organic solvents
		HW43	Any congener compound of polychlorinated dibenzo-furan
		HW44	Any congener compound of polychlorinated dibenzo-p-dioxin
		HW45	Organohalogen compounds
27	•	HW46	Nickel compound wastes
28	•	HW47	Barium compound wastes

If the components of waste are out of the range, the cement plant can not treat. For example, the army wants to send a set of chemistry substance to treat. Unfortunately they are out of the range, the cement plant can not treat.

7.3 The systems of waste disposal in Beijing cement plant

Based on the different wastes, there are 6 systems to treat the wastes in Beijing cement plant.

7.3.1 Mud and crust preparation system

In the mud and crust preparation system, some mud and crust can be made to pulpy mixture. And then these things will be put into the end of kiln by the pump. The capacity of mud and crust preparation system is 30 000 tons per year. The process of mud and crust preparation system is represented in Figure 20.

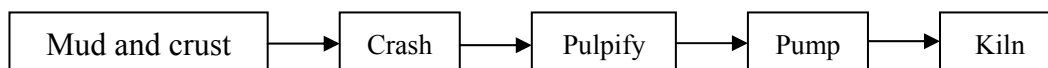


Figure 20: The process of mud and crust preparation system.

The waste states in mud and crust preparation system are given in Table 16.

Table 16: The waste states in mud and crust preparation system.

Physical characteristics	Main source	Water content
Solid/ Semi-solid	HW 02-05, HW 07, HW 11-14, HW 16-17, HW 19, HW 24, HW 32-33, HW 46-47	Medium

For the mud and crust preparation system, the feed point is in the end of kiln. The temperature of this point is more than 850 °C. The feed point of mud and crust preparation system is represented in Figure 21. And the real mud and crust preparation system is represented in Figure 22.

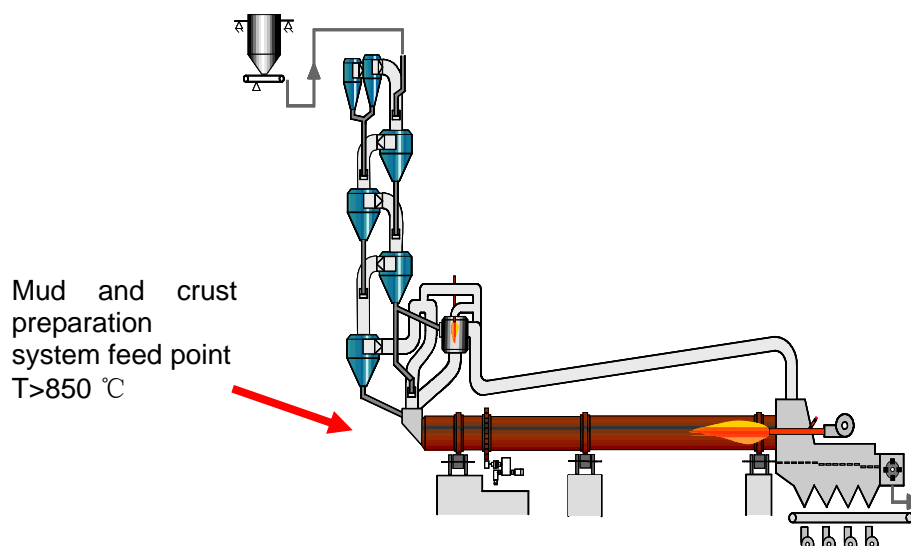


Figure 21: The feed point of mud and crust preparation system.



Figure 22: The real mud and crust preparation system.

7.3.2 Liquid disposal system

In the liquid disposal system, some liquid waste, like organic solvent and emulsion can be put into the head of kiln by the pump. The capacity of liquid disposal system is 10 000 tons per year. The process of liquid disposal system is represented in Figure 23.

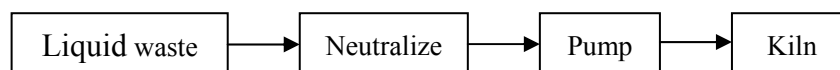


Figure 23: The process of liquid disposal system.

The waste states in liquid disposal system are given in Table 17.

Table 17: The waste states in liquid disposal system.

Physical characteristics	Main source	Water content
Liquid	HW 06, HW 08, HW 09, HW 34-35, HW 37-40, HW42	High

For the liquid disposal system, the feed point is in the head of kiln. The temperature of this point is more than 1 200 °C. The feed point of liquid disposal system is represented in Figure 24. And the real liquid disposal system is represented in Figure 25.

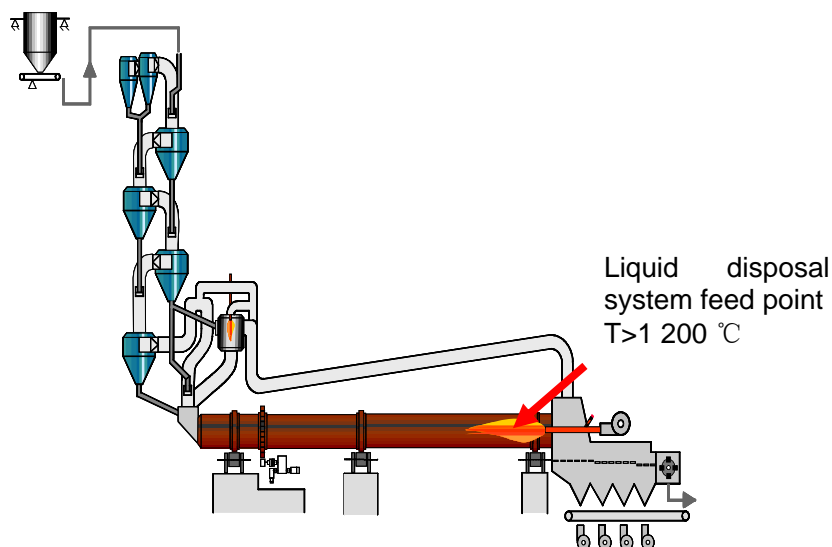


Figure 24: The feed point of liquid disposal system.



Figure 25: The real liquid disposal system.

7.3.3 Substituting fuel preparation and manufacturing system

In the substituting fuel preparation and manufacturing system, the waste paper, waste plastic, lacquer can be put into the head of kiln. The capacity of substituting fuel preparation and manufacturing system is 10 000 tons per year. The process of substituting fuel preparation and manufacturing system is represented in Figure 26.

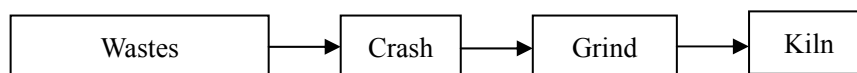


Figure 26: The process of substituting fuel preparation and manufacturing system.

The waste states in substituting fuel preparation and manufacturing system are given in Table 18.

Table 18: The waste states in substituting fuel preparation and manufacturing system.

Main Physical Characteristics	Main Source	LHV (kJ/kg)	Water content
Solid	Waste plastic, waste paper waste lacquer	>5 000	Low

For the substituting fuel preparation and manufacturing system, the feed point is in the burner. The temperature of this point is more than 1 450 °C. The feed point of substituting fuel preparation and manufacturing system is represented in Figure 27. And the real substituting fuel preparation and manufacturing system is represented in Figure 28.

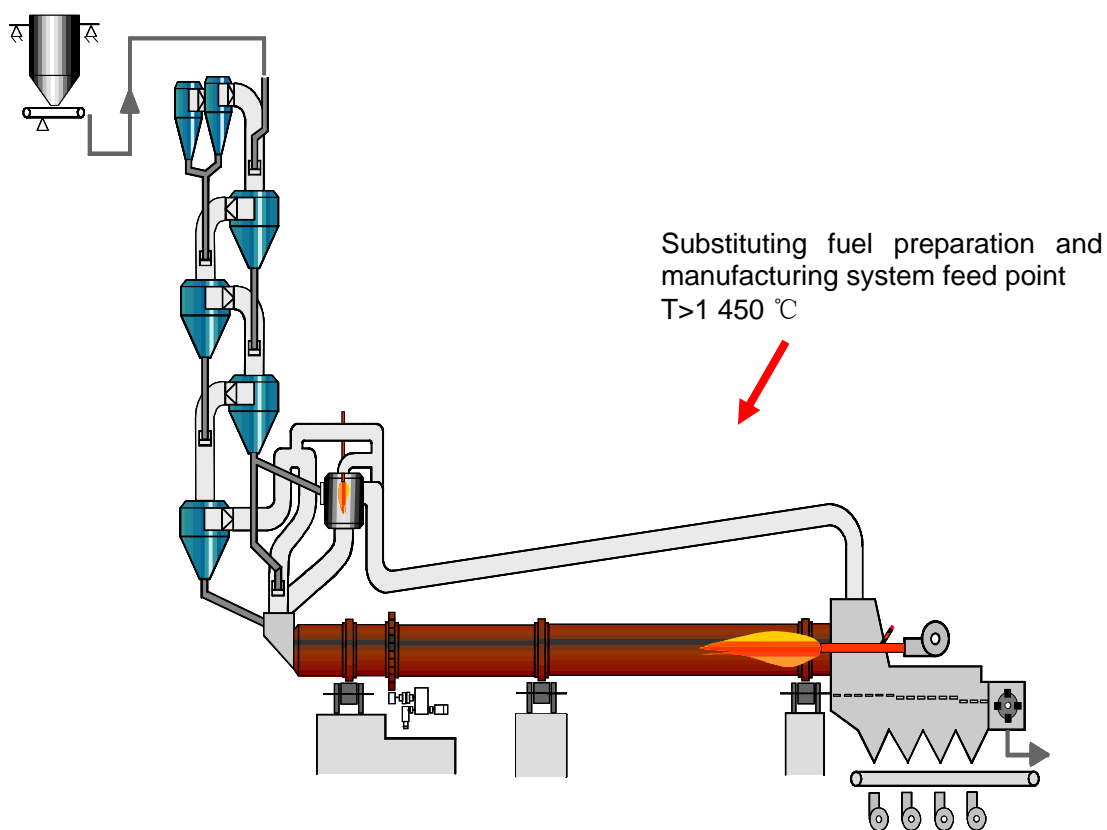


Figure 27: The feed point of substituting fuel preparation and manufacturing system.



Figure 28: The real substituting fuel preparation and manufacturing system.

7.3.4 Industrial sludge processing system

In the industrial sludge processing system, the sludge will be put into the precalciner to instead of some parts of raw materials. The capacity of industrial sludge processing system is 10 000 tons per year. The process of industrial sludge processing system is represented in Figure 29.

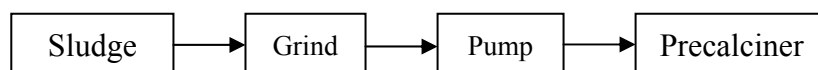


Figure 29: The process of industrial sludge processing system.

The waste states in industrial sludge processing system are given in Table 19.

Table 19: The waste states in industrial sludge processing system.

Physical characteristics	Main source	Water content
Solid/ Semi-solid	Waste water treatment plant	Medium

For the industrial sludge processing system, the feed point is in the precalciner. The temperature of this point is more than 1 000 °C. The feed point of industrial sludge processing system is represented in Figure 30. And the real industrial sludge processing system is represented in Figure 31.

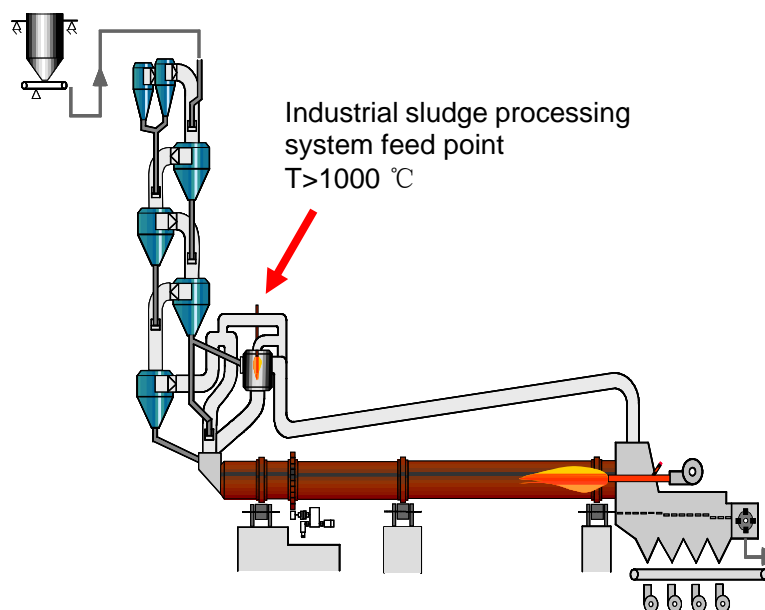


Figure 30: The feed point of industrial sludge processing system.



Figure 31: The real industrial sludge processing system.

7.3.5 Burned crust processing system

The burned crust comes from the bottom of the incineration. It is the residual of waste which is burned. In the burned crust processing system, the residue which comes from the waste incineration plant will be put into the preheater to instead of raw materials. The capacity of burned crust processing system is 37 000 tons per year. The process of burned crust processing system is represented in Figure 32.

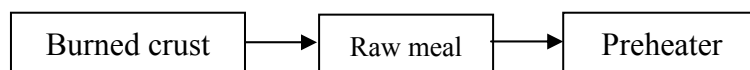


Figure 32: The process of burned crust processing system.

The waste states in burned crust processing system are given in Table 20.

Table 20: The waste states in burned crust processing system.

Physical characteristics	Main source	Water content
Solid	HW 18	Low

For the burned crust processing system, the feed point is in the preheater. The temperature of this point is more than 300 °C. The feed point of burned crust processing system is represented in Figure 33. And the real burned crust processing system is represented in Figure 34.

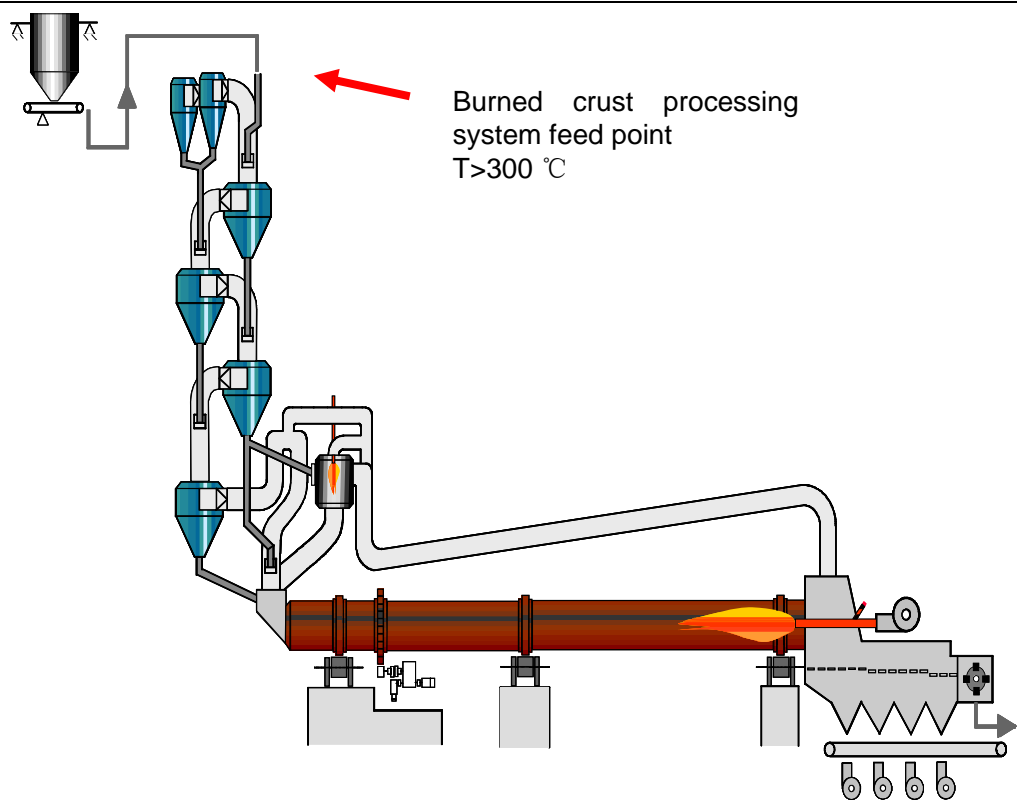


Figure 33: The feed point of burned crust processing system.



Figure 34: The real burned crust processing system.

7.3.6 Fly ash processing system

The fly ash is different from the burned crust. The fly ash is not at the bottom of incineration and it is collected by the bag filter in the incineration plant. In the fly ash processing system, the fly ash which comes from waste incineration plant be put into the head of kiln by the pump. The capacity of fly ash processing system is 3 000 tons per year. The process of fly ash processing system is represented in Figure 35.

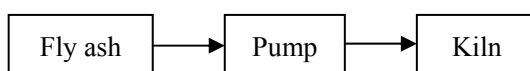


Figure 35: The process of fly ash processing system.

The waste states in fly ash processing system are given in Table 21.

Table 21: The waste states in fly ash processing system.

Physical characteristics	Main source	Water content
Solid	Incineration plant	-

For the fly ash processing system, the feed point is in the kiln. The temperature of this point is more than 1 450 °C. The feed point of fly ash processing system is represented in Figure 36. And the real fly ash processing system is represented in Figure 37.

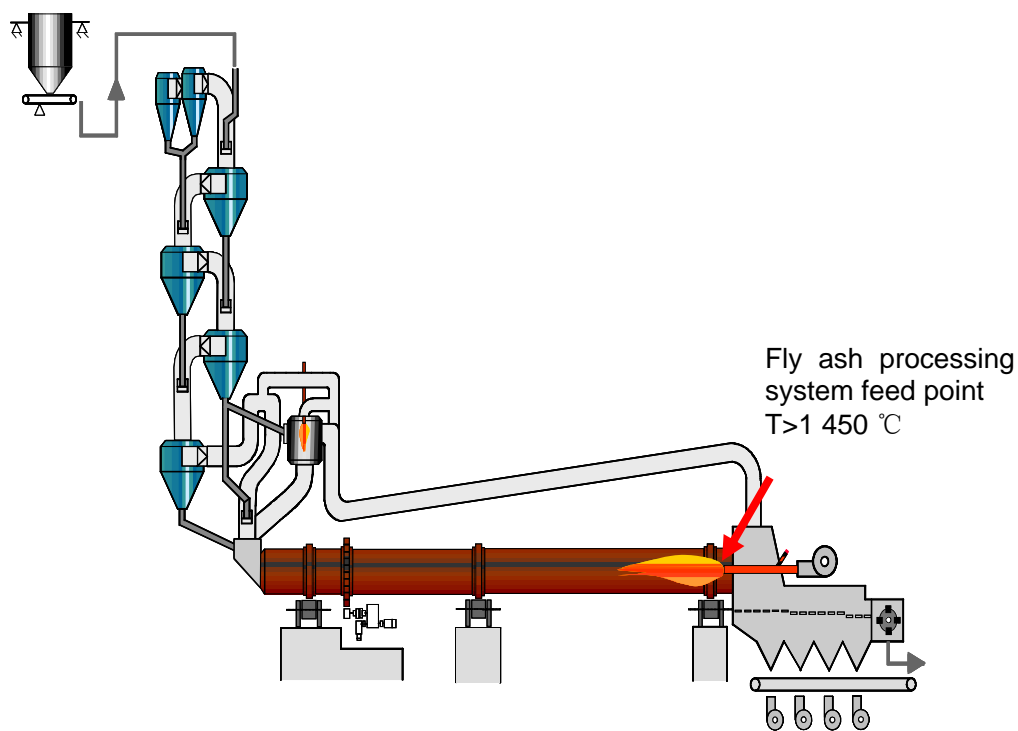


Figure 36: The feed point of fly ash processing system.



Figure 37: The real fly ash processing system.

7.4 The process of waste disposal

7.4.1 Collect the samples

The staff of Beijing cement plant will get the samples of the plants which have the wastes. In my report, I got a set of sludge from Gao Beidian waste water treatment plant.

7.4.2 Elements analysis

I need to know the components and loss of the sample. I use the X-fluorescence analyzer to analyze the components. And I use the crucible test the loss.

The result of the analysis is given in Table 22.

Table 22: The result of elements analysis.

H ₂ O <u>52.82 %</u>		Loss <u>65.39 %</u>			
Element	%	Element	%	Element	%
Na	1.478	Mn	1.597	Zr	0.072
Mg	3.044	Fe	9.003	Cd	—
Al	9.411	Co	—	Sn	2.104
Si	29.251	Ni	0.074	Sb	—
P	1.545	Cu	2.056	Ba	—
S	3.86	Zn	0.102	Hg	—
K	0.925	As	0.007	Tl	—
Ca	14.529	Se	—	Pb	0.034
Ti	1.197	Br	—	Bi	—
Cr	0.052	Sr	0.041	Cl	0.022
Ga	0.017	Rb	0.005	Nb	0.023

The silicon is 29.251%. The aluminum is 9.411%. The calcium is 14.529%. The ferric is 9.003%. So they can instead of some parts of the clay (SiO₂, Al₂O₃), the limestone (CaCO₃) and the iron (Fe₂O₃).

7.4.3 Contract with the company which has the waste

This sample is suit for treatment, so the Beijing cement plant can contract with the Gao Beidian waste water treatment plant. And Gao Beidian waste water treatment plant will pay the charge to the Beijing cement plant for treatment.

7.4.4 Transportation

This step is important. The process of transportation must be safe; otherwise it will be against to the environment. Beijing cement plant has a specialized transportation team. All

the vehicles are equipped with GPS system, which will master the situation of the transportation of waste from time to time so as to ensure the security in the section of the waste transportation.

The distance is depending on the position of plants which produce the wastes. Usually, the distance is about 20~80 km.

Each vehicle can take 6 tons of wastes. And each vehicle can run 2 or 3 times per day. Vehicles in Beijing cement plant is represented in Figure 38.



Figure 38: Vehicles in Beijing cement plant.

7.4.5 Storage

When the waste arrived at Beijing cement plant, the waste will be sent to the storage. The waste will be classified by physical state. The liquid substance will be put into the tanks. The sludge will be put into the plastic bags.



Figure 39: The wastes storage in Beijing cement plant (sludge).

7.4.6 Scheme

Before we send the sludge to the cement kiln, we need a scheme. The scheme of waste disposal is given in Table 23.

Table 23: The scheme of waste disposal.

Scheme	
1 Object	Sludge
2 Source	Gao Beidian waste water treatment plant
3 Main component	The silicon is 29.251 %
	The aluminum is 9.411 %
	The calcium is 14.529 %
	The ferric is 9.003 %
4 System	Industrial sludge processing system
5 Feed point	Industrial sludge processing system feed point
6 Handling capacity	1~3 t/h
Function	
1 Research and Development Center	Coordination
2 Production Department	Center Control
3 Quality Control Center	Testing and Monitoring

Based on this scheme, we can treat the sludge safely.

7.4.7 Disposal

Put the sludge into the precalciner by pump. And then the sludge is going to the kiln to calcine.

7.4.8 Monitoring

Beijing cement plant has the real time supervision to the end gas produced in the assembly line for disposing the waste. MCS100 EHW multi-group gas and smoke letting consistent supervising system will measure the content of eight kinds of pollutants in the air from the flue consistently- HCl, NH₃, H₂O, CO, NO_x, SO₂, O₂, and CO₂. The measurement data will form the real time tendency curve and the historical data result after the processing of the external computers and it will be uploaded to the Data and Information Center of Beijing Environment Protection Bureau in a real time way.

7.4.9 Impacts on the clinker quality

In general, the waste input is less than 5% of clinker, so it is too small to impact on the clinker in Beijing cement plant.

7.5 Cement testing

In order to check whether the waste disposal will impact the cement, it is necessary to test the cement.

7.5.1 Compressive strength and breaking strength

Based on the standard of Method of testing cements-Determination of strength (GB/T 17671-1999), we can test the compressive strength and breaking strength of cement.

1. Put 225ml of water and 450g of cement into the agitator kettle. Stir them in 30 seconds. Then put 1 350g of standard sand into the agitator kettle with the mixture. Stir them in 30 seconds again. Stop in 90 seconds. At last stir in 30 seconds. Cement mortar mixer is represented in Figure 40.



Figure 40: Cement mortar mixer.

II. Put the mixture into the mold.

Cement mold is represented in Figure 41.



Figure 41: Cement mold.

III. Put the mold onto the platform vibrator. And then make them flat.

Cement platform vibrator (before) is represented in Figure 42. And cement platform vibrator (after) is represented in Figure 43.

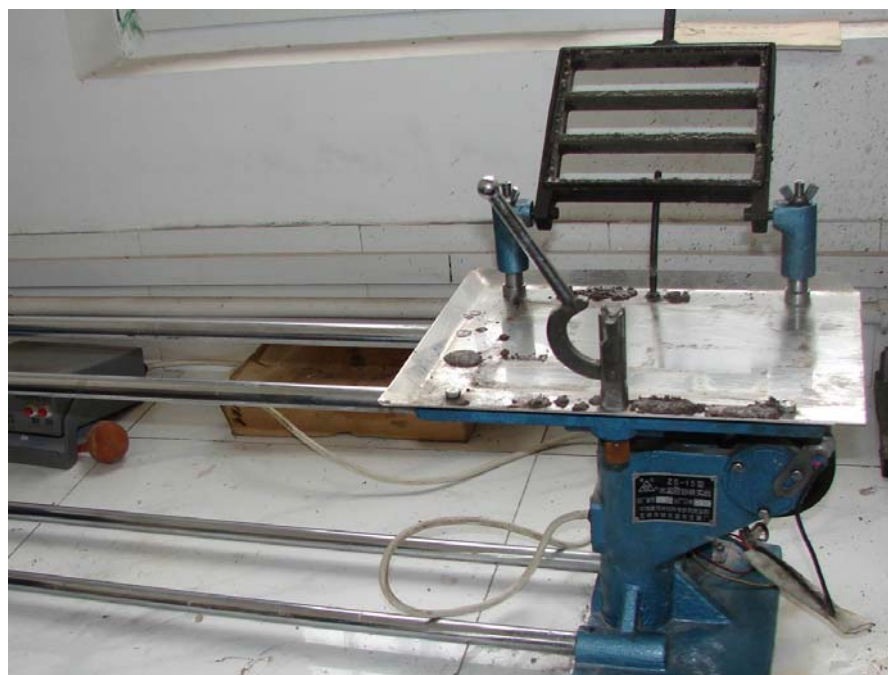


Figure 42: Cement platform vibrator (before).

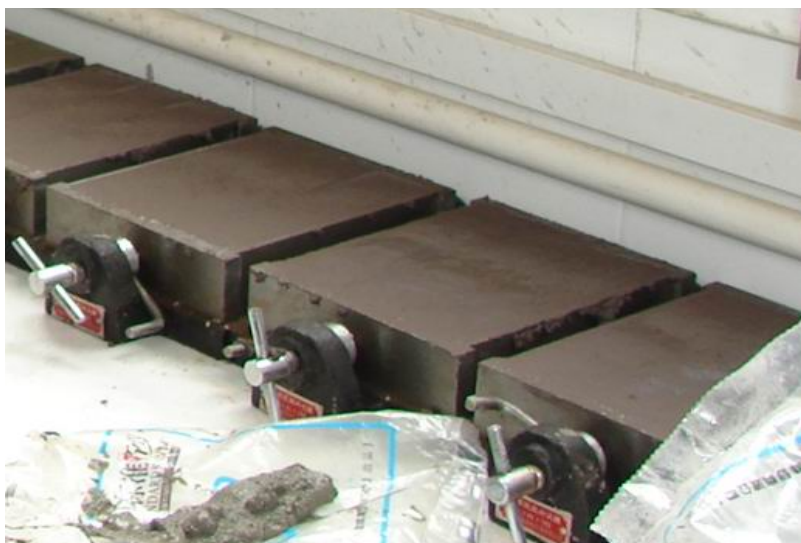


Figure 43: Cement platform vibrator (after).

IV. Put the mold into the box which has constant temperature and humidity for 24 hours. Constant temperature and humidity box is represented in Figure 44.



Figure 44: Constant temperature and humidity box.

V. Make the mold unloading, and then put the blocks into the water to hydrate.

VI. Test the compressive strength and breaking strength in 3 days and 28 days. Breaking strength testing machine is represented in Figure 45. And compressive strength testing machine is represented in Figure 46. The standard of compressive strength and breaking strength are given in Table 24. The result of compressive strength and breaking strength are given in Table 25.



Figure 45: Breaking strength testing machine.



Figure 46: Compressive strength testing machine.

Table 24: The standard of compressive strength and breaking strength.

Strength grade	Compressive strength (Mpa)		Breaking strength (Mpa)	
	3 days	28 days	3 days	28 days
32.5	11.0	32.5	2.5	5.5
32.5R	16.0	32.5	3.5	5.5
42.5	16.0	42.5	3.5	6.5
42.5R	21.0	42.5	4.0	6.5
52.5	22.0	52.5	4.0	7.0
52.5R	26.0	52.5	5.0	7.0

Table 25: The result of compressive strength and breaking strength.

Compressive strength (Mpa)		Breaking strength (Mpa)	
3 days	28 days	3 days	28 days
33.1	59.4	4.5	8.1
30.4	58.7	4.1	7.9
30.5	58.5	5.0	8.1
32.4	60.3	4.5	7.9
33.5	61.2	4.8	8.0
32.0	61.0	5.2	8.3

This set of cement matched the standard of 52.5 strength grade.

7.5.2 Heavy metal extraction ratio

In the testing of heavy metal extraction ratio, we want to know how much heavy metal is going out of the cement.

First we get 100 g of cement, put this sample into the bottle made by polyethylene. Put 1 000 ml of distilled water into the bottle and then shaking in 8 hours (the frequency is 110 ± 10 times per minute and the amplitude is 40 mm). At last, we test the liquid in the bottle by atom absorber. The result of heavy metal extraction ratio are given in Table 26.

Table 26: The result of heavy metal extraction ratio (%).

As	Cd	Cr	Cu	Ni	Pb	Zn
0	0	0.36	0.32	0	0.59	0.09

0% means we do not test the value of heavy metals. The rest of heavy metal extraction ratios are less than 1%. Most of heavy metals are solidified in the cement.

7.5.3 Setting time

Put the sample of cement into the testing equipment, and then we get the result below.

The result of setting time is given in Table 27.

Table 27: The result of setting time.

Standard		Testing	
Initial setting time (mins)	Final setting time (mins)	Initial setting time (mins)	Final setting time (mins)
> 45	< 390	58	374

The result of setting matches the standard. The waste treatment can not affect the setting time of cement.

7.5.4 Soundness

Make the sample of cement into the shape of flat cake with water. When the sample becomes hard, we put the sample into the boiled water within 3 hours. There is no crack on the surface of the sample. That matches the standard. So the waste treatment can not affect the soundness of cement.

7.6 Emissions

When the sludge was treated, we tested the emissions at the same time. The result is below.

The result of emissions is given in Table 28.

Table 28: The result of emissions (at 10:00 am 18th April)

	Standard (mg / Nm ³)	Testing (mg / Nm ³)
Dust	50	5.67
SO ₂	200	19.62
NO _x	800	258.65
F	5	0.82

All the testing values match the emission standard.

7.7 Economy analysis in Beijing cement plant

7.7.1 For Beijing cement plant

The Gate fee of sludge with organic is 40 \$/t and the capacity of sludge is 10 000 tons per year. Based on Equation (4), we can find

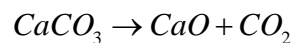
$$\begin{aligned}
 I_s &= G_s * M_s \\
 &= 40 \text{ \$/t} * 10\,000 \text{ t} \\
 &= 400\,000\$
 \end{aligned}$$

So Beijing cement plant can get about 400 000\$ per year from the sludge.

7.7.2 For the environment

Last year, Beijing cement plant disposed 50 000 tons of wastes. About 49 000 tons wastes were used as raw materials. And 1 000 tons of wastes were used as alternative fuels.

It is assumed that 60% of wastes can replace the CaCO_3 in raw materials. Based on the Equation (1), we can find:



$$m_{\text{CO}_2-\text{RawMaterials}} = \frac{49,000 * 0.6 * 44}{100} = 13,000t$$

So Beijing cement plant can reduce at least 13 000 tons CO_2 per year.

8. Discussion and Conclusion

8.1 Discussion

For the wastes treatment, safety is the most important. So I think some parts need to be improved in China.

Now we do not have professional pre-treatment plants to treat the wastes before going to the cement plants.

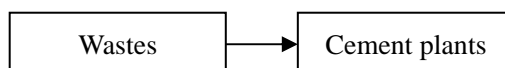


Figure 47: The status of waste treatment process.

It is not so safe for the treatment because of some hazardous wastes. It is better to add the professional pre-treatment plants to the process.

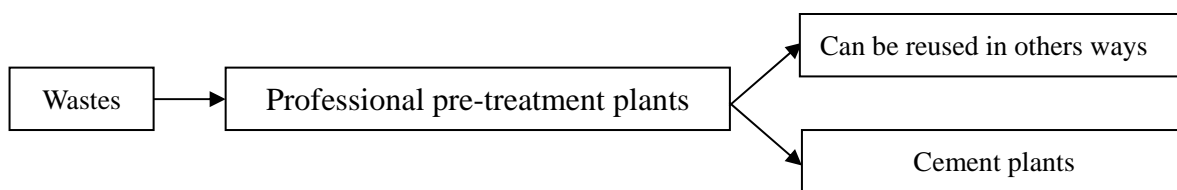


Figure 48: The amelioration of waste treatment process.

Based on this process, some wastes can be reused and some wastes can be sent to the cement plants. It is better way for economy and environment.

In addition, China government does not allow wastes transportation from one province to another province to treat. For example, Beijing cement plant just can treat the wastes from Beijing city. Last year, Beijing cement plant treated 50 000 tons wastes, but the waste treatment capacity of Beijing cement plant was 100 000 tons per year. Beijing cement plant has the potential to treat more wastes. So the government should change a little bit the law to allow disposing more wastes in cement plants.

Now China does not have emission standards especially for cement kilns co-incinerating waste. China government should establish the new emission standards.

And most of the wastes were used as raw materials. In the further, it is need to improve the amount of alternative fuels in cement kiln.

8.2 Conclusion

There are several advantages of disposing wastes in cement kiln.

- In cement kiln, the temperature can reach 1 450°C. It is enough to break down most of wastes.
- In cement kiln, the remaining time will be more than 20 minutes. The wastes can be treated during this time.
- In cement kiln, the heavy metal can be solidified in the clinker.
- The waste can turn into the components of cement and will not pollute again.
- The cement kiln can dispose different states wastes (Solid, Semi-solid or liquid).
- It is cheaper than building the incinerator plants.

So utilizing cement kiln to dispose the wastes is good way to choose. In China, there are more than 600 NSP cement kilns, if it is assumed that each cement kiln could dispose 100 000 tons wastes per year, the cement industry can dispose 60 million tons wastes per year.

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Appendix A

Law of the People's Republic of China on Prevention of Environmental Pollution Caused by Solid Waste

Chapter I General Principles

Article 1 To prevent the pollution of the environment by solid waste, ensure the good health of the public, and promote the development of socialist modernization, the following law is hereby established.

Article 2 This law applies to the prevention of environmental pollution caused by solid waste within the boundaries of the People's Republic of China. It does not apply to the prevention of marine environmental pollution caused by solid waste or of environmental pollution caused by radioactive solid waste.

Article 3 To prevent pollution of the environment by solid waste, the state shall carry out a principle of reducing the production of solid waste, making full and rational use of solid waste, and safely disposing of solid waste.

Article 4 The state shall encourage and support clean production to reduce the creation of solid waste. The state shall encourage and support the comprehensive utilization of resources, the full recovery and rational usage of solid waste, and the adoption of economic and technological policies and measures conducive to making comprehensive use of solid waste.

Article 5 The state shall encourage and support measures for the centralized disposal of solid waste that are conducive to environmental protection.

Article 6 The people's governments at the county level or above shall coordinate the prevention of environmental pollution caused by solid waste with environmental protection plans and shall adopt economic and technological policies and measures conducive to the prevention of environmental pollution caused by solid waste.

Article 7 The state shall encourage and support scientific research and technological development for the prevention of environmental pollution caused by solid waste, the

promotion of advanced technologies for prevention, as well as the popularization of scientific knowledge for the prevention of environmental pollution caused by solid waste.

Article 8 The people's governments at different levels shall give awards to those units or individuals that make remarkable contributions to the prevention of environmental pollution caused by solid waste as well as in the related activities of making comprehensive use of solid waste.

Article 9 Every unit or individual has an obligation to protect the environment and has the right to report or bring charges against those units or individuals that are responsible for environmental pollution caused by solid waste.

Article 10 The administrative department under the State Council in charge of environmental protection shall exercise unified supervision and administration throughout the whole country over the prevention of environmental pollution caused by solid waste. The relevant departments under the State Council shall be in charge of the supervision and administration of the prevention of environmental pollution caused by solid waste within the limits of their own responsibilities. The administrative departments under the local people's governments at the county level or above shall exercise unified supervision and administration over the prevention of environmental pollution caused by solid waste within the boundaries of the corresponding administrative division. The departments concerned under the people's governments at the county level or above shall be in charge of the supervision and administration of the prevention of environmental pollution caused by solid waste within the limits of their own responsibilities. The administrative department under the State Council in charge of construction and the administrative departments in charge of the environment and public health under the local people's governments at the county level or above shall be in charge of the supervision and administration of the cleaning, collection, storage, transportation, and disposal of urban residential refuse.

Chapter II Supervision and Administration of Prevention of Environmental Pollution Caused by Solid Waste

Article 11 The administrative department under the State Council in charge of environmental protection shall establish a monitoring system for environmental pollution caused by solid waste, formulate unified monitoring standards, and organize a monitoring network in conjunction with other relevant departments.

Article 12 In constructing those projects that may produce industrial solid waste as well as those for storage and disposal of solid waste, the state administrative regulations for environmental protection in construction projects must be abided by.

Reports on the effects of a construction project on the environment shall include an estimation of the pollution and other effects on the environment caused by the solid waste that is produced by the construction project, as well as the stipulation of measures for the prevention of environmental pollution, and shall be submitted to the administrative department in charge of environmental protection for approval in accordance with the procedures that are stipulated by the state. After the report on the environmental effects is ratified, the department in charge of examining and approving construction projects shall approve a feasibility study report or a design responsibility report for the project.

Article 13 A report on the effects of a construction project on the environment shall stipulate that the necessary facilities for the prevention of environmental pollution caused by solid waste must be designed, constructed, and put into operation in coordination with the principal part of the project. A construction project shall begin operation or use only after the facilities for the prevention of environmental pollution caused by solid waste are inspected and approved by the same department that examined and approved the report on the environmental effects. The facilities for the prevention of environmental pollution caused by solid waste shall be inspected and approved together with the principal part of the project.

Article 14 The administrative departments under the people's governments at the county level or above in charge of environmental protection and other supervisory and administrative departments in charge of the prevention of environmental pollution caused by solid waste shall have the right to conduct on-the-spot inspections of the units concerned with the prevention of environmental pollution caused by solid waste within their jurisdiction in accordance with their own responsibilities. The inspected units shall report the situation accurately and shall provide any necessary materials. The inspecting institutions shall maintain the technological and operational secrecy of the inspected units. The inspecting personnel shall show their credentials while conducting on-the-spot inspections.

Chapter III Prevention of Environmental Pollution Caused by Solid Waste

Section 1 General Stipulations

Article 15 The units and individuals that produce solid waste shall take measures to

prevent or reduce the environmental pollution caused by solid waste.

Article 16 The units and individuals that collect, store, transport, utilize, or dispose of solid waste shall take precautions against the spread, loss, and leakage of the solid waste as well as other measures for preventing the solid waste from polluting the environment. The abandonment or spread of solid waste during transportation is forbidden.

Article 17 Products shall use packing materials which are easily recycled, disposed of, or assimilated by the environment. The product manufacturer, retailer, or consumer shall recycle those product packages and containers that can be recycled in accordance with the relative regulations of the state.

Article 18 The state shall encourage scientific research institutions and production units to study and produce thin films for agricultural use that are easily recycled, disposed of, or assimilated by the environment. Those units and individuals that utilize thin films for agricultural use shall take measures such as recycling to prevent or reduce environmental pollution caused by the thin films.

Article 19 The administration and maintenance of the facilities, equipment, and sites for the collection, storage, transportation and disposal of solid waste shall be strengthened in order to guarantee their normal operation and use.

Article 20 It is forbidden to close, disuse, or dismantle without authorization the facilities and sites for preventing environmental pollution caused by industrial solid waste. Those facilities and sites that require closure, disuse, or dismantling must be examined and approved by the administrative departments in charge of environmental protection under the local people's governments at the county level or above, and measures shall be taken to prevent environmental pollution.

Article 21 Those enterprises and institutions that produce solid waste which causes serious environmental pollution shall be ordered to bring their pollution under control within a specified period of time. Those subject to such an order shall accomplish the task on schedule. The order shall be made by the people's government at the county level or above according to the authority granted them by the State Council.

Article 22 It shall be forbidden to construct facilities or sites for the centralized storage and disposal of industrial solid waste or burial sites for residential refuse in nature preserves, scenic spots, historic sites, drinking water sources, and other places of special protection designated by the State Council and the people's governments at the provincial, municipal, or autonomous regional levels.

Article 23 In the event that solid waste is transferred to other provinces, municipalities, or autonomous regions for storage or disposal, a report must be submitted to the administrative department in charge of environmental protection under the people's government of the province from which the solid waste will be transferred, and approval must be granted by the administrative department in charge of environmental protection under the people's government of the province to which the solid waste will be transferred.

Article 24 Within the territory of the People's Republic of China, it is forbidden to dump, pile, or dispose of solid waste from outside the People's Republic of China.

Article 25 The state shall forbid the import of solid waste which cannot be used as a raw material and shall restrict the import of solid waste that can be used as raw material. The administrative department in charge of environmental protection, together with the department in charge of foreign trade and economic cooperation under the State Council shall stipulate, adjust, and announce the list of solid wastes which can be imported for use as raw materials; the import of those kinds of solid waste that are not listed shall be forbidden. Those that require the import of solid wastes listed in the list stipulated in the preceding paragraph for use as raw materials must acquire approval through examination by the administrative department in charge of environmental protection and the department in charge of foreign trade and economic cooperation under the State Council. Specific measures shall be formulated by the State Council.

Section 2 Prevention of Environmental Pollution Caused by Industrial Solid Waste

Article 26 The administrative department in charge of environmental protection together with the department in charge of comprehensive economic affairs under the State Council and other departments concerned shall designate the environmental pollution caused by industrial solid waste, formulate policies on technologies for the prevention of environmental pollution caused by industrial solid waste, and organize the spread of advanced production technologies and equipment for the prevention of environmental pollution caused by industrial solid waste.

Article 27 The department in charge of comprehensive economic affairs together with other departments concerned under the State Council shall organize the research, development, and popularization of production technologies and equipment for reducing the amount of industrial solid waste, and shall promulgate a catalogue of backward production technologies and equipment that are responsible for industrial solid waste resulting in serious environmental pollution and that are to be eliminated within a specified time. The manufacturer, retailer, importer, or consumer must stop respectively producing,

marketing, importing, or utilizing the equipment listed in the catalogue stipulated in the preceding paragraph within the specified time granted by the department in charge of comprehensive economic affairs and other departments concerned under the State Council. The applier of production technologies must cease use of those technologies listed in the catalogue stipulated in the preceding paragraph within the specified time granted by the department in charge of comprehensive economic affairs and other departments concerned under the State Council. Any equipment required to be eliminated in accordance with the stipulations in the two preceding paragraphs shall not be transferred to others for use.

Article 28 The departments concerned under the people's governments at the county level or above shall formulate a plan for the prevention of environmental pollution caused by industrial solid waste, the popularization of advanced production technologies and equipment for reducing the amount of industrial solid waste, and the promotion of work on the prevention of environmental pollution caused by industrial solid waste.

Article 29 Those units that produce industrial solid waste shall establish and amplify a responsibility system for the prevention of environmental pollution and take measures for preventing environmental pollution caused by industrial solid waste.

Article 30 Enterprises and institutions shall rationally choose and utilize raw materials, energy and other resources, apply advanced production technologies and equipment, and reduce the amount of industrial solid waste.

Article 31 The state shall implement a reporting and registration system for industrial solid waste. Those units which produce industrial solid waste shall present data concerning the volume of waste they produce, its direction of flow, and the methods of storage and disposal to the administrative departments in charge of environmental protection under the people's governments at the county level or above in that locality, in accordance with the regulations of the administrative department in charge of environmental protection under the State Council.

Article 32 All enterprises or institutions which produce industrial solid waste that cannot be utilized, whether at all or temporarily, must, in accordance with the regulations of the administrative departments in charge of environmental protection under the State Council, construct facilities or sites for its storage or disposal.

Article 33 Those who store smelting residue, chemical residue, coal ash residue, discarded ore, tail ore, or other industrial solid waste out-of-doors shall construct special facilities or sites for its storage.

Article 34 Construction of the facilities and sites for the storage and disposal of industrial solid waste shall be in accordance with the environmental protection standards that have been stipulated by the administrative department in charge of environmental protection under the State Council. As to those units which produce industrial solid waste before this Law is implemented, if they fail to construct facilities or sites for the storage or disposal of industrial solid waste in accordance with the regulations of Article 32 of this Law, or if the facilities or sites they have already constructed do not conform to environmental protection standards, they shall carry out such construction or reconstruction within a specified period of time. During this time period, waste-discharge fees or other measures shall be implemented for any newly-produced industrial solid waste from the above-mentioned units which pollutes the environment. Those units which complete within the specified time period construction of the facilities or sites for storage or disposal of industrial solid waste, or make them conform to the environmental protection standards through reconstruction, may cease payment of waste-discharge fees from the day when the construction or reconstruction is completed. Those units which fail to complete construction before the deadline or which still cannot meet the standards after reconstruction shall continue to pay waste-discharge fees until the construction is completed or the standards are met through reconstruction. The relevant specific means shall be stipulated by the State Council. The waste-discharge fees shall be reserved for the prevention and amelioration of environmental pollution and shall not be appropriated for any other use.

Section 3 Prevention of Environmental Pollution Caused by Urban Residential Refuse

Article 35 All units and individuals shall obey the regulations of the administrative departments in charge of environment under urban people's governments by emptying and piling urban residential refuse at designated places. Throwing or piling rubbish outside these designated places is forbidden.

Article 36 The storage, transport, and disposal of urban residential refuse shall, with the purpose of preventing environmental pollution, comply with the regulations of the state concerning environmental protection and urban environment.

Article 37 Urban residential refuse shall be cleared and carried away without delay. Reasonable utilization and neutralization shall be actively conducted. The separate collection, storage, transport, and disposal of urban residential refuse of different classifications shall be gradually implemented.

Article 38 The urban people's governments shall make plans for improving the fuel

structure and developing urban coal gas, natural gas, liquefied petroleum gas, and other clean energy resources. The relevant departments under the urban people's governments shall arrange for clean vegetables to enter cities to reduce urban residential refuse. The relevant departments under the urban people's governments shall make comprehensive plans to reasonably arrange a purchasing network and promote the recycling of waste.

Article 39 The urban people's governments shall construct supporting facilities for the cleaning, collection, storage, transport, and disposal of urban residential refuse.

Article 40 The construction of the facilities and sites for the disposal of urban residential refuse shall be in accordance with the standards of environmental protection and urban environment stipulated by the administrative department in charge of environmental protection and the department in charge of construction under the State Council. Unauthorized closure, disuse, or dismantling of the facilities or sites for the disposal of urban residential refuse is forbidden; for those that require closure, disuse, or dismantling, inspection and approval must be made by the administrative department in charge of environmental sanitation as well as the department in charge of environmental protection under the people's governments at the county level or above in that locality; meanwhile, other measures shall be adopted to prevent environmental pollution.

Article 41 Those units carrying out construction shall, without delay, remove and dispose of refuse and shall adopt some measures to prevent environmental pollution.

Chapter IV Special Stipulations on the Prevention of Environmental Pollution Caused by Dangerous Waste

Article 42 The regulations in this Chapter apply to the prevention and cure of environmental pollution caused by dangerous waste. Those not mentioned in this Chapter shall accord with the other regulations of this Law.

Article 43 The administrative department in charge of environmental protection under the State Council shall draw up a national list of dangerous waste in conjunction with relevant departments under the State Council, and stipulate unified differentiating standards, methods, and identification marks for dangerous waste.

Article 44 Identification marks shall be placed on the containers and packing materials for dangerous waste and posted at the facilities and sites for the collection, storage, transport, and disposal of dangerous waste.

Article 45 Those units which produce dangerous waste shall report and register in accordance with the relevant regulations of the state.

Article 46 Those units which produce dangerous waste shall dispose of them in accordance with the relevant regulations of the state. Those who fail to properly dispose of the waste will be required to make rectification within a specified time period by the administrative department in charge of environmental protection under the people's governments at the county level or above in that locality; as to those units which fail to dispose of the waste before the deadline or which do not carry out disposal in accordance with the relevant regulations of the state, designated units of the administrative department in charge of environmental protection under the people's government at the county level or above in that locality shall undertake to dispose of the waste for them, and all expenses for disposal shall be born by those units which have produced the dangerous waste.

Article 47 The urban people's governments shall organize the construction of the facilities for the centralized disposal of dangerous waste. Article 48 Those who adopt the disposal method of burying dangerous waste but fail to conform to the regulations of the administrative department in charge of environmental protection under the State Council shall pay waste-discharge fees for dangerous waste. The specific means for levying the discharge fees for dangerous waste shall be stipulated by the State Council. The discharge fees for dangerous waste shall be reserved for the prevention and amelioration of environmental pollution caused by dangerous waste and shall not be appropriated for any other use.

Article 49 Those units which engage in operational activities concerning the collection, storage, and disposal of dangerous waste shall submit applications for operational licenses to the administrative department in charge of environmental protection under the people's government at the county level or above. The specific means for doing this shall be stipulated by the State Council. No unit may engage in operational activities concerning collection, storage, and disposal of dangerous waste without a operational license or fail to be in accordance with the regulations of the license. No unit may supply or consign dangerous waste to those units without operational licenses to engage in any operational activities concerning collecting, storage, and disposal of dangerous waste.

Article 50 Dangerous waste of different classifications shall be collected and stored separately according to their properties. Mixed collection, storage, transport, and disposal shall be forbidden for different dangerous waste materials which are not compatible and which have not undergone safety processing. Mixed storage of dangerous waste with

non-dangerous waste is forbidden.

Article 51 Those who require the transfer of dangerous waste shall fill in forms for the transference of dangerous waste in accordance with relevant state regulations and shall report to the administrative departments in charge of environmental protection under the local people's governments at the county level or above in the area from which the waste is being transferred and in the area which is receiving the waste.

Article 52 Measures for the prevention of environmental pollution shall be adopted during transport of dangerous waste; meanwhile, the state regulations concerning management of the transport of dangerous waste shall be obeyed. Transport of dangerous waste in a passenger vehicle is forbidden.

Article 53 The sites, facilities, equipment, containers, packaging, and other items used for the collection, storage, transport, or disposal of dangerous waste shall be treated to eliminate pollution before they are diverted for other use.

Article 54 Those workers who will engage in the collection, storage, transport, recycling, and disposal of dangerous waste shall undergo professional training and testing before being assigned such posts.

Article 55 Those units which produce, collect, store, transport, recycle, and dispose of dangerous waste shall draw up emergency measures and preventive measures in the event of accidents, and shall report to the administrative department in charge of environmental protection under the people's governments at the county level or above in that locality, for a relevant examination to be conducted by that department.

Article 56 Those units that cause serious environmental pollution due to accidents or emergencies involving dangerous waste shall without delay take measures to eliminate or decrease the environmental pollution, inform the units or residents that may suffer from the pollution, and report to the administrative department in charge of environmental protection and other relevant departments under the people's governments at the county level or above in that locality and await investigation and handling.

Article 57 The administrative departments in charge of environmental protection under the local people's governments at the county level or above shall report without delay to the people's governments at their own level in the event that dangerous waste seriously pollutes the environment or imperils the security of residents' lives or property. The people's governments shall adopt effective measures to eliminate or decrease the harm.

Article 58 Transit of dangerous waste passing through the territory of the People's Republic of China is forbidden.

Chapter V Legal Responsibilities

Article 59 Those who violate the regulations of this Law by engaging in any one of the following actions shall be required to make rectification within a specified period of time by the administrative department in charge of environmental protection under the local people's governments at the county level or above and shall be subject to a fine.

(1) failure to report and register industrial solid waste or dangerous waste in accordance with state regulations, or guilt of fraud in reporting or registration;

(2) refusing an on-the-spot inspection by the administrative department in charge of environmental protection, or guilt of fraud in the course of inspection;

(3) failure to pay waste-discharge fees in accordance with state regulations;

(4) transferring to others equipment which has been included in the list of equipment to be eliminated within a definite time;

(5) unauthorized closure, disuse, or dismantling of the facilities or sites for prevention and amelioration of environmental pollution caused by solid waste;

(6) constructing facilities or sites for the centralized storage or disposal of industrial solid waste or the burial sites for residential refuse in nature preserves, scenic spots, historic sites, drinking water sources, or other places which require special protection; or

(7) unauthorized transference of solid waste for storage and disposal out of the administrative territories of their own provinces, autonomous regions, or municipalities directly under the Central Government. Those who engage in actions mentioned in Items 1 or 2 of the preceding paragraph shall be subject to a fine of up to 10,000 yuan; those engaging in actions mentioned in Item 3 of the preceding paragraph shall be subject to a fine of up to 50 percent of the amount of the waste-discharge fees paid; those engaging in actions mentioned in Items 4, 5, 6, or 7 of the preceding paragraph shall be subject to a fine of up to 50,000 yuan.

Article 60 Those who violate the regulations in this Law by producing, selling, importing, or using outmoded equipment or by applying outmoded productive technology shall be required to make rectification by the department in charge of comprehensive economic

affairs under the people's government at the county level or above; if the case is serious, the said department shall submit an opinion to the people's government at the same level and order to terminate business or shut down according to the powers granted by the State Council.

Article 61 For construction projects needing supplementary construction for the prevention and amelioration of solid waste pollution, if the supplementary construction is put into operation or use before being completed or before passing the acceptance inspection, the administrative department in charge of environmental protection which examined the report of the effects of said construction project on the environment shall order production or operation to cease, and may levy a fine of up to 10,000 yuan.

Article 62 If those enterprises and institutions which have been ordered to bring their pollution under control within a specified period of time, do not accomplish the task within the time limit, they shall be subject to a fine of up to 100,000 yuan, to be determined according to the detrimental effects they have caused; or they shall be ordered to terminate business or shut down. The fine in the preceding paragraph shall be determined by the administrative department in charge of environmental protection, and the order to terminate business and shut down shall be made by the people's government at the county level or above according to the authority granted them by the State Council.

Article 63 Those who violate the regulations of this Law during the storage, transport, or disposal of urban residential refuse shall be penalized according to the State Council's regulations on environmental protection and urban sanitation.

Article 64 Those who violate the regulations in this Law concerning the prevention of dangerous waste pollution, if engaged in any one of the following actions, the administrative department in charge of environmental protection under the people's government at the county level or above shall order to cease said actions and make rectification within a limited time, and a fine of up to 50,000 yuan shall be levied.

(1) failure to install identification marks for dangerous waste;

(2) supplying or consigning dangerous waste to units that have no operational license for the collection, storage, or disposal of said waste;

(3) when transferring dangerous waste, failure to fill in the form for the transference of dangerous waste according to state regulations, or failure to make a report to the administrative department in charge of environmental protection under the people's government at the county level or above either in the area from which the waste is being

transferred or in the area which is receiving the waste;

(4) mixed storage of dangerous waste with non-dangerous waste;

(5) collecting, storing, transporting, or disposing mixtures of dangerous waste which are not compatible and which have not undergone safety processing;

(6) transportation of dangerous waste in a vehicle carrying travelers or passengers;

(7) failure to dispose of dangerous waste produced or failure to bear disposal fees according to law; or

(8) shifting use of sites, facilities, equipment, containers, packaging, or other items used for the collection, storage, transport, or disposal of dangerous waste without first eliminating all pollutants.

Article 65 For those engaged in the collection, storage, or disposal of dangerous waste without an operating license or in contradiction to the operating license, the administrative department in charge of environmental protection under the people's government at the county level or above shall order the cessation of any illegal activity, confiscate any illegal gains, and may impose a fine of up to the amount of the illegal gains. Violation of the regulations of the operating license and engaging in the activities of the preceding paragraph may result in the cancellation of the operating license by the license-issuing agency.

Article 66 Those who, in violation of the regulations of this Law, ship solid waste from outside China and dump, store, or dispose of the waste inside the country, and those who import solid waste for use as a raw material without permission from the relevant authoritative department under the State Council, shall be ordered by the customs office to ship the solid waste back, and may be subject to a fine between of 100,000 and 1,000,000 yuan. Evasion of customs office supervision constitutes smuggling and shall be prosecuted as a criminal act. Those who, under the pretext of raw materials utilization, import solid waste that cannot be utilized as a raw material shall be penalized according to the regulations of preceding paragraph.

Article 67 Those who, in violation of the regulations of this Law, transport dangerous waste through the territory of the People's Republic of China, shall be ordered by the customs house to ship the dangerous waste back, and may be subject to a fine of between 50,000 and 500,000 yuan.

Article 68 For solid waste that enters the border illegally, the administrative department

in charge of environmental protection under the people's government at the provincial level or above shall, according to law, submit suggestions for the handling of the waste to the customs office, and the custom office shall make a decision concerning punishment according to Article 66 of this Law. If environmental pollution has been produced, the administrative department in charge of environmental protection under the people's government at the provincial level or above shall order the importer to eliminate the pollution.

Article 69 Those who, in violation of the regulations of this Law, create solid waste pollution, shall be subject to a fine of up to 100,000 yuan by the administrative department in charge of environmental protection under the people's government at the county level or above. If heavy losses have occurred, the fine shall be 30 percent of the direct losses, but shall not exceed 500,000 yuan. The person in charge and other personnel of the polluting unit who have direct responsibility for the losses shall be subject to disciplinary actions by the unit to which they belong, or by the authoritative government department.

Article 70 All fines shall be handed in to the State Treasury, and may not be withheld by any unit or individual.

Article 71 Any unit or person suffering injury from solid waste pollution has the right to demand, according to law, compensation for losses. Disputes concerning the responsibility for and amount of compensation shall be mediated, at the request of the parties concerned, by the administrative department in charge of environmental protection or other supervisory and administrative departments in charge of the prevention of environmental pollution caused by solid waste. In the case of unsuccessful mediation the parties concerned may present the case to the people's court, or the parties concerned may present the lawsuit directly to the people's court without prior mediation.

Article 72 Those who, in violation of the regulations of this Law, collect, store, or dispose of dangerous waste resulting in serious environmental pollution with serious consequences such as heavy losses to state or private property or personal injury, shall be prosecuted for criminal liability according to Article 115 or Article 187 of the Criminal Law. Any unit which violates this Article shall be subject to a fine, and the person in charge and other personnel who are directly responsible for the losses shall be prosecuted for criminal liability according the regulations of the preceding paragraph.

Article 73 If the supervisors and managerial staff for the prevention and remedy of solid waste pollution abuse their authority, neglect their duties, play favoritism, or commit irregularities to such a degree as to constitute criminal action, they shall be prosecuted for

criminal liability. Those whose actions do not constitute a crime shall be subject to disciplinary action.

Chapter VI Supplementary Articles

Article 74 Clarification of terminology included in this Law:

(1) "Solid waste" refers to solid or semi-solid waste materials that are produced during production or construction activities, daily life, or other activities, and which pollute the environment.

(2) "Industrial solid waste" refers to the solid waste produced by industry, transportation, etc.

(3) "Urban residential refuse" refers to the solid waste produced in urban daily life, or which results from the activities that serve urban daily life. It also includes those solid wastes that are specified by laws and administrative regulations as urban residential refuse.

(4) "Dangerous waste" refers to the dangerous waste material which is placed on the national list of dangerous waste, or which is specified as dangerous waste by the differentiating standards and methods established by the state.

(5) "Disposal" refers to such activities that burn or alter the physical, chemical, or biological qualities of solid waste so as to reduce the amount and the volume of the solid waste which has been produced, or reduce or eliminate its dangerous components. Disposal also refers to such activities which ultimately deposit, with no intent to reclaim, the solid waste in sites or facilities which meet environmental protection standards.

Article 75 This Law also applies to the prevention of pollution by liquid waste and gas waste which is stored in containers, but not to waste water which is discharged into water, nor to waste gas emitted into the air.

Article 76 If an international treaty concerning protection of the environment against solid waste pollution to which the People's Republic of China is a signatory is at variance with this Law, the former shall be taken as the standard, except for those provisions for which the People's Republic of China has declared reservations.

Appendix B

Certification of quality management system ISO9001:2000



Perfecting the system of inspection measurement and test ISO10012:2003

完善计量检测体系合格证书
CERTIFICATE FOR PERFECTING THE SYSTEM OF INSPECTION
MEASUREMENT AND TEST

北京水泥厂有限责任公司

根据完善计量检测体系确认方法和原则要求，并参照国家标准 GB/T19022-2003(ISO 10012: 2003, IDT)，确认你单位在产品质量、经营管理、节能降耗等方面的计量检测体系基本完善，特发此证。

On the basis of the confirmation methods and principal requirements for the enterprises to perfect the system of inspection, measurement and test, and according to the national standard of GB/T 19022-2003(ISO 10012:2003, IDT), a certificate will be granted since the system of inspection, measurement and test in product quality, management and administration, and energy saving and loss producing has been basically perfected.

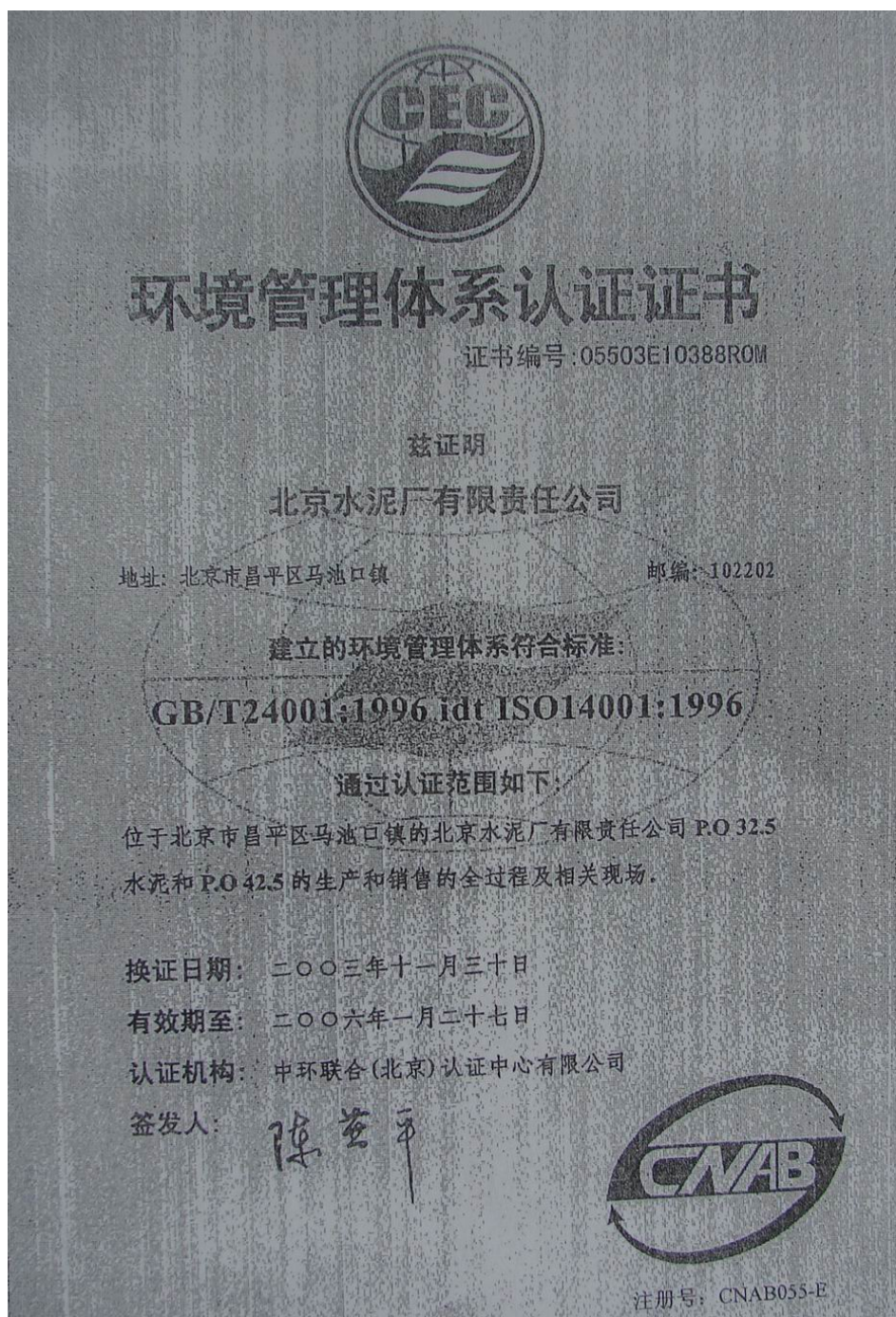
批准人签名 **王泰平** 批准部门盖章
Signed by Approved by

批准日期 二〇〇九年十二月三十日
Date of Approval 2009.12.30

有效日期至 二〇〇九年十二月三十日
Term of Validity 2009.12.30

证书编号 No. (2004)量企(国)字(0396)号

Environment management system ISO14001:1996



Appendix C

National Catalogue of Hazardous Wastes

The National Catalogue of Hazardous Wastes Explanatory Notes

1. In order to prevent environmental pollution by hazardous wastes, strengthen the management of hazardous wastes, protect the environment and safeguard the health of the public, The National Catalogue of Hazardous Wastes is formulated in accordance with The Law of The People's Republic of China on The Prevention and Control of Solid Wastes to The Environment.
2. The State formulates “Identification Standard for Hazardous Wastes”. Those wastes whose identification values are higher than The Identification Standard are classified as hazardous wastes; lower than The Identification Standard are classified as non-hazardous wastes.
3. The wastes that need formulating The Identification Standard for Hazardous Wastes are used for the hazardous wastes registration only before The Identification Standard is promulgated.
4. Hazardous wastes shall be managed in line with the relevant provisions in The Law of People's Republic of China on The Prevention and Control of Solid Wastes to The Environment.
5. The National Catalogue of Hazardous Wastes published this time is the first catalogue to be implemented. The Catalogue will be revised occasionally further along with the development of economy, science and technology.
6. The Catalogue is explained by National Environmental Protection Agency of China.

Code	Categories of the Waste	Sources of the Waste	The Common Hazardous Components or Name of Wastes
HW01	Clinical wastes	Clinical wastes from medical care in hospitals, medical centers and clinics —residues in operation and binding —residues in biological culture and animal experiment —residues in laboratory test —infectious wastes —sludge from wastewater treatment	Operation residues, dressing and laboratory testing wastes, Infectious wastes, animal experiment wastes
		Wastes from the production and preparation of pharmaceutical products, including veterinary medicine product(excluding Chinese medicine wastes) —residues in	Waste antibiotics, steroid medicine, anti-histaminic medicine, paregoric, cardio tonic, nerve system medicine, miscellaneous medicine, gene

HW02	Pharmaceutical wastes	distillation and reaction —waste high concentrated mother liquor and or culture medium —filtered substances (including carriers) —used and abandoned absorbent, catalysts and solvent —waste medicine and overdue raw material arising from production	waste
HW03	Waste pharmaceuticals, drugs and medicines	Overdue waste, unlabeled and confounding pharmaceuticals, drugs and medicines(excluding waste pharmaceuticals in HW01 and HW02) —waste pharmaceuticals arising from production(including pharmaceutical waste raw material and intermediate product reacting substances —overstocked or discarded pharmaceuticals, drugs and medicines in research units, monitoring units, schools and medical units and laboratories	Waste chemical agents, waste medicine and waste pharmaceutical
HW04	Pesticide wastes	Wastes from the production, selling, formulation and use of insecticide, bactericide, herbicide and plant growth regulator —residues from distillation and reaction —production mother liquor and (reactors and containers) cleaning liquor —absorbed and filtered substances(including carriers, absorbents and catalysts) —wastewater treatment sludge —overdue raw material from production and formulation —overdue and culled products from production, selling and use —package and containers contaminated by pesticide and herbicide	Waste organ phosphorous insecticide, organ-chlorine insecticide, organ nitrogenous insecticide, pyrethroid insecticide, miticide, organ phosphorous bactericide, organ-chlorine bactericide, organ sulfur bactericide, organ tin bactericide, organ nitrogenous bactericide, quinone bactericide, inorganic bactericide, organ arsenic bactericide, carbamate herbicides, ether-derivative herbicides, phenol-derivative herbicides, acetamide-group herbicides, phenyl urea-group herbicides, phenoxy carboxylic acid herbicides, triazine-group herbicides, inorganic herbicides
HW05	Wastes containing wood preserving chemicals	Wastes from the manufacture, formulation and use of wood preserving chemicals(excluding the waste duplicated with those in HW04) —wastewater treatment sludge, process reaction residues, filtered substances and carriers arising from manufacturers —overstocked, disabled and excess wood preserving chemicals in using units —disabled wood preserving chemicals from the selling departments	Wastes containing pentachlorophenol, phenyl hydroxide,2-chlorophenol,oxytoluol, parachlor-meta-oxytoluol, trichlorophenol, chrysene naphthalene, tetrochlorophenol, creasote, fluoranthene, benzo(a)pyrene,2,4-dimethyl phenol,2,4-dinitro phenol, benzo(a)anthracene, dibenz(a)anthracene
HW06	Organic solvent wastes	Wastes from the production, formulation and use of organic solvents(excluding the	Waste catalyst, cleaning and peeled substances, reaction and filtration residues, absorbed substances and

		waste organic solvents in HW42) —reaction residues, carriers arising, fragmentation, separation, catalysis, deposition and of organic solvents —cleaning substances containing organic solvents arising from formulation and use	carriers wastes
HW07	Cyanides wastes	Wastes from heat treatment and tempering operations containing cyanides —metal heat treatment containing cyanides —cooling of tempering tank for heat treatment containing cyanides —maintenance of heat treatment furnace containing cyanides —cementation furnace of heat treatment	Barium residue from heat treatment containing cyanides, sludge containing cyanides and cooling liquor, inner liner of heat treatment furnace containing cyanides, cyanides residues from cementation of heat treatment
HW08	Waste mineral oils	Waste mineral oils unfit for their originally intended use —oil sludge and oil foot arising from oil development and refining —deposit from storage of mineral oils —replaced oil and cleaning oil/sludge from mechanical, power and transporting equipment —waste oil(residue) arising from Metal rolling and mechanical processing —waste oil and oil sludge arising from treatment of oily wastewater —oil residue and filter medium arising from refining and regeneration of oil	Waste engine oil, raw oil, hydraulic oil, vacuum pump oil, diesel oil, gasoline, heavy oil, kerosene oil, thermal treatment oil, camphorated oil, lubricating oil or grease lubricant, coolant oil
HW09	Waste emulsion	Waste emulsion and waste oil/water mixture arising from mechanical and equipment rinsing —excess emulsion and/or emulsible paste arising from production, formulation and use —waste emulsion arising from mechanical processing, metal cutting and cold drawing —oil/water and hydrocarbon/water mixture arising from cleaning oil tank and oil articles —waste emulsion from regular replace of hydraulic machine	Waste soap liquor, emulsible oil/water, mixture of hydrocarbon and water, emulsion or emulsible paste, coolant, cooler, lubricants and wire drawing agent
HW10	Polychlorobiphenyl wastes	Waste substances and articles containing or contaminated with polychlorobiphenyl(PCBs), polychlorinated terphenyls(PCTs) and/or polybrominated biphenyls(PBBs) —excess, abandoned, sealed up and ready to be replaced power equipment(capacitors and transformers) containing PCBs, PBBs, and PCTs —medium oil, insulating oil, cooling oil and heat-transfer oil poured from power equipment that contain PCBs, PBBs, or PCTs or contaminated by them	Polychlorobiphenyl(PCBs), polybrominated biphenyls(PBBs), polychlorinated terphenyls (PCTs) wastes

		—soil or package material contaminated by PCBs, PBBs, and/or PCTs	
HW11	Residues of refinery or distillation	Waste tarry residues arising from refining, distillation and any pyrolytic treatment —tar residues arising from production of coal gas —tar residues arising from distillation of raw oil —pitch like tar and acid tar arising from fine purification of raw oil —distillation residues and substances at the bottom of distillation of distillation caldron arising from production of chemicals —tarry residues arising from pyrolyzation in production of chemical material —soil contaminated by tar or distillation residues arising from industrial production —package and containers that once contained tarry residues	Asphalt residues, tar residues, waste acid tar, phenolic residues, distillation residues in caldrons, rectified residues in caldrons, methyl benzene residues, liquefied petroleum gas residues(contain such wastes as benzo(a)pyrene, chrysene naphthalene, fluoranthene, multiring hydrocarbon)
HW12	Waste dyes and paints	Wastes from production, formulation and use of printing ink, dyes, pigments, oil varnish, lacquer and finish-coat paint —waste pigments, dyes, paints and unqualified products arising from production —waste mother liquor, residue and intermediate product waste arising from production of dyes and pigments in such reactions as nitration, oxidation, reduction, sulfonation, halogen-hydroxylation and halogenation —abandoned organic solvent which contain pigment and printing ink arising from the production, formulation and use of paint and ink —sludge like substances arising from rinsing container with acid, basic or organic solvent —waste packing material that contain dyes, pigments, printing ink and oil varnish residue —sludge from wastewater treatment	Waste acid dyes, basic dyes, mordant dyes, azoic dyes, direct dyes, ice dyes, reduction dyes, sulfur dyes, reactive dyes, alkyd resin paints, acrylic resin paints, polyaminoresin paints, polyethylene resin paints, epoxide resin paints, bicomponent paints, printing ink, heavy metal pigments
HW13	Organic resins wastes	Wastes from production, formulation and use of resins, latex plasticizers glues/adhesives —unqualified products and byproducts arising from production, formulation and use —waste catalysts and high concentration waste liquid from the process as synthetization, esterification and condensation —residue in tank, filtering medium and filtered substances arising from rectification, seperation and refining	Wastes containing phthalic esters, fatty dihydric acid esters, phosphoesters, epoxy compounds, trimellitic esters, polyesters, cholrparafins, dihydric/polybasic alcohol esters, derivate of sulfonic acid

		<ul style="list-style-type: none"> —peeled esters and bondants from articles and inside of containers by using solvent or acid or base —sludge arising from wastewater treatment 	
HW14	New chemical wastes	Waste chemical substances arising from research and development or teaching activities which are not identified and/or are new and whose effects on man and/or the environment are not known	Wastes arising from research and production of new chemicals
HW15	Explosive wastes	<p>Unqualified products, waste products and explosive wastes arising from the production, selling and use of explosive materials</p> <ul style="list-style-type: none"> —unstable, easy to change violently even without knock —To form explosive mixture when mixed with water —inflammable tendency exists when temperature raised, moisture absorbed and spontaneous chemical changes occurred —vibration or explosion occurs when heated or in the existence of initiator 	<p>Wastes containing azidoacetyl, acetyl nitrate, ammonium acid, ammonium chlorate, cobaltic ammonium hexamitrite, ammonium nitrate, ammonium nitride, ammonium periodate. Ammonium permanganate, ammonium picrate, ammonium perchromate, guanidine azidocarbonyl, barium azide, chlorinated diazobenzene, azimido-benzene, nitrowoguanidine, nitroglycerine, tetranitropentoic tetrahydroxy alcohol, trinitrochlorobenzene, polyvinyl nitric acid eater, potassium nitrate, silver azide, silver nitride, silver trinitro-resorcinate, silver tetrazene, anthraxite gunpowder, sodium azide, sodium picrete, tetranitromethane, tetrazotized tetraselenid, tetrazotized tetrasulfur, tetrazene, thallium nitride, dinitri-trilead, dinitritrimercury, trinitrobenzene, potassiu, chlorate, trinitrotoluene, trinitro-resoreinol, mercuric fulminate, silver fulminate</p>
HW16	Photographic chemical wastes	<p>Wastes from production, formulation and use of photographic chemicals and processing material</p> <ul style="list-style-type: none"> —unqualified and overdue product arising from production —residue and sludge of wastewater arising from production —waste developing and fixer solution, film and waste photographic paper arising from use and business by publishing houses, newspaper offices, printing plants and film studios —waste developing and fixer solution, film and waste photographic paper arising from Use and business by photo studios and developing shops — waste developing and fixer solution arising from X-ray and CT examination in hospitals and relevant medical 	Waste developing solution, fixing bath, positive and negative film, photographic paper, raw photographic material and chemicals

		establishment	
HW17	Wastes from surface treatment	Wastes resulting from surface treatment of metals and plastics —residues and wastewater from plating tanks and sludge from wastewater treatment of plating industries —corroding liquid, scrub solution and sludge arising from such processes as acid or base washing of metal and plastic surfaces, oil removal, rust removal and scrubbing. —residues and sludge arising from phosphatization and polishing of metal and plastic surfaces —liquid waste and residues arising from peeling the plating coat	Waste electroplating solvent, plating tank sludge, sludge arising from treatment of electroplating wastewater, acid or basic residue from surface treatment, residue from oxidation tank, phosphatization residue and nitrite residue
HW18	Residues of incinerating disposal	Residues arising from industrial waste disposal operations	Residues and ashes from incinerating disposal
HW19	Metal carbonyl compound wastes	Wastes from the production and use of metal carbonyl compound — products of fine chemical industry — synthetization of metal organic compound	Metal carbonyl compound wastes (iron pentacarbonyl, cobal tetra carbonyl, carbonyl nickel, cobal tricarbonyl, cobaltic hydroxytetracarbonyl)
HW20	Beryllium wastes	Wastes of beryllium and its compounds —smelting of rare metal —production of beryllium	Wastes containing beryllium, beryllium borohydride, beryllium bromide, beryllium hydroxide, beryllium iodide, beryllium carbonate, beryllium oxide, beryllium nitrate, beryllium
HW21	Chromium wastes	Wastes of hexa valent chromium compounds —chemical production of chromium compounds —leather processing(tanning) —electroplating of metal and plastics —coloring of acid medium dyestuff —production and use of pigment —smelting of chrome iron	Wastes containing chromic acid anhydride, potassium chromate, potassium dichromate, sodium chromate, sodium dichromate, chromic acid, dichromic acid, chromic acid, chromic anhydride, zinc chromate, potassium chromic, calcium chromate, silver chromate lead chromate, barium chromate
HW22	Copper wastes	Wastes of copper compounds —mining and smalting of nonferrous metal —electroplating of metal and plastics —production of copper compounds	Wastes containing copper bromide, cuprous bromide, copper hydroxide, copper sulfate, cuprous sulfate, copper iodide, cuprous iodide, copper carbonate, copper nitrate, copper sulfide, copper fluoride, cuprous sulfide, copper chloride, cuprous chloride, copper acetate, copper potassium oxide, copper phosphate, dihydrate copper ammonium chloride
HW23	Zinc wastes	Wastes of zinc compounds —mining and smalting of nonferrous metal —electroplating of metal and plastics —processing of pigment, paint and rubber —production of zinc compounds —manufacturing industry of zinc battery	Wastes containing zinc bromide, zinc iodide, zinc nitrate, zinc sulfate, zinc fluoride, zinc sulfide, zinc peroxide, zinc permanganate, zinc acetate, zinc oxalate, zinc chromate, zinc bromate, zinc phosphate, zinc pyrophosphate, pyrophosphate, zinc

			phosphide
HW24	Arsenic wastes	Wastes of arsenic and its compounds —mining and smelting of nonferrous metal —production of arsenic and arsenic compounds —petrochemistry —production of pesticide —tanning and dyestuff industry	Wastes containing arsenic, arsenic trioxide, arsenous acid anhydride, arsenic oxide, arsenic pentasulfide, arsenous sulfide, arsenical zinc, arsenical lead, arsenical iron, copper arsenide, calcium arsenide, silver arsenide, arsenic acid, arsenous acid, arsenous acid arsenic trifluoride, zinc arsenate, ammonium arsenate, calcium arsenate, ferric arsenate, sodium arsenate, mercuric arsenate, lead arsenate, magnesium arsenate, arsenic trichloride, selenium disulfide, potassium arsenate, hydrogen arsenide, ethyl dichloroarsine, arseniuretted hydrogen, copper aceto-arsenite
HW25	Selenium	Wastes of selenium and its compounds —smelting and electrolysis of nonferrous metal —production of selenide —production of pigment, rubber and glass	Wastes containing selenium, selenium dioxide, selenium trioxide, selenic fluoride, selenium hexafluoride, selenious chloride, selenic chloride, selenious acid, hydrogen selenide, sodium selenide, sodium selenate, sodium selenite, selenium disulfide, ferrous selenide, barium selenite, selenic acid, selenium dimethyl
HW26	Cadmium wastes	Wastes of cadmium and its compounds —mining and smelting nonferrous metal —production of Cadmic Compounds —battery process industry —electroplating	Wastes containing cadmium, cadmium bromide, cadmium iodide, cadmium hydroxide, cadmium carbonate, cadmium nitrate, cadmium sulfate, cadmium sulfide, cadmium chloride, cadmium fluoride, cadmium acetate, cadmium oxide, cadmium methide
HW27	Antimony wastes	Wastes of antimony and its compound —smelting of nonferrous metal —production and use of antimony compounds	Wastes containing antimony, antimonous oxide, antimonous acid anhydride, antimonous sulfide, antimonous fluoride, antimony pentafluoride, antimony pentachloride, antimony butter antimonous hydride, sodium antimonate, lead antimoniate, antimonine, sodium antimonite
HW28	Tellurium wastes	Wastes of tellurium and its compounds —smelting and electrolysis of nonferrous metal —production and use of tellurium compounds	Wastes containing tellurium, tellurium bromide, tellurium iodide, telluric oxide, tellurium hexafluoride, telluric chloride, tellurous acid, hydrogen telluride, telluric acid, tellurium diethyl, dimethyl tellurium
HW29	Mercury wastes	Wastes of mercury and its compounds —manufacture and use of mercury catalyst in chemical industry —manufacture industry of mercury battery	Wastes containing mercury, mercuric bromide, mercurous bromide, mercuric iodide, mercurous iodide,

		<ul style="list-style-type: none"> —smelting and recovery industry of mercury —production of organic and inorganic mercury —pesticide and pharmacy industry —manufacture and use of luminescent screen and mercury lamp —manufacture and use of mercury glass gauge —salt mud of mercury from production of caustic soda 	mercuric nitrate, mercurous nitrate, mercurous nitrate, mercurous praecipitatus, mercuric sulfate, mercurous sulfate mercuric chloride, mercurous chloride, mercuric sulfide, mercuric ethyl chloride, mercuric acetate, mercurous acetate, mercury dumethide, mercury ethyl, mercuric ammonium chloride, mercury methyl chloride, mercuric chloride
HW30	Thallium wastes	Wastes of thallium and its compounds smelting of nonferrous metal and Manufacture of pesticides — manufacture and use of thallium compounds	Wastes containing thallium, thallium monobromide, thallic hydroxide, thallic hydroxide, thallic iodide, thallic nitrate, thallic carbonate, thallic sulfate, thallic oxide, thallic sulfide, thallic oxide, thallic sulfide, thallic fluoride, thallium chloride, thallic chloride, thallic chlorate, thallium acetate, thallium chromate
HW31	Lead wastes	Wastes of lead and its compounds —slag and dust from lead smelting and electrolyzation —slag and sludge from lead acid batteries Production —wasted lead batteries —slag and sludge from lead casting and manufacture —waste from production and use of lead compounds	Wastes containing lead, lead acetate, lead bromide, lead hydrate, lead fluoride, lead iodide, lead carbonate, lead nitrate, lead oxide, lead sulfate, lead chromate, lead sulfide, lead chloride, lead tetraalkyl, lead tetra oxide, lead peroxide, basic lead met silicate, lead
HW32	Inorganic fluoride wastes	Wastes containing inorganic fluoride	Wastes containing cesium fluoride, fluorhydric acid, fluoroborate, fluorosilicic acid, fluorophosphoric acid, ammonium fluoroborate, ammonium fluosilicate, ammonium fluoride, potassium fluoride, chromic fluoride, iodine pentafluoride, potassium hydrogen, sodium bifluoride, sodium fluorosilicate, zinc fluorosilicate, sulfur hexafluoride, sulfur pentafluoride, sodium fluoride, fluorosulfuric acid
HW33	Inorganic cyanide wastes	Wastes from production and use of inorganic cyanide (excluding those wastes in HW07) — electrolyzation oil removal in metal product industry, and face-harden chemical technology —wastes including cyanide from electroplating and getting rid of cladding material from electrplating and production of electronic part —wastes from mining aurum ore and preparation by screening —wastes from chemical lapping	Wastes containing hydrocyanic acid, sodium cyanide, potassium cyanide, lithium cyanide, Mercuric cyanide, lead cyanide, cupric cyanide, zinc cyanide, barium cyanide, calcium cyanide, cuprous cyanide, silver cyanide, cyanogen bromide, nickel cyanide, cobaltous cyanide, mercury potassium cyanide, copper sodium cyanide, copper potassium cyanide, nickel potassium cyanide, cyanide solution

		technology of process —wastes and packing compose of cyanide from others including production, experiment and chemical analysis	
HW34	Waste acid	Waste acid liquor, acid solid and acid slag (acid liquor $\text{pH} \leq 2$) from industry production, formulation and use —production of chemical products —chemical analysis and test —acid corrosion, polishing, rust and oil removal, cleaning —wastewater treatment —pretreatment of textile printing	Wastes containing sulfuric acid, nitric acid, hydrochloric acid, phosphoric acid, hypochloric acid, chloric acid, bromic acid, hydrofluoric acid, hydrobromic acid, boric acid, arsenic acid, selenic acid, cyanic acid, chlorosulfonic acid, iodic acid, aqua acid
HW35	Waste alkali	Waste alkali liquor, alkali solid and alkali slag (alkali liquor $\text{pH} \geq 12.5$) from industry production, formulation and use —production of chemical products —chemical analysis and test —alkali corrosion, polishing, rust and oil removal, cleaning —wastewater treatment —pretreatment of textile printing waste liquor from papermaking	Wastes containing sodium hydroxide, potassium hydroxide, calcium hydroxide, lithium hydroxide, sodium carbonate, sodium hydrogen carbonate, borax, sodium hypochlorite, sodium chlorate, potassium chlorate, potassium hypochlorite, calcium chlorate, calcium hypochlorite, sodium orthophosphate, potassium carbonate, potassium hydrogen carbonate
HW36	Asbestic wastes	Wastes from production and use of asbestic —asbestic ore mining and asbestic product processing —production of building materials —maintaining asbestic facilities (heat insulation, heat insulator) —production and changing of brake lining	Asbestos dust, waste asbestos fiber, asbestos float, waste heat insulation and tailing of asbestos
HW37	Organic phosphorus wastes	Wastes from the production, formulation and use of organic phosphorus compounds excluding organic phosphorus pesticides —reactionary residua from the production —depleted filter residua, catalysts, carrier and absorbents from the production —sludge from the wastewater treatment —residua, sediments and their wrapping materials from the formulation and utilization	Wastes containing chlorothion, thionazin, tetraethyl propylphosphate, phosphoamide, hexaethyl tetraphosphate, nitro thiophosphate, furecide, phosphates, ethyl-p-nitrophenyl phenyl phosphonothionate (EPN), isopropyl phosphorus oxychloride and tributyl phosphate
HW38	Organic cyanide wastes	Wastes from the production, formulation and use of organic cyanides —high concentration waste liquid and reactionary residua from the process as synthetic reaction and condensation reaction —waste catalysts, autoclave-treated residua and filters from the catalytic, refining and filtering processes —unqualified products from the production and formulation —sludge from the wastewater treatment	Wastes containing acetonitrile, acrylonitrile, dicyanobutane, amino ethyl cyanide, chloroacrylonitrile, cyano acetic acid, cyano chloropentane, hydroxyacetonitrile, ethyl cyanide, tetramethyl succinonitrile, bromophenyl cyanide, phenyl cyanide, lactonitrile, pyruvonitrile, butyl cyanide, pheylisopropionate and cyanates
HW39	Phenols wastes	Wastes of phenol and its compounds, including chlorophenols and	Wastes containing aminophenol, bromophenol,

		nitrophenols —high concentration waste liquid and reactionary residua from the production —absorbed filtrate, wasted catalysts, refined autoclaved-treated residua (including phenol compounds from petroleum, chemical industrial and gas production)	chloromethylphenol, coal tar, dichlorophenol, dinitrophenol, hydroquinone, trihydroxy benzene, sodium pentachlorophenoxide, nitrophenol, trichlorophenol, chlorophenol, cresol, nitracresol, picric acid, sodium dinitrophenoxide and aminophenol
HW40	Ethers wastes	Wastes form the production, formulation and use of ethers —liquid residua, reactionary residua from the production and formulation of ethers, sludge from the wastewater treatment and filtered sludge —organic mixed solvents containing ethers from the formulation and utilization	Wastes containing methyl-phenate, ethylene glycol butyl ether, ethylene methyl ether, diallylether, dichloroethyl ether, phenetole, diphenylether, ethylene glycol methyl ether, ethylene glycol ether, isopropyl ether, chloro-methylether, chloromethyl methyl ether, propyl ether, tetrachloro propyl ether methyl-trinitrophenoxide, ethylene glycol diethyl ether, ethylene glycol butyl ether, dimethyl ether, allyl phenyl ether, methyl propyl ether, ethylene glycol isopropylether, ethylene glycol-phenoxide, ethylene glycol pentyl ether, chloromethyl ethyl ether, butyl ether, ethyl ether, diethylene glycol diethyl ether, ethylene glycol dimethyl ether and ethylene glycol ethyl ether
HW41	Waste halogenated organic solvent	Waste organic solvents from the production, formulation and use of the halogenated organic solvents — high concentration residua. Absorbed filtrate, reactionary Residua from the production and formulation, sludge from the wastewater treatment and wasted carrier —unqualified products from the production and formulation —wasted halogenated organic solvents from the production, formulation and utilization, including chemical analysis, production of plastic rubber products, cleaning of electron parts, production of chemical industrial products, formulation of printing and dyeing, and use of business dry-clean and home	Wastes containing methylene chloride, chloroform, tetrachloro-methane, dichloroethane, decorationdichloroethylene, chlorobenzene, dichloro difluoro-methane, bromoform, dichlorobutane, trichlorobenzene, dichloropropane, dibromoethane, tetrachloroethane, trichloroethane, trichloroethylee, trichloro trifluoroethane, tetrachloroethylene, pentachloroethane, bromoethane, bromobenzene and trichlorofluoromethane
HW42	Waste organic solvents	Waste organic solvents from the production, formulation and use of other organic	Wastes containing furfural, cyclohexane, napha, benzene, toluene, xylene, tetra hydrofuran,

		solvents (excluding halogenated organic solvents in HW41) — wasted solvents and residua from the production, formulation and use of the organic solvents, including chemical analysis, production of plastic rubber products, cleaning of electron parts, production of chemical industrial products, formulation of printing and dyeing, and use of business dry-clean and home decoration	butyl acetate, methyl acetate, nitrobenzene, isobutyl methyl ketone, cyclohexanone, diethyl ketone, isobutyl acetate, acrolein dimer, isobutanol, ethylene glycol, methanol, acetophenone, isopentane, cyclopentanone, cyclopentanol, propanol, dipropyl ketone, ethylene benzoate, butyric acid, butyl butyrate, ethylbutyrate, methyl butyrate, isopropanol, N,N-dimethylacetamide, formaldehyde, diethyl ketone, acrolein, acetaldehyde, ethyl acetate, acetone, ethyl methyl ketone, methylvinyl ketone, methyl propyl ketone, methyl butanol and benzyl alcohol
HW43	Any congener compound of polychlorinated dibenzo-furan	Wastes from any congener compounds of polychlorinated dibenzo-furan	Polychlorobenzofuran and its congener wastes
HW44	Any congener compound of polychlorinated dibenzo-p-dioxin	Wastes from any congener compounds of polychlorinated dibenzo-p-dioxin	Polychlorobenzodioxin and its congener wastes
HW45	Organohalogen compounds	Wastes from the production, formulation and use of other organohalogen compounds (excluding those wastes in HW39,HW41,HW42,HW43 and HW44) —High concentration residua, absorbed filtrate, reactionary residua from the production and formulation, sludge from the wastewater treatment and wasted catalysts and unqualified products —Unqualified products from the production and formulation —Organohalogen compounds wastes from chemical analysis, production of plastic rubber products, cleaning of electron parts, production of chemical industrial products, formulation of printing and dyeing, and use of business dry-clean and home decoration	
HW46	Nickel compound wastes	Wastes of nickel compounds — reactionary residua and unqualified products from the production — overdue nickel catalysts — nickel residua and tank liquid from the electroplating process —	Wastes containing nickelous bromide, nickelous nitrate, nickelous sulfate, nickelous chloride, nickelous sulfide, Nickelous oxide, nickelic oxide, nickelous hydroxide and nickelic hydroxide

		wasted nickel compounds from analysis, chemical examination and testing	
HW47	Barium compound wastes	Wastes of barium compounds excluding barium sulfate — reactionary residua and unqualified products from the production of barium compounds — salt bath residua from the heat treatment process — wasted barium compounds from analysis, chemical examination and testing	Wastes containing barium bromate, barium hydroxide, barium nitrate, barium carbonate, barium chloride, barium fluoride, barium sulfide, barium oxide, barium fluosilicate, barium chlorate, barium acetate, barium peroxide barium iodate, barium azide and barium polysulphide

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