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Strategies to Reduce Unintentional Production of POPs in China: BAT, BEP and Incremental Costs for Selected Sectors of Industry (Contract No. 2004/217)

The Contractor's Reports

(Enterprises Case Study Reports)

Submitted by

Foreign Economic Cooperation Office

State Environmental Protection Administration, China

December 2007

LIST OF ENTERPRISES CASE STUDY REPORTS

1. Case Study Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in Huzhou Century Clean Solid Waste Treatment Centre
2. Case Study Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in Jinan Hanyang Solid Waste Disposal Co., Ltd
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Strategies to Reduce Unintentional Production of POPs in China: BAT, BEP and Incremental Costs for Selected Sectors of Industry

Case Study Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in Huzhou Century Clean Solid Waste Treatment Centre

Submitted to

Foreign Economic Cooperation Office

State Environmental Protection Administration, China

Huzhou Century Clean Solid Waste Treatment Centre

Contents

1. Present Situation and Technical Development of Medical Waste Treatment in China

1.1 Present Situation of Medical Waste Treatment in China

Up to the present we haven't got authoritative statistic about Chinese medical waste disposal. According to the statistic from Project-"National hazardous waste and medical waste disposal establishment construction", which was established by State Environmental Protection Administration of China and National Developing & Innovation Committee, the situation about Chinese medical waste disposal is as follows:

1)The yield of the medical waste is huge.

It is hard to make out the yields of the medical waste exactly because the sources of the medical waste are too comprehensive. The total yield is usually calculating by the number of the sickbeds, the using rate and the average yield per bed per day. According to Project-"National hazardous waste and medical waste disposal establishment construction", in 2002, the total yield of the medical waste was 650,000 ton with average 1780 t/d. It is predicted that in 2010, compared with 2002, the number of the sickbeds in National medical treatment organization will increase by 5%, the total yield will reach to 680,000 ton and the average yield will be 1870 t/d. Junwei Ma et al estimated that the total yield of the national medical waste was 690,000 ton in 1996, 710,000 ton in 1997, and it would be 1,050,000 ton in 2010 if it was increasing by 3% per year.

Actually, the total yield is even larger, because a part of municipal solid waste is interfused into medical waste (which is charged by bed) without collecting by sort. These days, the government is doing research trying to find out the real yield of the medical waste.

2)The constuction of the disposal establishment is draggled, and the rate of the concentrate disposal is low.

Except Juangzhou, Hangzhou, Shenyang, Dalian, Huzhou et al, extremely few regions carry out concentrate disposal. Every hospital treats the medical waste by themselves separately in most areas. And the treating technology and treating effect are not in one level. In the period of SARS which happened in 2003, it fully exposures the fatalness of lacking the concentrate disposal establishment.

3)Low technical disposal, serious secondary pollution

Many hospitals use boilers or interval incinerators for medical waste disposal. This kind of treatment has many disadvantages, such as small scale, low techniques, simple and crude establishment, the incinerator was not designed based on the concerning about the characteristics of medical waste, and having no flue gas purification system, and the incinerate temperature is too low and running discontinuity, so this kind of treatment has low disposal efficiency and may produce flue gas, effluvium, bottom ash, sediment, waste water etc which cause secondary pollutions to the environment. The incinerator of the hospital disturbs surrounding residents, and the conflict between them becomes more and more serious. A large quantity of medical waste disposal establishments which were constructed during the SARS has same problems as upwards. State Environmental Protection Administration of China had already passed an Urgent Inform-"Strictly prohibit constructing simple hazardous waste and medical waste disposal establishment" in May, 2004. The Urgent Inform strictly prohibits constructing hazardous waste and medical waste disposal establishment, and enhances qualified management of disposal establishment construction.

4) Interfused into municipal solid waste, inflood to society, cause serious damages

A majority of medical waste was interfused into municipal solid waste, and straight landfilled. But the construct levels of refuse dump in our country, the establishment in case of leakage, the treatment for filtrate and the overlay of surface layer cannot reach the safety standard for medical waste disposal. So straight landfilled can easily pollute environment and ground water, becomes source of the disease.

These days, the reports about lawless businesses of medical waste become common occurrence. Some institutions or individual sell and buy medical waste illicitly, reuse one-off medical appliance. They are only simply disinfected and repackaged to "medical treatment appliance" or made as commodity. They inflood to society and do damage to people's lives.

1.2 The development of medical waste disposal technology

Medical waste disposal technologies have been developing for several decades, and many techniques came into being. Nowadays, there are about ten techniques used popularly for medical waste disposal. They are divided into two kinds: incineration technology and non-incineration technology.

1.2.1 Non-incineration technology

Medical waste disposal by incinerate cannot avoid producing dioxins or heavy metals and cannot avoid their transfer. Non-incineration technology is developing in the developed countries because of their complete medical waste classified collecting system. But incineration technology is still in dominating position. Nowadays, Chinese medical waste classified collecting system is not complete, so non-incineration technology is not suitable for China. But these technologies are still referenced for some developed cities.

1.2.1.1 Thermal Process

Thermal process is a technique destroying virus and bacilli in medical waste by heat energy. According to different temperature, it can be divided into Low-Heat Thermal Technologies, Medium-Heat Thermal Technologies and High-Heat Thermal Technologies.

Low-Heat Thermal Technologies: Operation temperature is usually controlled between 93℃~177℃, wate will not decompose combustion or pyrogenation. Low-Heat Thermal Technologies also can be divided as steam disinfection and hot air disinfection. Steam disinfection uses steam for waste disinfection, high pressure disinfector which commonly used in hospitals use this method to disinfect. Hot air disinfection has no moisture or steam, usually through heat conduction, nature convection, force convection and heat radiation to heat up waste.

Medium-Heat Thermal Technologies: Operation temperature is usually controlled between 177℃~370℃, under this condition, organic compounds may decompose. According to this phenomenon, new methods have been developed, such as High Density Wavelet In-Polymerization, High-temperature and High-Pressure Pyrolysis Polymerization etc.

High-Heat Thermal Technologies: Using resistance, natural gas or plasma to treat waste, the operation temperature usually exceed 540℃, the maximum can reach to 10000℃. Under this high temperature and high heat flow condition, the organic and inorganic compounds in the waste may physically and chemically transformed, the volume and mass of the waste can reduce by 90%~95%.

1.2.1.2 Chemical Process

Chemical Process is a technique destroying virus and bacilli in medical waste using disinfector such as chlorine oxidation solution, NaClO, peroxide acid, glutaraldehyde, NaOH, ozone, calcium oxide etc, through oxidation, deoxidization, neutralization etc chemic reaction. In chemical process, chemical and waste are asked to be contacted well and having proper concentration and enough disinfection time to make sure disinfection is thorough and efficient. At the same time, the form of the waste, the PH value of the solution, reaction temperature and other impurity will affect disinfection efficiency. Chemical process can be divided into Chemical Process with Cl-element and Chemical Process Without Cl-element according to if chemical with or without Cl element. NaClO is the mostly used disinfector in Cl-element Chemical Process and in medical waste disposal too. But recent years, more and more concern is on the use of disinfector with Cl element will produce some hazardous outgrowth. Chemical Process without Cl element avoid hazardous outgrowth. But disinfectors without Cl-element have different states (ozone is gas, NaOH or KOH solution is liquid, CaO is solid state), so disposal technologies are different. Chemical process needs pretreatment for the waste using mechanism disposal establishment.

1.2.1.3.Irradiative Process

Irradiative process is a technique using high density electron beam, Co-60 gamma ray or ultraviolet radiation (253.7nm). Electron beam radicalization destroy animalcule in waste using a large quantity of high density electron beam through chemolysis and rupture cell well. Pathogeny destroying efficiency depends on energy which waste absorbs, waste density and electron beam energy. UV-C mainly used as a complementarity to other technologies. Irradiative process can't change the physical state of the waste; it needs disintegrator to destroy medical waste. Besides, application of irradiative process needs to protect operator from radiation by using safeguard screen.

1.2.1.4. Biological Process

Biological Process uses oxidation of bacteria or other microorganism and synthesis catabolism of cell to stabilize and remove pathogen, pathogens and other harmful substance in medical wastes. Typically, place the microorganism in the waste stream to be treated, then optimize the microbial growth environment and regulate the other rate control variables to accelerate the biologic natural degradation process, finally, organic matter in the wastes is decomposed into carbon dioxide and water. It can be classified into aerobic and anaerobic treatments depending on the presence of oxygen content in the atmosphere

1.2.1.5. Mechanical Process

Mechanical Process deforms medical wastes under all kinds of mechanical method with mechanical equipment, and transforms the raw waste into mixed and easily-treated forms. Usually, place the medical wastes into a closed vessel, and then fracture them into particle substance so as to process by other treatment techniques. Maintain the vessel negative pressure to prevent the pollutants escaping. This treatment technique is suitable for solid waste, and also suitable for some fluid material. Mechanical Process suppresses gas in waste to realize volume reduction in physical form by fracturing vessel and bulk material. But it can not realize waste minimization. Mechanical Process itself can not kill the microorganism in the medical wastes, but it can improve the treatment efficiency of other processes by pre-treating the medical wastes as an assistant treatment technique for other processes.

1.2.1.6. Safety Landfill

Safety Landfill is an improved sanitary landfill, also named Safety Chemical Landfill. It is an ultimate treatment technique for the residual wastes after other processes. To prevent the release of toxic substances and reduce environmental pollution, the design, construction and operation of safety landfill site must strictly conform to concerned technical specifications. The main problems that must be paid attention to in the land design and planning are: (1) pretreatment before waste treatment; (2) collection and treatment of leaching solution; (3) groundwater protection; (4) Control and management of surface runoff in and around the landfill site. After sterilization, volume reduction and minimization with other processes, the medical wastes would ultimately flow to the safety landfill site, so the landfill site is the ultimate treatment site. Safety landfill site under strict design and planning could avoid production of secondary pollution effectively. But safety landfill site also has some shortcomings such as occupying large area, long treatment cycle, high investment cost and etc. After incineration and high temperature treatment of the medical wastes, the residue is sent to safety landfill site to be treated.

1.2.2 Incineration treatment technique

High temperature is the most effective method of sterilization, and high temperature produced by incineration can kill all harmful microorganisms instantly. Seen from the commercial application, incineration is the most widely used method. Incineration which can achieve reduction, stabilization, innocuity and energy recovery is a deep oxidative chemical process. It oxidize solid、liquid or gaseous combustible substance into CO2、water and ash, and sulfur, nitrogen, metal, halogen and other element impurity in the waste are converted into all kinds of ultimate product. It must be completed by some special incineration equipment, and require high and stable furnace temperature (Temperature), good mixture of oxygen (Turbulence), adequate gas residence time (Time) and extensive flue gas purification process. In all feasible medical wastes treatment technology, incineration process has been proved to be one of the most effective methods of destroying infectious and toxic substance and reducing volume and weight.

According to the different disposal conditions in the first combustor, the incineration process can be classed into the following two forms, shown in table 1.

Table 1-1. Comparison of the two incineration treatment technique

Treatment technique	Main equipment	Control of dioxin	Reaction residue	Treatment cost	Commercial application
Two-stage incineration	Rotary kiln, great furnace, compartment furnace	Moderate	Inert salt and oxide	Moderate	More
Pyrolysis/ Gasification incineration	Rotary kiln, multistage, furnace, CFB	Better	Fix carbon, inert salt and oxide	Less	Fewer

1.2.2.1 Two-stage Incineration

Such furnace is a typical conventional medical wastes incineration furnace. As shown in Fig. 1, wastes sent into the first combustor incinerate in sufficient oxygen environment, and the flue gas enters the second combustor to get further high-temperature incineration. High-temperature incineration guarantees that small amount of unburned organic substance in the flue gas from the first combustor as well as decompose and combust completely. According to the different thermal value of the medical wastes, one or many burners are needed in each combustor chamber in order to support the combustion. As the principle of this disposal method is simple, and the technology is matured and control is easier, it was widely used in the past. But it has some shortages: the production of fly ashes in flue gas is greater; auxiliary fuel is needed in the second combustor to supply combustion; energy consumption is relatively high in operation. In China, many two stage incineration furnace were built by hospitals themselves. As these furnaces dispose with low capacity, run discontinuously, and most of them have no flue gas treatment system and control system, which have difficult to meet environmental requirements.

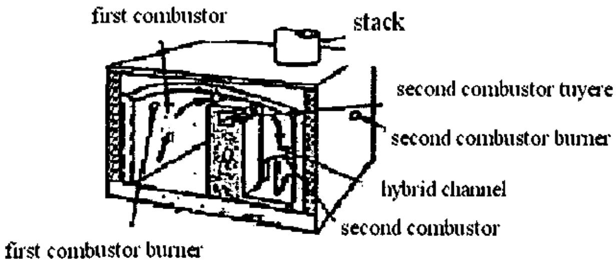


Fig 1 multi-combustor two-stage incineration furnace

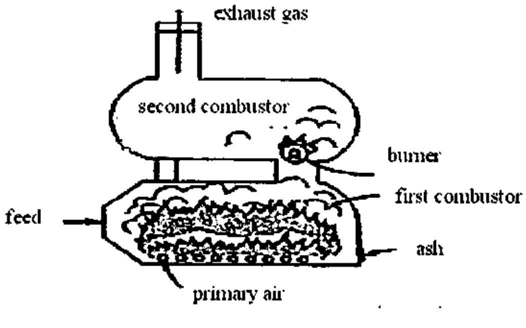


Fig 2 gasification incineration furnace

1.2.2.2.Pyrolysis /Gasification Incineration Disposal

Pyrolysis/ Gasification incineration disposal technique are composed of two parts; the main difference from two-stage incineration technique is that the first stage is pyrolysis/gasification furnace. The disposal principle is that firstly transfer the waste into a pyrolysis/gasification furnace and the temperature in the furnace is usually maintained within 100℃~600℃; organic matters and volatile matters in the waste are pyrolyzed and gasified in the condition that is without or lack of oxygen (usually 40~60% of theoretical air demand of combustion), then some residues containing inorganic matters; combustible gases produced by pyrolysis/ gasification enters the second high-temperature incineration furnace to incinerate at high temperature, burn out harmful substance and decompose harmful substance such as dioxin.

Pyrolysis/ gasification incineration disposal technique is an advanced incineration disposal technique because the fly ashes from the flue gas are few, which are in favor of control the product of harmful substance such as dioxin, and flue gas volume produced in per mass waste treatment is few. But the reaction principle is complex and it is not easy to control the whole disposal process. Many incineration furnaces were built by hospitals themselves in our country, shown in Fig. 2. As they have no advanced control system, can not adjust the air distribution and temperature in the furnace to the change of material properties and also have no flue gas treatment system, they also have difficult to meet environmental requirements.

1.2.2.3 The pyrolysis and gasification technology for medical waste

1.2.2.3.1 Fixed-bed pyrogenation and gasification furnace

As shown in Fig.3, it is a typical Fixed-bed pyrolysis and gasification furnace, from the top of which the pretreated medical waste was added in batches or continuously, and the preheated air or oxygen was send from the bottom of the furnace. During the reaction process, waste passed through drying and pre-heating section, devolatilization section and combustion section in the furnace. The slag or ash from pyrolysis was discharged from the bottom of the furnace, and the prolysis gas was discharged from the top. The quantity of heat for combustion reaction comes from partly combustion of waste or combustion of assistant fuel, which is determined by the heat value of waste. The heat value of medical waste is sufficient to maintain its self-combustion. In order to achieve a best heating effect, the reacting gas and waste flow directions are in reverse order. However, some furnaces with the same flow directions or crosscurrent can also achieve good thermal efficiency.

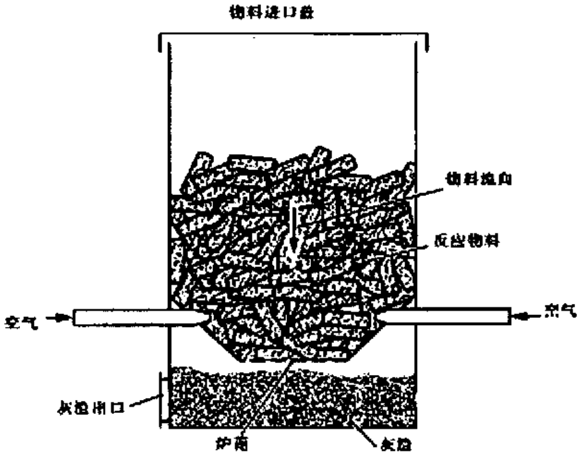


Fig1-3. fixed-bed pyrolysis and gasification furnace

Because the velocity of gas flow in pyrolysis furnace is low, so the gas carries much less particle matter, which in return reduces incomplete combustion loss, and alleviates second contamination to environment. The fixed-bed pyrolysis and gasification furnace has high demand for reaction material. To guarantee against forming cake, high water containing material: flesh, wet dressing etc. need drying and crashing before putting into the furnace. The big material in reaction furnace will produce groove flow, which will influence pyrolysis and gasification effect and carry more solid particles.

1.2.2.3.2 Fluidized-bed pyrolysis furnace

The main difference between fluidized-bed pyrolysis furnace and other pyrolysis furnaces is high gas flow velocity in fluidized-bed pyrolysis furnace, which can fluidize the material. In order to achieve a better fluidizing condition, material needs pre-crashing. This high demand for uniformity of material has limited the waste disposal range of fluidized-bed pyrolysis furnace. Fluidized-bed pyrolysis furnace system is shown in Fig.4.

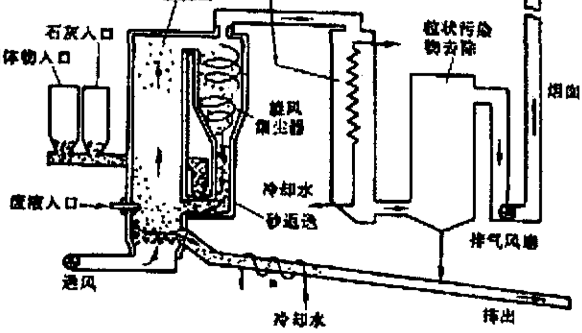


Fig1-4. Fluidized-bed pyrolysis furnace

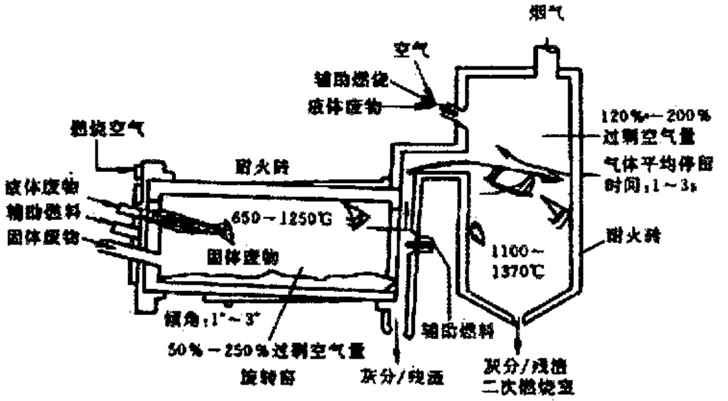
Compared with other furnaces, the main superiority of fluidized-bed pyrolysis furnace is that it has meliorated diathermancy and temperature control. Additionally, unlike fixed-bed pyrolysis furnace, fluidized-bed pyrolysis furnace is not influenced by clinkering property. This kind of equipment is also able to treat waste with high ash or water content, very fine particle or high fluctuating heat value such as municipal solid waste. Because of the high pyrolitic reaction rate in fluidized-bed, the dimension of the equipment is smaller than others.

The main disadvantage of fluidized-bed pyrolysis furnace is that the heat value of pyrolytic gas is less, and the gas will take more sensible heat. Because of heat loss, fluidized-bed pyrolysis furnace may need assistant fuel to maintain its natural operation. Moreover, compared with municipal solid waste the output of medical waste is relatively small, and has great change in size and components, therefore it must be pre-crashed before putting into fluidized-bed furnace.

1.2.2.3.3 Rotary kiln pyrolysis furnace

Rotary kiln pyrolysis furnace is mainly composed of a continuously rolling and slightly declining cylinder as first combustion chamber and a second high temperature combustion chamber. The pretreated waste is send to high end of kiln with a special feed equipment. The material in kiln will move towards the end of the kiln when the cylinder rotating. Pyrolysis residue was discharged from the low end, and pyrolytic gas was combusted in second combustion chamber or the pyrolytic product was cooled down for reclaiming fuel oil and fuel gas.

A typical rotary kiln pyrolysis furnace is shown in Fig.5. High temperature gas in kiln comes into contact with waste in reverse direction. Part of waste and pyrolyzed half-char combusted to provide heat for the pyrolysis of the other waste. Combustible gas and harmful waste formed from pyrolysis goes into the second combustion chamber for higher temperature combustion with the help of assistant fuel.



Figl-5. Rotary kiln pyrolysis furnace

1.2.2.3.4 Rotary-fluidizing multiple-stage pyrolysis-incineration furnace.

The Rotary-fluidizing multiple-stage pyrolysis-incineration furnace system was developed by Zhejiang University. The system sufficiently combined the virtues of both rotary kiln pyrolysis furnace and fluidized-bed pyrolysis furnace in waste pyrolysis and incineration, which make it more suitable for complicated medical waste. Detailed system information was introduced in the fifth section of the report.

2. Demonstrative Enterprise Introduction

Huzhou Century Clean Solid Waste Disposal Center is a multi-industry integrative private enterprise which combined solid waste disposal, pollutants fathering, water pollution fathering products developing, environment protection experiment and technology training. Since the foundation of the enterprise, it has accomplished 20 more environmental fathering projects for enterprises and hospitals, and the projects have all passed the check of EPA. Now the center has 85 staff including managers and technicians, and operation technician account for 30% of the work force, 9%of which have superior technical post, 20% of which have intermediate technical post. Since 2002, under the sustainment and promotion of Huzhou EPA and board of health, disposal center has centrally disposed and marketable operated the treatment medical waste in Huzhou city. Up to now, medical wastes from 22 county and city grade hospitals, 111 villages sanitation courtyard, 323 individual cliniques and 1624 country sanitation rooms have been centrally disposed by center. The disposal ratio of medical hazardous waste in citywide has reached 100%.

Under the demands of Law of the People's Republic of China on Prevention of Environmental Pollution Caused by Solid Waste and Law of the People's Republic of China on Prevention of Infectious Disease and the demands of fathering of Taihu valley put forward by State Department, Disposal center has invested 12 million Yuan in the first disposal project of Huzhou medical waste in 2001, collecting, transporting and standardized and innocuous disposal the medical waste and industrial hazardous waste from citywide.

Under the demand of Technical Criterion of Centralized Disposal of National Hazardous Waste, Disposal Center cooperated with Zhejiang University to construct a Rotary-fluidizing multiple-stage pyrolysis-incineration furnace system at the beginning of 2004, and has successfully put a 10t/d system into operation in November, 2004. With this integrate canonical medical waste disposal system developed by Zhejiang University, we have achieved the environment protection demands on innocuity and weight reducing during medical waste processing, and the synchronization principle of benefit for Social, environment and economy.

The second project of Huzhou medical waste disposal center has started. The new project will continue to introduce the advanced and up-graded medical waste disposal techniques developed by Zhejiang University, to achieve the environment protection demands on innocuity and weight reducing during medical waste processing, and finally reduce the discharge of dioxins.

3. Medical waste collection system and its improvement

3.1 Total process management system of medical waste in Huzhou

Total process management system of medical waste in Huzhou Century Clean Center includes: information management subsystem, transport subsystem, waste sort and pretreatment subsystem, waste incineration disposal subsystem and ash-slag disposal subsystem, education and training plan.

Total process management system of medical waste in Huzhou Century Clean Center is demonstrated as follow:

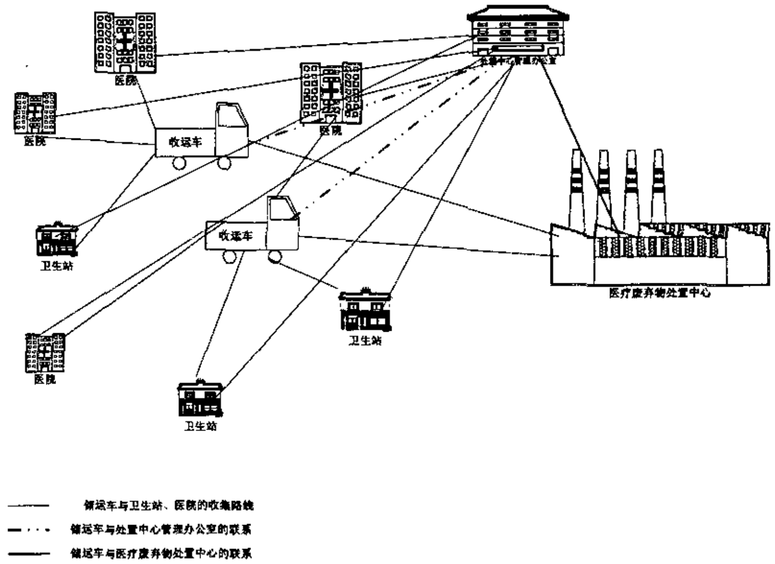


Fig3-1. Information management system of medical waste transportation

Information management subsystem: connect to all medical treatment organization in Huzhou medical disposal management range, collect and record statistical data of medical waste product from hospitals, health center and clinic. A timely waste collection and transportation dispatch is realized by this network record and statistic, the length of time before medical waste is transported from medical treatment organization is reduced, and the risk from too long shelf life is reduced. Information management system of medical waste transportation is showed in Fig.6.

Transport subsystem: eight only for medical waste transportation trucks which completely satisfy the demands of “Specification for Medical Waste Collection and transportation management” compose a fleet, the payload of each truck is 2 ton. Management office arranges the collection route of each truck according to on-line waste statistical data from information management subsystem. The collection trucks collect the medical waste directly from medical treatment organization. Medical waste is placed in appropriative labeled collection plastic bag, and then the bag contained waste is placed in a special medical waste collection plastic box for storing and feeding in disposal process.

Waste sort and pretreatment subsystem: carry out “Rule for Medical Waste Management” strictly, sort and disposal the waste respective. The waste from area of infection is sent for incineration disposal after disinfection.

Waste incineration disposal subsystem: this subsystem is a key link in medical waste disposal system. Medical waste is treated safely by high-temperature incineration, pollution emission conforms national standard.

3.2 Introduction of medical waste collection

Disposal center has conducted centralized disposal for medical waste from 22 county and city hospitals, 111 health centers, 323 individual clinics and 1624 village clinics in Huzhou city which has an area of 5800 square kilometers. The disposal rate of medical waste is 100%. A further improvement and layout was conducted on the basis of inhere collection system. This perfects the collection, transportation and disposal of medical waste in Huzhou city. The medical waste collection spot covers with precinct of Huzhou showed as Fig.7. Starting station and route of medical waste is shown as Fig.8.

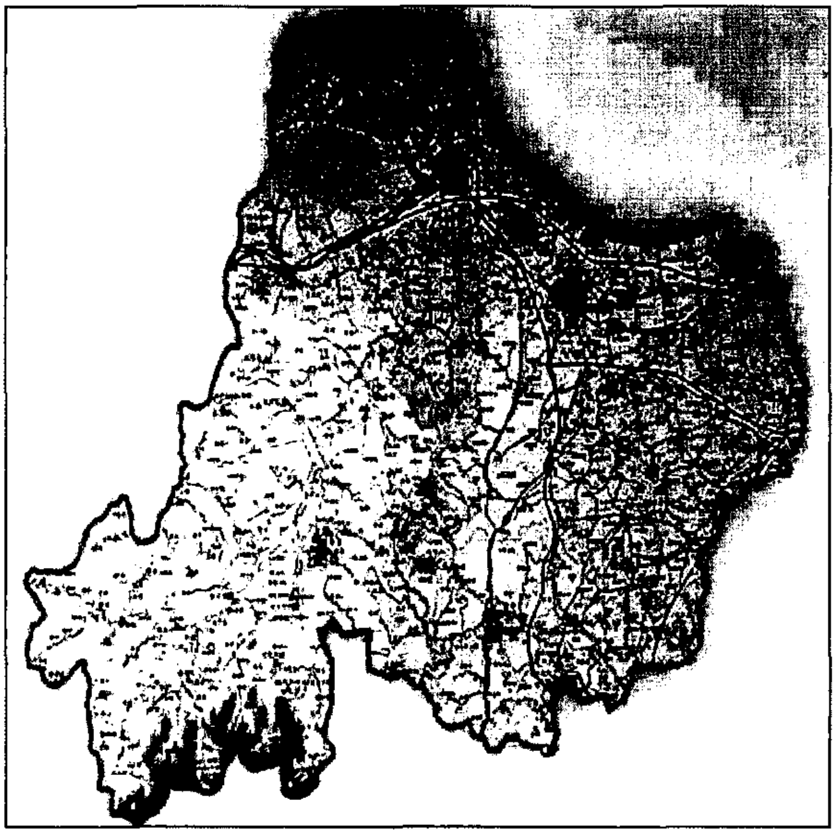


Fig3-2. Medical waste collection spots in Huzhou city (yellow points)

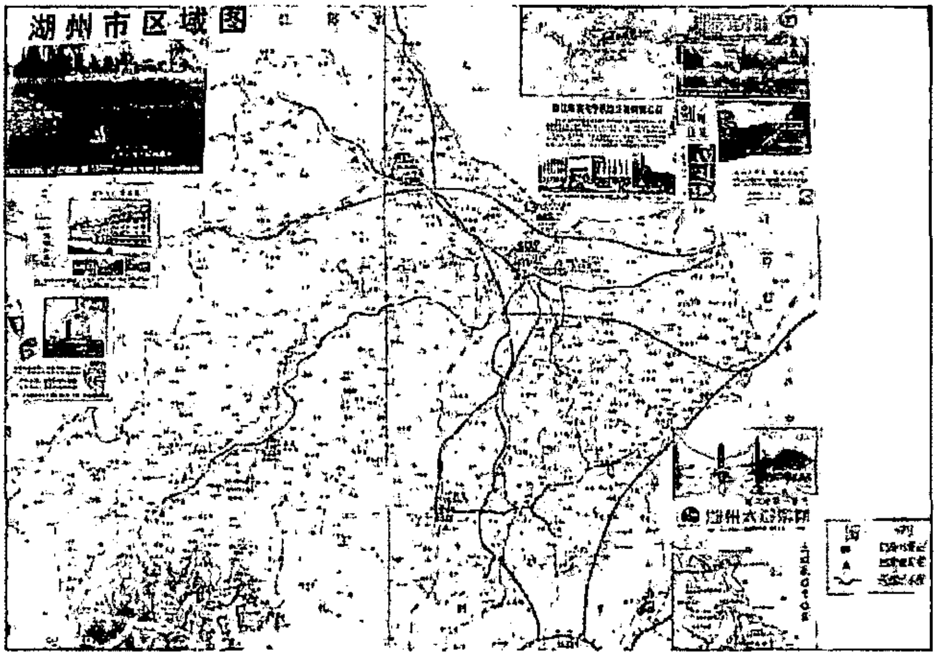


Fig3-3. Medical waste transportation routes in Huzhou city (red lines)

3.3 Rules obeyed in collection system

As medical waste and hazardous industry solid waste having its particularity, risk will exist in its collection, storing and transportation process. This waste may be a pollution source which will effect the environment safe. Therefore followed rules must be obeyed in waste collection and transportation process:

1) Medical treatment hazardous solid waste is collected in time, sorted and placed in leakage-roof, impenetrable packed ware or airtight boxes respectively. Special packed ware and container must have distinct warning sign and illuminate. High hazardous waste such as substrate and sample of pathogen, bacteria and virus strain preserving fluid etc. in medical waste must be disinfected before transporting to medical waste disposal centre.

2) National regulate about hazardous material transportation management must be obeyed. Join-bill of hazardous waste transfer process must be conducted according to national and regional regulate of hazardous waste transfer.

3) Transportation trucks must have completely sealed compartment, and must be only used for medical waste transfer. Drivers must be trained professionally. Trucks loading irrelevant persons are forbidden. Transportation safely is insured, discard and lost of hazardous waste is forbidden. Hazardous waste transportation system is set according to volume and route of transport. The transportation of hazardous waste must be obeyed to regulate of management of hazardous waste transportation, and secondary pollution and risk of environment pollution must be reduced.

4) Waste container must be in good condition, and load of container should be moderate. The container must be sealed after loading and the seal must be complete. Incompatibility waste or unpretreated flammable explosive hazardous waste is forbidden mixture transporting. Packed wares such as collection boxes must be replaced termly.

5) Hazardous waste is forbidden storing in the open air. Establishment and equipment of storage temporarily must be apart from medical treatment section, food processing section, personnel activity section, residential area, fountain protection area and traffic artery, and must be set obvious warning sign and conducted safety precautions such as leakage-proof, ratproofing, bug-proof, guard against theft and children reaching etc.. Establishment and equipment of storage temporarily must be disinfected and cleaned termly.

6) Waste of different characters must be stored respectively. Storage site of flammable waste must be set in shady and cool place, and must be separated with other waste. Storage time of different waste must be set by their characters.

7) Explosive material and radiated waste collection is forbidden.

3.4 Medical waste collection network

According to the above principles, the program has created a medical waste collection net, shown in Fig. 9, which comprised of the administrations of environmental protection and health supervise, the medical waste producers, and the treatment center.

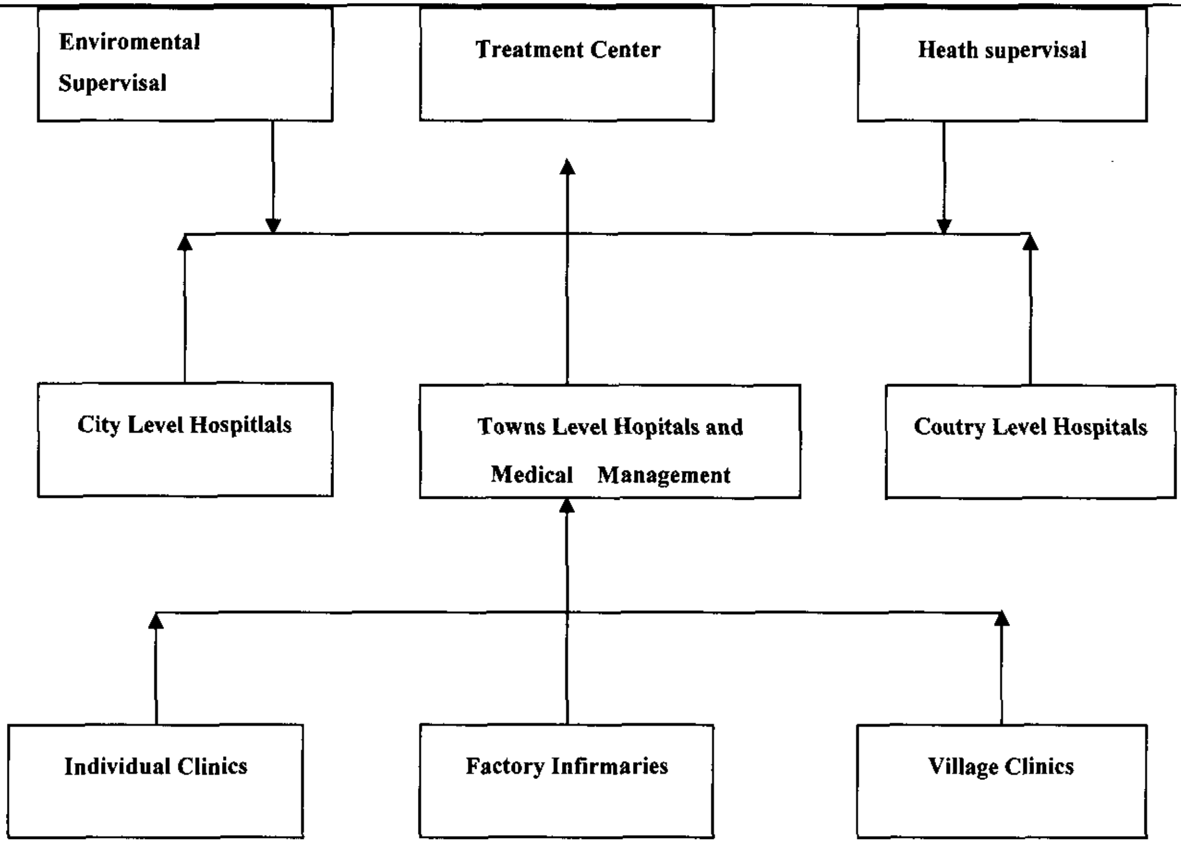


Fig3-4. Sketch map of the medical waste collection net

The medical waste in the hospitals and clinics is put into the specific medical waste collection bags and boxes that deposited in the medical or health center. The medical units below the villages and towns hospitals level should send their medical waste to the villages and towns hospitals or medical management associations for safety treatment. And then, the wastes are transported to the treatment center by the specific medical waste trucks of the center for focused final treatment.

3.5 Medical waste collection flow

The special medical waste such as the cut body and residues of surgery, the laboratory residues and the infective wastes, are filled into hard plastic boxes, sealed with doubled-faced adhesive tape, and combusted together with the boxes; the acuminate apparatus are put into boxes that made of hard materials; and the other medical waste is filled into the specific bags and sealed preserved in the hard plastic circulation boxes, and the boxes are circulated after washing and antisepsis.

Medical waste uses sealed container trucks for transportation, and the special medical waste uses freezing container trucks. Fig. 10 shows the scene that the specific medical waste trucks are collecting medical waste in the hospitals. Fig. 11 and Fig. 12 show that the specific medical waste trucks are discharging in the medical waste treatment center. And Fig. 13 show the medical waste collection process flow.

Fig3-5. The specific medical waste trucks are collecting medical waste in the hospitals

Fig3-6. The specific medical waste trucks are discharging in the medical waste treatment center

Fig3-7. The staffs are unloading the medical waste collecting boxes from the specific medical waste trucks

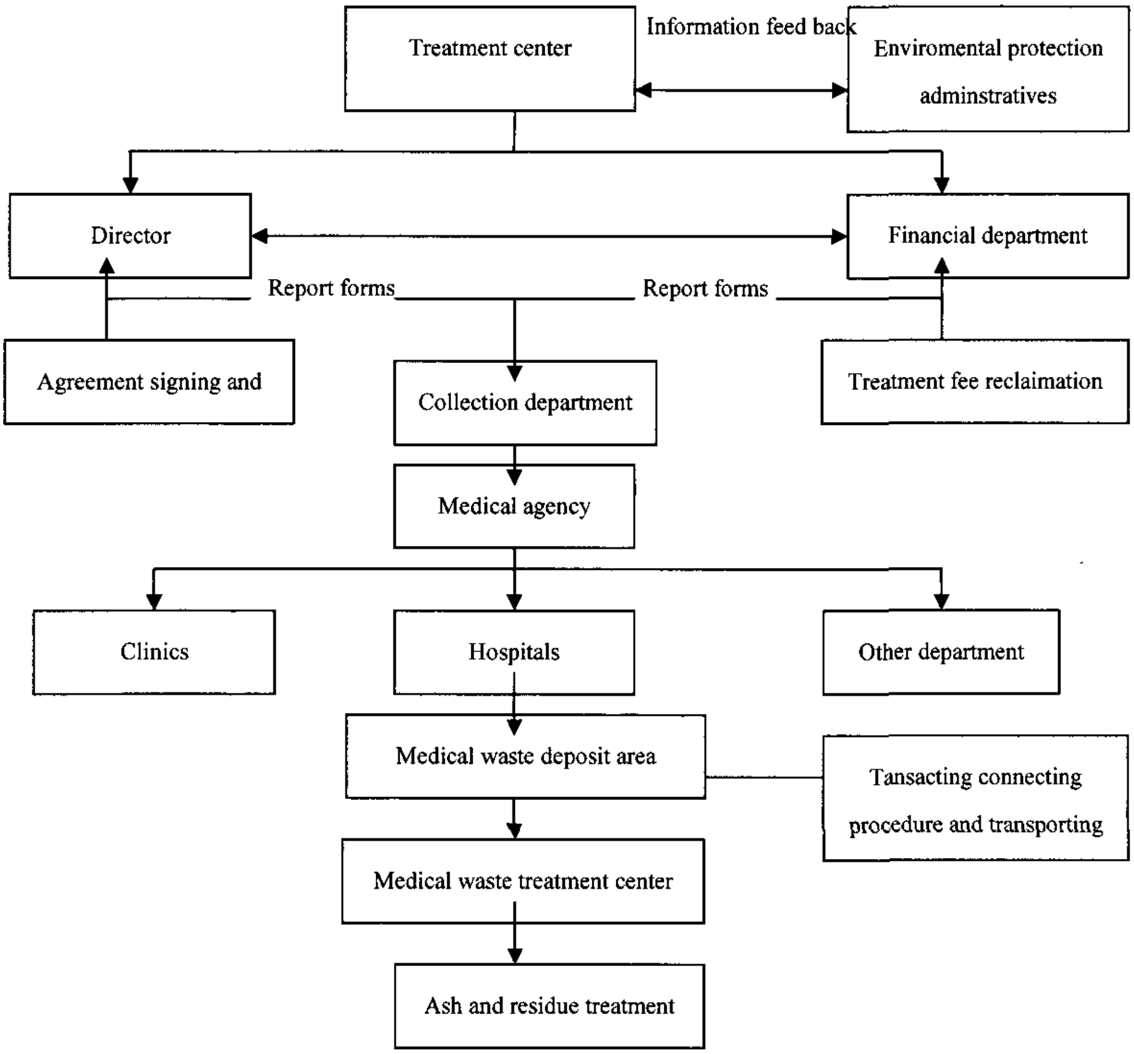


Fig3-8. The medical waste collection process flow

3.6 Education training and health protection

The medical treatment center will organized the managers and the staffs working on medical waste collection, transportation, deposition and treatment works, to process periodic trainings about the medical waste collection, transportation, deposition and treatment technologies, and also about the safety protection and emergency treatment. Several foreign experts are invited to give lectures and communicate with the staffs about their advanced experiences on the medical waste collection and treatment system, and in this way the managers and staffs working in the center are expected to improve their professional ability, and self-restriction in the work so as to avoid accidents.

The medical waste treatment center has equipped with necessary preserves for the managers and staffs working on the medical waste collection, transportation, deposition and treatment. The staffs of the center are afforded for two physical examinations or immunity inoculation every year, to protect from health damage.

4. General Information of Medical Waste Incinerator of Demonstrative Enterprise

Table 4-1. MW Treatment Center and Incinerator with capacity of 10t/d

Type of Plant	Municipal solid waste	[ ]
	Industrial waste	[ ]
	Hospital waste	[X]
	Light shredder	[ ]
	Sewage sludge	[ ]
	Waste wood and waste biomass	[ ]
	Animal carcasses	[ ]
Name of Plant	Huzhou Century Clean Solid Waste Treatment Centre	
Location (City/Province)	Huzhou /Zhejiang	
Address	Zheda road 38#, Hangzhou, 310027 And Fenghuang West Road 605#, Huzhou, 310000	
Contact (Name, position, phone and fax numbers, e-mail)	Yan Jianhua, Professor, 0571-87952629/13906510891, 0571-87952438, yanjh@cmee.zju.edu.cn and Shi Zheng, General management, 0572-2122542/13706522096, 0572-2122543, ogpjh@163.com	
Number of Furnaces	1+1, Primary (rotary)+FB	
Type of Operation	Batch (*e.g.*, 100 kg per batch)	[ ]
	Semi-continuous (*e.g.*, 8 hours per day)	[X]
	Continuous (24 hours per day)	[ ]
Annual Operation/Capacity (total)	t/h (tons per hour)	0.416
	h/d (hours per day)	12
	d/w (days per week)	

	t/d (tons per day)	5 -10
	d/a (days per year)	330
	h/a (hours per year)	
	t/a (tons per year)	3300
Type of Furnace	Mass burn waterwall (grate)	
	Fluidized bed	
	Stoker	
	Rotary kiln	X
	Other (please specify)	Afterburning : CFB
Temperature in fornace	Main furnace (°C)	500-600
	Afterburner/second chamber (°C)	850-1100
Type of Air Pollution Control System (APCS)	Electrostatic precipitator	[ ]
	Cyclone	[ ]
	Bag filter	[X]
	Wet scrubber	[ ]
	Semi-Dry scrubber	[X]
	Lime injection	[X]
	NaOH/alkali injection	[ ]
	Active carbon/coke injection	[X]
	Active carbon filter	[ ]
	Catalytic converter (SCR)	[ ]
	Induced or forced draft fan	[ ]
	Other (please specify)	
	None	[ ]
Heat Recovery System	Yes [X]	No [ ]
		At exit from APCS (if available)
Height of the stack	(m)	15
Diameter of the stack	(m)	0.6

Position of sampling port	(m)	4.5	
Flux of Off Gases	(m³/h) (dry gas)	3500~4000	
Temperature of Off gases	(°C).	180	
Oxygen	%	10 (8~13)	
Particulate matter	(mg/Nm^3)	80 (~100)	
Acids	(mg/Nm^3)	70	
Carbon monoxide	(mg/Nm^3)	80	
Sulfur dioxide	(mg/Nm^3)	200	
Nitroges oxides	(mg/Nm^3)	200	
Others (if available)		/	
Residues		Disposal of these Residues	
Generation of Bottom Ashes	Kg/h [100]	Recirculation [ ]	Landfill [x]
Generation of Fly Ashes	Kg/h [20-24]	Recirculation [ ]	Landfill [x]
Generation of (Waste)Water	t/a [ ]	Disposal	
Generation of Sludges (as dry matter)	t/a [ ]	Recirculation [ ]	Landfill [x]

"*": the air pre-heater was replaced by the quencher of atomization sprayer after BAT/BEP measures were applied

5. Project technology description

The demonstration project based on a 10 tons/day medical waste incineration plant in Huzhou, was developed by based on the concerning about the characteristics of medical waste, such as the strong variations of the heating value and of the components. The technology combines the advantages of rotary kiln pyrolysis and the advantages of fluidized bed incineration for high treatment efficiency and very low pollutants emissions.

The specification for the technology and plant are shown as follows:

Item	**Unit**
The capacity of incinerator	400Kg/h (10ton/day)
Heating value of medical waste	6974 kJ/Kcal (1427Kcal/kg)
The exit temperature of incinerator	≥ 850°C
The gas residence time in secondary furnace	≥ 2.0 sec.
The incineration efficiency	≥ 99.9%
The reduce efficiency of the organic pollutants	≥ 99.99%
The unborn material rate of the incineration residue	< 3%

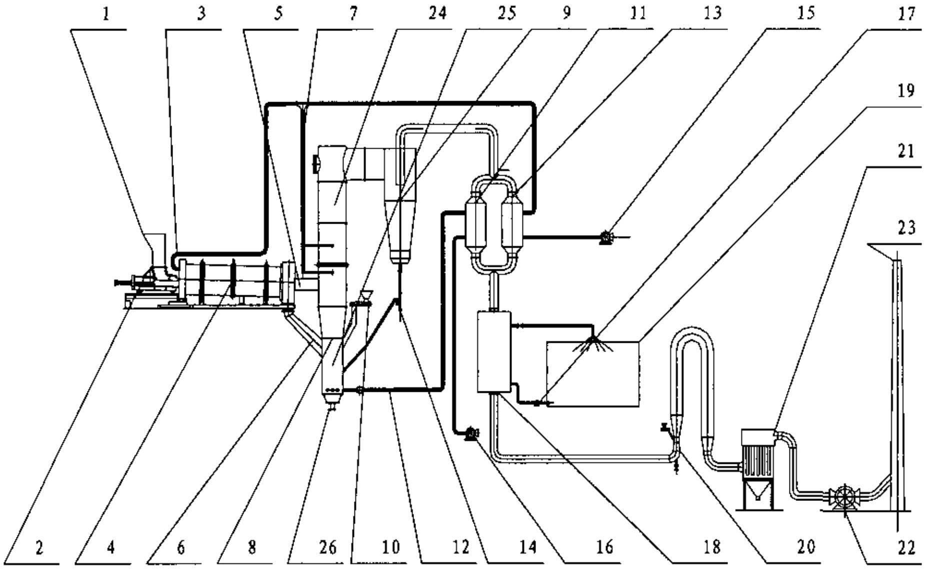


Fig5-1. Schematic of the rotary kiln and fluidized bed multi-stage incineration technology

1. waste hopper 2. feeder 3. Pyrolysis/gasification air 4. Rotary kiln 5. 6. connect pipe 7. secondary air 8. fluidized bed furnace 9. high temperature cyclone 10. lime stone feeder 11. air preheater 12. fluidized air 13. secondary air preheater 14. recycling device 15. secondary air fan 16. blower fan 17 water pump 18 quench 19.20 semi-dry scrubber 21 bag filter 22 ID 23 stack 24 thin phase zone in fluidized bed 25 dense phase zone in fluidized bed 26 slag outlet

The technical process diagram and schematic diagram of rotary kiln and fluidized bed multi-stage incineration system are shown in Fig.14 and Fig.15. The components of the system are introduced under basis of demonstrative project of Huzhou Medical Waste Incineration Center.

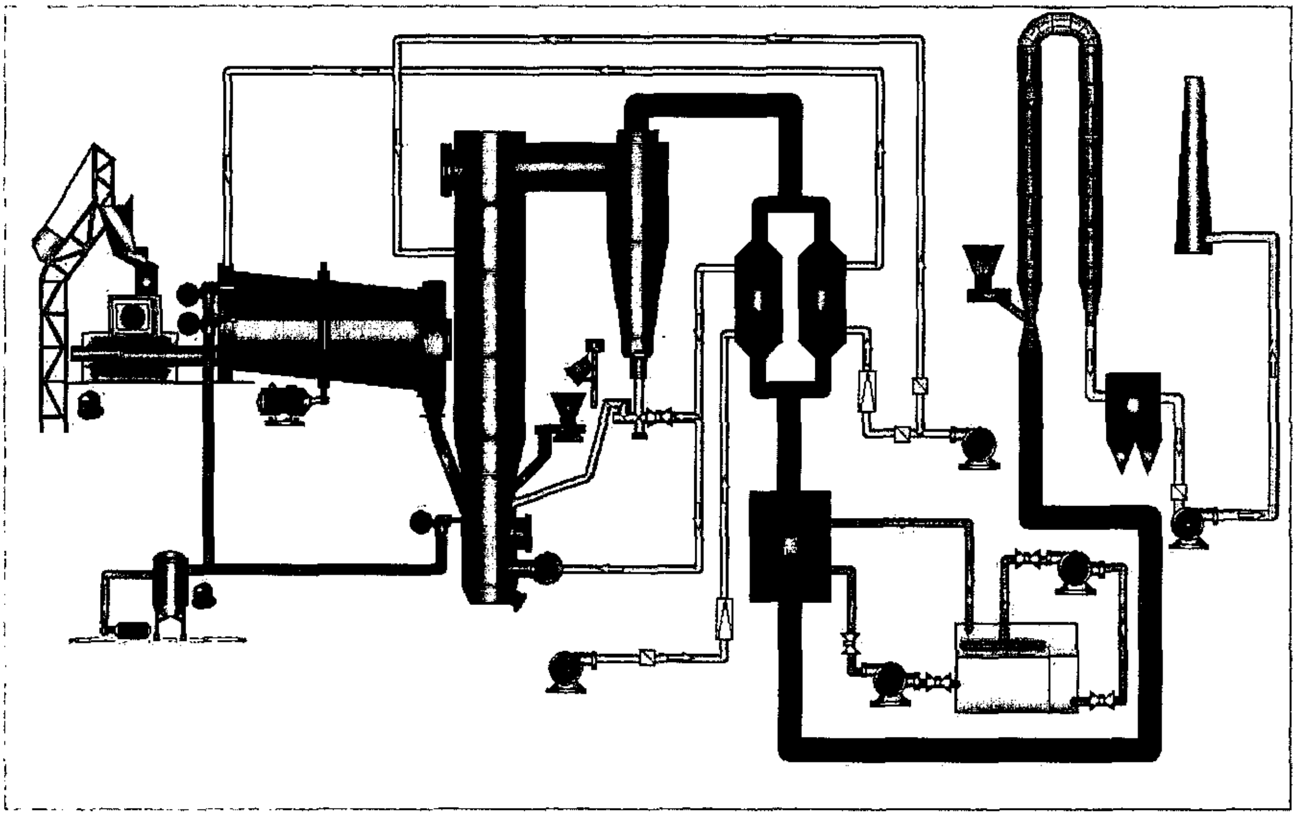


Fig5-2. Schematic diagram of the rotary kiln and fluidized bed multi-stage incineration system

6. Processing Flow of Medical Waste Incineration System

6.1 Transportation, Storage and Feeding of Medical Waste

Medical waste is transported into the Incineration plant by specialized trucks. After weighed on the track scale inside the treatment centre, the medical waste is dumped into the storehouse or directly incinerated in according to the instructions of waste storehouse operator. Medical waste is delivered into the hopper by a lift and then pushed into the rotary kiln by hydraulic pressure piston feeder.

Table 6-1. Composition and heat value of Medical Waste foe the 10t/d incinerator

Composition	Glass	Plastics	Cotton	Paper	Others	Total
Percentage/%	62	15	12	8	3	100
Low Heating Value/ kJ/kg	9797					

6.2 Rotary Kiln Fluidized Bed Multi-stage Pyrolysis-Incineration System

The incineration system consists of: 1) First pyrolysis/gasification chamber – rotary kiln; 2) Second incineration chamber – circulated fluidized bed (CFB), dense area of fluidized bed with special air distribution; 3) Third incineration chamber – suspense zone of the fluidized bed incinerator.

6.2.1 First pyrolysis/gasification chamber of rotary kiln

In this medical waste pyrolysis-incineration configuration system the rotary kiln is responsible for the pyrolysis and gasification of the waste. Medical waste is fed by feeding system into the first combustion chamber (rotary kiln) and moves towards the rear end of the kiln while the kiln is rotating. During the movement inside the kiln, the medical waste undergoes several stages including preheating, moisture vaporization, pyrolysis, gasification and partial combustion. At the head end of the rotary kiln, there is a burner for ignition and ensuring the temperature inside the kiln for pyrolysis to be 500°C~800°C. The fuel gas yield during pyrolysis goes into the freeboard of the CFB for the combustion. The solid residue goes into the dense area and is burnt there. The medical waste rolls inside the kiln and is exposed to the hot air alternately. As the temperature inside the kiln is moderate, the waste is heated equably and slowly, and the moisture and the volatile yield equably, which solves the problem of plastics deflagration by CFB solely.

The residence time of medical waste inside the kiln and the treating capacity of the rotary kiln can be regulated by adjusting the angle of inclination or rotary speed. The large capacity ability of rotary kiln can deal with the increasing amount of medical waste to be disposed of, and ensure the medical waste to be treated in time during equipment maintenance.

6.2.2 Second and third combustion furnaces of CFB

In the incineration system, the CFB is responsible for the afterburning of gas and solid residue produced from pyrolysis, gasification and partial combustion. The range of temperatures inside the CFB is usually 850°C~1100°C. After entering the CFB, the gas from rotary kiln pyrolysis combusts quickly while air supply offers high intensity turbulence and oxygen. The residence time of gas inside the CFB is more than 3~4 seconds, which can ensure the complete burning of combustible components of the gas and inhibit the yield of PCDD/F effectively. The solid residue is fluidized after entering the CFB and its residence time is over 40~60 minutes, which ensures the burn out of the solid residue. The ratio of not completely burnt material in discharged ash is less than 2%, which is far lower than the State Regulation for Hazardous Waste Incineration (GB18484-2001).

Limestone is added into the chamber and the calcium oxide reacts with acid gases like HCl produced by medical waste combustion, thus reducing their emission and avoiding the corrosive problem to the equipments after combustion stage.

The flue gas outlet from fluidized bed with high temperature firstly is cooled down to 500 by air pre-heater of high temperature, meanwhile, the assistant wind for pyrolysis, fluidized and burnout are heated to around 500℃, which can improve the temperature condition in combustion chamber without addition of complemented fuel.

The flue gas outlet from air pre-heater of high temperature is fast cooled down to 200 ℃ below by flue gas quencher. Water-pipe heat exchanger was adopted as flue quencher, i.e. hot flue gas flowing along outside of pipe as cooling water flowing inside of pipe without direct contact of the two media, so as to avoid the water pollution as well as its necessary treatment. As the stay of flue gas in quencher is within 0.5 s, the formation of Dioxin in this temperature shall be effectively reduced.

6.3 Key Technology of Rotary Kiln Fluidized Bed Multi-stage Pyrolysis-Incineration System

Based on the characters of MW as great variation in heat value, complex composition and great difference of physical form, and in well concern with the safety, reliability, superiority, the fluidized bed with multi-level wind distribution mode as main body in rear part of incineration system is one of the key technologies in the system.

The with multi-level wind distribution mode for MW has maintained the conventional advantages of fluidized bed incinerator in treatment of municipal waste with low heat value, high moisture and large variation in feeding, which were confirmed in practice, and solved the problem of combustion stability and slag discharge which were existed in old type of fluidized bed incinerator. Compare the new technology with old one, it own great advantages and new features, e.i. firstly, the conventional mode of old one for wind distribution by current distribution board being replaced with multi-pipe, where the space between the pipes is large enough to discharge for non-combustible waste in large size, so as to facilitate fluidization, and the requirement for particle size entering combustion chamber being reduced, which has strong adaptability and pertinence for MW treatment; secondly, combustible and non-combustible matters can be realized rough separation by this means. A high temperature air pre-heater is adopted to increase wind temperature for fluidization, so it suits to treat MW with low heat value and stabilization of combustion as well as incineration and slag cooling realized in one body. Below the pipes in fluidized bed, the fluidized bed contracts alone downward, where another wind distribution is installed to form a zone of movable bed for cooling under the previous dense phase zone in fluidized bed. The material with high temperature moves downward to outlet to incinerator, meanwhile, wind current blowing upward to cool the material, which has function of slag cooler. After slag being discharged, material of large size is separated by rotary selector, and fine sand is returned to combustion chamber to guarantee the material balance. The external selector of cooling slag generally used by conventional fluidized bed incinerator is removed. So the reliability and stability of operational condition based on the new technology are greatly upgraded.

6.4 The waste heat utilization system

A high temperature preheater has been designed in order to preheat the air which enters into the furnace, so as to reclaim some part of the heat. The high temperature flue gases from CFB are cooled down to 500°C by the air preheater. The generated air with high temperature can be used as pyrolysis gasification air of the rotary kiln, or first air and second air of fluidized bed. High temperature air increases the incineration temperature in the combustion chamber and makes the medical waste to be combusted without auxiliary fuel.

The flue gas exiting from the air preheater is quickly cooled down to 200°C in the quencher. The quencher uses water tubes to realize heat exchange. Gas is flowing outside the tubes while water is flowing inside. There is no direct contact between gas and water which avoids waste water problem and second treatment problem. The residence time of gas inside the quencher is less than 0.5 second which reduces the regeneration of PCDD/F at the low temperature range.

6.5 The flue gas treatment system

The flue gas treatment system (from air preheater outlet to stack inlet) includes flue gas quenching system, flue gas purification system, bag filter dust collector, lime slurry preparation, delivery system and control system, etc.

6.5.1 Flue gas quenching system

In the flue gas quenching flue gas temperature rapidly reduces even below 200°C, and inhibits effectively the PCDD/F regeneration.

6.5.2 Flue gas purification system

The flue gases from flue gas quenching system enter the absorption tower via Venturi pipe located under spray drying desulphurization tower. Screw feeder lied under absorption tower delivers hydrated lime and active carbon to absorption tower for the mixing with flue gas with a very high mass transfer rate. A funnel like absorbent device is used for adding activated carbon to the flue gas to eliminate the PCDD/F. Hydrated lime reacts with the SO2 present in the flue gas, and form CaSO4 and CaSO3. Active carbon can adsorb PCDD/Fs and heavy metals in the flue gas. After primary separating dry reactants from absorption outlet into cyclone separator, these mass enter absorption tower reactor, then come into bag filter dust collector via primary dust precipitator. Fly ash collected in bag filter dust separator is sent to ash combustion furnace.

6.5.3 Dust collection and bottom ash recycling system

The dust collection system is composed by a bag filter. It includes bag-type dust separator, bag-type dust ash hooper and conveying ash apparatus.

The flue gas air system is composed of flue and derivation fan. The actual air capacity of the derivation fan can not be increased too much and it is currently similar to the design value. If the actual air capacities exceed this value, the filtration flow rate of the bag filter system would be excessive, and affected the normal performance of the bag filter system. In this case, the fan valve must be adjusted to adapt the designed air capacity value.

Bag filter system is equipped with preheater cycling system and bypass system in order to prevent dew phenomenon of filter bag surface on the condition of start-up.

More than 99.8% fly ash discharged from incinerator are collected by the bag filter, then emitted via pump to the ash burnt furnace, and melted and solidified together with the first combustion generated slag.

6.6 Combustion system secondary pollutants control

The multi-stage air supplying technology used in this plant, in addition of the low Nitrogen content of the medical waste, can efficiently decrease the NOx concentration in the flue gas.

Heavy metals contained in the waste enter into the furnace chamber and combust with the waste. During the combustion process, different heavy metals can be transformed in two way; most of them are coagulated to the slag or solidified by reacting with sulphur and chlorine; the other part enter into the flue gas as the gas phase metals. Some analyses carried out previously indicate a low concentration emission of these heavy metals. The gas phase metals contained in the flue gases can be adsorbed by the low-temperature basic lime slurry and deposit in the purification tower.

The furnace temperature of the rotary kiln designed in this project is about 850~1200°C, and the flue gas has a 2 second retention time at 1200°C in the second combustion furnace, thus reducing the risk of presence of PCDD/F precursors. Moreover the flue gas quenching tower and the activated carbon absorption device also reduces the PCDD/F formation and emission.

There is a dedicated laboratory for PCDD/PCDF analysis, and the university staff carries out the analysis of the samples taken at the incineration plant.

7. Existed Problems Prior to the Demonstrative Project

1) In original design, activated carbon (AC) and lime were mixed to inject into semi-dry scrubber. The position and mode for AC injection have poor effect on Dioxin adsorption from flue gas. Under the instructions of experts, a retrofitted measure was applied to relocate injecting position of AC in flue gas, and addition of another activated carbon injection device before the bag filter was implemented in order to improve the PCDD/F adsorption efficiency.

2) The glass content in Huzhou MW can be over 27% which goes into bottom slag in a great bulk in fluidized bed incinerator (FBC), which demands to unceasingly separate it out from bottom slag. Up to now, this work is conducted by hand. A mechanical selective facility shall be installed in the bottom of FBC to replace the formal manual way and improve the work efficiency, at same time; the fine particle in bottom slag shall be recycled to FBC.

3) The former quencher was required to improve. The former one consisted of two stages, namely the air pre-heater in high temperature firstly connected with outlet of furnace chamber, and then an indirect water cooler follows up in the quenching system. As indirect cooling mode applied in the both stages, the problem of ash depositing on heating exchange surface is serious, this brought to the poor performance in flue gas cooling. So measures need to apply to retrofit the quenching system to instant cool the high temperature flue gas outlet from second combustion chamber to 200 ℃, so as to avoid formation of Dioxin in low temperature zone.

8. Implementation Plan of BAT/BEP in the Project

8.1 First Round Testing Results

In according to the current operational condition, different sampling position were chosen to measure dioxin concentration under normal work condition prior to the BAT/BEP retrofit project would be implemented. Next implementation plan was then advanced based on the first round *testing results and the suggestions of experts.*

The first round testing results before BAT/BEP retrofit project were shown in table 4. The results indicated the dioxin concentration of flue gas in the points where behind heat exchanger, in front of semi-dry flue gas pipe and the dioxin concentration of fly ash were relatively high, which was due to the poor performance of flue gas quencher. It was also relatively high in the sampling position of stack, which was mainly due to the broken of some bag filter and the malfunction of bypass valve, which leads to leakage of flue gas and fly ash. While, the dioxin concentration of bottom slag was relatively low, this proved the excellent performance of fluidized bed incinerator to treat the pyrolysis residual of Rotary Kiln. The Dioxin concentration of fly ash collected from bag filter was 21 ng I-TEQ/g. This makes the fly ash be properly treated as hazardous material.

Table 8-1. First Round Dioxin Testing Results

Huzhou century clean MW treatment center, incinerator(10t/d)	Testing result ng I-TEQ/Nm^3 (flue gas) ng/g (solid)	Flow rate 1 round Nm^3/h
First sampling behind heat exchanger, in front of semi-dry flue gas pipe	130	4365
Second sampling behind heat exchanger, in front of semi-dry flue gas pipe	130	4156
First sampling in Stack	74	6573
Second sampling in Stack	42	3727
Sampling during Startup operation	91	4197
Fly ash	21	24 kg/h
Bottom slag	0.003	100 kg/h
Operating hours (330days, 12 hours/day)	3960	
Feeding rate, kg/h	400	

8.2 Further Improvement of the System

In according to the original BAT/BEP system design of the project and the suggestion from domestic and abroad specialist, a improvement plan for equipment, operation was advanced, which mainly included following aspects:

8.2.1 Add another AC absorber

Add activated carbon adsorption equipment, the system design needs to be further chosen from injection, fixed bed or moving bed. It was planned to install another AC sprayer in flue gas treatment system, the tentative position can be chosen as: middle part of semi-dry absorber or exit of semi-dry absorber.

8.2.2 Storage of residue and fly ash

At the west side of the disposal center, a separated room will be set to store the residue and fly ash.

8.2.3 Equip a bottom residue classified system.

To promote the operating performance, a bottom residue classified system will be constructed at the bottom side of fluidized bed.

8.2.4 Modification of quenching system

To satisfy the request of low temperature testing and disposal of medical waste with high heating value, the quench cooler would be modified to realize the exhaust gas temperature lower than 200℃ when the furnace exit temperature is over 1100℃.

8.2.5 Improvement of bag filter

As the particulate concentration is relatively high at exit of stack, leakage of bag filter was observed in first round testing. The old bag filter was planned to replace by new one to stop leaking. A gas-proof valve was installed in the bypass of bag filter, which can prevent flue gas and fly ash leaking to induced fan then to stack.

8.2.6 System operation, testing and management

To compare and analyze the technical and economical performance for intermittent operation and semi-continuous operation in the following sides: operation performance, emission characteristics, device depreciation and maintenance, especially the increment cost.

Improve the integrated medical waste management system.

To optimize operational condition of the incinerator, the inhibitor based on sulfuric compounds was added to the feed of MW to reduce the dioxin formation.

9. Implementation Situation of the Project

9.1 System Retrofit

In according to the first round testing results and implementation plan for BAT/BEP retrofit, the main modifications carried out in the incinerator were as follows.

1) Two activated carbon injection devices before scrubber and before the bag filter were implemented.

2) At the west side of the disposal center, a separated room will be set to store the residue and fly ash.

3) An automatic device for the separation of glass from bottom slag was added and fine particles of slag were re-circulated in the fluidized bed chamber.

4) The quencher was modified. The old one named primary air pre-heater was removed; the water quenching tower was displaced. Additional injection nozzles for alkaline lime spraying were added as requested.

5) Bag filter are displaced with new ones and should be more frequently cleaned in the service time.

6) Some inhibitors were added into the feeding waste to prevent and decrease the formation of PCDD/Fs during combustion process.

After the modification, Institute for Thermal Power Engineering of Zhejiang University had conducted the experimental tests. The PCDD/Fs emission of stack gas for the modified system reduced greatly. The experimental operation and test concluded operation parameters for low PCDD/Fs emission as the following table showed. In such optimistic operation runs, the feed waste was 350~400kg/h, lime injection 10kg/h, activated carbon injection at mid-scrubber 2kg/h, activated carbon injection at bag house inlet 3kg/h, 32 g/box of inhibitor adding into the feeding waste. The practice had proved that the above operation parameters could make the stack emission controlled to be lower value as 1~10 ng I-TEQ/Nm^3.

Table 9-1. Operation parameters for the incineration system

Temp of kiln outlet ℃	Temp of mid-fluidized bed ℃	Temp of suspension section ℃	Temp of furnace outlet ℃	Temp after quenching tower ℃	Temp of inlet of bag house ℃	Speed of rotary kiln rpm
477	665	1002	921	215	137	0.31
453	670	1023	893	242	160	0.39

10. Second Round Testing Result

The second round test for Dioxin emission was conducted on the retrofitted incinerator of Huzhou century clean treatment centre by National Environmental Analysis Centre. The result shown the reduction rate of Dioxin concentration in flue gas was 90%~97%. It can be concluded that the BAT/BEP retrofit project obtained notable dioxin reduction effect.

Table 10-1. Second Round Dioxin Testing Results

Huzhou century clean MW treatment center, incinerator(10t/d)	Testing result ng I-TEQ/Nm^3 (flue gas) ng/g (solid)	Flow rate 2 round Nm^3/h
First sampling behind heat exchanger, in front of semi-dry flue gas pipe	79	5745
Second sampling behind heat exchanger, in front of semi-dry flue gas pipe	--	
First sampling in Stack	1.9	7042
Second sampling in Stack	4.3	2190
Sampling during Startup	--	
Fly ash	27	
Bottom slag	0.03	
Operating hours (330days, 12 hours/day)	3960	
Feeding rate, kg/h	400	

11. Main Proposals for Dioxin Emission Reduction

11.1 Selection of Incinerator Type

In GUIDE OF BAT AND BEP edited by UNEPA, several types of incinerator are recommended as High temperature pyrolysis furnace, rotary kiln, fixed bed incinerator, fluidized bed incinerator and standard module incinerator and etc. The incinerator applied in the demonstrative project was different with the recommended in the Guide, which combined the advantages of rotary kiln and fluidized bed, i.e. rotary kiln as primary combustion chamber, MW being delivered into chamber to pyrolysis under atmosphere of 400℃～500℃,which produce the combustible gas entering the upper zone in fluidized bed (thin phase zone) to combust, and the pyrolyis product entering the dense phase in low part of fluidized bed to sufficiently combustion, so as the pyrolysis combined with multi-stage combustion system were formed the treatment system. By means of system automatic control, MW can be guaranteed to sufficient combustion.

Details of incinerator technology refer section 1.2 and 1.3 as well.

11.2 Operational Adjustment and Control of Second Pollutants

1) First hand measures to reduce Dioxin formation: to reduce chlorine contained waste; decrease the frequency of startup and shutdown; additional burner need to install in kiln head and middle part of fluidized to guarantee the temperature for pyrolysis and combustion, retention time of flue gas being longer than 2 seconds in dense phase and thick phase in high temperature zone, the temperature of suspension zone over 950 ℃ and the O2 content maintaining around 6%; Adding

few quantity of $CaCO_3$ as bed material to neutralize HCl and some other acid gas produced by combustion as well as inhibits the formation of Dioxins.

2) Addition of some sulfur based inhibitor to MW can effectively inhibit the formation of Dioxins in flue gas. In this project, it was confirmed by pilot experiment that the Dioxin concentration in flue gas can be reduced more than 50% by addition of 32g for each box of MW.

3) The second hand measures for Dioxin reduction included as follows: The flue gas after the second combustion chamber contains much particulates of incomplete combustion. The high temperature cyclone will separate those comparatively bigger particulates and re-circulated into the fluidized bed to re-combustion. Such re-circulation will decrease the amount of products of incomplete combustion in end-pipe flue gas stream, and decrease the load of bag filter. After the high temperature cyclone is the atomizing water spraying quencher, which will quench flue gas from 900℃ or above to 200℃ quickly. Deposited ash in interior surface of heat exchanger needs to be removed frequently. The flue gas after quenching entering semi-dry sprayer tower, AC sprayer and bag filter, by all this means the dioxin emission can be effectively controlled.

11.3 BEP applied in the Project

1) The measure of source segregation for MW was applied, i.e. the MW being contained in specialized MW bag then being stored in specialized container

2) Try to reduce the usage of once using product, so as to minimize the production of MW from source;

3) To train staff with related knowledge, including hazard, classification, code and personnel responsibility, principle of BAT/BEP, assessment of incremental cost and etc.

4) In the place of MW occurring, different featured MW was stored in respective container. And each container would be labeled the characteristic of MW, i.e. infectious or no-infectious MW.

5) There was a fixed place for storage after MW being transported to transfer station, so as to facilitate clean the containers. The staffs who handle MW in charge of collection or storage must wear protective clothes, gloves and shoes.

12. Future strategy for Dioxin Emission Reduction from Medical Waste Incineration

In order to further control Dioxin emission, the new constructed Huzhou hazardous waste treatment centre of second phase will plan to apply the strategy measures as follows:

1) Separate the Chlorine contained waste from waste to reduce the formation from source;

2) Try to decrease the frequency of startup and shutdown to guarantee the combustion stability, so as to inhibit the formation of Dioxin precursors;

3) Deposited ash in interior surface of heat exchanger need to frequently remove to avoid the Dioxin by De novo mechanism;

4) The advanced flue gas control system with high efficiency will be adopted.

5) To develop and apply the dioxin formation inhibitor based on Sulfur or Nitrogen containing compounds with high efficiency to reduce the formation of Dioxin in incineration process.

13. Sum on Testing Results of Dioxin Emission Reduction of Medical Waste Incineration

Table 13-1. Sum on Testing Results of Dioxin Emission Reduction of Medical Waste Incineration

HUZHOU	Concentr. 1 round ngTEQ/Nm^3 ng/g	Flow rate 1 round Nm^3/h	Input/output per year 1 round mg TEQ/year	Concentr. 2 round ngTEQ/Nm^3 ng/g	Flow rate 2 round Nm^3/h	Input/output per year 2 round mg TEQ/year
After heat exchanger 1	130.0	4365	2247	79.0	5745	1797.3
After heat exchanger 2	130.0	4156	2140			
Stack 1	74.0	6573	1926	1.9	7042	53.0
Stack 2	42.0	3727	620	4.3	2190	37.3
Stack stop	91.0	4197	1512			
Fly ashes (ng/g)	21.0	24 kg/h	1996	27.0		2566.1
Bottom ashes (ng/g)	0.003	100 kg/h	1.2	0.03		10.7
Operating hours (330days, 12 hours/day)	3960					
Feeding rate kg/h	400					

Table 13-2. Dioxin Emission factor of Medical Waste Incinerator

HUZHOU	Emission factor 1 round	Emission factor 2 round	Emission factors Toolkit		
			Type of plant	Air µg TEQ/T	Residue µg TEQ/T
Stack 1	1216	33	Uncontrolled batch type combustion, no APCDs	40000	200
Stack 2	391	24	Controlled, batch type combustion, no or minimal APCDs	3000	20
Stack stop	955		Controlled, batch type combustion, good	525	920

			APCDs		
Fly ashes	1260	1620	High technology, continuous controlled combustion, sophisticated APCDs	1	150
Bottom Ashes	0.8	6.8			

14. Cost-effectiveness analysis

The effectiveness of a technological improvement consists in the reduction (or increase) of the emission rate of the pollutants or sum of pollutants which the modification is intended for. Effectiveness is usually measured as an annual output reduction, but can also be expressed as emission factor reduction.

It is illustrated as table 9 that incremental cost is computed by base line cost and retrofit cost, at the same time, the incremental effect is computed by baseline emission rate and emission rate after retrofit project being implemented.

Table 14-1. Incremental cost

	Capital cost (RMBs/year)	Operating Cost (RMBs/year)	Benefits (RMBs/year)	Emission rate (mg TEQ/year)
baseline	A	C	E	a
With modifications	B	D	F	b
	Incremental capital cost (RMBs/year)	Incremental operating cost (RMB/year)	Incremental Benefits (RMBs/year)	Incremental effectiveness (mg TEQ/year)
With modifications	IC= B-A	IO=D-C	IB=F-E	IE=b-a

For an economically correct comparison of technology options, the analysis must be incremental. In calculating a cost-effectiveness ratio for a given modification, both the cost and effectiveness are the increments in cost and effectiveness respect to the previous technology option.

Costs are expressed have two components: an initial capital investment, followed by annual operating and maintenance costs. Moreover, savings, avoided costs and revenues must be considered to calculate net annual costs.

A discount rate is required to reflect the effect of timing on the present value of all the costs, benefits and effectiveness. A real discount rate of 10% is normally used. The values derived by discounting are the Present values.

Amortization periods for different technology options are also required and it is generally assumed in a 10-yeard period since all technology options last at least 10 years, and would be likely to be resalable when remaining lifetimes of plants are shorter than this.

Present Value or Discounted Cost (y) = (Undiscounted Cost in year y) / (1 + d)y

Discounted effectiveness (y) = (Undiscounted effectiveness in year y) / (1 + d)y

d= discount rate (10%)

y = project lifetime

Cost data should be calculated and presented as annual costs.

There are two ways of calculating the present values.

The first is to calculate the present value of both total cost streams (investment expenditure plus net operating and maintenance cost) adopting a capital recovery factor. Present Costs of an option is the sum of the streams of discounted costs. The present value of effectiveness is calculated similarly

Approach 1: Total annual cost $=\left[\sum_{y=0}^{n} \frac{IC_y+OC_y}{(1+d)^y}\right]*\left[\frac{d\,(1+d)^n}{(1+d)^n-1}\right]$

The second approach is to annualise the capital cost by using a capital recovery factor, calculating the present value as annual capital (capital cost * capital recovery factor) plus the net annual operating and maintenance cost

Approach 2: Total annual cost $IC_0\left[\frac{d\,(1+d)^n}{(1+d)^n-1}\right]+OC$

Where:
IC: total investment cost
OC: total net operating and maintenance costs
d: discount rate
n: estimated economic lifetime
y=o base year of assessment

The first approach is more widely used because is more flexible and understood and will be used for our evaluation

In our case we have just one baseline and one modified scenario, and not many options to compare. For this reason two main ways can be followed. The first one is to calculate the "incremental" cost/effectiveness ratio for the modified scenario, with respect the total PCDD/F emission in air, and then compare the ratio with the equivalent ratio of the other incineration plant under study in this Project.

Otherwise, as second option, since it is not possible calculate the reduction of PCDD/F from a the previous "without incineration" to the baseline scenario, we can calculate the total annual costs over a period of time both of the baseline scenario and of the modified scenario, and the calculate the annual cost/incremental emission ratio for the two situations.

In the following tables data provided by the plant staff are reported

HUZHOU INCINERATOR

CAPITAL COST

CAPITAL COST **Installation expenditure**	**Baseline scenario**	**With modification scenario****	**Lifetime and period required to install**
Flue Gas Rate (a)	~4000 Nm^3/h	~6000 Nm^3/h	
Waste Incinerated Capacity (kg/h or t/day	**400kg/h**	**400kg/h**	
Process control			
Feeding system	180,000	200,000	
Supply of combustion air	40,000	40,000	
Rotary kiln	800,000	800,000	
Bottom ashes recirculation	40,000	40,000	
After burning chamber	900,000	900,000	
Heat exchanger (boiler)	80,000	40,000	
Quenching	120,000	120,000	
Water supply	80,000	130,000	
Pollution control (main and auxiliary equipment)			
Cyclone	40,000	40,000	
Acid removing tower (semidry scrubber)	250,000	300,000	
adsorber feeder and container	30,000	30,000	
Active Carbon injection devices	80,000	120,000	
Fabric Filter	100,000	100,000	

Instrumentation (fan valves preheater systems and bypass system)	140,000	140,000	
mechanical facility installed in the bottom of FBC to separate glass from bottom ashes	150,000	150,000	
Ash and slag storage room	50,000	60,000	
Stack	**80,000**	**80,000**	
Pipes and installation	**300,000**	**300,000**	
Electrical Supply	**80,000**	**80,000**	
Platform and Stairs	**250,000**	**250,000**	
Oil supply system	**40,000**	**40,000**	
Contingency allowance (unexpected costs)	100,000	100,000	
TOTAL CAPITAL COST*	3,930,000	4,060,000	

*The management fee, tax and patent cost are not included.

**The data in with modificaiton scenario column are the real cost of equipment with modification. If the equipment were canceled or changed, the former one is not calculated.

CAPITAL COST Installation expenditure	Baseline scenario	With modification scenario*
Management fee and Tax	200,000	200,000
Patent cost	1,000,000	1,000,000

OPERATING AND MAINTENANCE COST

Annual Operating and maintenance Cost	**Baseline scenario**	**With modification scenario**	**Modification**
Energy costs			
Electricity (unit price and overall cost)	0.6 140,000	0.6 120,000	Prolong the period of continuous operation
Fuel consumption	40,000	35,000	Prolong the period of continuous operation
Water consumption	1,800	3,200	----------

Rotary kiln			
Maintenance	30,000	30,000	
Bottom ashes disposal or recirculation (indicate average vs disposal)	470,000	470,000	Recirculation in the second chamber
Slags disposal in landfill			Increase due to Prolonged period of continuous operation
After burning chamber (FBC)			
Cost of sand	4,000	4,000	
Cost of oil	20,000	15,000	Optimization of secondary chamber temperatures
Cost of additives Calcium oxide	8,000	4,000	Addition of additives in the combustion furnace to reduce acids
Heat exchanger			
cleaning the heat exchanger pipelines	5,000	6,000	cleaning more frequently
Water consumption for steam production	-	-	-
Acid removing tower (semidry scrubber)			
Cost of adsorber consumption	72,000	7,2000	Variation in the amount of lime
Maintenance of spray dryers	3,000	8,000	Addition of more spray nozzles
Active carbon consumption	80,000	100,000	
Fabric Filter			
Cost of bags replacement or cleaning	30,000	40,000	
Fly ashes disposal costs	95,000	95,000	increase in fly ashes production
Active carbon consumption	-	40,000	Addition of carbon injection
Stack			
maintenance	2000	2000	
Labour			
(man-hours)	7200 hours	6400 hours	More or less staff

	Two persons 24,000(RMB)	Two persons 24,000(RMB)	due to increased automation
Total OPERATING AND MAINTENANCE COST	1,024,800	1,069,700	

BENEFITS

BENEFITS	**Baseline scenario**	**With modification scenario**	**Modification**
Revenues	6,000,000	6,000,000	
use of steam	-	-	Improvement process can reduce energy costs
Taxes paid for disposal	-	-	Change in the waste amount
Recover of materials (glass or metals)	-	--	
Avoided Costs	-	-	
Saving of energy use or fuel consumption	55,000	60,000	
Saving of maintenance	77,000	67,000	
Saving on disposal costs	-	-	Solid residue Storage room
Saving on capital due to improved efficiency of the plant	120,000	150,000	
Saving on Man-hours	64,00 hours	72,00 hours	
Total Benefits	6,255,000	6,277,000	

INCREMENTAL COST/EFFECTIVENESS EVALUATION

	Capital cost CC (RMB/year)	**Operating Cost OC (RMB/year)**	**Benefits B (RMBs/year)**	**Emission rate in air (mg TEQ/year)**
baseline	**A**	**C**	**E**	**1926**
With modifications	**B**	**D**	**F**	**53**
	Incremental capital cost	**Incremental operating cost**	**Incremental Benefits**	**Incremental effectiveness**

	(RMB/year)	(RMB/year)	(RMB/year)	(mg TEQ/year)
With modifications	IC= A-B	IO=D-C	IB=F-E	IE=a-b **1873**

Year	**Incremental Cost stream** (RMB) IC+(IO-IB)	**Incremental Discounted cost stream** (RMB) $[IC+(IO-IB)]/(1+d)^y$	**Effectiveness** (mg TEQ)	**Discounted effectiveness** (mg TEQ) $IE/(1+d)^y$
0	151,400	151400	1873	1873
1	21,400	19454.55	170.27	1702.73
2	21,400	17685.95	154.79	1547.93
3	21,400	16078.14	140.72	1407.21
4	21,400	14616.49	127.93	1279.28
5	21,400	13287.72	116.30	1162.99
6	21,400	12079.74	105.73	1057.26
7	21,400	10981.58	96.11	961.15
8	21,400	9983.26	87.38	873.77
9	21,400	9075.69	79.43	794.33
Present value SUM Σ	**344,000**	**274,643**	**2,952**	**12,660**
Present value*capital recovery factor $\Sigma^* \frac{d(1+d)^n}{(1+d)^n-1}$	-	-	-	-
Cost/effectiveness ratio discounted RMB/mg TEQ reduced	Sum of discounted cost stream / sum of discounted effectiveness 21.69			

COST/EMISSION EVALUATION

	BASELINE SCENARIO		MODIFIED SCENARIO	
Year	**Discounted cost stream** (RMB) $[CC+(OC-B)]/(1+d)^y$	**Discounted emission** (mg TEQ) $IE/(1+d)^y$	**Discounted cost stream** (RMB) $[CC+(OC-B)]/(1+d)^y$	**Discounted emission** (mg TEQ) $E/(1+d)^y$
0		1926		53
1	19454.55	1751	19454.55	48
2	17685.95	1592	17685.95	44

3	16078.14	1447	16078.14	40
4	14616.49	1315	14616.49	36
5	13287.72	1196	13287.72	33
6	12079.74	1087	12079.74	30
7	10981.58	988	10981.58	27
8	9983.26	898	9983.26	25
9	9075.69	817	9075.69	22
Present value SUM Σ	123243.11	11091.88	123243.11	305.23
Present value* capital recovery factor $\Sigma * \frac{d(1+d)^n}{(1+d)^n-1}$	-	-	-	-
Cost/emission ratio RMB/mg TEQ emitted	11.11		403.77	

Strategies to Reduce Unintentional Production of POPs in China: BAT, BEP and Incremental Costs for Selected Sectors of Industry

Case Study Report on the Demonstration Project “Controlling and Prohibiting POPs Unintentional Production” in *Jinan Hanyang Solid Waste Disposal Co., Ltd*

Submitted to
Foreign Economic Cooperation Office
State Environmental Protection Administration, China
Jinan Hanyang Solid Waste Disposal Co., Ltd

CONTENTS

1.ITEM NAME

Item Name: Reduce the discharge Tactic of the Sino-Italian Cooperation Program about Persistence Organic Pollutants Discharged Unconsciously in China: The Best Viable Technology, Best Environmental Practice and the Increment Cost Estimation in Experimental Industry(TF/ CPR/03/006)

Item Source: External Cooperation Center About Environmental Protection in State Environmental Protection Administration of China.

2.DESCRIPTION OF THE ENTERPRISE (history of development, organization, employees and expansion plan)

Jinan Hanyang Solid Waste Disposal Co., Ltd. established in May 2003, registering capital 12,000,000 yuan (RMB). It there are 40 professional staffs, including 3 senior engineers and 4 engineers.

The enterprise has been engaged in centralized disposal of medical waste. It obtained Shandong provincial license for the operation of hazardous waste in December 2003. Its average daily disposal capacity is eight tons (12 hours operation).The biggest daily disposal capacity is 24 tons(24 hours circulate).The year disposal capacity is about 3000 tons. It can basically ensure the safe disposal of all the medical waste in Jinan.

In recent years the enterprise has concentrated the efforts on medical treatment about safe-high performance disposal and standardized management. Moreover, we have improved on many devices, obtaining good effects and society benefits. The enterprise is also appraised to demonstrate corporation by Shandong environmental protection administration.

3.PLANT DESCRIPTION

The description of plant is shown in the table 3-1:

Table 3-1 **Plant description**

Type of Plant	**Municipal solid waste**	[ ]
	Industrial waste	[ ]
	Hospital waste	[√]
	Light shredder	[ ]
	Sewage sludge	[ ]
	Waste wood and waste biomass	[ ]
	Animal carcasses	[ ]
Name of Plant	**Jinan Hanyang Solid Waste Disposal Co., Ltd**	
Location (City/Province)	**Jinan/Shandong**	
Address	**Hehua Road No.1, Licheng District of Jinan**	
Contact (Name, position, phone and fax numbers, e-mail)	**Jianguo Zhang、 Zhenhua Guo** **Jiaheng Bisiness Building B#1404, Hualong Road No.1825** **（0531） 88914138 （0531） 88916387** **Jianguo-zhang @126.com**	
Number of Furnaces	**1**	
Type of Operation	**Batch (*e.g.*, 100 kg per batch)**	[ ]
	Semi-continuous (*e.g.*, 8 hours per day)	**8-10 h/d**
	Continuous (24 hours per day)	[ ]
Annual Operation/Capacity (total)	**t/h (tons per hour)**	**1**
	h/d (hours per day)	------
	d/w (days per week)	-------
	t/d (tons per day)	**24**
	d/a (days per year)	------
	h/a (hours per year)	------
	t/a (tons per year)	-------
Type of Furnace	**Mass burn waterwall (grate)**	**vertical revolving** pyrogenation **chamber**
	Fluidized bed	
	Stoker	
	Rotary kiln	
	Other (please specify)	
Temperature in fornace	**Main furnace (°C)**	**Exit of first chamber 800-950 °C**
	Afterburner/second chamber (°C)	**1000-1200 °C**
Type of Air Pollution Control System (APCS)	**Electrostatic precipitator**	[ ]
	Cyclone	[ ]
	Bag filter	[√]
	Wet scrubber	[ ]

	Semi-Dry scrubber	[√]
	Lime injection	[ ]
	NaOH/alkali injection	[√]
	Active carbon/coke injection	[ ]
	Active carbon filter	[√]
	Catalytic converter (SCR)	[ ]
	Induced or forced draft fan	[ ]
	Other (please specify)	
	None	[ ]
Heat Recovery System	**Yes [√]**	**No [X]**
		At exit from APCS (if available)
Height of the stack	**(m)**	**35**
Diameter of the stack	**(m)**	**800mm**
Position of sampling port	**(m)**	**About 4m from the ground**
Flux of Off Gases	**(m^3/h) (dry gas)**	**About 6500m^3/h**
Temperature of Off gases	**(°C).**	**140℃**
Oxygen	**%**	**13**
Particulate matter	**(mg/Nm^3)**	**52.1**
Acids	**(mg/Nm^3)**	
Carbon monoxide CO	**(mg/Nm^3)**	**62（80)**
Sulfur dioxide SO_2	**(mg/Nm^3)**	**24（300)**
Nitroges oxides NO	**(mg/Nm^3)**	**169（500)**
Others (if available)		

Residues		**Disposal of these Residues**	
Generation of Bottom Ashes	**t/a [ ]**	**Recirculation [ ]**	**Landfill [√]**
Generation of Fly Ashes	**t/a [ ]**	**Recirculation [ ]**	**Landfill [√]**
Generation of (Waste)Water	**t/a [ ]**	**Disposal [√]**	
Generation of Sludges (as dry) (matter)	**t/a [ ]**	**Recirculation [ ]**	**Landfill [√]**

4.PROCESS DESCRIPTION AND PROCESS PARAMETERS (with flow charts)

- **Project technology description**

The type of furnace is vertical revolving pyrogenation chamber.The hospital waste incineration is composed of five systems,which are the feeding system,waste combustion,flue gas treatment,control system and assistant system.

Feeding system,constituted by a storehouse system for the storage and a hopper charge and an airproof system in front of the furnace.Waste combustion,constituted by a main furnace and a secend chamber and a system to extract slages and a control system.Gas treament,constituted by a heat exchanger(quencher) and an acid removing tower and a bag filter.

The main flow about the hospital waste incineration(reported by the figure 4-1) is listed simply as follows:

Medical waste is fed by feeding system into the main chamber through the top of the furnace. Going with heating, drying, gasifying and burning, waste moves from top to bottom in the furnace.The temperature of discharging fume is about 800-900℃.Residue falls from the bottom of the furnace into a residue trolly with water seal and is discharged continually through the system of extracting slages.

Fume, from out the main chamber, goes into the secend chamber to burn fully in a high temperature at 1100℃,and then passes through the heat exchanger where heat is saved and the heat energy changes into steam,whereafter the temperature of fume falls to 350℃.Afterwards, the fume enters into the semidry acid-removing device,counteracted by lye and then goes into bag filter to be purified,passes through the forced draft fan,and finally, joins to atmosphere by the stack.

In the flow, hospital waste is set on fire and gasified.And fume goes into air endly after removing harmful ingredients such as dioxin, HCl, HF, CO, NO_2, NO, $S0_2$ and dust. A tiny amount of solid residues and fly ashes is directed to the landfill.

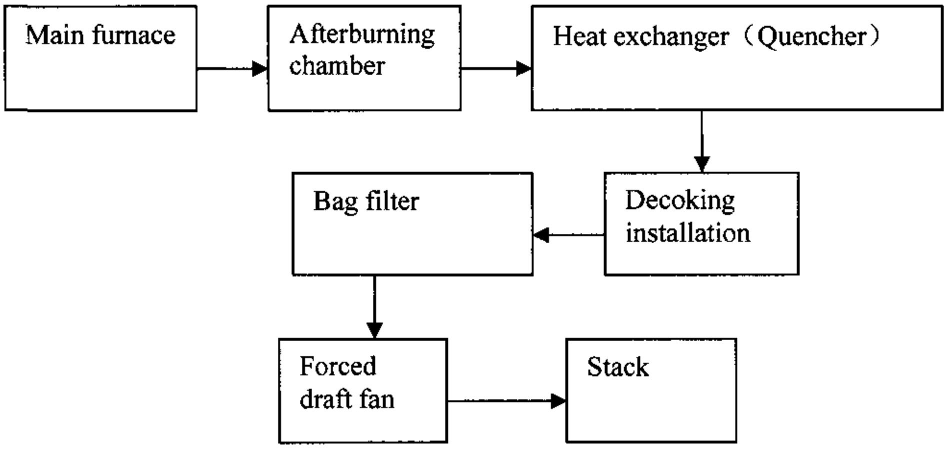


Figure 4-1 Process description

The detail information for the technology and plant is reported in the table 4-1：

Table 4-1 The specifications of 24 t/d medical waste incinerator

Item	Unit
The capacity of incinerator	1000Kg/h (24ton/day)
Heating value of medical waste	6974 kJ/Kcal (1427Kcal/kg)
The exit temperature of incinerator	≥ 1000°C
The gas residence time in secondary furnace	≥ 2.0 sec.
The incineration efficiency	≥ 99.9%
The reduce efficiency of the organic pollutants	≥ 99.99%
The unborn material rate of the incineration residue	< 3%

Table 4-2 shows the composition of the feeding medical waste.

Table 4-2 Feeding composition of the 24t/d medical waste incinerator

Composition	**Glass**	**Plastics**	**Cotton**	**Paper**	**Water**	**Other**
Percentage/%	12	30	18	10	15	15
Low Heating Value/ kJ/kg	8000-15000					

- **Hospital waste storehouse and feeding system**

Hospital waste is removed directly to waste storehouse from special trucks, pushed into the place for feeding by workers,and sent into a lift system,which lifts hospital waste to the feeding storehouse.There is an automatic overturn device before waste dumping into feeding storehouse.And the speed of feeding is controlled by double roller feeder.Transport chests are in support after sterilization in the room.

- **Hospital waste incineration system**

This system is composed of vertical revolving pyrogenation chamber(main chamber),second chamber, auxiliary burner,industry water-cooling device, accidental discharge door, induced and forced draft fan,slag extractor and any other facilities.

(1)Furnace

The type of furnace is vertical revolving pyrolytic chamber,constituted by main chamber and second chanmber.Main chamber includes a kiln body and a revolve grate.In the main chamber,waste comes through a process of oxygen deficiency,causes pyrolysis,and brings solid slags and combustible gases. The slags are separated to the bottom of the furnace.The gases are heated up to a high temperature and orgnic compounds among them are burned down in the second chamber.

(2)Others

The incineration system starts with the light diesel fuel No.0. In the secend chamber there are two imported oil burning units which the rated consumption of soil is 0-100kg per hour and the light diesel fuel No.0 is used for start-up.Burner is provided with functions of flame monitoring and protection.PLC can connect with DCS to realize long-distance auto control. The oil burning units turn on automatically when the temperature in the furnace becomes lower than designation;Contrarily, when the temperature grows exceed the design,the burns will close down.The secend chamber's temperature maintains above 1100℃.

If the pressure with the second chamber exceeds 5000Pa when device that heat exchanger, acid removing tower or induuced-draft fan appears trouble,or the temperature on the inlet of bag filter grows above 200℃,the discharge valve on the front part of second chamber will open automatically in condition impossible to recover 5 minutes later by long-distance control to reach replacement.Taphole of first chamber is sealed by water.Clinker discharged goes water-seal to cool quickly if temperature appropriate, and later it can be quenched in water.So there will not come into large piece of slag.Taphole machine transports slag by link plates,which is non-standard design with the power 4.5 kw.It discharges slags 125-200kg per hour and has rated output 1t per hour.At last,slages are transported to landfill by special truck to fill after solidify.

- **Waste heat callback system(quencher)**

Heat exchanger adopts the fashion of indirect heating,which main function is to carry out fume cooling quickly,secondly callback heat from the fume.The presence of fast-cooling mostly avoid dioxion creating again under some conditions.

The system takes an indirectly method of cooling.Cooling water is made use of lowering the temperature of fume and supplying steam for production and living.In the process,fume is cooled down from 1000°C to350°C,then enters into the flue gas treatment system.

- **The flue gas treatment system**

The flue gas treatment system includes scrubber with NaOH liquor(acid removing tower),bag filter and so on.These equipments are listed as follows:

(1)Acid removing tower

The system of acid removing adopts semi-dry technology.In the entrance of the spray drying tower, fume is sprinkled by alkaline water spray that comes from lye preparation equipment and its temperature is lowered.Acid gas in the fume meets atomization lye, has a chemical reaction in order to get rid of acid gas.

(2) Bag filter

At the present time, bag filter is a proven product at home.The bag filter has filtrat area about 150 centiare.Bags are made from PPS material and the keel is made from common carbon steel.It adopts the manner of compress gas and high-handed impulse to clear ash.

The technical schematic diagram of 24 tons/day medical waste incinerator is shown in Figure 4-2:

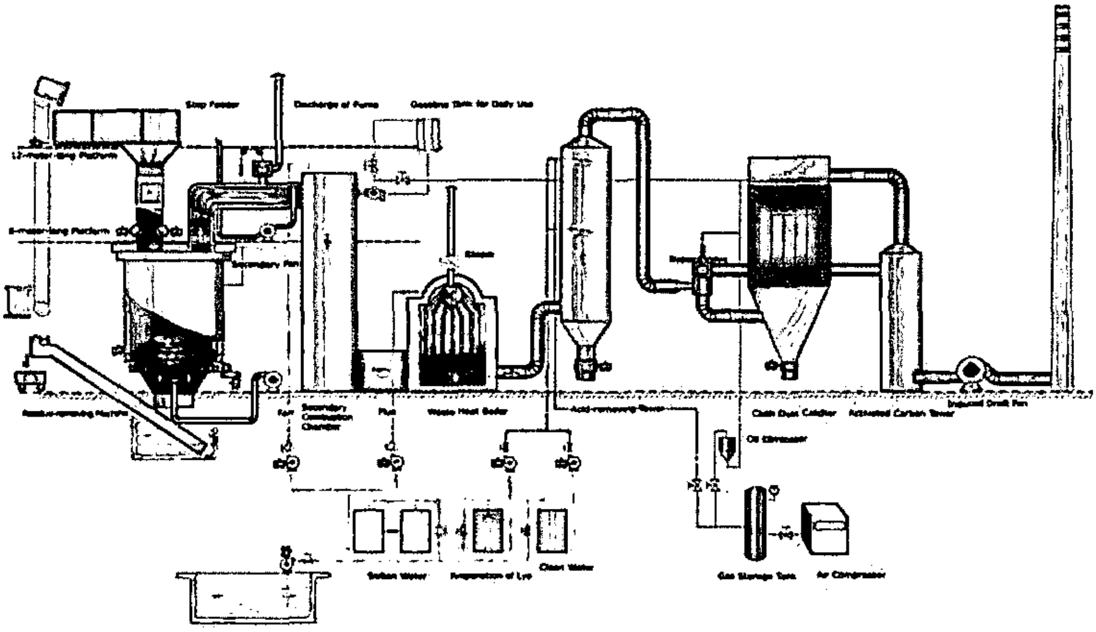


Figure 4-2 Schematic of the vertical revolving pyrogenation chamber incineration technology

5. Choice of BAT implemented (description of the new devices and change in process)

Dioxin is formed during the combustion process when HCl and O_2 react with the pre-substances produced during the combustion of volatilized hydrocarbon substances of low boiling point in *insufficient* oxygen.

Dioxin is formed after combustion when the pre-substances, which are products of incomplete combustion, chloride and oxygen is catalyzed by Cu, Ni, Fe contained in the fume at a temperature of approximately 300 °C. Dioxin is formed because of unsatisfactory treatment of fume.

The actual disposal capacity fails to meet the designed capacity, leading to the daily operation of only about ten hours and more than twelve idle hours. Frequent start-up and close-down of the furnace give rise to operation difficulty and increase of equipment maintenance load. During the start-up and close-down of the furnace, unstable combustion situation and failure to meet the designed combustion conditions lead to the formation of significant amount of dioxin.

The major problem of this combustion system lies in the unsatisfactory effect of the splat cooling step. It takes three to four seconds for the temperature of the fume to drop from 600°C to 200 °C after waste heat boiler absorbs the heat in the high-temperature area of the fume, resulting in the re-composition of dioxin.

The exceedingly high level of acid in the fume discharged by the combustion system has severely eroded the facilities. The main acid substance contained in the fume is HCL, which is also shown by the high level of chlorine in the fume, constituting the necessary conditions for the formation of dioxin. The problem is caused by the low efficiency of the semidry acid-removing device adopted in the system.

On the basis of the surveillance results and analysis of the current combustion technology, the following scheme is proposed for adoption.

(1) Prolong the period of continuous operation of the combustion system to reduce the frequency of start-up and close-down of the furnace.

(2) Regularly clean the heat exchange pipelines in the waste heat boiler to guarantee the fast-cooling effect.

(3) Reduce the formation of HCl by adding additives in the combustion furnace to resolve the problem of removing the acid substances in the fume.

(4) To add an active carbon absorber in front of the dust remover.

6.IMPLEMENTATION SCHEDULE and PROGRAM ORGANIZATION

The enterprise proposed the following implementation schedule:

Surveillance of dioxin. A surveillance point will be established to monitor dioxin in accordance with the suggestions of foreign and domestic industry experts and the actual conditions of the enterprise.

Implementation Program:

(1) From May to June 2005, the program implementation plan is to be prepared. Surveillance point is to be determined and preparation is to be made for surveillance.

(2) From June to July 2005, surveillance of dioxin is to be implemented and, based on the surveillance results, technical transformation plan is to be proposed and the incremental cost is to be calculated.

(3) In July 2005, the feasibility of the technical transformation plan is to be demonstrated.

(4) From August to October 2005, the reduction and discharge plan is to be implemented. The second test will be made during October to November 2005 after the renovation.

(5) From November to December 2005, the effect of the reduction and discharge plan is to be evaluated and the final report is to be produced.

- **ACTION LIST(in the table 6-1)**

Table 6-1 Action list

Item	Action	Deadline	Status	Notes
	Provide information about the enterprise and primary work plan	June 1, 2005,	OK	
	site training for the project and determination of sampling points	July	OK	
1	First sampling round	September	OK	
2	Implementation of the BATs	October		
3	provide the treatment and operation audit report	November	In progress	
4	Second sampling and testing	November	-----------	Postponed to December

5	Integrated report of the project	March 2006	-----------	

- **Program Organization (managerial, technical and financial personnel, others.)**

For the project well processing, the demonstration enterprise established a work group according to the Sino-Italian project request. The group members and their relation framework are shown in the Figure.

The program organization consists of managerial personnel, technical personnel and financial personnel. Information of the members is listed in the table 6-2:

Table **6-2 Information of the members**

Name	Title	Major Functions
Chengzhi Zhang	Senior Technician	In charge of the overall planning and implementation of the program
Jianguo Zhang	Senior Technician	In charge of the preparation of the implementation plan and the final report of the program
Zhenhua Guo	Senior Technician	In charge of the implementation of surveillance and coordination of production activities of the program
Zhixiang Chi	Senior Technician	Participated in the preparation of the implementation plan and the final report of the program
Baoli Han	Accountant	In Charge of the financial management of the program and the estimation of the incremental cost of technical transformation in the enterprise
Lili Deng	Engineer	Participated in the implementation of surveillance and the preparation of the technical transformation plan
Shiqing Ju	Engineer	Participated in the implementation of surveillance and the preparation of the technical transformation plan

7. SAMPLING PLAN AND ANALYTICAL RESULTS

In order to adequately evaluate the performance of the implemented BAT/BEP in POPs reduction, some essential positions for gas sampling activities through the technological process closely related to the formation of POPs were chosen as follows(in the figure 7-1), after a discussion with the experts and the plant staff.

- **POPs** SAMPLING **PLAN (description of point and number of samples)**

First campaign:

1 gas sample at the stack during start operation

1 gas sample after the waste heat boiler

1 gas sample after scrubber

1 gas sample after scrubber (before carbon tower)

2 gas samples at the stack

2 ashes (filter fly ashes and slags)

Total: 8 samples (6+2)

Second campaign

1 gas sample after the waste heat boiler (after clean the heater exchanger)

1 gas sample after scrubber (after increase of lime injection)

1 gas sample after scrubber (after adding the new carbon injection device before the filter)

2 gas samples at the stack

2 ashes (filter fly ashes and slags)

Total: 7 samples (5+2)

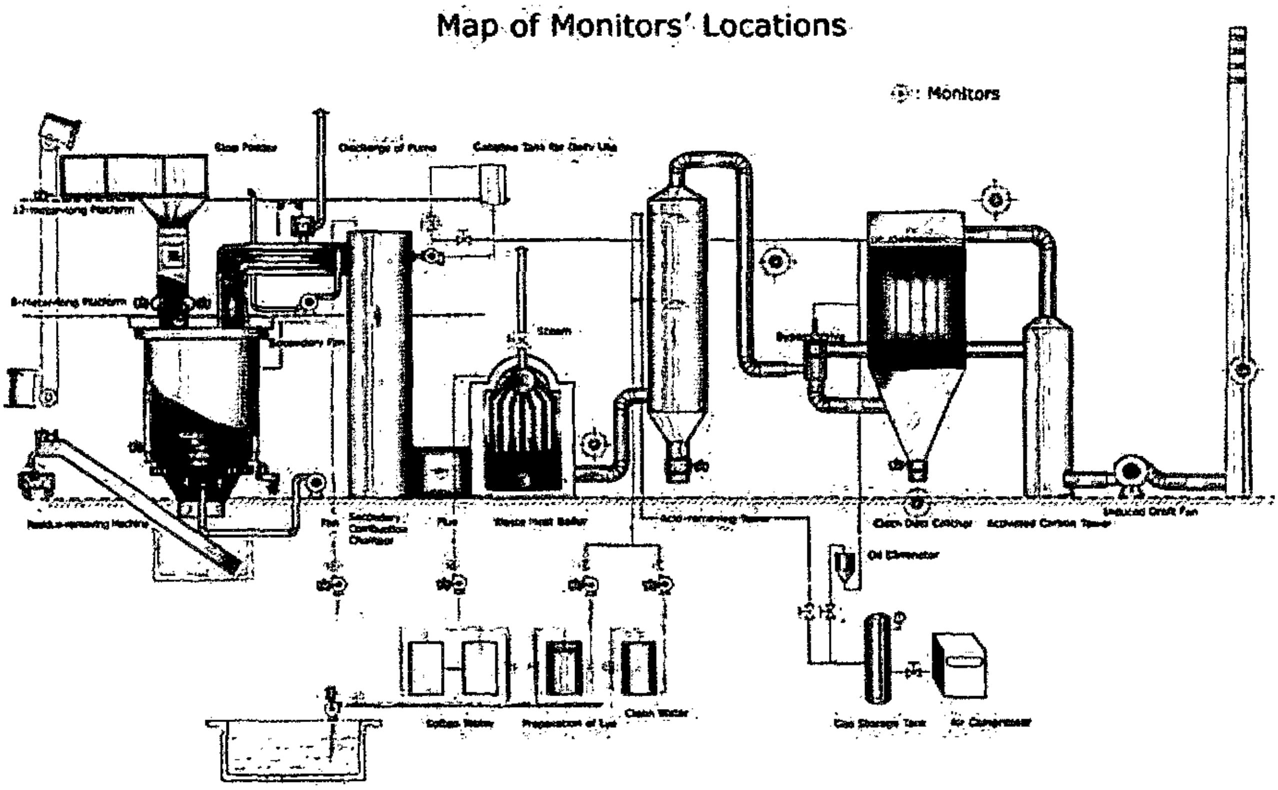


Figure 7-1 Map of monitors' location

The results of the two sampling rounds are provided in the table 7-1 for an easy comparison:

Table 7-1 The results of the two sampling rounds

SAMPLE	CONCENTR. 1 ROUND ngTEQ/Nm^3 (gas) pg TEQ/g (solid)	CONCENTR. 2 ROUND ngTEQ/Nm^3 (gas) pg TEQ/g (solid)	INPUT/OUTPUT PER YEAR 1 ROUND mgTEQ/year	INPUT/OUTPUT PER YEAR 2 ROUND mgTEQ/year
AFTER HEAT EXCHANGER1	18	66		
AFTER HEAT EXCHANGER2	4.0			
AFTER FILTER	26	54		
STACK 1	21	6.2	672	198
STACK 2	12	11.0	48.0	44
STACK START	19		3.8	
FLY ASHES	9.1	11.0	1820	2200
BOTTOM ASHES	0.2	1.2	160	960

STACK MASS FLOW RATE m^3/h	8000			
FEEDING RATE Kg/h	1000			
FLY ASHES PRODUCTION RATE Kg/H				
SLAGS PRODUCTION RATE Kg/h				

•Observation analysis

According to the observations after the improvements of the system, dioxins' concentration in the flue gas emissions behind the waste heat boiler is not reduced but increased, which shows that there is of no effect on the waste heat boiler adopted simple measures. It is difficult to carry into effect unless great improvements.

From the test data behind the bag filter, the concentration of dioxins is reduced in a degree, but not very obvious. More tests and improvements should be done on the active carbon injection device.

From the test data at the stack, the test results for the second time is better than the first time. And the adsorption in the active carbon tower is very good, which says that the tower can bring into play well if management can develop the bigger function. It should be affirmed.

8.COMMENTS ON THE EFFECTIVENESS OF THE IMPLEMENTED BAT

- **Process control**

(1)Because the actual capacity of medical waste produced deeply fails to meet the designed disposal capacity, we try to prolong the period of continuous operation of the combustion system to reduce the frequency of start-up and close-down of the furnace, to reduce the amount of dioxin.

(2)Strengthen operating management to keep the temperature of the combustion furnace and the stationary period of the fume to meet the technical specification requested.

(3)Regularly clean the heat exchange pipelines in the waste heat boiler to guarantee the effect of the heat transfer surface and to make the fume fast-cooling.

- **Pollution control**

(1) The maintenance of the acid removing tower: regularly replace spray nozzles, ensuring the lye having a good effect to be fog and ensuring the effect of acid removing and fume cooling.
(2)Install an active carbon injection device before the bag filter, making the best of the percolation and adsorption of the bags, and adsorbing harmful materials in the fume most possibly.
(3)Change bags in the bag filter more frequently to guarantee the filter to remove dust better.
(4)Change the steel stack to be glass fiber reinforced plastic stack, having solved the problems of corrosion for stack, and making the system move steadily. According to the request, test hole and test desk have also been installed.
(5)Replace the carbon material in the carbon tower more frequently to guarantee the efficiency of adsorption.

9. COST-EFFECTIVENESS ANALYSIS

- **Analysis of cost increased**

As a result of some measures adopted, costs related also change, which is shown as follow:
(1)That prolonging the period of continuous operation increases electric charge, however, temperature of the furnace lowers small and the fuel consumption cuts down.
(2)Cleaning the waste heat boiler more frequently increases costs.
(3)Increase the maintenance of the acid removing tower and the times of replacing spray nozzles, increasing costs.
(4)Install an active carbon injection device and replace the carbon material in the carbon tower more frequently, increasing costs.
(5)Change bags in the bag filter more frequently, increasing costs.
The capital cost is reported in the table 9-1. The operation and maintenance cost is reported in the table 9-2 and the benefits saved is reported in the table 9-3.

- **Analysis of effectiveness increased**

The effectiveness of a technological improvement consists in the reduction (or increase) of the emission rate of the pollutants or sum of pollutants which the modification is intended for. Effectiveness is usually measured as an annual reduction with the output, but can also be expressed as emission factor reduction.

For an economically correct comparison of technology options, the analysis must be incremental. In calculating a cost-effectiveness ratio for a given modification, both the cost and effectiveness are the increments in cost and effectiveness respect to the previous technology option.

When making cost comparison between pollution abatement devices it is important that all raw data are expressed on an equivalent price basis (the price of the baseline year)

A procedure for this is using a price adjuster, derived from appropriate price indexes

(Price adjuster= price index for the base year/price index for the year to which the cost data pertains)

(Adjusted cost data=original cost data * price adjuster)

European price indexes are available

The same procedure must be followed in order to consider inflation and appropriate price deflator indexes can be used.

Costs are expressed have two components: an initial capital investment, followed by annual operating and maintenance costs. Moreover, savings, avoided costs and revenues must be considered to calculate net annual costs.

A discount rate is required to reflect the effect of timing on the present value of all the costs, benefits and effectiveness. A real discount rate of 10% is normally used.

The values derived by discounting are the Present values

Amortisation periods for different technology options are also required and it is generally assumed in a 10-yeard period since all technology options last at least 10 years, and would be likely to be resalable when remaining lifetimes of plants are shorter than this

Present Value or Discounted Cost (y) = (Undiscounted Cost in year y) / $(1 + d)^y$

Discounted effectiveness (y) = (Undiscounted effectiveness in year y) / $(1 + d)^y$

d= discount rate (10%)

y = project lifetime

Cost data should be calculated and presented as annual costs.

There are two ways of calculating the present values

The first is to calculate the present value of both total cost streams (investment expenditure plus net operating and maintenance cost) adopting a capital recovery factor. Present Costs of an option is the sum of the streams of discounted costs. The present value of effectiveness is calculated similarly

$$\text{Approach 1: Total annual cost} =\left[\sum_{y=o}^{n} \frac{(IC_y+OC_y)}{(1+d)^y} \right]*\left[\frac{d\,(1+d)^n}{(1+d)^n-1} \right]$$

The second approach is to annualise the capital cost by using a capital recovery factor, calculating the present value as annual capital (capital cost * capital recovery factor) plus the net annual operating and maintenance cost

$$\text{Approach 2: Total annual cost } IC_0 \left[\frac{d\,(1+d)^n}{(1+d)^n-1} \right] + OC$$

Where:

IC: total investment cost

OC: total net operating and maintenance costs

d: discount rate

n: estimated economic lifetime

y=o base year of assesment

The first approach is more widely used because is more flexible and understood.

The increased capital cost a year is reported in the table 9-4 and the calculation about cost-effectiveness is reported in the Table 9-5.

Table **9-1 Capital cost**

CAPITAL COST Installation expenditure	**Baseline scenario**	**With modification scenario**	**Modification**	**Lifetime and period required to install**
Flue Gas Rate				
Waste Incinerated Capacity (kg/h or t/day			500 kg/h	
		Process control		
Feeding system				160000

				yuan(RMB)
Supply of combustion air				50000 yuan(RMB)
Vertical Rotary kiln			Optimization of process and temperatures	3950000 yuan(RMB)
After burning chamber				2860000 yuan(RMB)
Heat exchanger			replacement of pipelines	680000 yuan(RMB)
Water supply				310000 yuan(RMB)
Pollution control (main and auxiliary equipment)				
Acid removing tower (semidry scrubber)			Installation of more spray nozzles	
adsorber feeder and container				
Active Carbon injection device		Increase 13000 yuan(RMB)	Installation of carbon injection before filter	
Bag Filter			optimization of temperatures, more frequent cleaning of bags	20000 yuan(RMB)
Carbon tower			Replacement of charcoal	8000 yuan(RMB)
Instrumentation (fan valves, preheater systems and bypass system)				
Monitoring System				
Stack		Increase 12300 yuan(RMB)	replacement	3 year
Monitoring device between afterburning chamber and heat exchanger				
Contingency allowance (unintentional costs)		Increase 45000 yuan(RMB)		
TOTAL CAPITAL COST		Increase 181300 yuan(RMB)		

Table **9-2 Operating and maintenance cost**

ANNUAL OPERATING AND MAINTENANCE COST	**Baseline scenario**	**With modification scenario**	**Modification**
Energy costs			
Electricity (unit price and overall cost)		Increase 30000 yuan(RMB)	Prolong the period of continuous operation
Fuel consumption		Decrease 24000 yuan(RMB)	Prolong the period of continuous operation
Vertical Rotary kiln			
Maintenance			
Cost of alkaline additives			Addition of alkaline additives to reduce acids was scheduled
Slags disposal device			
Slags disposal in landfill			
After burning chamber			
Cost of maintenance			More frequent maintenance
Heat exchanger			
Cleaning of the heat exchange pipelines		Increase 4000 yuan(RMB)	More frequent maintenance
Water consumption for steam production			
Acid removing tower (scrubber)			
Cost of adsorber		Increase 27000 yuan(RMB)	Variation in the amount of lime
Maintenance of spray dryers		Increase 3000 yuan(RMB)	Addition of more spray nozzles
Fabric Filter			
Fly ashes disposal costs (indicate the average of disposal and recirculation)			increase in fly ashes production
Active carbon consumption		Increase 55200 yuan(RMB)	Addition of carbon injection

Cost of bags replacement		Increase 15000 yuan(RMB)	
Carbon tower			
Cost of charcoal material		Increase 19000 yuan(RMB)	More frequent replacement of carbon material
Stack			
maintenance)			
Labour			
man-hours		Increase 54000 yuan(RMB)	Variation in staff due to automation
TOTAL OPERATING AND MAINTENANCE COST		Increase 183200 yuan(RMB)	

Table 9-3 **Benifits saved**

BENEFITS	**Baseline scenario**	**With modification scenario**	**Modification**
Revenues			
Sale of electricity or use of steam			
Sale of ashes			Increased performance of bag filter
Sale of slags			Improved pyrolysis process
Fees receive for waste incineration from hospital and clinics			Increase in the waste disposed of
Use of steam for heating staff offices			
Recover of materials (glass or metals)			
Avoided Costs			
Saving of energy use or fuel consumption			
Saving of maintenance			
Saving on disposal costs			
Saving on capital due to improved efficiency of the plant			
Saving on Man-hours			

TOTAL BENEFITS			

Table **9-4 Increased capital cost a year**

	Capital cost (RMBs/year)	**Operating Cost (RMBs/year)**	**Benefits (RMBs/year)**	**Emission rate (mg TEQ/year)**
baseline	**A**	**C**	**E**	**a**
With modifications	**B**	**D**	**F**	**b**
	Incremental capital cost (RMBs/year)	**Incremental operating cost (RMB/year)**	**Incremental Benefits (RMBs/year)**	**Incremental effectiveness (mg TEQ/year)**
With modifications	IC= A-B 182300 yuan	IO=D-C 183200	IB=F-E	IE=b-a 239

Table **9-5 The calculation about cost-effectiveness**

Year	**Incremental Cost stream** (RMB)	**Incremental Discounted cost stream** (RMB)	**Effectiveness** (mg TEQ)	**Discounted effectiveness** (mg TEQ)
0	IC+(IO-IB) 364500	$[IC+(IO-IB)]/(1+d)^y$ 140700	IE 239	$IE/(1+d)^y$
1	IO-IB 183200	$(IO-IB)]/(1+d)^y$ 78000	IE 239	
2	IO-IB 183200		IE 239	
---------	---------	---------	---------	---------
9	IO-IB 183200		IE 239	
Present value Annual cost		$\Sigma^* \frac{d(1+d)^n}{(1+d)^n-1}$ 194900(Annual cost) 1196600(Present value)		$\Sigma\, IE/(1+d)^y$ 1470 (Present value)
Cost/effectiveness ratio discounted RMB/mg TEQ reduced	Sum of discounted cost stream / sum of discounted effectiveness 1196600/1470=814			

Since we have just one modification scenario, I think that we can calculate the cost/effectiveness ratio for the baseline scenario only considering not-discounted sum (for 10 years) of pre-modification emissions. So if the baseline scenario was 100 ng/Nm^3 of PCDD/F, we can assume 100*10=1000 ng/Nm^3 as the total emission in ten years. On the contrary as far as the costs of baseline are concerned, we can follow the same procedure described for the modified scenario.

Otherwise we should limit to consider only the incremental costs.

10. Improvement suggestions in the future

Seeing from the observation analysis, it still has a certain distance for the total emission of pollutants to meet the demands. We should make some further work improve the splat cooling step (the waste heat boiler).Because the cooling time of the waste heat boiler can not reach the request in the technical specification, the waste boiler should be changed. It needs large funds and long time to change the waste boiler, and the company has no enough money to carry on replace currently. Further more, it is a long time to replace it and must have a bad effect on disposing medical waste, therefore, it need wait for a fit opportune moment to do that. If the Sino-Italian Cooperation Program for Environmental Protection goes on providing funds help, we will do our best to replace the waste boiler.

If we want to have a good effect and do the BAT/BEP action plan well, we should replace all parts of gas treatment and perfect the systerm with combined investment hitting 20 million yuan. In a word, we have obtained some methods and experiences from this cooperation. We will go on making a search for better and more advanced method to acquire greater success.

Strategies to Reduce Unintentional Production of POPs in China: BAT, BEP and Incremental Costs for Selected Sectors of Industry

Case Study Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in Tiger Forest & Paper Group

Submitted to
Foreign Economic Cooperation Office
State Environmental Protection Administration, China

泰格林纸
TIGER FOREST & PAPER GROUP CO.,LTD

Contents

Case Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in Tiger Forest & Paper Group

1. Background

Persistent Organic Pollutants (POPs) are synthetical chemical substances that persist in the environment and pose adverse effects to human health. These substances may cause endocrine disordered, damage to the recreation and immunology system, and even lead to cancer and neurosystem disease. *The Stockholm Convention* was signed by Chinese government at the conference of Plenipotentiaries on May 23, 2001 and taken affect in China on November 11, 2004. In order to implement the obligations in the convention, China is taking active part in the implementation of POPs program in nationwide with the subsidy from Italian Ministry of Environment and Territory (IMET) through China-Italy cooperation office.

Of the 12 Priority POPs addressed in the global treaty, 9 POPs (DDT, hexachlorobenzene, etc.) are from organochlorine pesticides; polychlorinated biphenyl from industrial chemical; main byproducts from pulp and paper industry are dioxins and furans.

On January 17-18, 2005, POPs Convention Implementation Office of State Environmental Protection Administration held a seminar on reducing POPs (Dioxins) emission in Beijing. Since Tiger Forest & Paper Group takes priority in production scale and encompasses a variety of pulping lines (chlorine bleaching reed/wood pulp line), it was recommended by China Paper Association as one of the four candidates in paper industry, and attended this seminar. On this seminar, Mr. Guo Yongwei, the vice chief engineer from Tiger Forest & Paper Group, gave a presentation about the group's environment protection and possible sources of POPs. The group's top management shows great interests to this programme, and have a common understanding that the group would set a good example in China paper industry if applying the BAT/BEP project, and sincerely hope to get the instructions and supports from the experts in this area. On January 30, 2005, the group delivered *a letter of intent to participate in BAT/BEP project.*

The convention implementation office invited candidate enterprises and related experts to Beijing on March 1-3, 2005, for a meeting, the topic of which is to share the experiences and techniques in controlling and prohibiting POPs unintentional production. Tiger Forest & Paper Group appointed the environment protection engineers, Mr. Wang Xuwang and Mr. Zhuo Zhiguo, to attend this meeting, and presented a preliminary plan to implement the BAT/BEP project. On March 8-10, 2005, Mr. Sun Xuecheng Mr. Zheng Minghui and Mr. Luigi Pistone from UNIDO office made a mill-site investigation and discussed on the preliminary plan. After further investigation and study by the experts from the convention implementation office, Tiger Forest & Paper Group was elected as one of the two demonstration enterprises in BAT/BEP project.

2. Company Profile

Tiger Forest & Paper Group Ltd. (Formerly Yueyang Forest & Paper Group Ltd.) is a large scale state-owned company integrated with pulp & papermaking, forestry management, power generating, machinery manufacture, wood processing, export & import trade, real estate and etc. . It is the leading company in implementing "Top Ten Demonstration Projects" to boost the industrialization, and also one of the 520 key enterprises in China. The group has been successively awarded as "May 1st Medal", "National plantation Advanced Unit", "National Quality Advanced Unit", "the Advanced Unit of National Equipment Management", "National Audit Advanced Unit", "National Top 500 information-based Enterprise", "National Advanced Unit of Quality and Profitability", "National Advanced Unit of Environment Protection", "Provincial Advanced Unit of Quality Management" and etc.

By the end of 2006, the annual production capacity of paper and paperboard is up to 900,000 ton; total asset value above 10.7 billion Yuan RMB; forest plantation area is 253,333 hectare and reed base 23,333 hectare. At present, the group has 5 production bases in Yueyang, Yiyang, Yongzhou, Huaihua and Changde.

The company mainly produces writing and printing paper including over 40 paper grades with 100 specifications, such as Light Weight Coated Paper (LWC), fine newsprint, pigmented offset print paper and so on. They are well sold both at home and abroad (east and west Asia, Southeast Asia and North Africa). The company successfully passed ISO9001-2000, International Quality System Certificate (October, 2000), and a complete quality management system from raw material to end products and sales services was established; and on January, 2006, Yueyang Paper, the A stock share company of the group, passed ISO4001 Environmental Management System and GB/T28001, Occupational, Healthy & Safety management System Certificate.

In recent years, Tiger Forest & Paper Group has intensified its innovations in system, technology and management; and put much energy on the afforestation, waste recovery and environment protection. A circulative industry chain with both good economic benefit and demonstration effect was formed up. With respect to the development of circulative economy to realize the sustainable development, Tiger is the flagship of its kind in China and driving into an expressway with rapid speed.

3. Demonstration Project

3.1 Introduction

Elected as the demonstration enterprise of reducing unintentional POPs production, we set up a special project group headed by Mr. Zhang Dongji, the vice president of Tiger Forest & Paper Group.

According to the project schedule, Mr. Li Ming and Mr. Zhuo Zhizhuo from Tiger Forest & Paper Group, took part in the related training by The convention implementation office in Beijing on June 1, 2005. During the training, the preliminary plan especially sampling in the mill was further discussed. On June 4-7, 2005, Mr. Sun Xuecheng and Mr. Luigi Piston visited our company again, investigated the related production lines, such as kraft wood/reed pulp lines, alkali recovery plant, DIP, aerobic effluent treatment line and etc., and set down the preliminary sampling points. According to the suggestions from experts, we compiled "*Strategies to Reduce Unintentional Production of POPs in Tiger Forest& Paper Group: BAT, BEP and Incremental Costs for paper Industry*", and delivered it to the convention implementation office.

3.2 BAT/BEP Project implementation plan in Hunan Tiger Forest & Paper Group

Considering the different discharging source of dioxins in paper industry, the best available technology (BAT) could be adopted in the mills with chlorine bleaching process, seen as follows:

a) effective pulp washing;

b) raw materials(wood or reed) free of polychlorinated contaminants;

c) ECF e.g.chlorine dioxide bleaching instead of chlorine;

d) to adopt DDT (deeply delignification technology), reducing residue lignin into the bleaching plant;

e) to adopt oxygen delignification technology to further remove the remained lignin;

f) to use bioenzyme for pre-bleaching, reducing chlorine use;

g) to use H2O2/ozone as bleaching agent;

h) properly sludge handling;

i) to optimize the combustion process in the alkaline recovery system;

j) effective disposal of deinking sludge.

With respect to BAT/BEP implementing in the demonstration companies, Hunan Tiger Forest and Paper Group has taken some measures, such as: innovation for existing washing and screening and new adding H2O2 bleaching stage after CEH in chemical wood/reed pulp line in Yueyang Paper. The total investment for the project is about 80 million RMB. In Yuanjiang Paper of Tiger Group, in order to reduce the dioxins discharge amount new technologies such as: DDT (deeply delignification technology), close screening, chlorine free bleaching e.g. O (oxygen delignification)-D0(chlorine dioxide)-E-D (chlorine dioxide) have been adopted. The investment for the project is about 100 million RMB. These two projects stated above have been put into production. At present, these lines are running smoothly.

3.3 Measurements

According to the project plan, we have made a series of tests to the samples from chemical softwood/reed pulp plant, chemical recovery plant in Yueyang Paper and Yuejiang Paper mill.

First round sample test: August- September 2005

Place: Yueyang Paper Mill

Samples:

a) raw material: reed and masson pine (2 pcs)
b) unbleached reed and wood pulp (2pcs)
c) reed and wood pulp after chlorine stage of the bleaching process (2)
d) reed and wood pulp after sodium hydroxide stage of the bleaching process (2)
e) bleached reed and wood pulp (2)
f) wastewater of chlorine stage of reed and wood bleaching process (2)
g) wastewater of sodium hydroxide stage of reed and wood bleaching process (2)
h) lime mud and Alkali ashes
i) drainage of effluent treatment plant
j) sludge of effluent treatment plant

Second round sample test: August- September 2005

Place: Yueyang Paper Mill/Yuanjiang Paper Mill

Samples:

a) wood pulp after chlorine stage of the bleaching process

b) wood pulp after sodium hydroxide stage of the bleaching process
c) wastewaters of chlorine stage wood bleaching process
d) wastewaters of sodium hydroxide stage wood bleaching process
e) drainage of wastewater treatment plant
f) sludge of wastewater treatment plant
g) Paper product
h) Sediments outside the plant after all treatment device

3.4 Sampling and data evaluation before BAT/BEP implementation

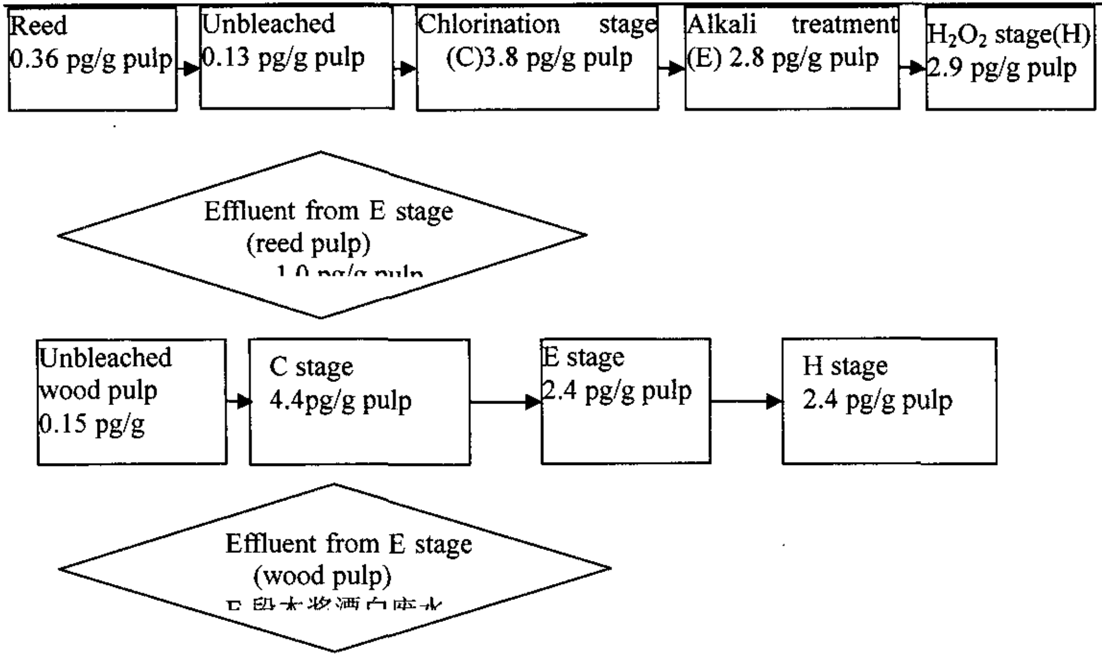
It was identified with the international community that in the paper industry, dioxin is mainly discharged from chlorine bleaching process, DIP and chemical recovery system. In the process of chlorine bleaching, dioxin as a chlorizate of oil antifoaming agent is discharged, which is prime potential source of dioxin. In DIP plant, dioxin mainly comes from the waste paper and the sludge. In chemical recovery system, dioxin is produced due to incomplete combustion of black liquor, which lies in the flue gas, alkaline dust absorbed by electric precipitator, as well as white lime in the causticizing stage.

According to the sampling in the first stage before the BAT/BEP and the results of sample analyzing and relative process parameter, there is a preliminary estimation for annual output of dioxins for each stage in the companies. Here are the formulas:

Source Strength (dioxin emission per year) = Emission Factor x Activity rate

PCDD/F grams TEQ per year = Σ Emission Factorair x Activity rate
Σ Emission Factorwater x Activity rate
Σ Emission Factorland x Activity rate
Σ Emission Factorproduct x Activity rate
Σ Emission Factorresidue x Activity rate

The following chart shows the consistency of dioxin in Hunan Tiger Forest and Paper Group which takes reed and wood as main raw material for pulping. (the data triangle frame is estimated).



According to the data shown in above chart, considering the source of dioxin in Hunan Tiger Forest & Paper Group, it is estimated the annual discharge amount of dioxin as follows: flue ash in alkali recovery system 0.0001828g I-TEQ, wood pulp 0.142955 g I-TEQ, reed pulp 0.159472g I-TEQ, sludge 0.0697 g I-TEQ.

From the above data, we can know that dioxin in straw pulp bleaching line mainly exists in the products of bleaching pulp and paper. In order to reduce it ,we need implement BAT/BEP to reduce or replace the chlorine in bleaching phases.

3.5 New process after BAT/BEP implementation

Attachment 1 is the flow sheet of Chemical reed pulping line of Yuanjiang Paper Mill after BAT/BEP implementation. The detailed process parameters are shown in the table below :

Table 3-1. PLANT DESCRIPTION（YUANJIANG PAPER MILL）

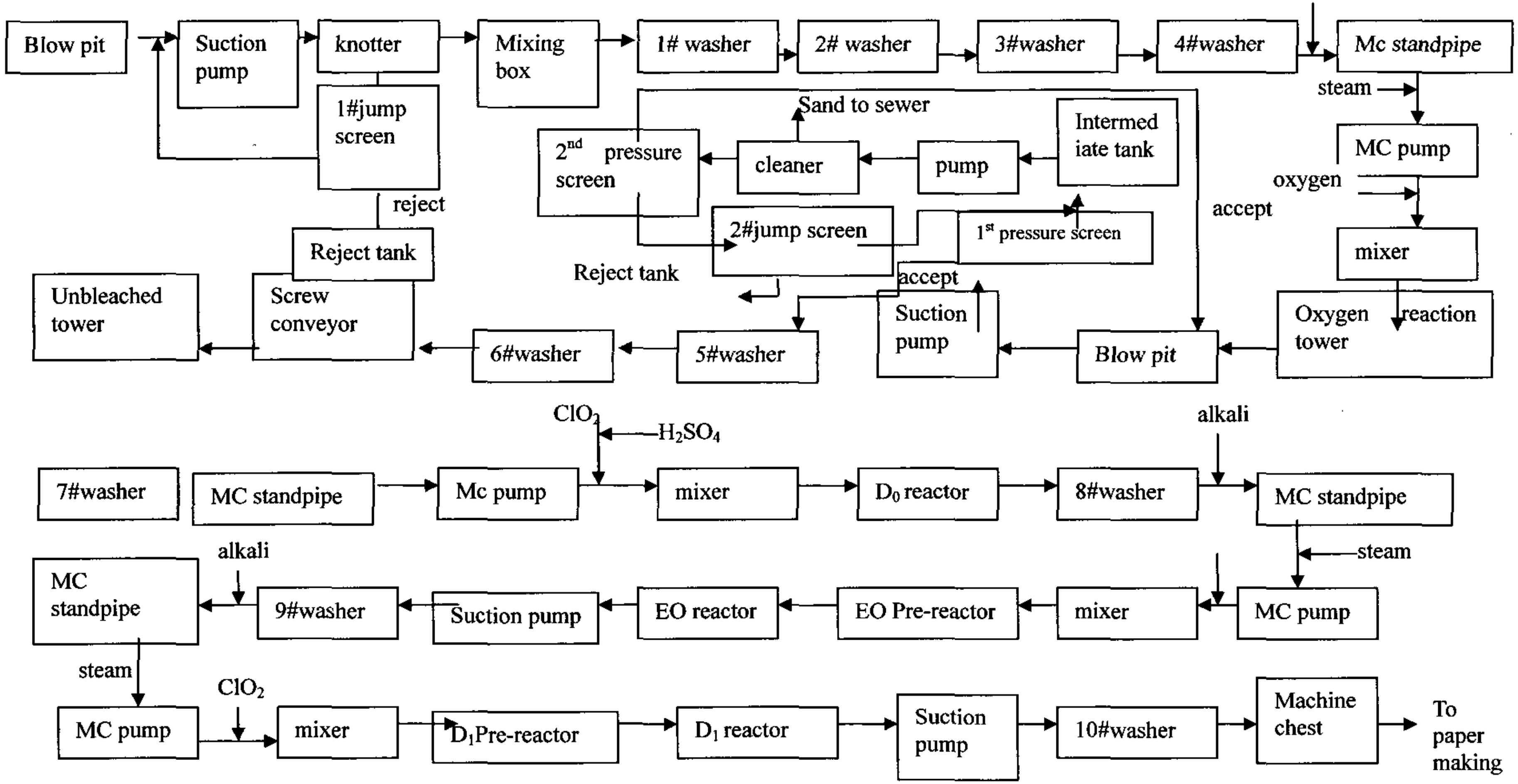
Type of Plant	**Pulp and paper industry: Pulp**	**[ ]**	
	Pulp and paper industry: Paper (primary or recycling)	**[ ]**	
	Pulp and paper – integrated	**[X]**	
Address	**HUAN province YUANJIANG city**		
Contact (Name, position, phone and fax numbers, e-mail)	**Mr Long Zhisha, director of technology department** **Phone 0737-2816681** **mobile 13511127208 fax 0730-2850258** **E-mail: kjc@yj-paper.com**		
Capacity: Consumption of Raw Materials (type, quantity = t/a)	**Raw**		
	Reed	**220,000 tons (including 18%water ）**	
	Waste paper		
	Wood	**150000m3**	
Capacity: Final Product (type, *quantity = t/a*)	**tone/ day**	**Reed pulp 250** **Wood pulp *110***	
Annual Operation/Capacity (per Unit)	**h/d (hours per day)**	**22.5**	
	d/w (days per week)	**7**	
	t/d (tons per day)	**360（including reed pulp and wood pulp ）**	
	d/a (days per year)	**340**	
	h/a (hours per year)		
	t/a (tons per year)	**122400**	
Bleaching	**Chemical (Y/N)**	**Y**	
	Bleaching sequenze(s)	**D0-E0-D1**	
Deinking	**Yes [ ]**	**No [X]**	
	Capacity		
Type of Operation	**Batch**	**[ ]**	
	Semi-continuous	**[ ]**	
	Continuous	**[X]**	
Black liquor boiler	**Amount**	**2**	
	Capacity	**130 tons +250 tons *(solid of black liquor)/day***	
Operation/ Production Temperature	**Raw material**	**Reed**	
		Temperature	**Pulp Production**
	Cooking	**155---165 °C**	**302 tons /day**
	Volume before bleaching		**280tons /day**
		Temperature	**Reacting Time**

	Oxygen treatment stage	**90-95 °C**	**30 minute**
	D0 bleaching stage	**45-55 °C**	**50 minute**
	E0 bleaching stage	**65-70 °C**	**120 minute**
	D1 bleaching stage	**65-75 °C**	**100--120 minute**
	Volume after bleaching		**250 tons /day**
Operation/ volume of chemical material		**Chemical Volume (Kg/Ton pulp)**	**Pulp Consistency (%)**
	Oxygen treatment stage	**15—20**	**10---12**
	D0 bleaching stage	**9---12**	**10—12**
	E0 bleaching stage	**16—18(alkali)** **4 (Oxygen)**	**10--12**
	D1 bleaching stage	**6—8**	**10-12**
Water discharge	**D0 bleaching stage**	**250 tons/hour (22.5 tons water /ton pulp)**	
	E0 bleaching stage	**Recycling use inside**	
	D1 bleaching stage	**30 tons/hour (2.7 tons water /ton pulp)**	
Water treatment	**Settling pond**	**[X]**	
	Aerated lagoon	**[X]**	
	Secondary treatment	**[X]**	
	Tertiary Treatment	**[ ]**	
	Others (please specify)	**[ ]**	
Wastewater treatment volume	**25,000 tons/day**		
Sludge volume	**Sludge of waster water treatment plant**	**9t (dry) /day**	
	lime mud	**65tons(dry)/day**	
	Alkali ash	**5 tons/day**	
Disposal of sludge	**Landfill (t/a)**	**[3060 tons /year]**	
	Land farming (t/a)	**[ ]**	
	On-site (t/a)	**[ ]**	
	Incineration (t/a)	**[ ]**	
	Others (specify) (t/a)	**[ ]**	
Disposal of fly alkali ashes	**Reuse into black liquor**		
Disposal of bottom ashes	**To make brick**		

Type of Air Pollution Control System (APCS)	**Electrostatic precipitator**	**[x]**
	Cyclone	**[ ]**
	Bag filter	**[ ]**
	Wet scrubber	**[ ]**
	Dry scrubber	**[ ]**
	Lime injection	**[ ]**
	NaOH/alkali injection	**[ ]**
	Active carbon/coke injection	**[ ]**
	Active carbon filter	**[ ]**
	Catalytic converter (SCR)	**[ ]**
	Induced or forced draft fan	**[ ]**
	Other (please specify)	**[ ]**
	None	**[ ]**
Height of the stack	**(m)**	**80--120**
Diameter of the stack	**(m)**	**2.5~6.0**
Position of sampling port (if any)	**(m)**	**Don't taking sample**
Flux of Off Gases	**(m^3/h) (dry gas)**	
	At entry to APCS (if available)	**At exit from APCS (if available)**
Temperature of Off gases	**(°C).**	**116**
Oxygen	**%**	
Particulate matter	**(mg/Nm3)**	
Acids	**(mg/Nm3)**	
Carbon monoxide	**(mg/Nm3)**	

Sulfur dioxide	**(mg/Nm3)**	
Nitroges oxides	**(mg/Nm3)**	
Others (if available)		

Figure 1 Cooking, washing and screening stage in chemical reed pulping plant



3.6 Measured data after implementation of BAT/BEP

Demonstrate corporation takes different BAT/BEP plan, thus sampling points are different. The measured data for each sampling point in Tiger Group (Yuanjiang Paper) are shown in the table below:

Table 3-2. REVISED DATA IN YUANJIANG

YUANJIANG	CONC. pg TEQ / g (L)	PRODUCTION (Ton/day)	INPUT/OUTPUT PER YEAR (340d) 1 ROUND mgTEQ/year	EMISSION FACTOR µgTEQ/Ton (dry pulp)
DRY PULP FROM REED PAPER		250		
Do PULP	0.43	280	40.94	0.48
D1 PULP AFTER BLEACHING	0.67	250	56.95	0.67
Do WATER	0.43	5625	0.822	0.0097
D1 WATER	0.45	675	0.103	0.0012
PAPER FROM REED	0.65	280	61.88	0.65
SLUDGE	1.5	9	4.59	0.038
EFFLUENT	0.48	25000	4.08	0.033

3.7 The data comparison and analysis before VS. after BAT/BEP

Table 3-3. The data comparison before and after BAT/BEP

YUEYANG Paper mill	CONC. YUEYANG pg TEQ/g (L)	INPUT/OUTPUT PER YEAR 1 ROUND mgTEQ/year	YUAN JIANG Paper mill	CONC. YUANJIANG pg TEQ/g (L)	INPUT/OUTPUT PER YEAR 1 ROUND mgTEQ/year
REED	0.36	43.2			Preliminary Based on Yueyang
REED PULP BEFORE BLEACHING	0.13	7.1	Do PULP BEFORE BLEACHING	0.43	40.94
C PHASE REED PULP	3.8	206.7	D1 PULP AFTER BLEACHING	0.67	56.95
E PHASE REED PULP	2.8	152.3	Do WATER	0.43	0.82
H PHASE REED PULP	2.9	157.8	D1 WATER	0.45	0.103
WOOD PULP BEFORE BLEACHING	0.2	12.2			
C PHASE WOOD PULP	4.4	269.3	PAPER FROM REED	0.65	61.88
E PHASE WOOD PULP	2.4	146.9			
H PHASE WOOD PULP	2.4	146.9			
ALKALI ASH	0.24	1.63	EFFLUENT	0.48	4.08
SLUDGE	8.2	69.7	SLUDGE	1.5	4.59

YUEYANG	EMISSION FACTOR µg TEQ/AdT product paper	YANJIANG	EMISSION FACTOR µg TEQ/AdT product pulp or paper	CHLORINE BLEACHING µg TEQ/AdT product pulp	ECF TCF µg TEQ/AdT
REED	0.79	Process data based on Yueyang	Could be lower	TOOLKIT	
REED PULP BEFORE B.	0.13				
C PHASE REED PULP	3.8	Do PULP	0.43	8-30	0.5
E PHASE REED PULP	2.8				
H PHASE REED PULP	2.9	D1 PULP AFTER BLEACHING.	0.67	8-30	0.5
WOOD PULP BEFORE Bleaching.	0.15			8-30	0.5
C PHASE WOOD PULP	4.4			8-30	0.5
E PHASE WOOD PULP	2.4			8-30	0.5
H PHASE WOOD PULP	2.4			8-30	0.5
ALKALI ASH	0.014	EFFLUENT	0.033	4.5	0.06
		Do WATER	0.01	4,5	0,06
		D1 WATER	0.001	4,5	0,06
		PAPER REED	0.65	8-30	0.5
SLUDGE	0.60	SLUDGE	0.038	4,5	0.2

From the compared data shown in the table aboved, it is obvious that the amount of PCDD/PCDF is remarkably reduced by (2.9-0.67)/2.9×100%＝77% after BAT/BEP implementation. The emission amount PCDD/PCDF is 0.67μg TEQ/AdT product, which is close to the emmission factor (0.5μg TEQ/AdT product) in the toolbag. It is similar to the sludge emission factor, which reduced by (0.6－0.038)/0.67×100%＝94%. All these show that BAT/BEP implementation is very successful, just as expected.

To evaluate the environmental benefits after implementing BAT/BEP, we caculate the emission amount PCDD/PCDF in the the pulp (H&D1 stage) and effluent from bleaching stage. The formulas are as follows:

Total emmission amount of PCDD/PCDF before BAT/BEP: 2.9＋0.9=3.8μg TEQ/AdT PULP (PCDD/PCDF in the effluent at C stage not included)

PCDD/PCDF total amount after BAT/BEP: 0.67+0.01+0.001=0.68μg TEQ/AdT PULP.

The difference of PCDD/PCD in bleached reed pulp per ton before and after BAT/BEP =3.8－0.68＝3.12μg TEQ/AdT PULP

The emmission amount of PCDD/PCDF in the effluent at stage C before BAT/BEP is not calculated, therefore 3.12μg TEQ/AdT PULP is the minimal value for environment benifites.

3.8 Increment cost and environment benefits analysis

Table 3-4. CAPITAL COST

CAPITAL COST Installation expenditure				
Items	**Baseline scenario In Yueyang**	**Baseline scenario In Yuanjiang**	**Main difference**	**Lifetime and period required to install**
Washing stage for raw material	**Total cost** **na**	**Total cost** **2,300,000**	**In Yueyang no washing stage, in Yuanjiang closed washing stage**	**10years**
cooking	**Total cost** **9,600,000**	**15,300,000**	**In Yueyang not continuous, in Yuanjiang continuous cooking**	**10years**
Bleaching in Yueyang (not including stage P)	**Total cost** **16,600,000** **(305yuan/ton)**			
C phase	**partial cost**			**10years**

	5,300,000			
E Phase	**partial cost 4,600,000**			**10years**
H phase	**partial cost 4,600,000**			**10years**
P phase	**partial cost 1,200,000**			**10years**
Water supply cost	**partial cost 100,000**			**10years**
Chlorine supply	**partial cost 200,000**			**10years**
Sodium Hydroxide	**partial cost 150,000**			**10years**
Hypochlorite supply	**partial cost 500,000**			**10years**
hydrogen peroxide supply	**partial cost 200,000**			**10years**
Chlorine container	**partial cost 200,000**			**10years**
Sodium Hydroxide container	**partial cost 200,000**			**10years**
Hypochlorite container	**200,000**			**10years**
hydrogen peroxide container	**200,000**			**10years**
Heating of E stage	**50,000**			**10years**
Chemical preparation	**500,000**			**10years**
Bleaching in Yuanjiang		**Total cost 49,500,000 (582yuan/ton)**		
O (oxygen delignification) phase	**Partial costs**	**2,800,000**		
D_0 (chlorine dioxide) phase	**Partial costs**	**4,600,000**		
E (sodium hydroxide) phase	**Partial costs**	**2,800,000**		
D_1 (chlorine dioxide) phase	**Partial costs**	**5,200,000**		
Oxygen container	**Partial costs**	**3,800,000**		

sodium hydroxide container	**Partial costs**	**300,000**		
chlorine dioxide container	**Partial costs**	**300,000**		
Sodium Hydroxide supply	**Partial costs**	**600,000**		
chlorine dioxide supply	**Partial costs**	**28,000,000**		
Sodium Hydroxide container	**Partial costs**	**300,000**		
chemicals preparation	**Partial costs**	**800,000**		
BOILER	**28,000,000**	**45,000,000**		
Pollution control (main and auxiliary equipment)				
Electrostatic precipitator	**4,500,000**	**6,000,000**		
Water treatment plant	**28,000,000**	**35,000,000**		
Contingency allowance				
TOTAL CAPITAL COST	**88,300,000**	**153,100,000**		

Table 3-5. ANNUAL OPERATING COST

ANNUAL OPERATING COST	**Baseline scenario In Yueyang**	**Baseline scenario In Yuanjiang**	**Action**
	Annual chemical reed pulp 54400ton	**Annual chemical reed pulp 85000ton**	
Annual operating cost(bleaching stage)(not stage P)	**16,700,000**	**28,570,000**	**28,480,000**
Pulp Operating cost per ton (same standard)(bleaching)	**307yuan/ton**		**335yuan/ton**
Energy costs for bleaching process			
Electricity (unit price and overall cost)	**Unit price: 0.36 元/kw.h**	**Unit price: 0.525 元/kwh**	**0.36yuan/kw.h(85,000ton)** **Annual total price:**

	Annual total price: 1,530,000 78.5kwh/ton pulp	Annual total price: 5,530,000 124kwh/ton pulp	3,800,000
Steam consumption	Unit price: 29.66yuan/GJ Annual total price: 4,840,000yuan 3。0GJ/ton pulp	Unit price:24yuan/GJ Annual total price: 5,440,000yuan 2.7 GJ/ton pulp	Unit price:29.66yuan/GJ Annual total price: 6,800,000
Bleaching in Yueyang			
Water supply cost	Unit price:0.497yuan/ton 64 ton water/1ton pulp	Unit price:0.37yuan/ton 25ton water/1 ton pulp	Unit price: 0.497yuan/ton 25 ton water/1ton pulp
	1,730,000yuan	780,000yuan	1,060,000yuan
Chlorine supply	5,880,000		
	6% chlorine, 1,800yuan/ton		
sodium hydroxide supply	2,720,000yuan 2．5%alkaline 2000yuan/ton		
hydrogen peroxide supply	4,300,000yuan(6.0 yuan/kilogram) 1.8 %		
Heating of E stage			
Bleaching in Yuanjiang			
chlorine dioxide supply		8,780,000(15Kg/ton pulp, 6900yuan/ton)	
Oxygen supply		1,020,000(600yuan/ton, 2。0 % oxygen treatment)	
sodium hydroxide supply		5,600,000(bleaching 18kg/ton pulp, oxygen treatment 15kg/ton pulp,2000yuan/ton)	
Black liquor boiler			
Electrostatic precipitator			
Fly ashes disposal costs			Recirculation in the

(indicate the average of disposal and recirculation)			**boiler not to be considered**
Waste Water Treatment plant			**Change in the amount of water in the bleaching lines**
Disposal of sludge			**Sold to farmers**
Labour (man-hours			

Table 3-6. BENEFITS

BENEFITS	Baseline scenario In Yueyang	Baseline scenario In Yuanjiang	Modification
Pulp cost(yuan/ton)(including routine maintenance,regular maintenance, facility depreciation)	2278	2371	
Paper cost(yuan/ton)	3940	4156	
Pulp/paper%	46.25	45.64	Calculated 80% bleached reed pulp per 1 ton paper
Paper price per ton	5100	5500	
Paper benefit per ton	1160	1344	
Pulp benifite per ton	536.5	613.4	
Sale price difference (yuan/ton pulp)	------	76.9	
The amount of effluent treatment in bleaching	58	22.5	
Cost of effluent treatment in bleaching(yuan/ ton pulp)	46.4	18	(0.8yuan/ton effluent, including water cost depreciation)
Effluent treatment operating	-------	28.4	

difference(yuan/ ton pulp)			
Sum of Benefit difference(yuan/ ton yuan)	------	105.3	

Table 3-7. The summation of COST and BENEFITS

	Capital cost (RMB)	Operating cost (RMBs/year)	Benefits	Emission rate (mg TEQ/year)
baseline	305A	307C	490.1E	3.8A
With modifications	582B	335D	595.4F	0.68B
	Incremental capital cost (RMB)	Incremental operating cost (RMB/year)	Incremental Benefits	Incremental effectiveness (mg TEQ/year)
With modifications	IC= A-B	IO=D-C	IB=F-E	IE=b-a
	277	28	105.3	3.12

Table 3-8. The analysis of Increment cost and Environment benefits in future years

Year	Incremental Cost stream (RMB)	Incremental Discounted cost stream (RMB)	Effectiveness (mg TEQ)	Discounted effectiveness (mg TEQ)
0	IC+(IO-IB)	$[IC+(IO-IB)]/(1+d)^y$	IE	$IE/(1+d)^y$
0	199.7	199.7	3.12	3.12
1-9	IO-IB	$(IO-IB)]/(1+d)^y$	IE	
1	-77.3	− 70.3	3.12	2.84
2	-77.3	-63.9	3.12	2.58
3	-77.3	-58.1	3.12	2.34
4	-77.3	-52.8	3.12	2.13
5	-77.3	-48.0	3.12	1.94
6	-77.3	-43.6	3.12	1.76
7	-77.3	-39.7	3.12	1.60
8	-77.3	-36.1	3.12	1.46
9	-77.3	-32.8	3.12	1.32
Present value		$\Sigma^* \frac{d\,(1+y)^n}{(1+d)^n-1}$	Σ IE	
		-245.6	31.20	21.09

Cost/effectiveness ratio discounted RMB/mg TEQ reduced	**Sum of discounted cost stream / sum of discounted effectiveness** **Cost of increases 277yuan from the first year(calculated with annual *output), Pulp per ton benefits is 77.3yuan. In 10 year's depreciation* period, discount rate is 10%. The net present worth of Benefits for 10 years after discounting is 245.6yuan(net income), the difference between the sum of pulp for 10 years and TEQ is 21.1ug**
Discount rate d	**Calculated with 10%,depreciation is 10 years**

According to the analysis of the cost and benefits above, for a paper mill with annual production 100,000 ton, the incremental cost is about 28 million yuan with ECF bleaching instead of conventional CEH bleaching. But thanks to the improved pulp quality, the higher selling price of paper and less effluent treatment is achieved. The benefit from it is about 10,500,000 yuan. Calculated with 10% discount rate, in 10 years' depreciation period, the net income is 2, 4560, 000yuan (net income). The reduced amount of PCDD/F is 2.1gTEQ.

4. Conclusion

After controlling POPs and reducing the ejection of BAT/BER, the compared data and the evaluated results show that the amount of PCDD/PCDF is remarkably reduced 77 % after BAT/BEP implementation. The emission amount PCDD/PCDF is 0.67μg TEQ/AdT product, which is close to the emmission factor (0.5μg TEQ/AdT product) in the toolbag. It is similar to the sludge emission factor, which reduced 94 %. All these show that BAT/BEP implementation is very successful, just as expected.

For a paper mill with annual production 100,000 ton, the incremental cost is about 28 million yuan with ECF bleaching instead of conventional CEH bleaching. But thanks to the improved pulp quality, the higher selling price of paper and less effluent treatment is achieved. The benefit from it is about 10,500,000 yuan.

Implementing the demonstration project of controlling and prohibiting POPs shows that environment-friendly and clean production technology not only can improve the product quality, but also reach the purpose of controlling and reducing the emission factor and integrated the economic benefit and environmental benefit. It will play a very important role to promote the upgrading of pulp&paper industry of China and implement the sustainable development strategy.

5. Acknowledgement

We would like to express my cordial gratitude to the leaders and specialists of Stockholm Convention Implementation Office of State Environmental Protection Administration, Mr. Sun Xuecheng, the secretary-general of environmental protection committee of papermaking association of China, Professor Yu Gang of Tsinghua University, the researcher of Chinese Academy of Sciences——Mr. Zheng Minghui, Dr. Huang Qifei of Environmental Science Academy of China and Environment & Territory Ministry of Italy. Thanks for their supports and help to the Demonstration Project of Tiger Forest & Paper Group.

Strategies to Reduce Unintentional Production of POPs in China: BAT, BEP and Incremental Costs for Selected Sectors of Industry

Case Study Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in HUATAI Group

Submitted to
Foreign Economic Cooperation Office
State Environmental Protection Administration, China

华泰集团
HUATAI GROUP

CONTENTS

Report of case research

1. Name of Enterprise: Huatai Group Co. ltd

2. Date: June of 2007

3. Implementing plan of Shandong Huatai Project:

(1) Cooperation with the specialists both from domestic and abroad, take samples and do the measurements for all possible Pops sources on site under normal production conditions including: raw material handling system, DIP, bleaching plants (traditional CEH), alkaline recovery plant, effluent treatment plants. Building up a material balance sheet, analyze and quantify the sources of POPs, by measuring the actual input and output material.

(2) Rebuilding the existing wheat straw bleaching line (production 130t/d, bleaching stage CEH). Regarding the bleaching stage, the rebuilding will increase "enzyme management" Preliminary bleaching stage and put a little of hydrogen peroxide (P) into E(sodium hydroxide) bleaching stage. This way can reduce amount of elemental chlorine in the C bleaching stage.

(3) Cooperation with the specialists, take second samplings and measurements for bleaching baseline after rebuilding under normal production conditions. Building up a material balance sheet and providing related finacial data as well as technical data. Preparation of implementation strategies and likely incremental costs of improvement measures representing BAT/BEP. The time table for measurement and reporting will be start form January and finished by February 2006.

(4) Under instructions from specialists both from domestic and abroad, the company should finish final enterprise report for publication as a case-study setting out the principal findings, the timetable will be Feb to Mar,2006.

4. Process auditing after BAT/BEP was implemented:

Huatai Paper group implements BAT/BEP program, Pre-bleaching enzyme is added and H_2O_2 is add in E stage to improve bleaching performance based on previous process. Following is process parameter after technical modification:

(1) Screening Stage

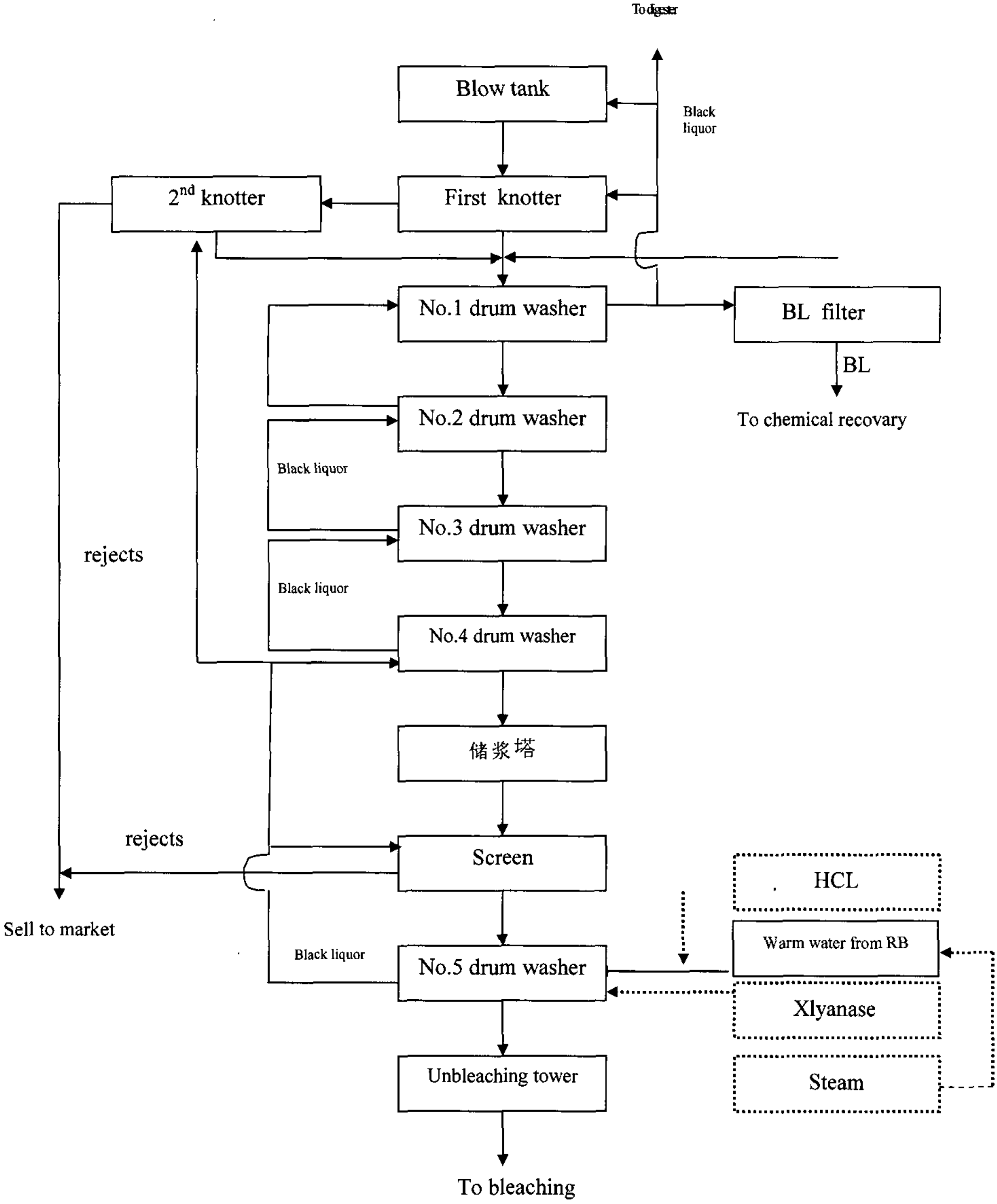
Black liquor Baume to	VE 4.0~5.0°Be' (80°C)
Fiber content in black liquor to VE	≤50mg/l
Extraction Rate of black liquor	≥80%

Xylanase dosage	45g/adt pulp
HCl dosage	3~5kg/adt pulp

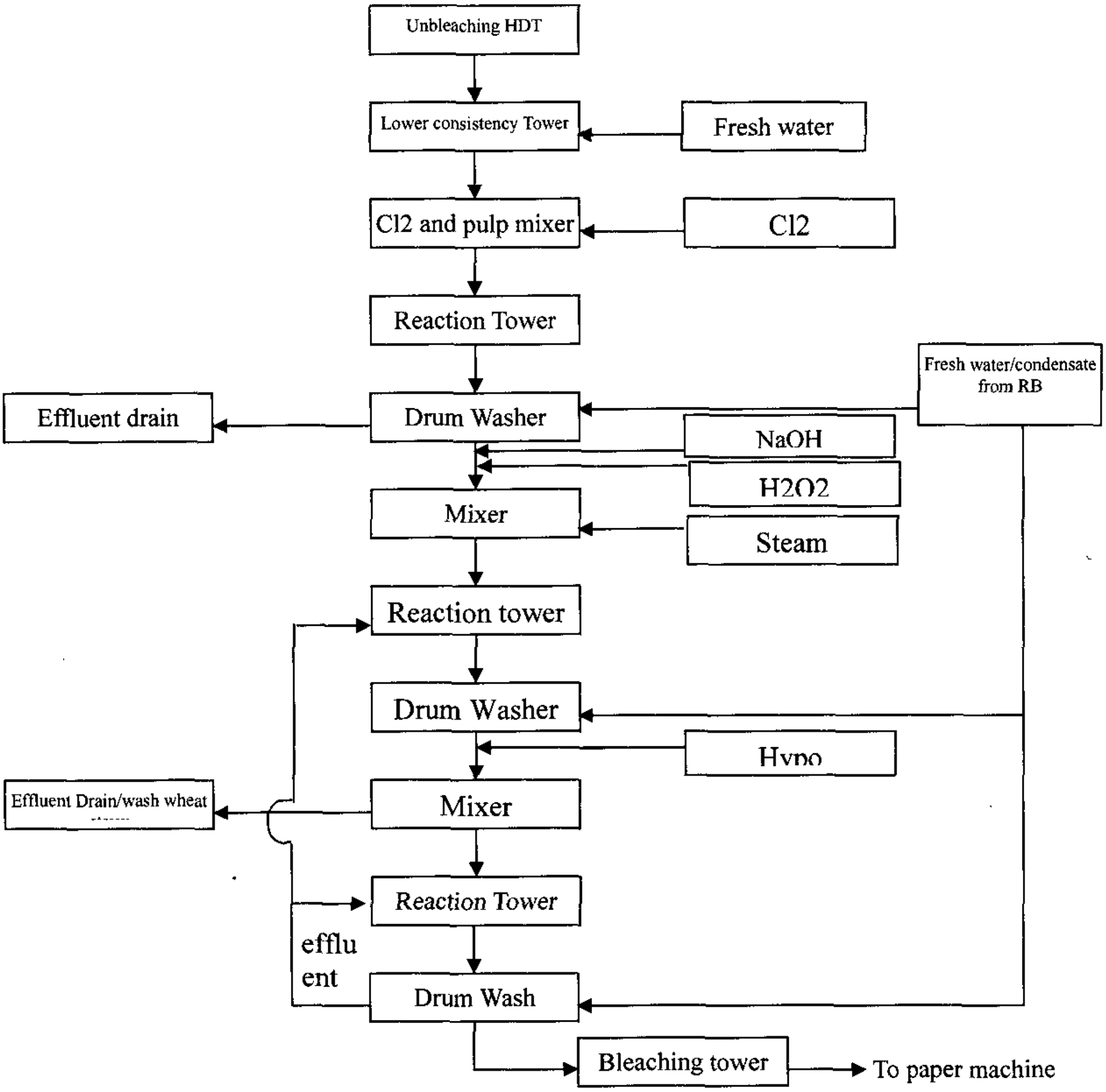
(2) Bleaching stage

Residual Cl_2(outlet of chlorine stage)	≤0.056g/l
Residual alkali in unbleaching tower	≤0.10g/l
Residual Chlorine after washing	≤0.021 g/l
pH in E stage (with H_2O_2)	8.5~10.5
Alkali usage	2~3%
H_2O_2 usage	0.3~0.7%
Hypochlorite usage (as effective Cl_2)	4~5%
Hypochlorite concentration	6~9%

Pre-bleaching enzyme is added in last screening stage, after No.5 Drum washer, HCl is added before pre-bleaching enzyme to adjust pulp pH which give enzyme suitable environment to react with pulp in unbleaching tower until C stage..


To digester
Blow tank
Black liquor
2nd knotter
First knotter
No.1 drum washer
BL filter
BL
To chemical recovary
No.2 drum washer
Black liquor
No.3 drum washer
rejects
Black liquor
No.4 drum washer
储浆塔
rejects
Screen
HCL
Sell to market
Black liquor
No.5 drum washer
Warm water from RB
Xlyanase
Unbleaching tower
Steam
To bleaching

Above flowchart is about that pulp from cooking stage was cleaned and washed to remove rejects and black liquor. Then send to bleaching stage. The dashed line in the flowchart is pre-bleaching enzyme treatment, and some equipment was added to get this unit. After BAT/BEP program was implemented, chemical usage was adjusted, there is no other process parameter change, following is process chart:



Capacity: Consumption of Raw Materials (type, quantity = t/a)	**raw reed Waste paper**	**700000 440000**	
	Wood		
Capacity: Final Product of Raw Materials	**colourful offset Paper: 60% wheat straw pulp, 40% wood pulp**	**100000 tons/year,**	
(type, quantity = t/a)			
Annual Operation/Capacity (per Unit)	**15t/h (tons per hour)**		
	22.5h/d (hours per day)		
	7d/w (days per week)		
	300t/d (tons per day)		
	340d/a (days per year)		
	7650h/a (hours per year)		
	100000t/a (tons per year)		
Bleaching	**Chemical (Y/N)**	**Y**	
	Bleaching sequenze(s)	**Enzyme－CEpH**	
Type of Operation	**Batch Semi-continuous Continuous**	**[ ] [ ] [X]**	
Black liquor boiler	**Yes [X]**	**No [ ]**	
Operation/ Production Temperature	**Volume**	**-----------**	
	Volume before bleaching	**130 tons/day**	
	Volume after bleaching	**120 tons/day**	
	Boiler	**150 tons (solid of black liquor)/day**	
	Cooking	**150---160℃**	
		Temperature	**Chemical volume**

	Enzyme Pre-treatment	**30---40℃**	**Enzyme 45g/ton pulp**
			hydrochloric acid 3 ~ 5kg/ton pulp
	C bleaching stage	**25 ℃**	**60—70kg/ton pulp**
	E bleaching stage	**60 ℃**	**Alkali 20--30 kg/ton pulp**
			hydrogen peroxide 3-7 kg/ton pulp
	H bleaching stage	**40 ℃**	**Effective chlorine 40--50 kg/ton pulp**
Water discharge	**Cooking**	**------------**	
	C bleaching stage	**23--25 tons /ton pulp 2990-3250tons/day**	
	E bleaching stage	**23--25 tons /ton pulp 2875-3125 tons/day**	
	H bleaching stage	**----------**	
Water treatment	**Settling pond**	**[ ]**	
	Aerated lagoon	**[X]**	
	Secondary treatment	**[ ]**	
	Tertiary Treatment	**[ ]**	
	Others (please specify)	**[ ]**	
Wastewater treatment volume	**45,000 tons/day**		
Sludge volume	**20t (dry) /day**		

Mud volume of deinking	12—14tons(dry)/day	
Discharges of boiler	lime mud	40 tons(dry)/day
	Alkali ash	about 8 tons/day
Disposal of sludge	Landfill (t/a)	[X]
	Land farming (t/a)	[ ]
	On-site (t/a)	[ ]
	Incineration (t/a)	[ ]
	Others (specify) (t/a)	[ ]
Disposal of alkali ashes	No	
Disposal of bottom ashes	No	
Disposal of fly ashes	Electrostatic precipitator	
Type of Air Pollution Control System (APCS)	Electrostatic precipitator	[X]
Height of the stack	(m)	80
Diameter of the stack	(m)	bottom:10m;top:2.5 m
Position of sampling port (if any)	(m)	Electrostatic precipitator
Flux of Off Gases	(m^3/h) (dry gas)	15000
	At entry to APCS (if available)	At exit from APCS (if available)
Temperature of Off gases	(°C)	65
Particulate matter	(mg/Nm^3)	150
Sulfur dioxide	(mg/Nm^3)	0.02
Nitroges oxides	(mg/Nm^3)	6

5. Sampling point and data analysis after BAT/BEP was implemented in Huatai Paper Group

BAT/BEP program was implemented in Huatai Paper Group, the program included using pre-bleaching enzyme and using H2O2 in E stage. Therefor, sampling point was focused on the pulp and effluent from C and E stage, and the sludge in main discharge port, following is sampling point and test result:

HUATAI PAPER MILL	CONC. pg TEQ / g (L)	PRODUCTION (Ton/day)	INPUT/OUTPUT PER YEAR (340d) 1 ROUND mgTEQ/year	EMISSION FACTOR µgTEQ/Ton (dry pulp)
PAPER MADE FROM PULP EVER BEING IN C PHASE	1.2	300	122.4	----
C PHASE PULP (WITH ENZYME ADDITION)	2.9	130	128.2	3.1
E PHASE PULP (WITH ENZYME ADDITION)	0.73	125	31.0	0.76
C PHASE WASTE WATER (WITH ENZYME ADDITION)	0.72	3120	0.76	0.017
E PHASE WASTE WATER (WITH ENZYME ADDITION)	1.6	3000	1.63	0.038
SLUDGE	5.7	20	38.76	0.45
EFFLUENT	0.67	45000	10.25	0.12

SEDIMENT IN LOW REACHES OF ZHINIU RIVER	3.5	------	-------	-------

6. Comparison before and after BAT/BEP program and analysis

Compared data before and after BAT/BEP program was implemented, and we also calculated PCDD/PCDF reduction.

Following is data comparison before and after BAT/BEP program was implemented

HUATAY	CONCENT R 1 ROUND pg TEQ/g (L)	CONCENT R.2 ROUND pg TEQ/g (L)	INPUT/OUT PUT PER YEAR 1 ROUND mgTEQ/year	INPUT/OUT PUT PER YEAR 2 ROUND mgTEQ/year
WASTE PAPER (BEFORE DE–INKING)	1.2	--	432	--
WASTE PAPER (AFTER DE–INKING)	0.70	--	252	--
STRAW	0.25	--	18	--
WHITE MUD	0.18	--	1.5	--
ALKALI ASH	0.69	--	1.17	--
PULP (BEFORE BLEACHING)	0.31	--	8.0	--
C PHASE PULP	0.45	2.9	10.8	128.2
E PHASE PULP	0.33	0.73	7.9	31.0
H PHASE PULP	0.53	--	12.7	--
C PHASE WATER	1.9	0.72	1.1	0.76
E PHASE WATER	2.2	1.6	1.3	1.63
PAPER (WASTE PAPER)	0.6	--	94.5	--
PAPER (FROM GRASS)	1.2	1.2 Art	43.2	43.2 Art
SLUDGE	2.8	5.7	16.8	38.76
EFFLUENT	--	0.67	--	10.25

HUATAY	EMISSION FACTOR 1 ROUND µg TEQ/AdT product pulp or paper	EMISSION FACTOR 2 ROUND µg TEQ/AdT product pulp or paper	CHLORINE BLEACHING Toolkit µg TEQ/AdT product pulp or paper	ECF-TCF Toolkit µg TEQ/AdT product pulp or paper
WHITE MUD	0.06 µg /AdT bleached pulp	—	—	--
ALKALI ASH	0.046 µg /AdT bleached pulp	—	--	NA
PULP (BEFORE BLEACHING)	0.33 µg /AdT bleached pulp	—	—	--
C PHASE PULP	0.47 µg /AdT bleached pulp	3.14 µg /AdT bleached pulp	8-30	0.5
E PHASE PULP	0.33 µg /AdT bleached pulp	0.73 µg /AdT bleached pulp	8-30	0.5
H PHASE PULP	0.53 µg /AdT bleached pulp	—	8-30	0.5
C PHASE WATER	0.046 µg /AdT	0.017 µg /AdT	4,5	0,06 after WT
E PHASE WATER	0.053 µg /AdT bleached pulp	0.038 µg /AdT bleached pulp	4,5	0,06 after WT
PAPER (WASTE PAPER)	0.63 µg /AdT paper	—	8-30	3-10
PAPER (FROM STRAW)	1.20 µg /AdT paper	1.20 µg /AdT paper	8-30	0.5
SLUDGE	0.31 µg /AdT bleached pulp	0.63 µg /AdT bleached pulp	4,5 (100 µg/ton)	0.2 (10 µg/ton)
EFFLUENT	--	0.17 µg /AdT bleached pulp	4.5	0,06

After compared data before BAT/BEP program was implemented, we found that PCDD/PCDF increased after BAT/BEP program was implemented, instead of reduced, following is possible reasons which bring this result.

1. Lignin structure in Wheat straw is different from that in wood, this is methoxy group in benzene ring, the bond between each lignin unit is also different, PCDD/PDCF quantity which generated during chlorine bleaching is different. Before bleached, wheat straw pulp was pre-treated by enzyme which will break part of lignin to small molecular, therefore, it can be easy be chlorined and produces PCDD/PDCF. So after pre-bleaching enzyme treatment, more PCDD/PDCF will be produced.

2. The material is non wood material, compared with wood pulp, wheat straw pulp is difficult to become mat in washing stage, and fiber loss is bigger than wood pulp. Even the same material, due to equipment difference, fiber loss will have some difference. Usually, PCDD/PDCF is absorbed in small fiber, so that make monitoring number is lower than exactly number.

3. In CEH bleaching process, there are 3 stages, in each stage, there will have some fiber loss, so PCDD/PDCF will loss with fiber too, So in test result, C stage > E stage. If wheat straw with pre-bleaching enzyme, C stage (3.14pg/g), E stage （0.73pg/g） which means that PCDD/PDCF in C stage is lost in E stage washing with small fibre. So the number in E stage is lower than C stage.

7. Increment cost and environment gains after Huatai implements BAT/BEP

Asset cost **Installation cost**				
Item	Reference Value	**Modified Value**	**Modification contents**	**Installation time**
Continue digester	RMB 22,219,400	RMB 22,219,400	Process improvement	10 years
Capacity	**40000 tons/year**	**40000 tons/year**		
Wheat straw pulp bleaching				
Total invest in	**RMB**	**RMB 7,799,000**		

bleaching stage	**7,489,000**			
C stage	RMB 2583,600	RMB 2583,600	Reinstall bleaching line	10 years
E Stage	RMB 2303,000	RMB 2303,000	Reinstall bleaching line	10 years
H Stage	RMB 2303,000	RMB 2303,000	Reinstall bleaching line	10 years
Water cost	RMB 150,000	RMB 150,000		
Cl2	RMB 100,000	RMB 100,000		10 years
NaOH	RMB 20,000	RMB 20,000		10 years
Xylanase dosing equipment		RMB 150,000	Enzyme adds before C stage	10 years
NaOH dosing equipment		RMB 160,000	H2O2 adds in E stage with NaOH	10 years
Steam cost in E stage	RMB 30,000	RMB 30,000		10 years
Pollution discharge control （main body and accessories）				
Electrostatic precipitor	RMB 1,100,000	RMB 1,100,000		10 years
Effluent treatment	RMB45,010,0	RMB45,010,000		10

	00			years
Monitoring system				
stacking	RMB 120,000	RMB 120,000		10 years
others（see detail explanation）				
Unpredictable cost				
Total asset	RMB 758,360,00	RMB 761,460,000		

Bleaching stage	Reference Value	**Modified Value**	**Modification contents**
Annual operation and maintain cost			
Electricity （unit cost and total cost)	RMB 6,500,000（RMB 0.41/KWH)	RMB 6,500,000	
Energy cost	RMB 6,272,200	RMB 6,272,200	
Washing stage			
Bleaching stage			Enzyme adds before C stage
Water	RMB 2,671,600（RMB 1/m3)	RMB 2,671,600	
Cl2	RMB 6,443,300（RMB 1.8/Kg)	RMB 5,154,600(Cl2 usage is 7.2%)	Reduce Cl2 consumption

	Cl2 usage is 8.9%		
NaOH	RMB 4,775,600（RMB 1.27/Kg）	RMB 4,775,600	
Xylanase		RMB 926,600（RMB 658.11/Kg）	
H2O2		RMB 1,143,400（RMB 8.6/Kg）	Usage H2O2
Steam in E stage			
Black liquor evaporator			
Electrostatic precipitator			
Dust treatment	RMB 500,000	RMB 500,000	
Sludge handling	RMB 630,000	RMB 630,000	Waster consumption change in bleaching stage
Stacking(maintain)	RMB 30,000	RMB 30,000	
Lab cost（cost/ cost/capital	RMB 3,165,200（RMB 17,600/person.year）	RMB 3,165,200	
TOTAL	RMB 30,987,900	RMB 30,987,900	

8. conclusion:

After implementation of BAT/BEP program, Huatai Paper Group invested RMB 310 thousand for technical innovation in 40,000 tons/year wheat straw pulp line, production cost increases RMB 782.7 thousand/year(RMB 19.6/t pulp). Chlorine dosage reduces 17kg/adt. Return from environment doesn't calculated because of PCDD/PCDF monitoring basis is high after BAT/BEP program was implemented.

Strategies to Reduce Unintentional Production of POPs in China:
BAT, BEP and Incremental Costs for Selected Sectors of Industry

Case Study Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in BAOSTEEL

Submitted to
Foreign Economic Cooperation Office
State Environmental Protection Administration, China

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RESEARCH ON DEMONSTRATION PROJECT OF REDUCING UNINTENTIONAL PRODUCTION OF POPs IN BAOSTEEL

1. Introduction

Stockholm Convention on Persistent Organic Pollutants (POPs) is an international convention that aims to eliminate and control the release of 12 POPs, which are most harmful to human health and environment. After Vienna Convention on the Protection of Ozone Layer in 1987 and Framework Convention on Climate Change in 1992, POPs Convention are the third international convention requiring forcible release reduction. The Convention was passed in Stockholm Sweden on May 22nd, 2001. China government signed the Convention on July 25th, 2004. The Tenth Plenary Session of the Tenth National People’ s Congress Committee of China ratified the Convention. Stockholm Convention on POPs took effect in China on November 11th, 2004.

Among the first listed 12 POPs in the convention, dioxins are known to be the most toxic persistant organic pollutants, including Polychlorinated dibenzo-*p*-dioxins (PCDDs), Polychlorinated dibenzofurans (PCDFs), and Coplanar Polychlorinated biphenyls (co-PCBs). The term "dioxin/dioxins" has been widely used to refer to PCDDs/PCDFs.. The three types of compounds share certain similar structures, physical and chemistry properties, and biological characteristics. Any or all of the eight hydrogen atoms of dibenzo-*p*-dioxin (DD) and dibenzofuran (DF) can be replaced with chlorine, giving rise to 75 PCDDs and 135 PCDFs, respectively.

Different from other pollutants, dioxins are more harmful to human health and environment. Dioxins are resistant to degradation in the environment and can be long range transported. It is hardly to be degraded in the organism body and will be accumulated through food chain. They are carcinogenic, teratogenic, and mutagenic, even can interfere body incretion system. Scientific studies show that POPs will have a continuous negative effect on human for generations and it becomes a serious threat to public health and to sustainable development of human being.

Each party to this Convention ought to take the necessary legal and administrative measures to reduce and eliminate POPs releases from emission resources, and implement BAT/BEP. China signed the Convention on July 25th, 2004. POPs Convention Implement Office (POPs CIO) of State Environmental Protection Administration (SEPA) takes in charge of the Convention implementation task and work of China. UNDP and UNOPS are international executive organization for POPs Convention. The Italian Ministry of Environment and Territory （IMET） cooperate with China SEPA and provide financial support and technical assistance for eliminating POPs releases in China, which is produced by human being unintentionally.

POPs CIO of SEPA organized domestic and foreign experts to discuss on POPs Emission Reduction Project on January 17th-18th, 2005. Six enterprises were selected to implement the POPs emission reduction project by SEPA/CIO with CISA (China Iron and Steel Association) and CPA (China Paper Association).

POPs CIO of SEPA organized Information Exchange Conference of Candidate Enterprises for Sino-Italy Dioxin Reduction Project on January 1st - 3rd, 2005. Domestic and foreign experts and specialists visited candidate enterprises after the conference.

SEPA/CIO organized technical training for the enterprises which would implement demonstration project on June 1st, 2005. Experts at home and abroad introduced UP-POPs analysis method and sampling requirements. Baosteel and TISCO were recommended as demonstration enterprises to implement Sino-Italy Emission Reduction Project in the iron and steel industry. The reasons for the 2 enterprises to be selected are as follows: (1)Steel-making capacity: Baosteel 20 million tons, TISCO 3 million tons; (2)Raw material: Baosteel uses import iron ore, TISCO uses owns local iron ore; (3)Process and equipment: Baosteel and TISCO both own sintering and EAF process; (4)Location: Baosteel located in coastal area, TISCO located in inland area; (5)Products: Baosteel produces carbon steel and special steel, TISCO produces stainless steel.

On June 2005, experts and officers from Italy, CISA, SEPA/CIO and RCEES/CAS(Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences) investigated sintering and EAF processes in Baosteel and confirmed dioxin monitoring location and the sampling numbers.

According to the request of Dioxin Monitoring Research Plan signed between Bureau Abroad Corporation Center of SEPA and NEAC, the project was divided into two sections (2 phases) from August to November in 2005: baseline scenario and modified scenario in No1 sintering plant of Baosteel Subsidiary Company and 100-t EAF of Special Steel Subsidiary Company. Baseline scenario was from Aug.8th to 10th, NEAC totally collected 14 flue gas samples and 4 ash samples from Baosteel for dioxin monitoring. Modified scenario was from Dec.19th to 21th, NEAC collected 12 flue gas samples and 4 ash samples. Dioxin concentrations of all the samples were analyzed using US EPA1613 Method.

2. Enterprise Outline of Baosteel

Shanghai Baosteel Group Corporation (referred to below as Baosteel) is a large iron and steel conglomerate set up on Nov. 17, 1998, with the former Baoshan Iron and Steel (Group) Corporation as the core, and absorbing the former Shanghai Metallurgical Holding Group Corporation and the former Shanghai Meishan Group Co., Ltd.

Baosteel is a large iron and steel conglomerate with the largest scale of production and the most complete varieties and specifications of products in China. It focuses on high value-added market segments. Baosteel's iron and steel business has such main players as Baoshan Iron and Steel Co., Ltd., Baosteel Group Shanghai No. 1 Steel Co., Ltd., Baosteel Group Shanghai No.3 Steel Co., Ltd., Baosteel Group Shanghai No.5 Steel Co., Ltd., Baosteel Group Shanghai Meishan Co., Ltd., Ningbo Baoxin Stainless Steel Co., Ltd. etc. Its annual steel-making capacity has reached 20 million tons. Baosteel's product mix is dominated by steel plate & tube supplemented by steel bar & wire. It is also currently developing stainless steel products. High grade steel products, such as automobile steel, shipbuilding steel, household electric appliance steel, pipeline steel and oil tube, produced by Baosteel dominate the domestic market. Baosteel is also a main supplier of high quality tool & die steel, bearing steel, spring steel, wire rod steel and steel for aviation and space flight. Baosteel's e-mart platforms with consummate business functions provide E-commerce convenience. The modern steel deep processing centers set up in Shanghai, Hangzhou, Guangzhou, Tientsin, Qingdao, Chongqing and Shenyang provide value-added services for customers.

Along with the implementation of the new development strategy, Baosteel is quickening its step to conduct integrative operation. Aiming at upgrading the integrative competence of China's iron and steel industry, Baosteel makes effort to develop high demand premium products, which need strategic investment in the industrial structure adjustment in China and are comparable with world top-quality steel products.

Baosteel has a registered capital of 45.8 billion Yuan. It possesses 22 wholly owned subsidiaries (including 9 overseas subsidiaries) and 14 holding companies (including 2 overseas subsidiaries) and 24 equity-sharing companies. Among the wholly owned subsidiaries and share holding companies, 11 are iron and steel companies, 2 financial companies, 8 trading companies.

Baosteel is one of the most profitable steel enterprises in the world enjoying international competence, and its annual production capacity is about 20 million tons. Baosteel produces high demand products in the domestic and international market. On Dec. 6. 2004, Standard & Poor has raised the credit rating of Shanghai Baosteel Group Corporation from BBB to BBB+ with a "stable" outlook. Baosteel was ranked No. 372 on the list of 2003 Global 500 by "Fortune" magazine on July 2004, and became the first of its kind in the competitive industry and the manufacturing sector in China to enter the world's top 500 enterprises.

Baosteel follows its "premium products" strategy and aims to become the prime research and development base for new processes, new technologies and new materials in China's iron and steel industry. Baosteel's premium products include automobile steel, oil and gas exploitation and transportation steel, stainless steel, household electric appliance steel, transportation facilities steel, silicon steel, boiler and pressure vessel steel, food and beverage packing steel, metal production steel, special material steel, high-grade construction steel. Baosteel follows a strategy of "one main industry of exceptional quality with appropriate and relevant diversified trades". Besides its main steel business, Baosteel also engages in diversified industries such as trade, finance, engineering & equipment manufacturing, information, coal chemical industry, deep processing of steel products and recycling.

Baosteel conducts internationalized operation. The global network, including 20 overseas and domestic trading companies, has taken shape. Baosteel cooperates and establishes joint ventures with international steel giants; it has made strategic alliances worldwide to achieve win-win result on the basis of mutual benefit.

Baosteel has committed itself to clean production and paid great attention to environmental protection to make a green Baosteel. Baoshan Iron & Steel Co., Ltd. is the first enterprise among the domestic metallurgical circle to get the ISO14001 certificate. Its greenbelt covers 42.71% of total plant area, and its air quality in the plant area has reached the standard of a State-level scenic spot. The Company has been recognized as the first State-level industrial showplace in China.

Baosteel has devoted itself to social charity causes such as the establishment of the Baosteel Arts Award and the Baosteel Education Fund. Many outstanding artists, teachers and students have received the awards. Baosteel has also donated nine million Yuan to the "Hope Project" to build up 25 Hope Primary Schools and a middle school. Baosteel grows together with society, and giving back to society is Baosteel's sustained pursuit.

3. Processes Status relative to Unintentional Production of POPs in Baosteel

According to literatures, dioxins could be formed and emit from the production processes of iron and steel as unintentional production. Sintering and EAF process are the major sources of dioxin emission from Iron and steel processes. There are sintering and EAF process for producing sinter and steel in Baosteel. Therefore, dioxin emission and pollution as unintentional production should exist with the two types of processes in Baosteel.

The No. 1 sintering plant of Baosteel Subsidiary Company and 100-t EAF of Special Steel Subsidiary Company selected as Demonstration processes for reducing unintentional production of POPs. The description of the two processes in Baosteel are as the following.

3.1. Process Description of the No. 1 sintering plant of Baosteel Subsidiary Company

The No. 1 sintering plant of Baosteel Subsidiary Company has been chosen as demonstration plant for the UP-POPs reduction project. The sintering machine was put into production in 1985 with an effective area of 450 m^2. The effective area of the sintering strand was enlarged to 495 m^2 on March 2005. The designed annual production is 5,500,000 t. Blending ore used for sintering contains 86.5% imported ore and 13.5% inner recycled materials. Each stockpile of blending ore is about 230,000 t, and feed to No 1 and No 2 DL sintering plants at the same time for 8 ~ 10 days. Inner recycled material contains pressed dense material from the bottom of stock yard, dust from ESCS precipitators, slag sized iron, rolling mill scales, steel-making slag, and returned fine sinter. Additives added to the blend include quicklime (420 t/d), limestone (600 t/d), dolomite (380 t/d), and serpentine (190 t/d). Coke breeze (550 t/d) and anthracite coal (150 t/d) are added as solid fuels. Solid fuels are transported into the coarse-coke bin by conveyer belt from blast furnace, coke-making, and stockyard. Then the solid fuel are crushed into fine particle of 1.4 mm (mean size) by coke crushing system with screening (twice) and crushing (twice). The fine coke is put into a bin and used as sintering solid fuel. Return fines is the undersize fine material (< 5 mm) which is produced in the sinter cake sizing system, and are sent back to the measuring pocket by conveyer belt. Sinter fine is the undersize sinter (< 8 mm), which is produced by screening before the sinter is charged into the blast furnace, and returned back to sintering plant. Flux materials (limestone, dolomite, and serpentine) are fetched from stockyards, and transported into the measuring pocket by conveyer belt. Quicklime is transported into measuring pocket by tank car. Blending ore is fetched from stockyard and transported into the measuring pocket by conveyer belt.

According to the blending ratio, the quantity of each kind of sintering feed are calculated automatically, and controlled by CFW. After weighing, all sintering feeds are transported into the first and second drum mixers. Then they are mixed together, and granulated by spraying water, and made into raw mixture. The mini pellets of dry ash, which is the dust collected from dust-precipitators, are directly put into the secondary drum mixer after treating by mini alletizing equipment. A typical composition of the sintering feed is reported in Table 1.

Table 1 Chemical composition of sintering feed, %

Item	Tfe	CaO	SiO_2	Al_2O_3	MgO	TiO_2	P_2O_5	S
Sintering mixture	52.4	7.9	3.8	1.4	1.1	0.1	0.11	0.02

Several APCDs are in use for controlling dust emission during the preparation stages of the raw materials. Bag filters are used to remove dust from ore stock bin, coke crushing, and sinter production transportation system. A pulsed-jet bag filter is used to remove dust above the quicklime bin when charging quicklime. Dust from the treatment process of dry ash is abated by using an electrostatic precipitator.

The specification of Dwight-Lloyd sinter strand is 90m×5.5m (495 m^2). Under the normal production, the speed of the sinter strand is 2.0~2.8 m/min. Sintering bed height is around 650~720 mm and it could produce 16580 tons of sinter per day. The annual operating rate is 96.5 % (8453 h/a).

The sintered material proceeds to a cooler after coming off the strand. The area of the circular cooler is 460 m^2. The sinter is cooled by air, which is forced upwards through the sinter layer by 5 sets of blower fan. The sensible heat in the sinter cooling waste gas from the discharge zone and the hot crusher is used in the sinter grate ignition hoods. Cooled sinter is transferred to screens that separate the pieces to be used in the blast furnace from the pieces to be returned to the sinter process as "return fines". A typical composition of the produced sinter is reported in Table 2.

Table 2 The quality data of sinter product

Tfe %	FeO %	SiO_2 %	Al_2O_3 %	S %	C/S	TI %	RDI %	MS mm	RI %
58.8	7.8	4.6	1.7	0.01	1.8	75.4	29.6	23.1	68.6

Energy consumption in the sintering plant is as follows (average data of 2004):

- COG: 3.56 m^3/t-sinter,
- Electricity: 41.16 kW•h/t-sinter,
- Coke breeze (include fine coal): 50.41 kg/t-sinter
- Compressed air: 6.0 Nm^3/t sinter

Wastewater is recycled in internal systems and also delivered through connection pipes to other water supply networks for reuse and intermediate water is treated as a substitute for clean water.

Sinter production unit has relatively independent water circulation and wastewater treatment systems; clean and unclean waters are thus separately delivered supplied. Wastewater discharged by each production unit will be first treated and reused in the internal system. Water consumption is 0.08 ~ 0.095 m^3/ t-sinter. Water recycling rate amounted to 97.62% in 2004.

The process flow chart of Baosteel No.1 sintering plant is show as Figure 1.

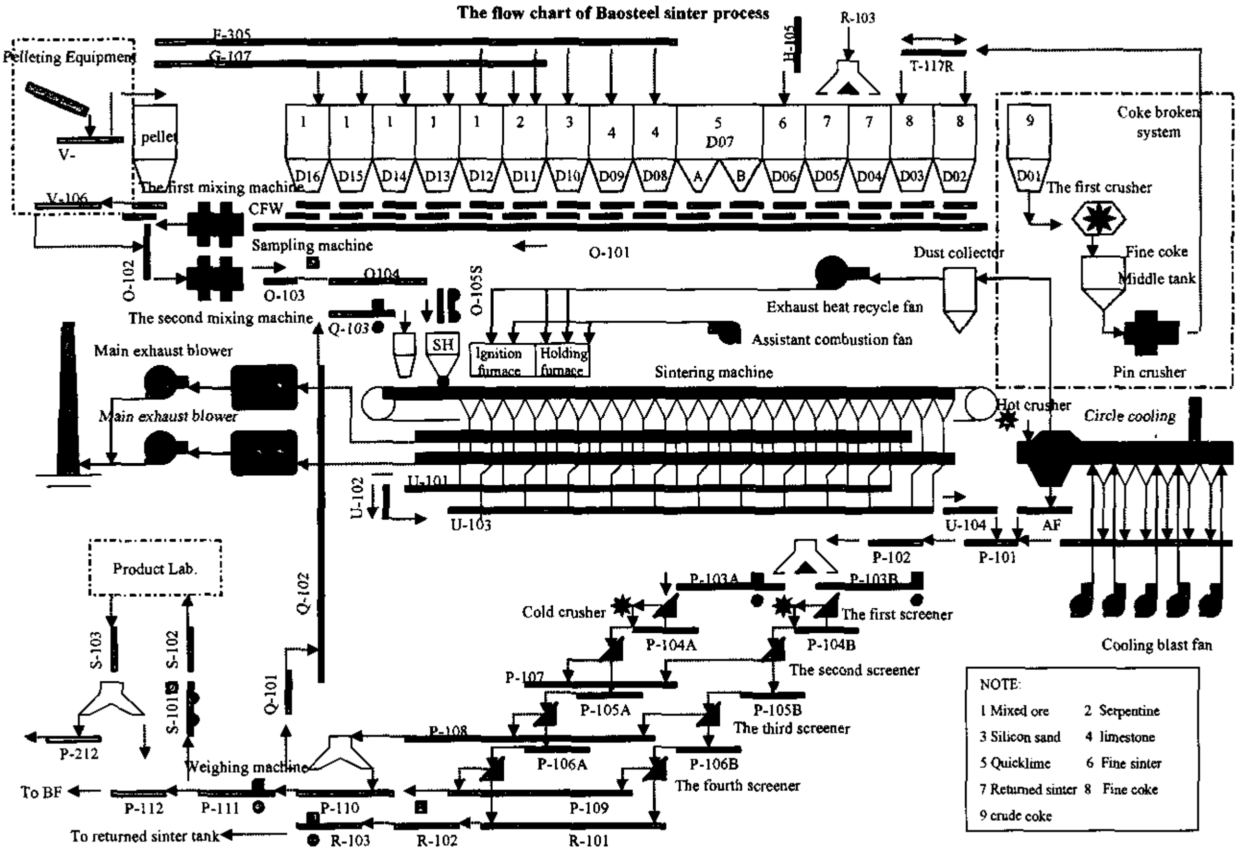


Figure 1 The process flow chart of Baosteel No.1 sintering plant.

The layout of the off gases collection system is reported in Figure 1. Two fans draw process air through the entire length of the sinter bed into 23 wind-boxes located underneath the sinter strand. The waste gas collection system is divided into two sub-systems, called North (N) system and South (S) system, respectively. Wind boxes from #1 to #6, #22, and #23 belong to the S system while wind boxes from #11 to #19 belong to the N system. The #7 to #10, #20, and #21 wind boxes change their direction according to the practical operation. Only the N system is connected to a desulphurization plant.

The main exhaust flow gas rate is 1,260,000 m^3/h. Before discharging into the atmosphere, flue gases are treated in two electrostatic precipitators (ESCS-A and ESCS-B) in order to remove dust from the main flue of sintering machine. Estimated dust abatement efficiencies of both ESCSs are 84 – 97 %. Experimental data collected on June 19th, 2005 gave dust abatement efficiencies of about 91% (see Table 3).

Table 3. Dedusting Efficiency of ESCSs of No.1 sintering plant (June 19th, 2005).

ESCS	Speed of waste gases (m/s)		Temperature of waste gases (°C)		Flux of waste gases (Nm^3/min)		Dust (mg/Nm^3)	
	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet
N system	14.5	16.38	122	110	9,977	10,898	811.7	74.8
S system	16.3	18.2	161	150	10,055	10,632	857.1	79

Cleaned gases from the sintering strand are emitted into the atmosphere through a stack with a height of 200 m and a diameter of 6.2 m. The particulate matter concentration is less than 80 mg/Nm^3. Suitable ports for sampling the flue gases are located at the inlet and outlet of both ESCSs.

The waste gas (900,000 m^3/h) at high temperature (290~300°C) from the discharge zone and the hot crusher is partially reused as combustion-supporting air for igniting furnace and holding furnace after removing the dust by a multi-tube dust cleaner. Steam is produced when sinter fume flows into surplus heater boiler, the steam produced reaching 68.2 kg/t-sinter.

Waste gases (390,000 m^3/h) from the annular cooler are treated separately in an electrostatic precipitator. Cleaned gases from the cooling and crushing section are emitted into the atmosphere through a stack with a height of 50 m and a diameter of 4 m. The particulate matter concentration is less than 100 mg/Nm^3. A suitable port for sampling the flue gases is located at the outlet of the electrostatic precipitator.

The amounts of dust separated by the off-gas treatment systems are as follows:

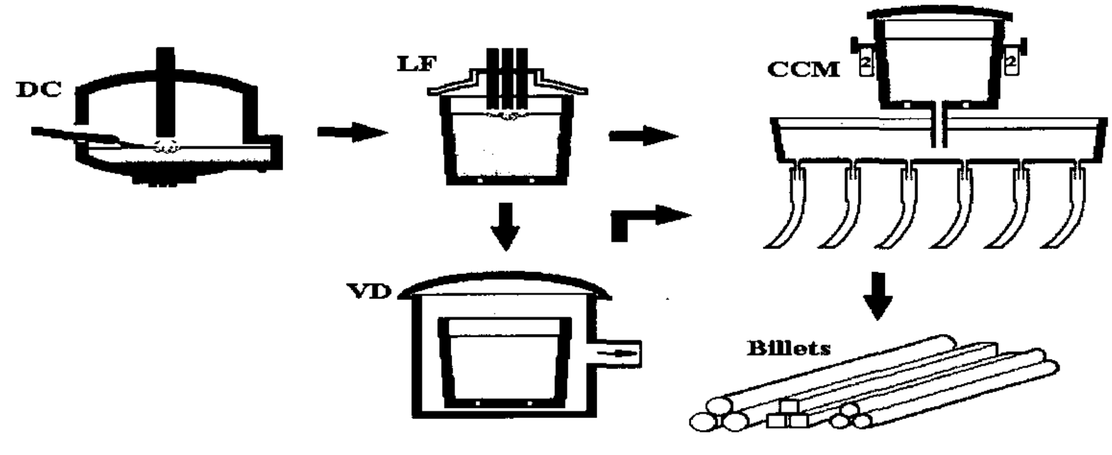
- Dust from main exhaust: 20 t/d
- Dust from discharge zone and hot crusher: 85 t/d
- Dust from cooling and crushing: 80 t/d

3.2. Process Description of the 100-t EAF plant of Special Steel Subsidiary Company

There are 5 EAF plants in Special Steel Subsidiary Company. The demonstration EAF at Special Steel Subsidiary Company is a direct current (DC), one graphite electrode furnace, with a capacity of 100 tons. The furnace is enclosed in a dog-house. The furnace was put into operation on March 28, 1997 and revamped on March 3, 2003. A pre-treatment furnace of hot metal was built up in 2000. The plant produces carbon steel, low alloyed steel, and high-alloyed steel with a total annual production of 550,000 tons/year

Feed source is 100 % scrap steel. Primary emissions are extracted by the 2nd hole. A sedimentation chamber allows the sedimentation of coarse particles. After cooling, primary emissions are mixed with the secondary emissions that are captured by the hood on the roof of the building. The gaseous streams are treated in a common bag-house and emitted into the atmosphere through a common stack. Total waste gas flow from the plant is about 0.85 million Nm^3/h. However, the instantaneous total flow is dependent on the secondary flow rate, which is modulated depending on the particular phase of the productive cycle (charging, melting and tapping).

The product process flow sheet of the 100-t EAF plant is shown in Figure 2.



Main Process of EAF Steel Making Plant of Baosteel

Figure 2 Product process flow sheet of Baosteel 100-t EAF plant

Feedstock for the 100-t EAF is ferrous scrap. The following main operations are performed:

- raw material handling and storage;
- furnace charging;
- melting;
- steel and slag tapping;

- ladle furnace treatments;
- vacuum degassing;
- continuous casting.

Scrap is loaded into charging baskets in the scrap-yard. Lime is added as a fluxing agent for the slag formation and coke is also added. For charging, the furnace electrode is raised in top position and the roof of the furnace is then swung away. The furnace is charged with about 50-60% of its capacity, the roof is closed and the electrode lowered to the scrap. After the first charge has been melted, the remainder of the scrap is added from a second basket. Oxygen lances and oxy-fuel burners are used to assist the melting stage. Oxygen is used for ecarburization of the melt and removal of undesired elements (phosphorous, manganese, silicon and sulfur). At the end of the process, the furnace is tilted backwards and the slag is poured through the slagging door. The steel is then tapped through a bottom tapping system (EBT, Eccentric Bottom Tapping) with a minimum slag carry over into the ladle.

Primary off-gases, generated during the melting phase, are extracted from the 2nd hole, which is attached by a ductwork to the gas cleaning system. This device only works when the furnace is upright and the roof is in position. The duct connected to the 2nd hole is cooled by means of water-cooled panels. Off-gases are sent to an air-cooled heat exchanger and then to the main pipe. A canopy hood located just above the EAF and the doghouse, collect secondary emissions from charging and tapping, as well as from EAF leakage during melting. Off gases captured by both hood and doghouse are sent through the main pipe to the bag filter.

Primary and secondary raw gases are treated in the same air pollution control system (bag-filter) for dust abatement. The estimated de-dusting efficiency of the fabric filters is about 99%. The amount of generated dust is 15 kg/t steel. The separated dust is recycled for zinc recovery and as a cement additive.

Cleaned flue gases are emitted into the atmosphere through a stack with a height of 20 m and a diameter of 5 m. The flue gas flow is of about 850,000 Nm^3/h at a temperature of 60-110 °C. The particulate matter emitted after abatement is about 10 mg/Nm^3. Suitable ports for sampling the flue gases are located at the inlet of the bag-house and on the stack (see Figure 3).

Figure 3 shows the flue gas collection and cleaning system of Baosteel 100-t EAF plant.

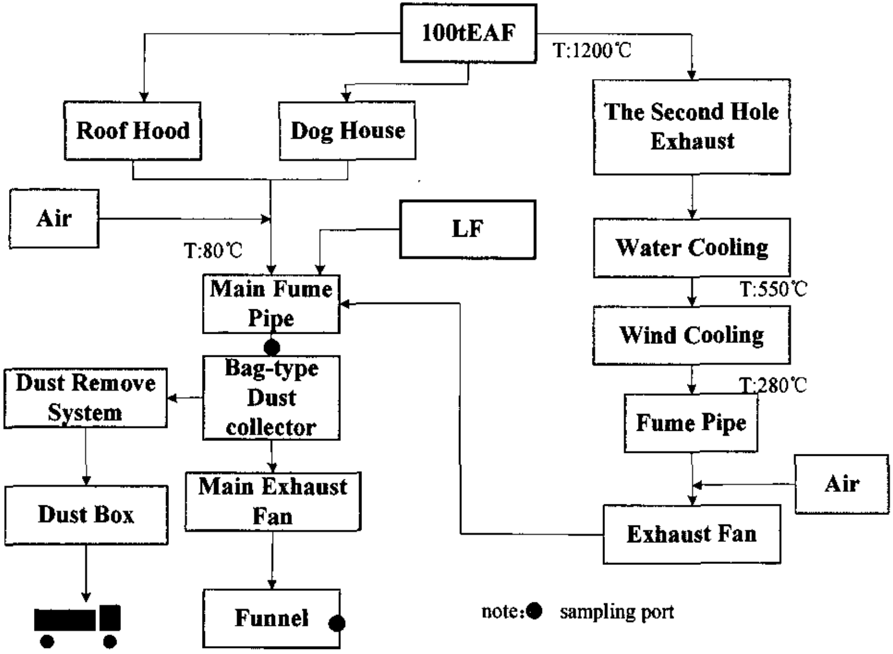


Figure 3 Flue gas collection and cleaning system of Baosteel 100-t EAF plant

Secondary metallurgy is carried out in ladles (LF) at the ladle treatment station and covers the processes and treatments of molten steel after the tapping up to the point of casting. Carbon is added according to the produced grade of steel. Fluxes are added as deoxidant and oxygen is blown for ecarburization. The amount of produced slag from ladle furnace is about 0.5 t/ladle. Consumption of graphite electrodes is 0.8 kg/t-steel. Emissions from secondary metallurgy (ladle furnace) are collected and sent to the main pipe.

For high alloyed and special steels the operation sequence is more complex and include a vacuum degassing (VD) for the elimination of dissolved gases like nitrogen and hydrogen in order to improve the quality of the steel. Degassing is performed by keeping 20 minutes under vacuum at a pressure of 66.7 Pa.

Once the final steel quality has been achieved, the liquid steel leaves the ladle treatment station and is cast as billets by means of a five strands, continuous casting machine (CCM) with curved strand (diameter 10.2 m). Continuous casting is a process that enables the casting of a sequence of ladles of liquid steel into a continuous strand of billet. Steel is tapped from the ladle into a tundish from which it is distributed at a controlled rate into water-cooled copper moulds of appropriate dimensions.

The operational data of the Baosteel 100-t EAF was listed in Table 4.

Table 4 Operational data of the Baosteel 100-t EAF

In operation since	1997
Furnace type	DC, UHP
Number of graphite electrodes	one
Produced steel grade	carbon steel, low alloyed steel, high-alloyed steel
Nominal capacity (t)	100
Batch capacity (t)	106
Metallic charge weight, t	120.8
Raw materials	scrap
Productivity, t/hour	84.8
Capacity (t/a)	550,000
Operational time (d/a)	323
Additional fuels	Coal, gas
Additional burners	six (one oxygen lance and five side-wall oxy-fuel burners)
Nitrogen, argon or other inert gases injection in the bottom of the EAF	None
Duration of the cycle (tap to tap)	75
Cooling system	Water cooled side walls, water cooled ducts, air-cooled heat exchanger
Tapping system	EBT
Emission collection	Direct extraction (2nd hole), dog-house, roof hood
Off gas cleaning system	Fabric filter
Heat recovery	None
Secondary metallurgy	Ladle furnace, vacuum degassing

Energy consumption of the Baosteel 100-t EAF is as follows (average values of 2004).

- Electricity: 420 kWh/t (231,000,000 kW·h/a)
- Oxygen: 42 m^3/t steel (23,1000,000 m^3/a)
- Gas: 4 m^3/t (2,200,000 m^3/a)

4. Monitoring Results of Dioxin Emission from Baosteel Sintering and EAF Processes

4.1. Monitoring Results of Dioxin Emission from No.1 Sintering Plant

In order to understand dioxin emission situation of No.1 sintering plant in Baosteel Subsidiary Company, the first round sampling and monitoring were carried out in the locale of No.1 sintering plant on August 10, 2005. The first round period is called baseline scenario. Under the normal operating situation of No.1 sintering plant, total 13 samples were taken and analyzed. Sampling positions in No.1 sintering plant were visualized in Figure 4.

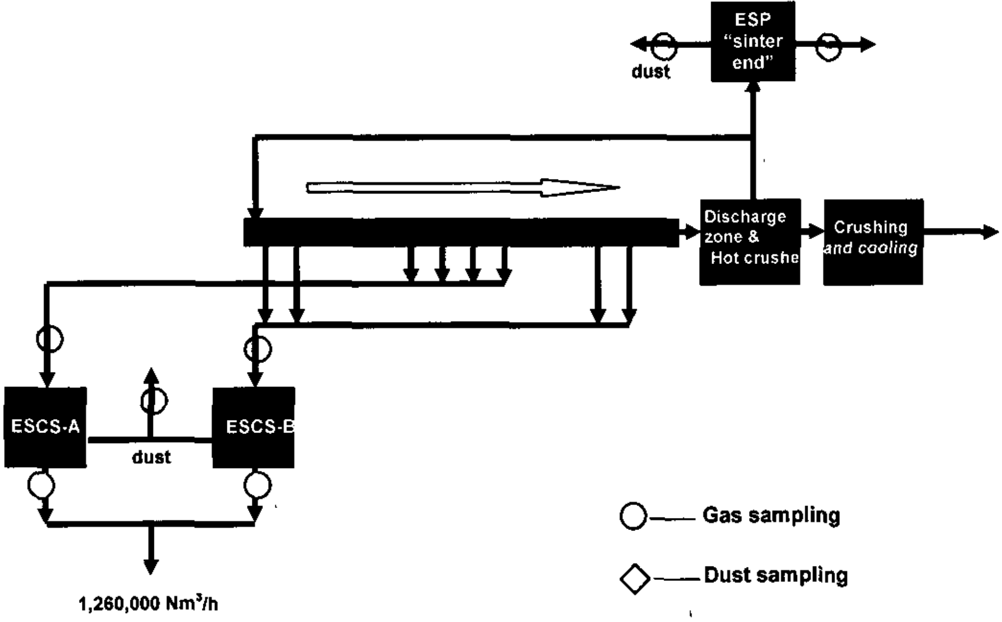


Figure 4 Schematic plot of sampling positions in No.1 sintering plant

The following samples were collected at the No.1 sintering plant of Baosteel on August 10th, 2005:

Flue gas samples

- inlet ESCS-A : 2 samples ;
- outlet ESCS-A : 2 samples ;
- inlet ESCS-B : 2 samples ;
- outlet ESCS-B: 2 samples;
- outlet ESP sinter end: 2 samples;

Dust samples

- front container ESCS dust (1st and 2nd fields): 1 sample;
- back container ESCS dust (3rd field): 1 sample;
- ESP dust sinter end: 1 sample.

Table 5 reports the concentration values of flue gas samples and dust samples in International Toxic Equivalent (ng I-TEQ/Nm^3 or ng I-TEQ/g) measured by the National Research Center for Environmental Analysis and Measurement.

Table 5 Analysis results of dioxin samples from Baosteel No.1 sintering plant

Samples			Baseline scenario (first round)
Flue gas	ESCS-A Inlet	1	4.60 ng I-TEQ/Nm^3
		2	2.88 ng I-TEQ/Nm^3
		Average	3.74 ng I-TEQ/Nm^3
	ESCS-A Outlet	1	0.006 ng I-TEQ/Nm^3
		2	1.28 ng I-TEQ/Nm^3
		Average	1.28 ng I-TEQ/Nm^3
	ESCS-B Inlet	1	5.71 ng I-TEQ/Nm^3
		2	4.24 ng I-TEQ/Nm^3
		Average	4.98 ng I-TEQ/Nm^3
	ESCS-B Outlet	1	2.91 ng I-TEQ/Nm^3
		2	3.69 ng I-TEQ/Nm^3
		Average	3.30 ng I-TEQ/Nm^3
	ESP Outlet	1	0.26 ng I-TEQ/Nm^3
		2	0.22 ng I-TEQ/Nm^3
		Average	0.24 ng I-TEQ/Nm^3
Dust	Front container (1st and 2nd fields of ESCSs)		267 ng I-TEQ/kg
	Back container (3rd field of ESCSs)		2551 ng I-TEQ/kg
	ESP dust		46 ng I-TEQ/kg

According to the analysis results shown in Table 5, the dioxin concentration values of ESCS-A and ESCS-B outlet flue gas emitted into atmosphere reached are 1.28 and 3.30 ng I-TEQ/Nm^3, respectively. The dioxin concentration in ESCS inlet flue gas is in the range of 2.88 to 5.71 ng I-TEQ/Nm^3. The analysis results of dioxin emission from No.1 sintering plant at normal operating condition is higher than that of similar plants unequipped dioxin reduction apparatus in west Europe. Emission Factors (Efs) calculated from available analytical and process data are reported in Table 6.

Table 6 Emission Factors (Efs) calculated from available analytical and process data during baseline scenario (the first round monitoring)

Item	Unit	Index of production and emission of No.1 sintering plant	
Annual operational time	d/a	352.2	
Annual production	t/a	5,500,000	
Emission position		ESCS	EP
Annual flue gas emission	Nm^3	21,301,560,000	7,607,700,000
Annual abandon dust	t	1761	
Dioxin concentration in flue gas	ng I-TEQ/Nm^3	2.29	0.24
Dioxin concentration in abandon dust	ng I-TEQ/kg	2551	
Annual dioxin emission by flue gas	g I-TEQ/a	48.781	1.826
Annual dioxin emission by abandon dust	g I-TEQ/a	4.492	
Dioxin Emission Factor by flue gas per ton sinter	µg I-TEQ/t-sinter	9.201	
Dioxin Emission Factor by *abandon dust per ton sinter*	µg I-TEQ/t-sinter	0.817	
Total Dioxin Emission Factor per ton sinter	µg I-TEQ/t-sinter	10.018	

Dioxin emission factor of flue gas per ton sinter reaches at 9.201 µg I-TEQ/t-sinter. This value is much higher than the value (0.3 – 5.0 µg I-TEQ/t-sinter) referred to the Standardized Dioxin Toolkit.

Dioxin concentrations in ESCS dust are also relatively high, reaching values of 267 ng I-TEQ/kg for the dust collected in the front container (1st and 2nd fields of the electrostatic precipitation filter ESCS) and 2551 ng I-TEQ/kg for the dust collected in the back container (3rd field). The difference is not surprising since dust collected at different fields should have distinct differences in composition and particle size. In particular, dust collected by the last field should have smaller particle size and thus a higher surface area if compared with dust collected by the 1st field.

Due to the dust collected in the front container was recycled in sintering and the dust collected in the back container was abandoned, the corresponding Emission Factors are 0.817 µg I-TEQ/t-sinter for the dust collected by the 3rd field. The value is two orders of magnitude higher than the one reported in the Dioxin Toolkit, 0.003 µg TEQ/t-sinter.

Probably, the difference should be found in the fact that the Toolkit value is based on UK plant data, which produced sinter dust with quite low PCDD/PCDF concentrations (29-90 ng I-TEQ/kg). In addition to that, in UK plants most of the sinter dust is recycled to the process and only a very small amount (0.05 kg dust per ton of sinter) is disposed of. The Emission Factor reported in the Toolkit and calculated from UK plant data is not comparable to Baosteel. In Baosteel, sinter dust collected by the 1st and 2nd fields is recycled to the process but dust collected by the 3rd field (approximately 0.3 kg dust per ton of sinter) and with a concentration of 2551 ng I-TEQ/kg-dust is disposed of. Therefore, we should consider this route of releases in Baosteel with an Emission Factors to residues of 0.817 µg I-TEQ/t-sinter.

Dioxin released from the ESP located at the end of the sinter strand was approximately one order of magnitude lower than releases from the main flue gases after treating by the ESCSs. Observed concentrations were 0.24 ng I-TEQ/Nm^3 in clean flue gas and 46 ng I-TEQ/kg dust. Corresponding Emission Factor to air was calculated in 1.826 µg I-TEQ/t sinter by EP flue gas.

It can be concluded from the monitoring results that the total Emission Factor of No.1 sintering plant is 10.018 µg I-TEQ/t-sinter. The actual sinter production by No.1 sintering plant in 2006 is about 17 Mt, the total dioxin emission in 2006 is estimated to be 170.3 g I-TEQ.

4.2.Monitoring Results of Dioxin Emission from 100-t EAF Plant

In order to grasp the dioxin emission state of 100-t EAF plant, the first stage sampling for dioxin monitoring was carried out at the 100-t EAF of Special Steel Subsidiary Company, Baosteel on August 9th, 2005, as the baseline scenario comparing with the modified scenario of dioxin reducing experiment period.

Under normal operating condition, five samples were collected in total, 2 samples from bag-house inlet flue, 2 samples from stack flue, and 1 sample from bag-house dust. Sampling positions in 100-t EAF plant were shown in Figure 5.

Flue gases samples

- bag-house inlet: 2 samples;
- bag-house outlet: 2 samples;

Dust samples

- filter dust: 1 sample.

The concentration values of flue gas samples and dust samples in International Toxic Equivalent (ng I-TEQ/Nm^3 or ng I-TEQ/g) measured by the National Research Center for Environmental Analysis and Measurement were shown in Table 7.

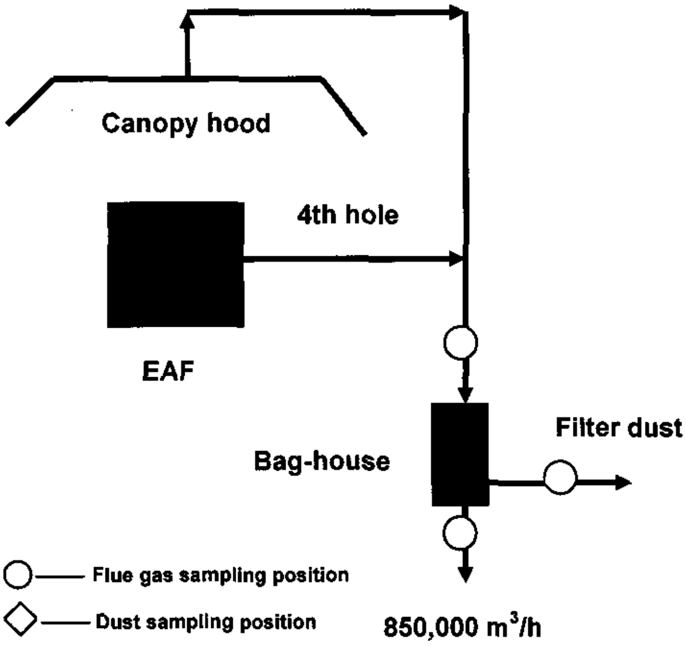


Figure 5 Schematic chart of sampling positions in 100-t EAF plant

Table 7 Analysis results of dioxin samples from 100-t EAF plant

Sample type	Sampling position		Baseline scenario (first round)
Flue gas	Bag-house Inlet	1	0.29 ng I-TEQ/Nm^3
		2	0.099 ng I-TEQ/Nm^3
		Average	0.195 ng I-TEQ/Nm^3
	Bag-house Outlet	1	0.11 ng I-TEQ/Nm^3
		2	0.048 ng I-TEQ/Nm^3
		Average	0.079 ng I-TEQ/Nm^3
Dust	Bag-house dust		610 ng I-TEQ/kg
Flue gas flow volume of stack			850,000 m^3/h
Bag-house dust			15 kg/t-steel
Steel production			106 t/furnace

The analytical results obtained under current operating conditions (baseline scenario) of the 100-t EAF of Baosteel showed quite low dioxin atmospheric releases (0.048 to 0.11 ng I-TEQ/Nm^3). The dioxin concentration in the flue gas of Bag-house inlet is un the range of 0.099 to 0.29 ng I-TEQ/Nm^3, and the dioxin content in the Bag-house dust is 610 ng I-TEQ/kg-dust.

Emission Factors (EFs) derived from available analytical and 100-t EAF process data are listed in Table 8.

Table 8 Emission Factors derived from available analytical and process data during baseline scenario (the first round monitoring)

Item	Unit	Data of 100-t EAF production and emission
Annual operational time	d/a	323
Annual production	t	550,000
Annual flue gas emission	Nm^3	6,589,200,000
Annual bag-house dust	t	8,250
Dioxin concentration in flue gas	ng I-TEQ/Nm^3	0.079
Dioxin concentration in dust	ng I-TEQ/kg	610
Annual dioxin emission by flue gas	g I-TEQ/a	0.521
Annual dioxin emission by dust	g I-TEQ/a	5.033
Dioxin Emission Factor by flue gas per ton steel	µg I-TEQ/t-steel	0.946
Dioxin Emission Factor by dust per ton steel	µg I-TEQ/t-steel	9.150
Total Dioxin Emission Factor per ton steel	µg I-TEQ/t-steel	10.096

It can be seen, dioxin emission factor by flue gas per ton steel is 0.946 µg I-TEQ/t-steel in this100-t EAF plant, this value is one order of magnitude lower than that of No.1 sintering plant.

Due to all the bag-house dust from the 100-t EAF was sold out, the pollution of dioxin is transfer to other place or process although it was reused. Thereby, dioxin emission factor by bag-house dust reached at 9.150 µg I-TEQ/t-steel. The total dioxin emission factor by flue gas and dust is 10.096 µg I-TEQ/t-steel, is the same level of No.1 sintering plant. The total dioxin emission of the EAF plant is estimated to be 5.55 g I-TEQ.

Analytical results obtained under current operating conditions (baseline scenario) of the 100-t EAF of Baosteel showed quite low dioxin atmospheric releases (0.08 ng I-TEQ/Nm3) and comparable with that obtainable with the application of Best Available Technology / Best Environmental Practice (BAT/BEP) in developed countries, for example BAT and BEP established in support of the IPPC (Integrated Pollution Prevention Control) Directive in Europe (EU, 2000) or to the achievable performance level using the appropriate BAT/BEP for secondary steel production (EAFs) of less than 0.1 ng TEQ/Nm^3, as determined by the Expert Group established as a subordinate body of the Stockholm Convention and reported in the Advance Draft of the "Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants" (UNEP, 2004).

According to experiences performed in West Europe, values below 0.1 ng TEQ/Nm^3 in the atmospheric emissions from EAFs can be achieved if careful controls are placed on the scrap used (i.e. excluding cutting oils and heavily contaminated scrap) and advanced technologies are applied (i.e. post-combustion in combination with a water quench, lignite coke injection in raw gases and an efficient gas cleaning system like fabric filters). From available data, an efficient post-combustion of the primary emission at a temperature above 800-850 °C in order to ensure full combustion of the organic compounds within the off-gas duct system or in a separate post-combustion chamber is not performed at the 100-t EAF of Baosteel Group Shanghai, No.5 Steel Co., Ltd. Moreover, raw gases captured from the 2nd hole are air-cooled (from 550 °C to 280 °C), so that the possibility of dioxin production through de novo synthesis (reformation window: 250 °C - 500 °C) is not minimized.

Probably, the low measured emission data can be related to the relatively clean scrap feed to the furnace. Mainly heavy and middle scrap was used as feed during the emission tests. Raw materials with a high potential for PCDDs/PCDFs formation such as turning and shredded steel (since they are usually contaminated with organics) were not used as raw materials when sampling was performed. Another possible reason is disadvantages existed in sampling method and sampling apparatus.

5. Results of pilot experiments for reducing dioxin emission from sintering and EAF process in Baosteel

5.1.Results of pilot experiment for reducing dioxin emission in No.1 sintering plant

In order to cut down the dioxin emission from No.1 sintering plant of Baosteel, a pilot experiment had been carried out on the sinter producing line during December 19 to 28, 2005. The second round dioxin sampling and monitoring (Modified scenario) were carried out on December 21, 2005, so as to obtain the dioxin emission data during experiment period.

The guidance principle of the pilot experiment for dioxin reduction is to suppress dioxin formation during sintering process, i.e. to control dioxin from headstream, so as to cut down dioxin emission.

The following technologies and measures were taken in No.1 sintering plant during pilot experiment period.

(1) Before pilot experiment, one stockpile of blending iron ores (BA1-334) were prepared as main raw material of the experiment. The stockpile was piled without blending 5 recycling materials, i.e. steel rolling scrap (ZSC-S), blast furnace dust (ZBG-S), sintering dust (ZES-S), sinter powder (S1C-F) and slag iron (ZFG-S). The total amount of the stockpile is 235,000 tons.

(2) During experiment period, mini-pellet produced from dust was stopped adding into sintering mixture.

(3) During experiment period, sinter powder returned from blast furnace was stopped blending into sinter feed, eliminate the negative effect of $CaCl_2$ used to suppress RDI of sinter.

During experiment period (Modified scenario), total 11 dioxin samples were taken and analyzed. Modified scenario ampling positions in No.1 sintering plant is the same as those of Baseline scenario (see Figure 4).

The following samples were collected at No 1 sintering plant of Baosteel on December 21, 2005.

Dust samples:

- front container ESCS dust (1st and 2nd fields): 1 sample;
- back container ESCS dust (3rd field): 1 sample;
- ESP dust "sinter end": 1 sample.

Flue gas samples:

- inlet ESCS-A: 2 samples;
- outlet ESCS-A: 2 samples;
- inlet ESCS-B: 2 samples;
- outlet ESCS-B: 2 samples.

The dioxin analysis results of all samples collected during pilot experiment period were shown in Table9. For comparing, the results of baseline scenario (the first round monitoring) were listed into the same table.

The analysis results in Table 9 show that the dioxin concentration values of ESCS-A and ESCS-B outlet flue gas emitted into atmosphere were 0.58 to 1.77 ng I-TEQ/Nm^3 during pilot experiment period. The dioxin concentrations in ESCS outlet flue gas inlet flue gas were in the range of 2.76 to 4.10 ng I-TEQ/Nm^3. The dioxin average value of ESCS outlet flue gas in Modified scenario decreased to 1.35 ng I-TEQ/Nm^3, was reduced 41% comparing with the average value (2.29 ng I-TEQ/Nm^3) in Baseline scenario.

Table 9 Analysis results of dioxin samples collected during pilot experiment period from Baosteel No.1 sintering plant comparing with those of baseline scenario.
(Baseline scenario: August 10, 2005; Modified scenario: December 21, 2005)

Samples			Results of Baseline scenario (first round)	Results of Modified scenario (second round)
Flue gas	ESCS-A Inlet	1	4.60 ng I-TEQ/Nm^3	**2.76 ng I-TEQ/Nm^3**
		2	2.88 ng I-TEQ/Nm^3	**3.47 ng I-TEQ/Nm^3**
		Average	3.74 ng I-TEQ/Nm^3	**3.12 ng I-TEQ/Nm^3**
	ESCS-A Outlet	1	0.006 ng I-TEQ/Nm^3	**1.31 ng I-TEQ/Nm^3**
		2	1.28 ng I-TEQ/Nm^3	**1.77 ng I-TEQ/Nm^3**
		Average	1.28 ng I-TEQ/Nm^3	**1.54 ng I-TEQ/Nm^3**
	ESCS-B Inlet	1	5.71 ng I-TEQ/Nm^3	**2.89 ng I-TEQ/Nm^3**
		2	4.24 ng I-TEQ/Nm^3	**4.10 ng I-TEQ/Nm^3**
		Average	4.98 ng I-TEQ/Nm^3	**3.50 ng I-TEQ/Nm^3**
	ESCS-B Outlet	1	2.91 ng I-TEQ/Nm^3	**1.72 ng I-TEQ/Nm^3**
		2	3.69 ng I-TEQ/Nm^3	**0.58 ng I-TEQ/Nm^3**
		Average	3.30 ng I-TEQ/Nm^3	**1.15 ng I-TEQ/Nm^3**
	ESP Outlet	1	0.26 ng I-TEQ/Nm^3	-
		2	0.22 ng I-TEQ/Nm^3	-
		Average	0.24 ng I-TEQ/Nm^3	-
Dust	Front container (1st and 2nd fields of ESCSs)		267 ng I-TEQ/kg	**336 ng I-TEQ/kg**
	Back container (3rd field of ESCSs)		2551 ng I-TEQ/kg	**1186 ng I-TEQ/kg**
	ESP dust		46 ng I-TEQ/kg	**25 ng I-TEQ/kg**

In the pilot experiment, analyzed dioxin concentrations for the dust collected in the front container (1st and 2nd fields of ESCS) and in the back container (3rd field) were down to 336 and 1186 ng I-TEQ/kg, respectively. Comparing with baseline scenario, the concentration of 1st and 2nd fields of ESCS changed little, but the concentration of 3rd fields of ESCS decreased 45%.

The implemented process modification at the No 1 sintering plant of Baosteel (avoid the use of CaCl$_2$ to limit chloride content in sinter feed; avoid processing electrostatic precipitator dust) led to somewhat contradictory results in terms of reduction of dioxin releases. However, the reduction was evident only for ESCS-B, where PCDDs/PCDFs concentrations in clean gases decreased from (on average) 3.30 ng I-TEQ/Nm^3 to 1.15 ng I-TEQ/Nm^3 (about 70%). On the contrary, ESCS-A showed almost unchanged PCDDs/PCDFs concentrations, from 1.28 ng I-TEQ/Nm^3 of the baseline scenario to (on average) 1.54 ng I-TEQ/Nm^3 (modified scenario). On the other hand, PCDDs/PCDFs concentrations in raw gases showed comparable values at the inlet of both ESCSs and in both baseline and modified scenario. However, analytical concentration values in raw gases should be treated with cautions because larger sampling errors can be expected due to the higher dust load (about 1 g/Nm^3 in raw gases of sintering plant of Baosteel). Dioxin concentrations in raw gases before APCD seem to be of little help for evaluating the effectiveness of the implemented process modification.

Table 10 shows the Emission Factors (EFs) comparison of modified scenario and baseline scenario, which derived from analytical and process data.

Table 10 Emission Factors derived from available analytical and process data during modified scenario and comparing with those of baseline scenario
(Baseline scenario: August 10, 2005; Modified scenario: December 21, 2005)

Item	**Unit**	**Index of production and emission of No.1 sintering plant**			
Annual operational time	d/a	352.2			
Annual production	t/a	5,500,000			
		Baseline scenario		**Modified scenario**	
Emission position		ESCS	EP	ESCS	EP
Annual flue gas emission	MNm^3	21301.56	7607.70	**21301.56**	**7607.70**
Annual abandon dust	t	1761		**1761**	
Dioxin concentration in flue gas	ng I-TEQ/Nm^3	2.29	0.24	**1.345**	**0.24***
Dioxin concentration in abandon dust	ng I-TEQ/kg	2551		**1186**	
Annual dioxin emission by flue gas	g I-TEQ/a	48.781	1.826	**28.651**	**1.826**
Annual dioxin emission by abandon dust	g I-TEQ/a	4.492		**2.089**	
Dioxin Emission Factor by flue gas per ton sinter	µg I-TEQ/t-sinter	9.201		**5.541**	
Dioxin Emission Factor by abandon dust per ton sinter	µg I-TEQ/t-sinter	0.817		**0.38**	

Total Dioxin Emission Factor per ton sinter	μg I-TEQ/t-sinter	10.018	**5.921**

*Presume that the dioxin concentration in outlet flue gas of EP is no change due to lack of data.

It can be seen that Emission Factor to air by flue gas felt down to 5.541 μg I-TEQ/t sinter in the modified scenario from a baseline value of 9.201 μg I-TEQ/t-sinter. Emission Factor by abandon dust felt down to 0.380 μg I-TEQ/t sinter in the modified scenario from a baseline value of 0.817 μg I-TEQ/t-sinter.

Dioxin in clean gases emitted into the atmosphere (outlet of both ESCSs) and in abandon dust showed a distinct reduction between baseline and modified scenario. The implemented process modification at the No 1 sintering plant of Baosteel turned down dioxin emission more than 40%.

The first question is to ascertain if the observed 40% reduction in atmospheric emission can be considered statistically significant. The uncertainty associated with emission values comes from two types of uncertainties: the variation of emissions with time due to the process and the uncertainty about the measurements. In Europe, there is a general agreement (EU, 2005) that by using the EN 1948 standard for measuring dioxin emissions from the metal industry, the relative standard deviation is 60 % if "stable" processes (i.e. large plant, continuous processes with limited time periods of inactivity and with emissions evolving fairly slowly, like the iron ore sintering process) are monitored. This value includes both types of uncertainties, process and measurements.

It is difficult to establish if a similar standard deviation can be applied to the measurements performed by NEAC in the framework of the UP-POPs demonstration project since the sampling and analytical methods were different (NEAC used a sampling equipment partially satisfying the requirements of the USEPA method 23 and analyses were performed according to a modified USEPA 1613 method). Moreover, the sampling duration (1 - 2 hours) was generally shorter and the sampled volume (1 – 2 Nm^3) was generally smaller than those usually reached when sampling according to the EN 1948-1 method (up to 8 hours and up to 10 Nm^3, respectively).

Dioxin concentration values measured in two consecutive samples (sampling duration of 1 – 2 hours) collected at No sintering plant in Baosteel generally show a relative standard deviation of 15-70 % (median 21 %). Performing consecutive samplings, the uncertainty about the measurement is included but only short-term variations of dioxin emissions due to the process are taken into account. Long-term variations of emissions due to the process are more important if the goal is the evaluation of annual dioxin emissions from the plant under a particular scenario. If long-term variations of dioxin emissions due to the process are taken in consideration, then the assumption of a relative standard deviation of 60 % for the measurements performed at No 1 sintering plant of Baosteel Group Shanghai, Ltd. should be not very far from the reality.

One more complication could derive from the fact that the two scenarios were monitored during two different seasons, summer (August 2005) for the baseline scenario and winter (December 2005) for the modified scenario. It is well known that there is a positive correlation between PCDDs/PCDFs emission and off-gases temperature (EU, 2000; ENEA/MATT/AIB, 2003) due to the semi-volatile character of dioxins and furans. According to their physical-chemical properties, the higher-chlorinated PCDD are the first to condense onto the particulate matter while the lower-chlorinated PCDF are the last to condense as the gas temperature decrease. No significant differences in temperatures at the inlet and the outlet of ESCS-B can be observed between measurements performed in August (inlet = 146 °C, outlet = 132 °C; baseline scenario) and December (inlet = 147 °C, outlet = 133 °C; modified scenario) suggesting that no temperature influence is to be expected on PCDDs/PCDFs emissions. This kind of analysis is precluded for ESCS-A since during sampling performed under the baseline scenario the temperature at the outlet was higher than the one at the inlet (inlet = 105 °C, outlet = 135 °C in the baseline scenario and inlet = 105 °C, outlet = 94 °C in the modified scenario), probably because some errors performed during temperature measurements. In any case, the possibility of *de novo* synthesis of PCDD/PCDF inside the ESCSs should not be considered since maximum temperature does not exceed 150 °C, which is well below the optimal temperature range of 300-350°C for heterogeneous formation temperature.

On these bases, it is not possible to establish with certainty if a reduction of atmospheric emission of PCDDs/PCDFs was obtained with the implementation of the process modification.

Some additional indications about reduction of PCDDs/PCDFs releases after implementing process modification are provided from the PCDDs/PCDFs concentration values in the ESCS dust. Dust collected in the front container (1st and 2nd fields) showed quite similar PCDDs/PCDFs concentrations in the baseline scenario (267 ng I-TEQ/kg) and in the modified scenario (336 ng I-TEQ/kg). However, PCDDs/PCDFs concentration in ESCS dust collected in the back container (3rd field) decreased from 2551 ng I-TEQ/kg in the baseline scenario to 1186 ng I-TEQ/kg dust in the modified scenario. The observed decrease, about 53%, was similar to that observed for the emission into the atmosphere (about 48%). PCDD/PCDF concentrations in dust collected at the ESP at the discharge zone of the sinter strand also decreased from 46 ng I-TEQ/kg dust in the baseline scenario to 25 ng I-TEQ/kg dust in the modified scenario (a 46 % decrease).

According with these observations it is possible to conclude that the implemented process modification at the No 1 sintering plant of Baosteel was probably effective in reducing PCDDs/PCDFs releases from the plant of approximately above 40 %.

5.2. Results of pilot experiment for reducing dioxin emission in 100-t EAF plant

The dioxin formation during EAF process is related to the impurity in the scrap steel used in EAF, such as paint, plastics, PVC and oil etc. The chlorine resource in the scrap comes from plastic, salt and oil.

The guidance principle of the pilot experiment for dioxin reduction for 100-t EAF plant is similar to that for No.1 sintering plant. The aim is to suppress dioxin formation during steelmaking process, i.e. to control dioxin from headstream, so as to cut down dioxin emission. The measure taken in 100-t EAF plant during pilot experiment period is to improve the scrap quality of the furnace feed, to prevent unwanted contaminants into the furnace feed.

The pilot experiment of reducing dioxin emission in 100-t EAF plant was carried out on December 19, 2005. Three batches of clean scrap steel as feed for the 100-t EAF production were prepared for the pilot experiment. During the 3 batches furnace operations, flue gas samples and dust sample were collected and analyzed. Sampling points is the same as the above-mentioned (see Figure 5).

The following samples were collected at 100-t EAF plant of Baosteel during modified scenario on December 19, 2005.

Flue gases samples

- bag-house inlet: 2 samples;
- bag-house outlet: 2 samples;

Dust samples

- bag-house filter dust: 1 sample.

The comparison of scrap steel used as EAF raw material between modified scenario and baseline scenario was show in Table 11. In order to avoid contamination, cold steel block, special steel block and Cr structure crop were not used in the pilot experiment period, and clean shredded steel was used in the pilot experiment.

The dioxin analysis results of 5 samples collected during the EAF pilot experiment period were shown in Table12. For comparing, the results of baseline scenario (the first round monitoring) were also listed into the same table.

Table 11 Raw material comparison of the 100-t EAF plant between baseline scenario and modified scenario

Material code	Material description	Baseline scenario (Augest 9, 2005)	Modified scenario (December 19, 2005)
		Consumption, t/t-steel	Consumption, t/t-steel
1020200001	Standard iron	0.200	0.207
1030100030	Shredded steel	-	0.148
1030200006	Heavy machine steel	0.070	0.156
1030300011	Machine steel	0.572	0.527
1032200001	Cold steel block	0.108	-
1032500001	Special steel block	0.049	-
1041200010	Cr structure crop	0.038	-

Table 12 Analysis results of dioxin samples collected during pilot experiment period from Baosteel 100-t EAF plant comparing with those of baseline scenario.
(Baseline scenario: August 9, 2005; Modified scenario: December 19, 2005)

Sample type	Sampling position		Baseline scenario (first round)	Modified scenario (second round)
Flue gas	Bag-house Inlet	1	0.29 ng I-TEQ/Nm^3	**0.62 ng I-TEQ/Nm^3**
		2	0.099 ng I-TEQ/Nm^3	**0.63 ng I-TEQ/Nm^3**
		Average	0.195 ng I-TEQ/Nm^3	**0.625 ng I-TEQ/Nm^3**
	Bag-house Outlet	1	0.11 ng I-TEQ/Nm^3	**0.071 ng I-TEQ/Nm^3**
		2	0.048 ng I-TEQ/Nm^3	**0.011 ng I-TEQ/Nm^3**
		Average	0.079 ng I-TEQ/Nm^3	**0.041 ng I-TEQ/Nm^3**
Dust	Bag-house dust		610 ng I-TEQ/kg	**300 ng I-TEQ/kg**
Flue gas flow volume of stack			850,000 m^3/h	
Bag-house dust			15 kg/t-steel	
Steel production			106 t/furnace	

It can be seen from the results in Table 12, the implemented process modification at the 100-t EAF of Baosteel (improvement of scrap quality) led to a reduction of PCDDs/PCDFs concentration in the flue gases emitted into the atmosphere from (on average) 0.079 ng I-TEQ/Nm^3 to (on average) 0.041 ng I-TEQ/Nm^3. The reduction amount is about 50%.

More meaningful indications can be obtained from PCDDs/PCDFs concentration values in the filter dust collected at the bag-house. PCDDs/PCDFs concentration in filter dust decreased from 610 ng/kg dust in the baseline scenario to 300 ng/kg dust in the modified scenario. The observed decrease, over 50%, was similar to that observed for the emissions into the atmosphere, approximately 50%.

Emission Factors (EFs) derived from available analytical of modified scenario and 100-t EAF process data are listed in Table 8, comparing with those data of baseline scenario.

Table 13 Emission Factors derived from available analytical and 100-t EAF process data during modified scenario and comparing with those of baseline scenario
(Baseline scenario: August 9, 2005; Modified scenario: December 19, 2005)

Item	Unit	Data of 100-t EAF production and emission	
Annual operational time	d/a	323	
Annual production	t	550,000	
Annual flue gas emission	Nm^3	6,589,200,000	
Annual bag-house dust	t	8,250	
		Baseline scenario	**Modified scenario**
Dioxin concentration in flue gas	ng I-TEQ/Nm^3	0.079	**0.041**
Dioxin concentration in dust	ng I-TEQ/kg	*610*	**300**
Annual dioxin emission by flue gas	g I-TEQ/a	0.521	**0.270**
Annual dioxin emission by dust	g I-TEQ/a	5.033	**2.475**
Dioxin Emission Factor by flue gas per ton steel	μg I-TEQ/t-steel	0.946	**0.491**
Dioxin Emission Factor by dust per ton steel	μg I-TEQ/t-steel	9.150	**4.500**
Total Dioxin Emission Factor per ton steel	μg I-TEQ/t-steel	10.096	**4.991**

It can be seen that Emission Factor to air by flue gas of 100-t EAF plant felt down to 0.491 μg I-TEQ/t-steel in the modified scenario from a baseline value of 0.946 μg I-TEQ/t-steel. Emission Factor by bag-house dust felt down to 4.50 μg I-TEQ/t-steel in the modified scenario, only half of a baseline value (9.15 μg I-TEQ/t-steel).

The first question is to ascertain if the observed 50% reduction in atmospheric emission can be considered statistically significant. In other words, we want to know if the analytical values obtained during the two sampling rounds are really representing the emissions from the plants under two different scenarios.

The uncertainty associated with emission values comes from two types of uncertainties: the variation of emissions with time due to the process and the uncertainty associated with the measurements. In Europe, there is a general agreement (EU, 2005) that by using the EN 1948 standard for measuring dioxin emissions from the metal industry, the relative standard deviation is 200 % if "unstable" processes (i.e. batch or cyclic processes using metal scrap, with emissions strongly related to each individual charge, like the EAF steel-making process) are monitored. This value includes both types of uncertainties, process and measurement.

It is difficult to establish if a similar standard deviation can be applied to the measurements performed by NEAC in the framework of the UP-POPs demonstration project since the sampling and analytical methods were different (NEAC used a sampling equipment partially satisfying the requirements of the USEPA method 23 and analyses were performed according to a modified USEPA 1613 method). Moreover, the sampling duration was generally shorter (1-2 hours) and the sampled volume was generally smaller (1.5 – 2 Nm^3) than those usually reached when sampling according to the EN 1948-1 method (up to 8 hours and up to 10 Nm^3, respectively).

PCDD/PCDF concentration values measured in two consecutive samples (sampling duration of 1-2 hours) collected at the 100-t EAF steel-making plant in Baosteel generally show a relative standard deviation of 50-100 %. Performing consecutive samplings, the uncertainty about the measurement is included but only short-term variations of dioxin emissions due to the process are taken into account. Long-term variations of emissions due to the process are more important if the goal is the evaluation of annual dioxin emissions from a plant in a particular scenario. If long-term variations of dioxin emissions due to the process are taken in consideration, then the assumption of a relative standard deviation of 200 % for the measurements performed at the 100-t EAF of Baosteel should be not very far from the reality.

One more complication in the comparison derives from the fact that the two scenarios were monitored during two different seasons, summer (August 2005) for the baseline scenario and winter (December 2005) for the modified scenario. The differences in the sampling conditions are fully reflected by the different temperatures of the sampled stack gases, 71 °C in August (baseline scenario) and 39 °C in December (modified scenario). It is well known that there is a positive correlation between PCDDs/PCDFs emission and off-gases temperature (EU, 2000; ENEA/MATT/AIB, 2003) due to the semi-volatile character of dioxins and furans. According to their physical-chemical properties, the higher-chlorinated PCDD are the first to condense onto the particulate matter while the lower-chlorinated PCDF are the last to condense as the gas temperature decrease. This explains why TCDF and PeCDF dominate in electric arc furnace atmospheric emissions and, since they represent an important fraction of TEQ emission, why the TEQ concentration in stack gases decrease very rapidly as the temperature drops. At a temperature of 39 °C (the flue gas temperature found when sampling the modified scenario) more PCDDs/PCDFs condense onto the particulate matter if compared with a flue gases temperature of 71 °C (baseline scenario). PCDDs/PCDFs adsorbed onto the particulate can be more easily removed by the filtration system.

The comparison of PCDDs/PCDFs concentrations in raw gases (before APCD) is of little help since PCDDs/PCDFs concentrations before the bag-house in the modified scenario are about three times higher than the baseline scenario. PCDDs/PCDFs concentrations in raw gases before APCD seem to be of little help for evaluating the effectiveness of the implemented process modification. Probably, these measurements are affected by a very large uncertainty because of the very high dust loading in raw gases, in the order of 1 g/Nm^3. It does not seem likely that the observed differences should be attributable to an increased performance of the fabric filters.

On these bases, it is impossible to establish with certainty if a reduction of atmospheric emission of PCDDs/PCDFs was obtained with the implementation of the process modification. It is only possible to say that both baseline and modified scenario atmospheric emissions are comparable to the achievable performance level using BAT/BEP for secondary steel production (EAFs) of less than 0.1 ng TEQ/Nm^3 (UNEP, 2004).

PCDD/PCDF concentration values measured in two different dust samples collected at EAF steel-making plant in Baosteel in the modified scenario show a relative standard deviation of 20%. This value can be considered reasonable and typical of the variability that can be encountered when analyzing solid samples containing PCDDs/PCDFs concentrations in this order of magnitude. The differences in PCDDs/PCDFs concentrations in filter dust between the baseline scenario and the modified scenario can be considered significant.

According with these observations it is possible to conclude that the implemented process modification at the 100-t EAF of Baosteel was probably effective in obtaining a reduction of PCDDs/PCDFs from the plant of approximately 50 %.

6. Incremental cost analysis for implemented sintering and EAF process modification in Baosteel

6.1. Incremental cost analysis for implementing process modification of No.1 sintering plant

The measures been taken in the pilot experiment for reducing dioxin emission from No.1 sintering plant of Baosteel during December 19 to 28, 2005 were mainly by means of avoiding the use of $CaCl_2$ to limit chloride content in sinter feed and avoid processing electrostatic precipitator dust and other recycle materials.

Comparing with the stockpile (BA1-326) used in baseline scenario, the stockpile of blending iron ores (BA1-334) for modified scenario disused 5 recycling materials, i.e. steel rolling scrap (ZSC-S), blast furnace dust (ZBG-S), sintering dust (ZES-S), sinter powder (S1C-F) and slag iron (ZFG-S). The disuse of these recycle material directly results in the cost of sintering main raw material increasing. Based on the actual prices and data of production and process, the production costs analysis on blending ore and sinter in baseline scenario and modified scenario were done by the financial department Baosteel Subsidiary Company. The financial analysis results were shown in Table 14 and Table 15.

Table 14 Comparison of blending ore cost of Baosteel No 1 sintering plant (August 10 and December 21, 2005)

Item	Baseline scenario	Modified scenario
Date	Augest 10, 2005-	December 21, 2005-
Block number of blending ore	BA1-326	BB1-334
Blending ore cost, Yuan/t-ore	**497.49**	**524.76**

Note. 1.The cost of auxiliary materials and energy and fix cost didn't change significantly;
2.The prices of raw materials used in the cost calculation is the new prices in 2007.

Table 15 Comparison of sinter cost of Baosteel No 1 sintering plant between dioxin suppressing experiment period and normal operation period. (August 10 and December 21, 2005)

		Baseline scenario	**Modified scenario**
Time	**Average of 2005**	**2005-Aug-10**	**2005-Dec-21**
Block number of blending ore		BA1-326	BB1-334
Blending ore cost, Yuan/t-sinter	451.82	371.55	495.53

Auxiliary materials cost, Yuan/t-sinter	61.62	47.86	26.49
Fuel and public facilities cost, Yuan/t-sinter	46.48	46.74	50.70
Subtotal variable costs, Yuan/t-sinter	**559.92**	**466.16**	**572.73**
Subtotal fixed costs, Yuan/t-sinter	**28.27**	**28.27**	**28.27**
Sinter cost, Yuan/t-sinter	**588.19**	**494.43**	**601.00**

Note: 1. The prices of raw materials used for the cost calculation are the newly prices in 2007;
2. The influence of experiment on sintering production is ignored.

It can be seen that the cost of blending ore used in modified scenario is 27.27 Yuan/t-ore higher than that of blending ore used in baseline scenario, due to disuse of 5 recycling materials.

The production financial analysis data in Table 15 showed that all the costs for main raw material, fuel and public facilities increased, except auxiliary materials cost decrease in modified scenario for sintering dioxin reduction. Thus, the cost for sinter production is 106.57 Yuan and 12.81 Yuan higher than the cost of baseline scenario and annual average cost of 2005, respectively. Incremental cost percentage is 21.5% and 2.2%, respectively. Figure 6 shows the difference clearly. Comparing with annual average cost of 2005, the cost of blending ore used in baseline scenario is distinctly lower.

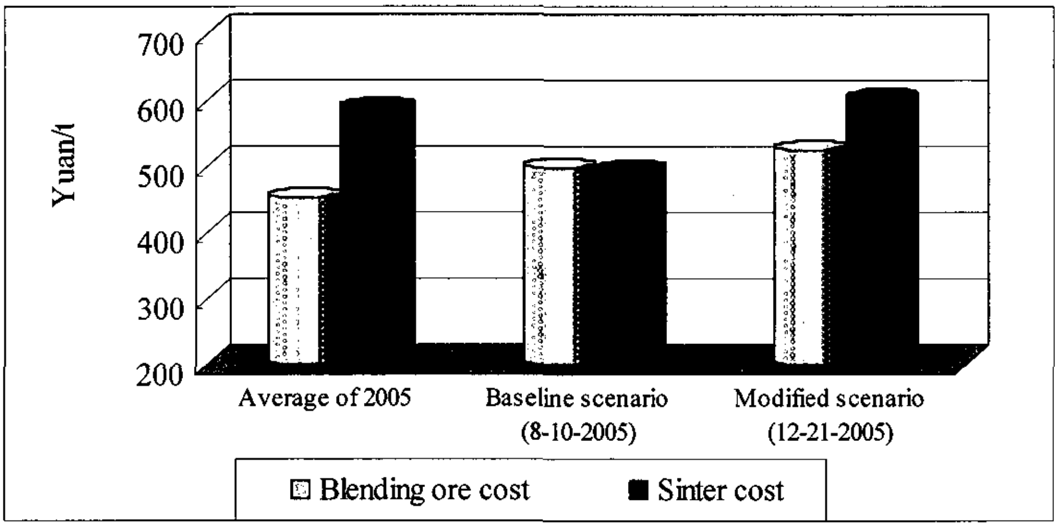


Figure 6 Production cost comparison of raw material and product of No.1 sintering plant

Based on the data of incremental sinter cost of 12.81 Yuan/t and annual production of 5.5 Mt-sinter, annual total incremental cost will reach at 70.45 million Yuan for implementing process modification in No.1 sintering plant. The total production of 3 sintering plants of Baosteel Subsidiary Company in 2006 is about 17 Mt sinter, the total incremental cost of 3 sintering plants could reach 217.7 million Yuan/a.

It should be indicated that indirect cost was not taken into account in the above analysis on incremental cost. If the inner recycling materials, such as steel rolling scrap (ZSC-S), blast furnace dust and sintering dust etc. were disused, the treatment and reuse of these material will bring indirect cost.

6.2.Incremental cost analysis for implementing process modification of 100-t EAF plant

In the pilot experiment for dioxin reduction of 100-t EAF plant on December 19, 2005, the measure taken is to use more clean scrap than ever as feed for steelmaking, so as to suppress dioxin formation and cut down dioxin emission. In the 3 batches of clean scrap steel as feed for the 100-t EAF pilot experiment, clean shredded steel was used, and contaminated scrap, i.e. cold steel block, special steel block and Cr structure crop were not used.

The measure taken in the pilot experiment of reducing dioxin emission in 100-t EAF is relatively simple. Therefore, incremental cost analysis for implementing process modification of 100-t EAF plant is simple, incremental cost only comes from the changes of outsourcing scrap raw material. The production raw material costs analysis for 100-t EAF plant in baseline scenario and modified scenario were done by the financial department Special Steel Subsidiary Company, and the financial analysis results were shown in Table 16.

Table 16 Comparison of raw material cost of Baosteel 100-t EAF plant between dioxin suppressing experiment period and normal operation period.
(August 9 and December 19, 2005)

Item			**Baseline scenario**		**Modified scenario**	
Time			August 9, 2005		December 19, 2005	
Production batch number			511-2966~2968		511-3838~3840	
Liquid steel output			315 t		330 t	
Material code	Material description	Price Yuan/t	Consumption t/t-steel	Cost Yuan/t-steel	Consumption t/t-steel	Cost Yuan/t-steel
1020200001	Standard iron	1950	0.200	391	0.207	403
1030100030	Shredded steel	2100	0	0	0.148	311
1030200006	Heavy machine steel	1850	0.070	130	0.156	289
1030300011	Machine steel	1780	0.572	1017	0.527	939
1032200001	Cold steel block	1320	0.108	143		

1032500001	Special steel block	1780	0.049	87		
1041200010	Cr structure crop	2100	0.038	80		
Total cost, Yuan/t-steel				**1848**		**1942**

According to the production financial analysis results in Table 16, the raw material cost of the 100-t EAF in the pilot experiment period for reducing dioxin emission is 1942Yuan/t-steel. Comparing with the cost in baseline scenario, incremental cost reaches 94 Yuan/t-steel, incremental cost percentage is 5.1 %.

For implementing the process modification of 100-t EAF plant to reduce dioxin emission, it will result in a total annual incremental cost of 51.7 million Yuan based on the 100-t EAF annual product of 0.55 Mt.

7. Conclusions

(1) The initial monitoring results of No.1 sintering plant of Baosteel Subsidiary Company show that the concentration of PCDDs/PCDFs in the main exhaust flue gas is 1.28 - 3.30 ng-TEQ/m^3. Meanwhile, the concentration of PCDDs/PCDFs of the abandon dust collected in 3rd field of ESCSs is 2551 ng I-TEQ/kg. Derived from the dioxin analysis results and the process data, the emission factor of exhaust flue gas and abandon dust of ESCS are 9.201 and 0.817 μg I-TEQ/t-sinter, respectively, evidently higher than the data cited from Dioxin Standardized Toolkit, 0.3~5 and 0.003 μg I-TEQ/t-sinter.

(2) The total emission factor of No.1 sinter plant calculated from the dioxin analysis results and the process data is 10.018 μg I-TEQ/t-sinter. Based on the annual output of 17 million ton sinter produced by 3 sintering plants, the total PCDDs/PCDFs release mass will reach 170.3 g I-TEQ/year.

(3) According to the analytical results of first round dioxin monitoring, the concentration of PCDDs/PCDFs in the flue gas emitted into atmosphere from 100-t EAF of Special Steel Subsidiary Company of Baosteel is 0.048 - 0.11 ng I-TEQ/m^3, and the concentration of PCDDs/PCDFs in the filter dust from the 100-t EAF was 610 ng I-TEQ/kg. It indicates that the analyzed data of PCDDs/PCDFs in the flue gas from the 100-t EAF of Baosteel has met the emission standard of the other advanced Iron & Steel Corporation in the world.

(4) Considering the filter dust was sold to outside plants for reuse, the emission factors of the exhaust gas of the 100-t EAF and filter dust calculated from the analytical results and process data are 0.946 and 9.150μg I-TEQ/t-steel, respectively. The total emission factor of the 100-t EAF

reached 10.096 μg I-TEQ/t-steel, which is similar to the emission factor of the No.1 sintering plant of Baosteel. The annual total release mass of PCDDs/PCDFs of the 100-t EAF with annual capacity of 550,000 t steel arrives at 5.55 g I-TEQ.

(5) After implementing the technique to reduce the PCDDs/PCDFs emission from the No.1 sintering plant of Baosteel during the pilot experiment period, the emission factor of exhaust gas, abandon dust, and the total emission factor of sinter decreased to 5.541, 0.380 and 5.921μg I-TEQ/t-sinter, respectively. That means the emission of PCDDs/PCDFs from No.1 sintering plant could be cut down over than 40% by implementing the process modification technique adopted on December, 2005.

(6) The atmospheric emission of PCDDs/PCDFs from the 100-t EAF in modified scenario decreased approximately 50% comparing with the baseline scenario with the value of 0.041 ng I-TEQ/m^3 by means of implementing the process modification. And the content of PCDD/PCDF in the filter dust decreased more than 50% comparing to the baseline scenario with the value of 300 ng I-TEQ/kg. During the pilot experiment period, the emission factor of exhaust gas and the filter dust decreased to 0.491 μg I-TEQ/t-steel and 4.50 μg I-TEQ/t-steel, respectively. Half reduction of atmospheric emission of PCDDs/PCDFs can be obtained by implementing the process modification.

(7) Incremental cost analysis showed that the sinter cost of No.1 sintering plant in modified scenario increased 106.57 and 12.81 Yuan/t-sinter comparing to those in baseline scenario and the average value of 2005 year, respectively. The total increment cost could arrive at 70.45 million Yuan per year for implemented the process modification in No.1 sintering plant with annual capacity of 5.5 million tons. And the total increment cost could reach 217.7 million Yuan if all of the 3 sintering plants with annual output of 17 million tons implement the process modification. Indirect cost was not considered in the incremental cost analysis.

(8) The analysis results of incremental cost of the 100-t EAF showed that the scrap raw material is 1942 Yuan/t-steel in modified scenario, 94 Yuan/t-steel higher than that in baseline scenario. Based on the 100-t EAF annual capacity of 550,000 tons, the total annual increment cost could be 51.7 million Yuan for implementing the process modification.

(9) Because of high difficulty and complexity of ultra-trace dioxin analysis and sampling technology, inexperience and the limitation of iron and steel process particularity, the sampling and monitoring data of the project are quite insufficient to make accurate conclusion. Moreover, some data are self-contradictory and reliabilities are lower. Big deviation maybe exist in the derived total dioxin emission data for these reasons. No other than to monitor continuously and study deeply,

regularity of dioxin emission from iron and steel processes could be grasped, thus to seek the low cost and high efficiency ways for reducing dioxin emission.

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Baoshan Iron & Steel Co., Ltd.

Strategies to Reduce Unintentional Production of POPs in China: BAT, BEP and Incremental Costs for Selected Sectors of Industry

Case Study Report on the Demonstration Project "Controlling and Prohibiting POPs Unintentional Production" in TISCO

Submitted to
Foreign Economic Cooperation Office
State Environmental Protection Administration, China

TISCO太原钢铁（集团）有限公司
TAIYUAN IRON&STEEL(GROUP)COMPANY LTD.

Contents

THE REPORT ON DIOXIN EMISSION REDUCTION

Ⅰ. Background of TISCO Pilot Project:

POPs is the chemical substance synthesized by human beings which may exist in the air permanently accumulating through the biologic food chain, and do harm to human health and environment. They are bio-accumulate in fatty tissues, persistent in the environment and are able to travel long distances through the air and through the water reaching other areas. It attracts large international concern. On May 22nd, 2001, UNEP held and passed <Stockholm convention on POPs>, in which dioxin is listed as one of the twelve POPs to be controlled at the first group. On May 23rd, 2001, China joined <Stockholm convention on POPs>. The projects are organized by SEPA Execute Office, international applied by UNDP and UNOPS. IMET would support China to carry out project on POPs emission reduction through SICO, which is produced by human being unintentionally.

SEPA (State Environment Protection Administration) POPs convention performance office organized experts at home and abroad to select pilot enterprises on Jan. 17th-18th 2005. Six enterprises were selected to implement POPs emission reduction project with CISA and environmental protection commission of China paper association.

SEPA POPs convention performance office organized <information exchange meeting between the candidate enterprises of emission reduction pilot project of China-Italy by-product > on Mar. 1st-3rd 2005. The experts and specialists at home and abroad visited the enterprises after the meeting.

SEPA POPs convention performance office organized pilot projects technic training on Jun 1st,2005. The experts and specialists at home and abroad explained the UP-POPs analysis methods, sample requests. Bao Steel and TISCO were recommended as the enterprises of dioxin unintentional emission reduction pilot project of China-Italy by-product in the iron and steel industry of China as: 1, production scale: Bao Steel 20 million tons, TISCO 3 million tons; 2, raw material: Bao Steel mainly uses import iron ore, TISCO uses local iron ore; 3, process and equipment: owned sinter and EAF equipment and process; 4, location: Bao Steel located by sea, TISCO inside of the main land; 5, products: Bao Steel produces carbon steel, TISCO produces stainless steel.

June 2-4th, 2005, Mr. HUANGDAO, expert in China Iron and Steel area, Doc. SUN YANGZHAO, SEPA POPs convention performance officials, Doc. ZHEN MINGHUI, Ecology Research Center in Chinese Academy of Sciences and Mr. SPEZZANA, Italy environmental specialist, investigated

TISCO sinter and EAF process, confirmed monitoring points, frequency and sequence in TISCO. According to the request of <TISCO dioxin monitor research plan> made by State Environment Protection Administration Bureau Abroad Corporation Center, NEAC made the first group samples in No.1 Steel-Making and Sinter Plant, TISCO, from Dec. 8th thru Dec. 10th, 2005. There are 12 off-gas samples and 6 ash samples in USEPA1613B method.

NEAC made the second group samples in TISCO from Jun.19th thru Jun. 23rd 2006. There are 12 off-gas samples and 3 ash samples in EN1948 method. Simples and analysis follow Dioxin Laboratory Standard Operation Proceed （SOP）, and I-TEQ variation is less than 10% after the international calibrate tests and compare analysis with Dioxin Laboratory of Examination And Quarantine Academy Of China.

Sinter second group sample data and EAF first group sample data were treated as the description data research before emission reduction. Sinter first group sample data and EAF second group sample data were treated as the description data research after emission reduction.

Ⅱ. The process status of dioxin produced and discharged unintentionally:

It is internationally accepted that dioxin is mainly created during sintering and EAF process. The sintering and EAF process now adopted in TISCO are as following:

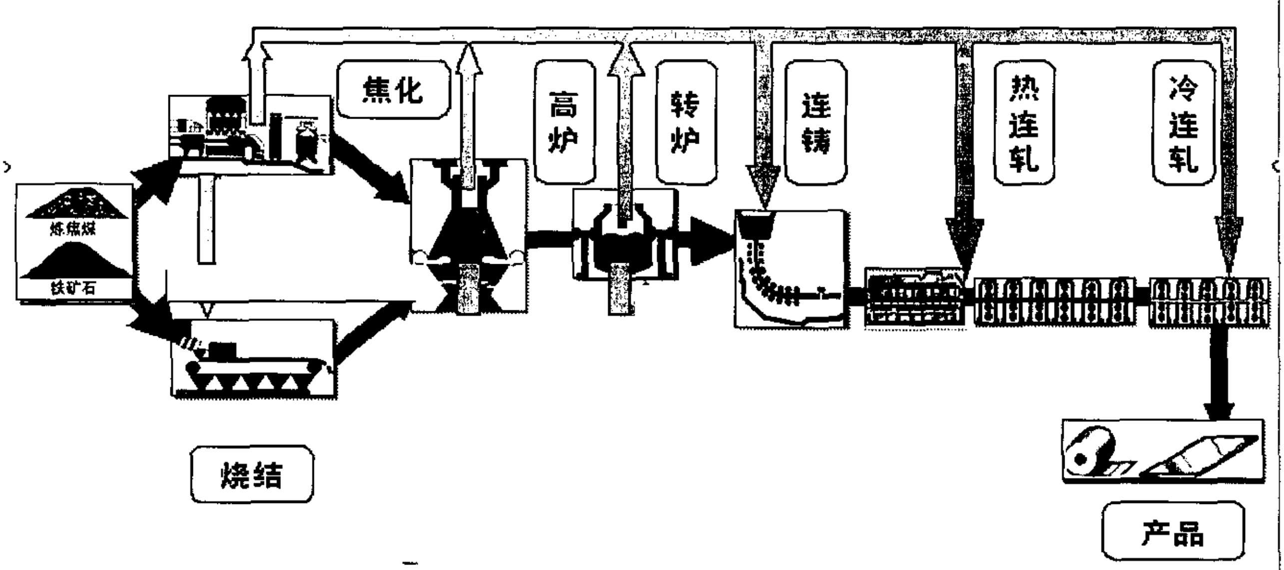
1. The pollution source and contaminant analyze in sinter process

Process	Pollution source	Contaminant
Raw material	Unload, crush, sieves, dry, mix, conveyer	dust
batch	Batch, mix, ball	dust
cooking	Sinter and cook fuel such as gas, coke powder, coal powder etc.	Off-gas（dust）、SO2、NOx、CO、 CO2 、Dioxin
Finished article	Crush, sieves	dust

2. The pollution source and contaminant analyze in EAF process

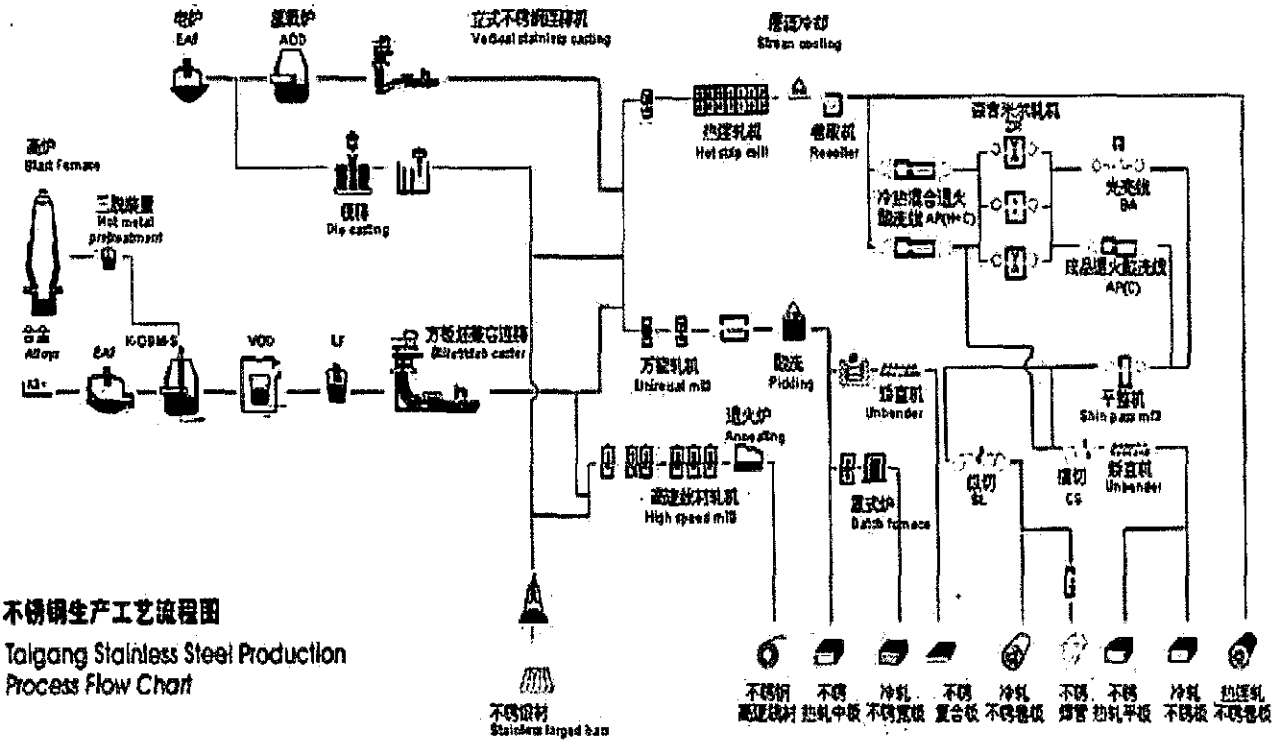
Off-gas	Pollution source	Contaminant
EAF OFF-GAS	EAF load、melt、scrap steel（organic matter）	SO_2、NO_X、exhaust dust、dioxin
ROOF HOOD OFF-GAS	The overhead off-gas flee from EAF during melt	SO_2、NO_X、exhaust、dust、dioxin

3. The main processes which create dioxin in iron and steel production ，



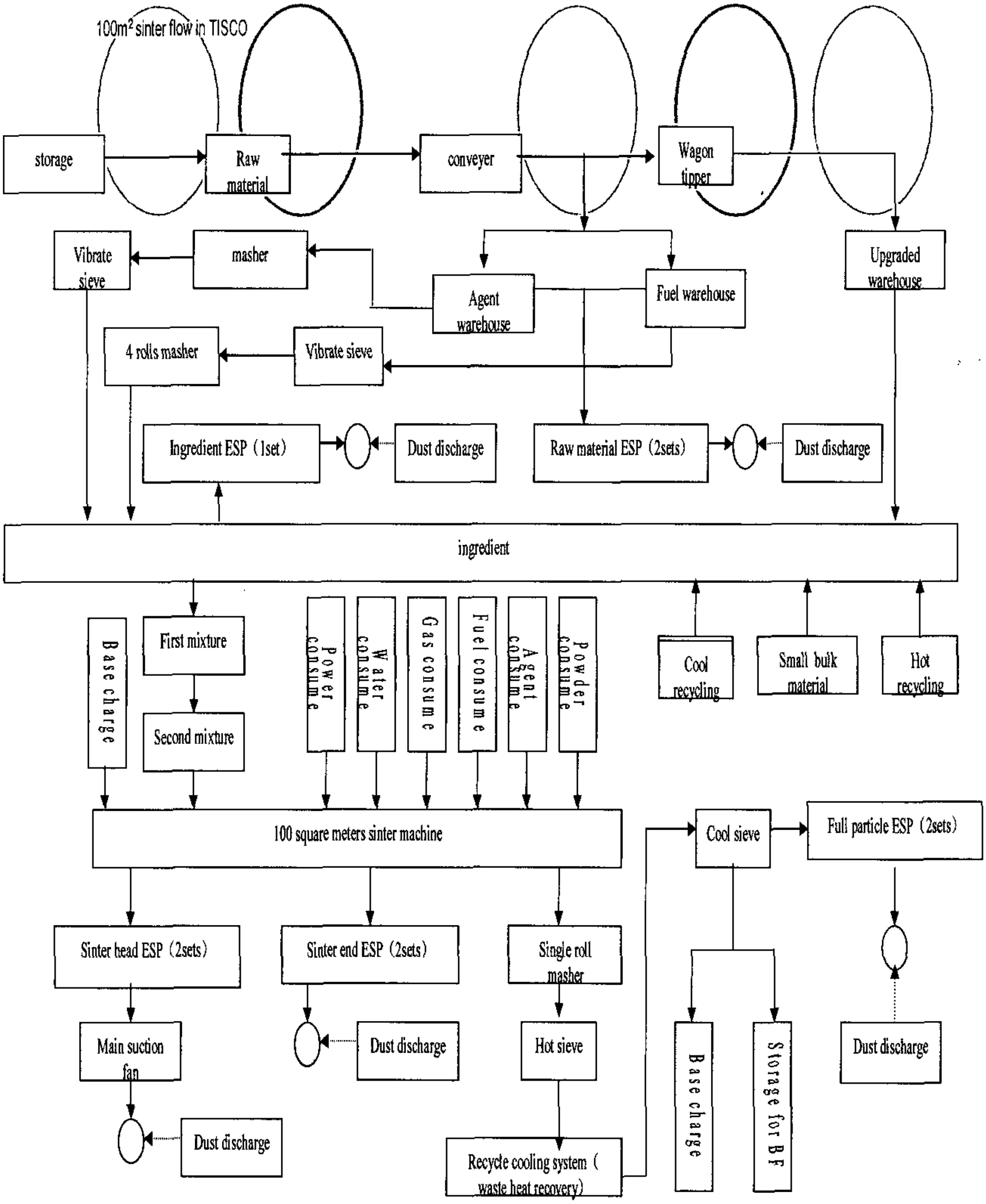
工艺流程

Process Flow Chart



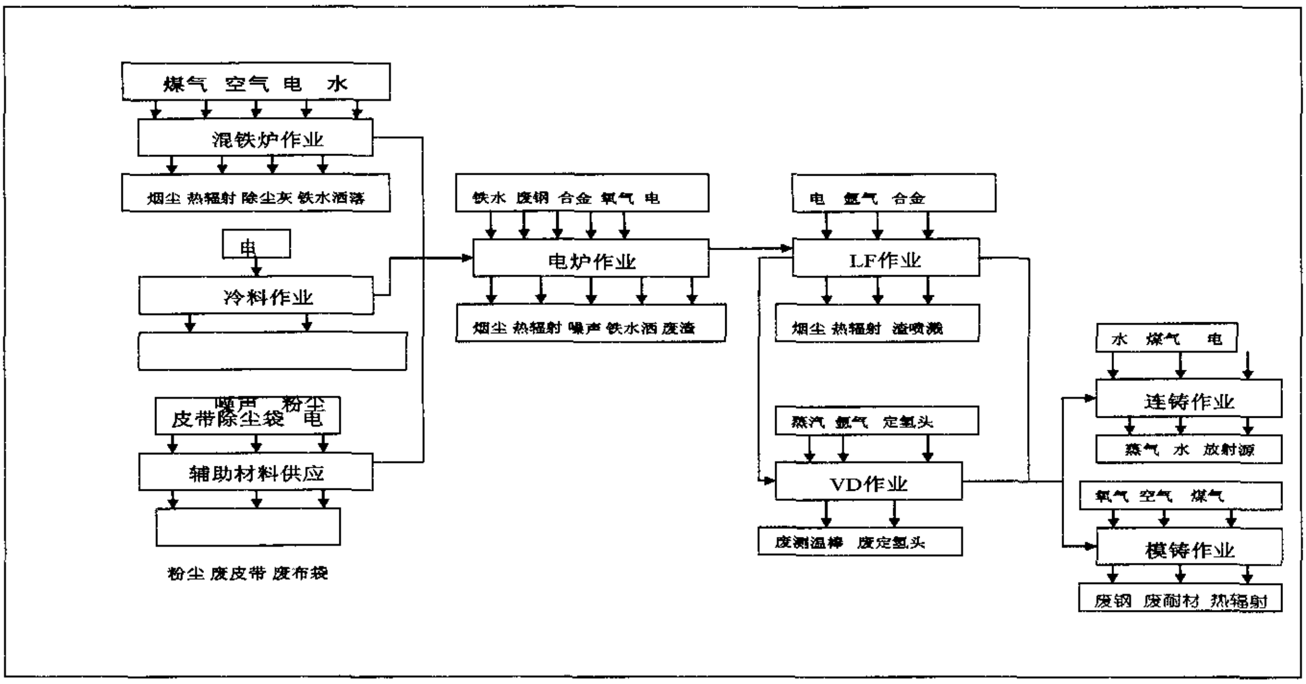
不锈钢生产工艺流程图

Taigang Stainless Steel Production
Process Flow Chart



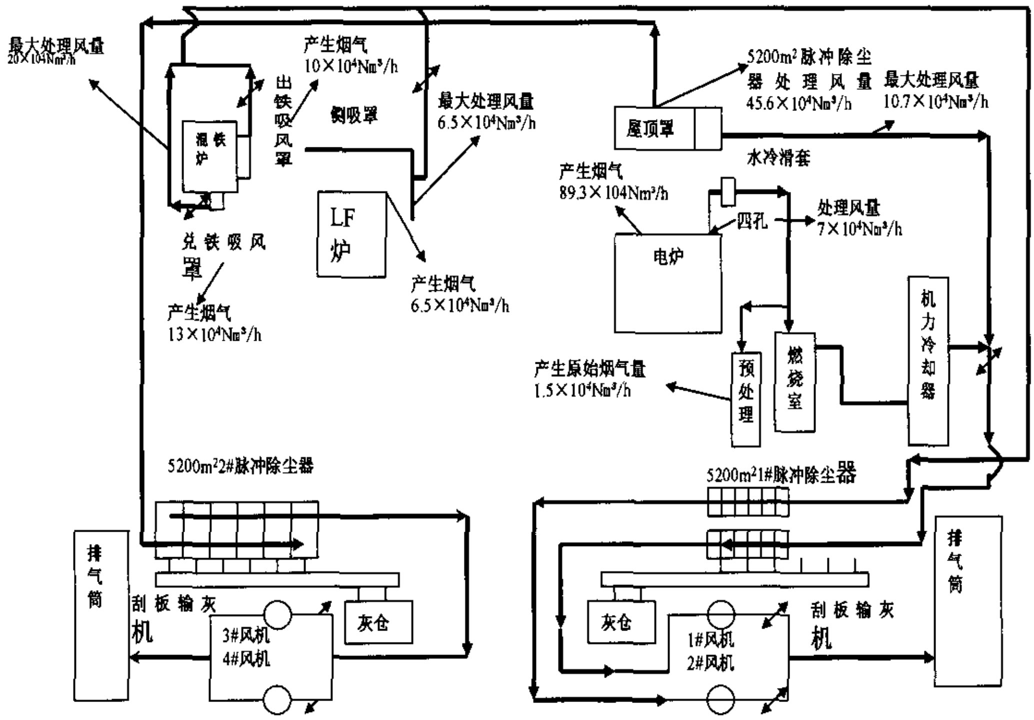
Mix proportionally with mineral powder (rich mineral powder, fine mineral powder and other iron ore articles), melt agent (lime rock, dolomite, lime etc. powder), fuel (coke powder, coal powder), uniform, granulation, heat(preheat), distribute, ignite, take the advantage of the high temperature made by the oxidation of the furnace charge (mainly the fuel combustion), vaporize the water inside of the sinter material, a series of chemical reaction occurred, produce some liquid phase bind, be particles when cool down, it is sinter product after being mashed and classified. TISCO sinter raw material based on local iron ore powder.

4. TISCO 50 ton EAF process and de-dust chart



No.1 Steel-Making dedust chart

一钢厂除尘工艺图



EAF process raw material is: scrap steel and cool iron-steel such as ferrum reductum etc. melt and fining with electric. There is also 50% hot iron as the EAF raw material in TISCO.

Ⅲ. TISCO Dioxin monitor result and analysis

1. Sinter process: compared with ESP off-gas sample at No.3 sinter head and ESP ash sample at No.3 sinter head.

Period	Monitor point	sample	Average concentration
First round	Off-gas at No.3 sinter head after ESP	Off-gas sample ngI-TEQ/Nm^3	0.25
	Ash at No.3 sinter head after ESP	Ash and slag sample ngI-TEQ/g	0.188
Second round	Off-gas at No.3 sinter head after ESP	Off-gas sample ngI-TEQ/Nm^3	0.235
	Ash at No.3 sinter head after ESP	Ash and slag sample ngI-TEQ/g	0.19

In the first round, proportionality of ore powder from JIANSHAN in the total ore powder amount is respectively 80.06%、88.64%、without adding integration powder(i.e. various re-dust ash); In the second round, proportionality of ore powder from JIANSHAN in the total ore powder amount is 83.63%, with adding integration powder (i.e. various re-dust ash) 5.8%, without adding serpentine, proportionality of calcium lime is 29.11% less than the first round. Si, Mg content of the sinter raw material was reduced accordingly.

Conclusion from the data: for the dioxin concentration in off-gas at No.3 sinter head after ESP, the second round result is 0.94 times of the first round result. The dioxin concentration in ash at No.3 sinter head after ESP, the second round result is 1.01 times of the first round result.

2. EAF process: compared with off-gas and ash samples at EAF after BF and EAF roof hood after BF.

PERIOD	sample	Monitor point	Average concentration
First round	Off-gas sample ngI-TEQ/Nm³	EAFoff-gas after BF	0.02
		EAF roof hood after BF	0.0155
	Ash and slag sample ngI-TEQ/g	EAF off-gas at BF	0.063
		EAF roof hood at BF	0.012
Second round	Off-gas sample ngI-TEQ/Nm³	EAF off-gas after BF	0.132
		EAF roof hood after BF	0.167
	Ash and slag sample ngI-TEQ/g	EAF off-gas at BF	0.0075
		EAF roof hood at BF	0.055

In the first round, the sync monitoring for EAF off-gas and after roof hood re-duster, proportion of steel scrap added about 69.8%, 1.4% red mud ball(the ball squashed with the re-dust ash of steel making) added; In the second round, EAF off-gas re-duster was monitored in 19th-20th,Jun. roof hood re-duster was monitored in 21st-22nd,Jun. The proportion of steel scrap added between 26.1%～32.2%, 1.5 % red mud ball(the ball squashed with the re-dust ash of steel making) added.

Conclusion from the data: for the dioxin concentration in off-gas after EAF de-duster and after the roof hood de-duster, the second round result is higher than that of the first round. The second round dioxin concentration is 6.6 times and 10.77 times of that of the first round respectively. For the ash at roof hood de-duster, the second round result is 4.58 times more of the first round result. For the ash at EAF de-duster, the second round result is 0.12 times of the first round result.

Ⅳ. Incremental cost analysis

1. EAF process incremental cost analysis

In the first round, proportion of steel scrap added about 69.8%, 1.4% red mud ball(the ball squashed with the re-dust ash of steel making) added; In the second round, The proportion of steel scrap about 29.15%, 1.5 % red mud ball. The dioxin reduction measures were taken for the second round: The raw material cost increase RMB86.75/t steel, scrap steel was less, but all of them were selected manually, increased cost RMB1.18/t steel. Low iron proportion cost is RMB50.28/t steel more than that of high iron proportion. The total emission reduction increase cost is RMB37.65/t steel.

2. Sinter process incremental cost analysis

In the first round, emission reduction measures were taken: without adding integration powder and JIANSHAN fine powder proportion is 4.8% more than that of the second round, and add 1% serpentine. Sinter ore cost increase RMB17.67/t sinter; the serpentine selection manually cost RMB1.33/t sinter. After using reduction emission process, sinter cost increased RMB19/t.

3. General incremental cost analysis

For the sinter process after emission reduction: cost increase RMB19/t sinter. In 2006, each 100m^2 sinter produced 950thansand ton/a, after the emission reduction, the cost increase RMB18.05 million/a. The sinter production in TISCO is 3.8502 million tons/a, after the emission reduction, the cost increase RMB73.1538 million/a. The sinter process uses various of integration powder 651009 tons in 2006. In the view of logistic economic and integration utility, after emission reduction, we have to find some other way to use integration powder.

For EAF process after emission reduction: cost increases RMB37.65/t steel. In 2006, 50 tons EAF produced 390 thousand tons/a, after the emission reduction, the cost increase RMB14.6835 million/a. EAF uses red mud ball 9600 tons in 2006. It is economic and integration utility, and make de-S and de-P quick.

V. conclusion

1. The monitor data is quite less and not so much presentative because of our continual production and speciality in TISCO. To find dioxin emission rule and then find the efficient method to reduce the emission, we need to continue our monitor.
2. Now 50 tons EAF has hot iron around 50% in TISCO. We can not find any rule from the monitor data. needs to be improved.
3. The integration powder in sinter is a key effect to dioxin emission.

The statistic of 100m^2 sinter、 50 tons EAF dioxin emission in Iron and Steel Industry

attach:

equipment	Sample point	Operation days	product （thousand tons）	Off-gas/a （Nm^3）	Ash/a （ton）	Dioxin concentration in off-gas （ngI-TEQ/Nm^3）	Dioxin concentration in ash （ngI-TEQ /g）	Dioxin emission in off-gas （g/a）	Dioxin emission in ash （g/a）	Dioxin emission/t product （μg/t product*a）
100m^2 sinter	**Sinter head ESP**	300	950	2.02×10^9	1200	0.235	0.19	0.47	0.23	0.736
50 tons EAF	**EAF BF**	320	390	1.01×10^9	6400	0.132	0.0075	0.13	0.05	1.923
	EAF Roof-hood BF			2.33×10^9	3200	0.167	0.055	0.39	0.18	