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Technical Analysis of Coal Utilization and Environmental Pollution

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ABSTRACT: Coal is known as black gold, the food of industry. It has been used as one of the main energies for human being since the 18th century. Although its important place has been taken by petroleum nowadays, due to the daily drying up of petroleum for quite a period of time in the future, the large quantity of coal reserves and with the rapid development of science and technology, especially maturity and wide use of integrated coal gasification technology, coal will become one of the energies that cannot be replaced in human life and production. Coal increased fastest for five successive years. Coal consumption increased by 4.5% in the world which is higher than the average level 3.2% of last ten years. However, the use of coal has brought up serious ecological environment problems. In the 20th century, serious air environmental pollution events, such as acid rain, damage to ozonosphere, global warming, photochemical smog and urban coal smog, are all related to coal burning. The principal source of main pollutants in air, for example, SO_2, NO_x, CO, fume dust, particles, organic pollutants and heavy metals, are caused by coal burning. These pollutants have caused irreversible damage to human health and ecological environment. Finally this paper describes coal consumption and environmental problems due to coal utilization.

KEYWORDS: Coal Consumption, Environmental Problems, Acid Rain Pollution, NO_X Pollution, Organic Pollutant, SO_2 Emission, CO_2 Emission.

1 INTRODUCTION

Global energy consumption in 2007 reached 16.73 billion tons of standard coal with increase rate of 2.5%, of which coal consumption is 4.849 billion tons of standard coal, natural gas consumption is 3.943 billion tons of standard coal, consumption of mineral oil is 5.923 billion tons of standard coal, consumption of nuclear energy is 960 million tons of standard coal, water energy consumption is 1.055 billion tons of standard coal. According to the forecast of International Energy administration (IEA), global energy consumption in the future will increase steadily at a rate 1.8% per year [1]-[2],[4].

Coal consumption can be divided into two parts, coal for industry and coal for living. In industries, coal consumption concentrates in power, building materials, steel & iron and chemical industries, where power industry is a big consumer. In 2004, the coal consumption was 1.8 billion tons in China in which 0.85billion tons are for thermal power plant (incl. heat supply), accounting for 47% against total coal consumption in China. In 2006, the proportion of coal consumption in power industry increased to 53% [3]-[4]. Therefore, it's imperative under the situation to control the environmental protection

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issues caused by coal combustion. Until now, many countries issued policies and regulations in respect of pollutants emission and control from coal-fired power plant, and as the development of economy and the increase of understanding level of human being, the requirements will be more stringent. So it's an important means for ensuring sustainable economic development based on coal-fired power and the health of human being to understand flue gas cleaning technologies for coal-fired power plant.

2 COAL RESOURCE AND UTILIZATION

2.1 COAL RESOURCE AND UTILIZATION IN THE WORLD

Global hard coal output in 2007: Germany, 22 million tons; UK, 17 million tons; Spain, 11 million tons; Poland, 87 million tons; Czech, 13 million tones; Romania, 3 million tons; Russia, 314 million tons; Kazakhstan, 96 million tons; Ukraine, 75 million tons; Canada, 37 million tons; U.S.A., 1.043 billion tons; Colombia, 69 million tons; Venezuela, 8 million tons; South Africa, 243 million tons; Australia, 322 million tons; India, 430 million tons; China, 2.523 billion tons; Indonesia, 230 million tons. World coke output is 580 million tons and 510 million tons in 2006 [6],[7].

Coal producing countries in Pacific Region has seen significant increase of coal output. China's coal output in 2007 reached 2.523 billion tons, an increase of 197 million tons as compared with 2006 (2.326 billion tons). China's coal output was increased by about 1.3 billion tons from 2000 to 2007. According to industry sources, China's coal output will be increased to 6 billion tons in the year 2013/2015. India is also one of the big coal producers in the world. The country is now building new coal mines to meet the coal demand of its electric power industry [5]-[6]. For details see Table.1

Table 1. Output of hard Coal of the Producing Countries in Pacific Region in 2007

Coal Producing Country	2004	2005	2006	2007
China	19.92	21.90	23.26	25.23
India	3.50	3.70	3.90	4.30
Australia	2.97	3.06	3.02	3.22
Indonesia	1.35	1.53	2.05	2.30
Vietnam	0.28	0.34	0.44	0.50
Total	28.02	30.53	32.67	35.55

Unit: Hundred Million Ton

In addition to the above countries, Korea, Mongolia and New Zealand in Asia have also seen significant increase of coal output.

Output of coal in North America decreased due to the lack of coal demand in power generation. Canada has increased the output of coke due to the large demand in the international market. In South America, Colombia has seen a continuous increase in output of coal. According to industry sources, coal export of Colombia will exceed that of South Africa in the coming few years. Output of coal in Venezuela will remain unchanged. Venezuela government has restricted its annual output of coal at 10 million tons.

In the Commonwealth of Independent States (CIS), Russia and Kazakhstan have seen increase of coal output. The coal output in Ukraine has seen a decrease due to the geological conditions and the operation problems of main coal enterprises. The output of hard coal in South Africa sees no increase. New coal mining projects are executed in Mozambique, Botswana and Zimbabwe. Recently, Madagascar is also in search for establishment of new coal mines.

According to forecast of International Energy Administration (IEC), output of hard coal will increase from 5.6 billion tons to 8.7 billion tons in 2030. Countries having seen increase of coal output mainly concentrate in Asia. Second to Asia is North America and CIS [7].

According to estimation, coal can still be mined for another 130~140 years when reckoned based on the world coal output of 5.6 billion tons in 2007 [8]. See Table.2 for details. For coal consuming status of countries, see fig.1 for reference.

Table 2. Coal Reserves and Mining in the World

Region	Coal Reserve in 2006	Coal Output in 2007
Europe	190	1.53
CIS	1110	4.85
Africa	530	2.43
North America (Canada)	2190	10.43
South America	200	0.77
China	1670	25.23
Rest of Asian countries	1060	7.4
Australia/New Zealand	410	3.27
Rest of the world	0	0.09
Total	7360	56.00

Unit: Hundred Million Ton

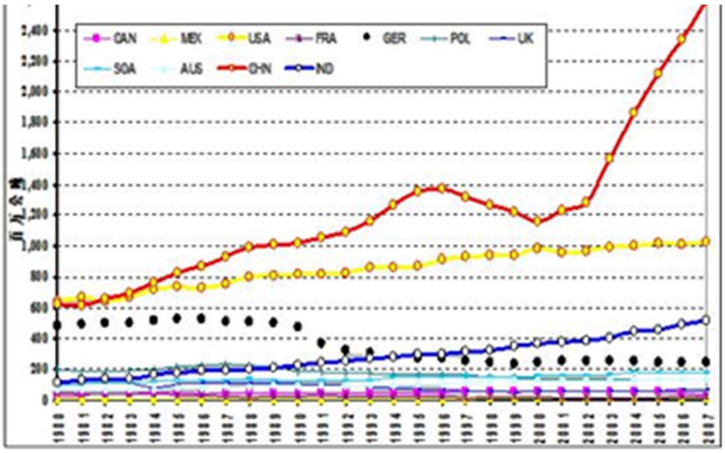

Fig. 1. Coal Consumption in main Coal Consuming Countries in the World (Million Tons)

2.2 Coal Resource and Utilization in China

China is rich in coal resources. According to the third nationwide coalfield prediction data, total sum of coal resources above vertical depth of 2000m of China (Taiwan province) is 5,569,749 million tons, of which total sum of proven resource reserves is 1,017,645 million tons, predicted resource reserves is 4,552,104 million tons. In the proven resource reserves, resource reserve occupied by production and collieries under construction is 191,604 million tons. The resource reserve not utilized is 826,041 million tons [8]-[9]-[10].

2.2.1 Geographical Area Distribution of Coal Resource in China

Coal resource in China is mainly distributed in the north from Kunlun-Qinling-Dabieshan Mountains. The sum of coal resource in the north provinces from Kunlun-Qinling-Dabieshan line is 5,184,282 million tons, accounting for 93.08% of the total coal resources of the whole country while the sum of the coal resources for the other provinces is 385,467 million tons, accounting only for 6.98% of the total coal resources of the whole country. The proven resource reserve in the northern regions from Kunlun-Qinling-Dabieshan mountains accounts for over 90% of the proven resource reserve of the whole country while the proven resource reserve in the southern part from this line accounts for less than 10% of the proven resource reserve of the whole country. Obviously, the coal resources of China characterize as more in the north and less in the south in geographical distribution [11].

If divided by Daxing'anling-Taihang Mountain-Xuefengshan Mountain, the coal resource in the 11 provinces and autonomous regions including Inner Mongolia, Sichuan, and Guizhou, in the west from the line is 5,114,571 million tons, accounting for 91.83% of the total coal resources of the whole country. In the western region from this line, the proven resource reserve accounts for 89% of the proven resource reserves while the proven resource reserves in the eastern part from this line account for 11% of the proven resource reserves. Obviously, the coal resource distribution in China is characterized as more in the west and less in the east in geographical distribution [12][13].

The feature of the coal resource in China, "more in the north and less in the south and more in the west and less in the east" in geographical distribution determines the basic production pattern of "coal transportation from the west to the east and from the north to the south" in China.

2.2.2 Coal Resource Distribution in the Main Provinces and Regions in China

China is rich in coal resource which distributes almost in all the provinces and regions excepting Shanghai. However, the distribution is very unbalanced. The coal resource of Xinjiang Uygur Autonomous Region which owns the largest quantity of coal resource is up to 1919353 million tons while that of Zhejiang Province which has the least coal resource is only 50 million tons. Provinces and regions having coal resource more than 1,000 billion tons include Xinjiang and Inner Mongolia autonomous regions, of which the sum of coal resource is 3,365,009 million tons, accounting for 60.42% of the total coal resource of the whole country. The sum of proven resource reserve of these two regions is 336,235 million tons, accounting for 33.04% of the proven resource reserves of the whole country [14].

Provinces and regions having coal resource over 100,000 million tons in China include Xinjiang, Inner Mongolia, Shanxi, Shaanxi, Henan, Ningxia, Gansu, Guizhou, of which the sum of coal resources is 5,075,083 million tons, accounting for 91.12% of the total coal resources in the whole country. The sum of proven resource reserves of these 8 provinces and regions is 856,624 million tons, accounting for 84.18% of the total sum of the proven resource reserves.

There are 12 provinces and regions having coal resources over 50 billion tons in China including the 8 provinces and regions having coal resources over 100 billion tons plus the 4 provinces of Anhui, Yunnan, Hebei and Shandong, the sum of coal resource of which is 5,377,378 million tons, accounting for 96.55% of the total sum of the coal resources of the whole country; the total sum of proven resources of the 12 provinces is 953,322 million tons, accounting for 93.68% of the total proven resources. The sum of the coal resources of the 17 provinces excluding Taiwan having coal resources less than 50,000 million tons is only 192,971 million tons, accounting only for 3.45% of the coal resources of the whole country. The proven resource reserve is only 64,323 million tons, accounting only for 6.32% of the proven resource reserves of the whole country [15]-[16].

2.2.3 Main Coal Industry Bases of China

In the regions between Daxing'anling-Taihangshan, Helanshan mountains in the north of China, the geographical range includes the whole or most part of the 6 provinces and regions of Inner Mongolia, Shanxi, Shaanxi, Ningxia, Gansu and Henan having coal resources more than 100 billion tons each and is the coal resource concentration area of China, the sum of coal resources of which accounts about 50% of the total coal resources of the whole country and over 55% of the coal resources of the northern part of China. The proven resource reserves in this area account for about 65% of the proven resource reserves of the northern part of China. Obviously, this region is not only rich in coal resources with good coal quality, but also the geographical position of this region is relatively close to the east and southeast parts China lacking of coal resources, hence is the most important coal producing base [17].

In the south of China, the coal resources mainly concentrate in the three provinces of Guizhou, Yunnan and Sichuan. The sum of coal resources of these three provinces is 352,574 million tons, accounting for 91.47% of coal resources in the south of China. The proven resource reserves of these three provinces also account for over 90% of the proven coal resources in the south regions. Especially, the west part of Guizhou, the south of Sichuan and the east of Yunnan are the richest regions in coal resources in the south of China. Obviously, this region is the most important coal producing base in the south area of China [18].

2.2.4 Coal Utilization in China

In 2006, Chinese coal mining and washing and screening industries have realized RMB 698,829,619,000 Yuan of total accumulated production value, a 23.45% increase as compared with that of the same period of previous year; RMB 709,234,867,000 Yuan of accumulated sales income of product, an increase of 23.72% as compared with the same period of the previous year; and RMB 67,726,662,000 Yuan of accumulated total profit, an increase of 25.34% as compared with the same period of previous year [19]. In 2007, Chinese coal mining and washing and screening industries realized RMB 916,447,509,000 Yuan of accumulated total production value, an increase of 28.06% as compared with the same period of the previous year. In 2008, the whole country saw a continuous large increase in raw coal output, achieving 2,621,832,400 tons of raw coal production, a growth of 12.79% year-by-year, still saw an increase of 3.4% as compared with the same period of the previous year. In the two years from 2006 to 2008, the coal consumption in China increased by over 600 million tons [17],[20].

The "11_{th} Five-Year-Plan " period is the best period of structural adjustment and industry transformation of coal industry. Coal is the basic energy of China, accounting for about 70% in the constituent of primary energy (see Table.3). A basic principle of "Coal-Based Diverse Development has been established in the planning proposal of "11_{th} Five-Year-Plan " which has laid a base for the thriving development of Chinese coal industry. In the "11_{th} Five-Year-Plan" period, new coal mines sizing about 300 million tons will be constructed, of which 200 million tons will be produced, 100 million tons will be transitioned to the "12_{th} Five-Year-Pan" period. China's coal industry will continue to maintain a thriving development tendency and will see a very wide developing prospect for quite a long period of time in the future.

Table 3. Composition of Primary Energy in China

Year	Coal	Petroleum	NG	Hydro-Nuclear- Wind Electric Power
1980	72.2	20.7	3.1	4.0
1985	75.8	17.1	2.2	4.9
1990	76.2	16.6	2.1	5.1
1995	74.6	17.5	1.8	6.1
2000	67.8	23.2	2.4	6.7
2001	66.7	22.9	2.6	7.9
2002	66.3	23.4	2.6	7.7
2003	68.4	22.2	2.6	6.8
2004	68.0	22.3	2.6	7.1
2005	69.1	21.0	2.8	7.1
2006	69.4	20.4	3.0	7.2

Percentage of the Total Energy Consumption/%

3 ENVIRONMENTAL PROBLEM CAUSED BY COAL UTILIZATION

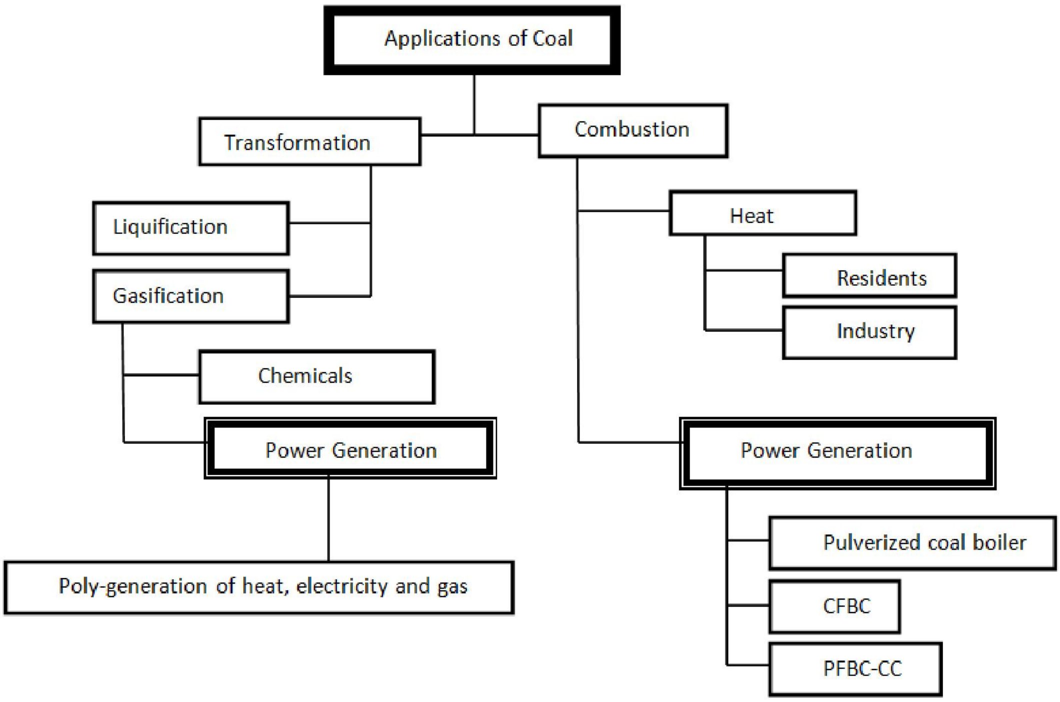

Fig. 2. IGCC- Integrated Coal-Gasification Combined Cycle; CFBC-Circulating Fluidized Bed Combustion; PFBC-CC-Pressurized Fluidized Bed Combustion Combined Cycle

Main applications of coal are as shown in Fig.2. Larger amount of soot, sulfur oxide, nitrogen oxide, heavy metal (like mercury) oxides and large quantity of carbon dioxide will be produced in the use of coal. In addition, environmental problems brought up by solid coal cinder and discharge of sewage which, if not properly controlled, will produce serious damage to human health and ecological environment. This problem is even more evident in China due to the use of coal on a large scale. According to statistics, 90% of CO_2 emission, 67% of NO_x, 70% of flue dust and 35% of inhalable particles come from coal combustion in China.

3.1 SO_2 Pollution and Acid Rain

3.1.1 Sulfur Dioxide Emission in China

In more than a decade, emission of sulfur dioxide in China has been exhibiting a gradual increasing trend. In 1995, emission of sulfur dioxide in China reached 23.7 million tons, exceeding that of Europe and U.S.A. for the first time and China has become the first big country in the world in the emission of sulfur dioxide. Thereafter, the emission of sulfur dioxide was under control for a time due to the execution of a series of control and emission reduction measures. However, with the rapid development of electric power industry in recent years, emission of sulfur dioxide starts to rise again. Since 2005, the total emission of sulfur dioxide in China has been ranking the first in the world continuously for several years and reached record-breaking value of 25.888 million tons in 2006. In 2007, emission of sulfur dioxide saw decreased as compared in the same period, however, still in the high rankings [21]-[22]-[23]. Fig.3 shows the emission conditions of sulfur dioxide in our country in more than 10 years in the past.

Energy consumption in China has been growing abnormally since the "10_{th} Five-Year-Plan" period. Consumption of coal rapidly increased from 1.32 billion tons in 2 to 2.167 billion tons in 2005. Emission of sulfur dioxide increased from 19.95 million tons in 2000 to 25.49 million tons in 2005. According to forecast of energy planning, total consumption of coal in China will maintain continuous increase. Till 2015, installed capacity of coal-fired power generation unit will increase to 1500 million kW. Coal used for power generation will reach to 2200 million tons [23]. Thus sulfur dioxide produced by burning of coal in the whole country will reach to about 45 million tons, of which thermal power generation industry will produce about 30 million tons [24]. From 2010 to 2020, the total consumption of coal in the whole country will be growing continuously. The generation capacity of sulfur dioxide by burning coal will also grow continuously. The increase in consumption of coal and the generation capacity of sulfur dioxide in thermal power industry will be higher than the mean increase of the whole country. According to the estimation by the World Bank, if sulfur dioxide remains uncontrolled, till 2020, loss of life caused by pollution due to burning of coal will amount to 600,000 cases; People suffering from chronic bronchitis and respiratory track or chest disorder will reach to 25,500,000 cases and economic costs thus paid will amount to 390 billion US dollars, accounting for 13% of GDP at that time [17],[24]. Therefore, the control of SO_2 emission in China will face a very serious situation.

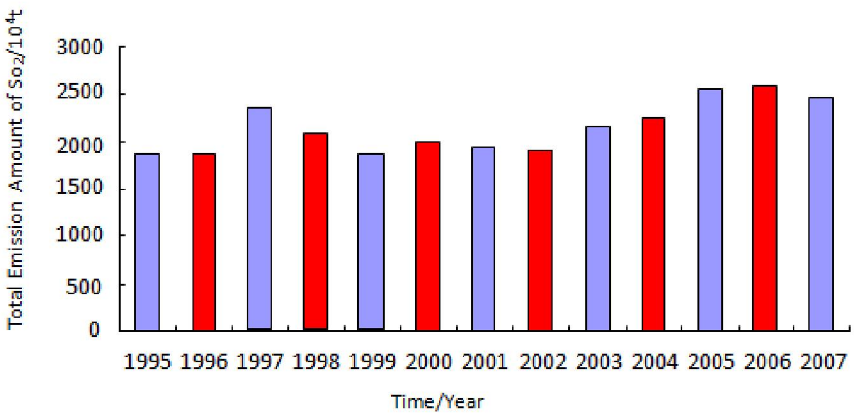

Fig. 3. SO_2 Emission Conditions of Our Country in Recent Years

(Sourced from Nation-Wide Environmental Conditions Bulletine)

3.2 POLLUTION OF SULFUR DIOXIDE

Abundant of environmental monitoring data shows that the clouds over most part of the earth are becoming acidified due to the increase of acidic substances in the atmosphere. If this situation remains uncontrolled, the area of acid rain will continue to expand and the harm thus brought up to human being will also increase daily. It has been recognized that sulfur dioxide and nitrogen dioxide in the air are the main substances forming acid rain. Sulfur dioxide and nitrogen dioxide in air mainly come from burning of coal and petroleum. According to statistics, sulfur dioxide emitted into air in the whole world each year is about 100 million tons and nitrogen dioxide emitted in to the air each year is about 50 million tons [25]. Therefore, acid rain is mainly caused by production activity and living of human being. In the constituents of acid rain measured by U.S.A., sulfuric acid accounts for 60%, nitric acid accounts for 32%, hydrochloric acid accounts for 6% and the rest percentage includes carbonic acid and small amount of organic acid. The acid rain in China belongs to sulfuric acid type and most of the acid rain is caused by emission of sulfur dioxide.

At the present time, three major acid rain regions have formed in the entire globe. In China, the acid rain deposition covers part of the provinces and cities of Sichuan, Guizhou, Guangdong, Guangxi, Hunan, Hubei, Jiangxi, Zhejiang, Jiangsu and Qingdao with an area over 2 million square kilometers which is one of the three largest regions with heavy acid rain deposition in the world. The other two major acid rain regions include North Europe centered by Germany, France and U.K. affecting better half of Europe and North America including U.S.A. and Canada. The speed the acid rain region expands and the acidification rate of rain water in China is very unusually seen in the world. In the "8_{th} Five-Year-Plan" period, acid rain polluted zone expanded from a few areas in the southwest to the south of Yangtze River, most of the areas in the east of Qinghai-Tibet Plateau and Sichuan basin. In 1995, areas with pH value of average rainfall less than 5.6 accounts for about 40% of the land, area with supercritical load of sulfur deposition is 2.1 million km^2 , cover 21.9% of the land. In 1998, the acid rain region in China expanded very quickly from the south to the north and exceeded 40% of the land [19],[26], sees in fig. 4.

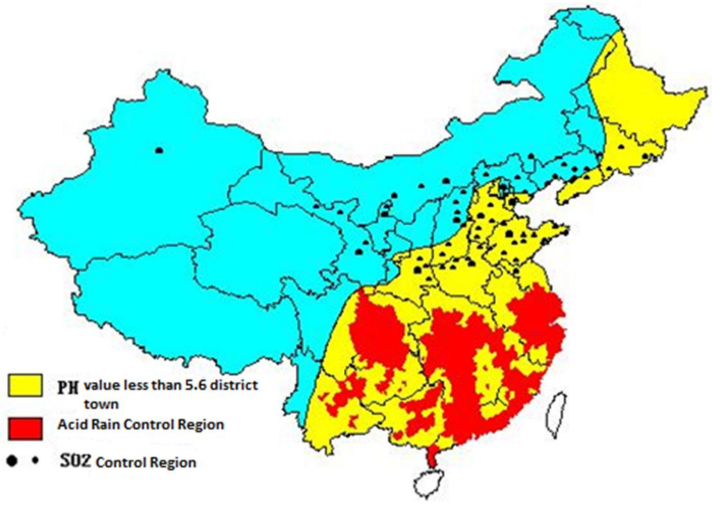

Fig. 4. Designation of Acid Rain and SO_2 Control Zones (1998)

At present, pollution caused by sulfur dioxide in China is characterized by the following main features:

3.2.1 ACID RAIN POLLUTION IS GETTING MORE AND MORE

Acid rain monitoring result shows that acidity of precipitation in the whole country in the 90s of 20^{th} century remained stable on the whole. The acidity of precipitation after 2000 exhibited an overall upward trend. Till 2005, the average concentration of sulfate radical and nitrate radical in the deposition were increased by 12% and 40% respectively.

The acid rain region in China is mainly distributed in the south of Yangtze River and the east of Qinghai-Tibet Plateau, including most part of the provinces and cities of Zhejiang, Jiangxi, Fujian, Hunan, Guizhou and Chongqing and part of the provinces and cities of Guangdong, Guangxi, Sichuan, Hubei, Anhui, Jiangsu and Shanghai. Acid rain deposition also began to appear in some regions in the north. The area of heavy acid rain is increased from 4.9% of the land in 2002 to 6.1% in 2005

[27].

In 2006, 524 cities (counties) participated in acid rain monitoring statistics, of which 283 cities (counties) experienced at least over one acid rain, accounting for 54.0%. The acid rain frequency of 6 cities (counties) (Jiande City, Xiangshan County, and Huzhou city, Anji County and Shengsi county of Zhejiang Province, Jiangjin of Chongqing City) was 100% [28]-[29]. The area distribution of nationwide acrid rain frequency in 2006 is shown in Fig.5.

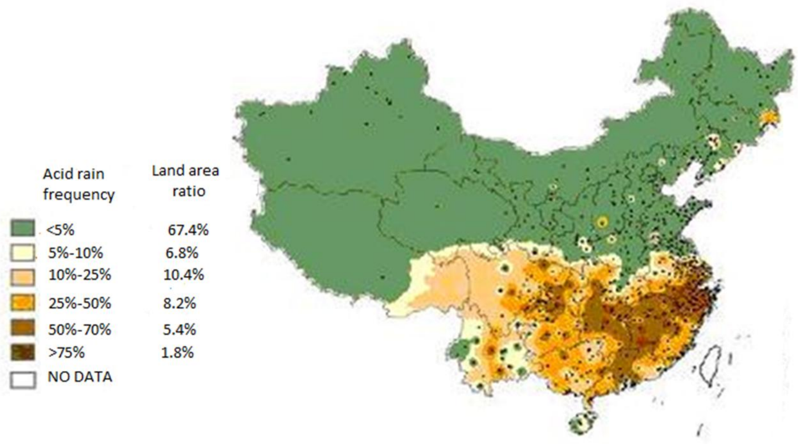

Fig. 5. Area Distribution of the National-Wide Acid Rain frequency in 2006

In 2006, the nation-wide acid rain distribution mainly concentrated in the south of Yangtze River and the east of Sichuan and Yunnan Provinces, including most part of Zhejiang, Jiangxi, Hunan, Fujian, Guizhou and Chongqing as well as the Yangtze River Delta and Zhujiang River Delta (see Fig.6).

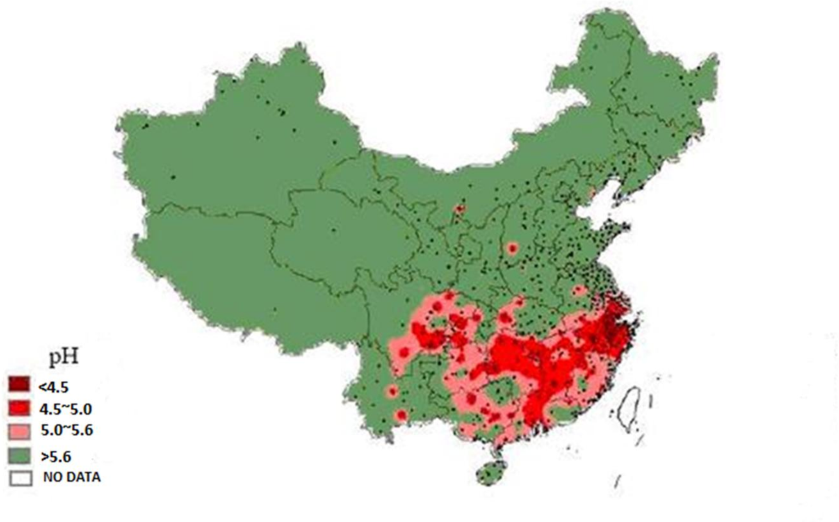

Fig. 6. Nation-Wide Area Distribution of Acid Rain

In 2006, 22 provinces of the whole country were affected by acid rain, of which, over 70% cities in the 5 provinces and cities of Zhejiang, Hunan, Jiangxi, Chongqing and Sichuan were suffered from acid rain (See Fig.7).

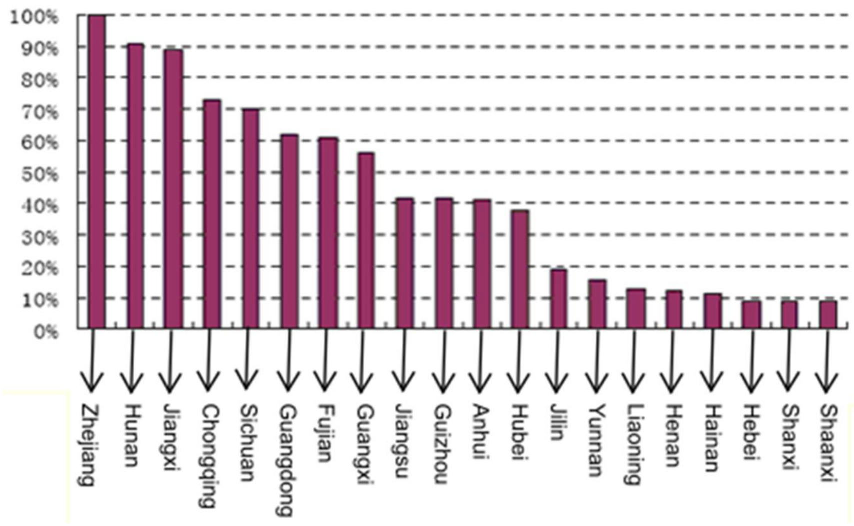

Fig. 7. The Percentage of Cities with Average pH value of Precipitation <5.6 in each Province or Municipality

3.2.2 THE AMOUNT OF SULFUR DEPOSITION IS INCREASING CONTINUOUSLY

Monitoring and research results show that 5 high intensity value sulfur deposition regions exist in China: southwest region with Guizhou as the center, east China region with Yangtze River delta as the center, south China region with Zhujiang River Delta as the center, Hebei-Shandong-Henan region and Beijing-Tianjin region. Regions with sulfur deposition intensity exceeding critical load cover an area accounting for over 20% of the land, where sulfur deposition intensity in Chongqing-Guizhou region, Yangtze River delta and Zhujiang River Delta has exceeded critical load by a large extent.

3.2.3 PRODUCTION OF FINE PARTICLES

Sulfur dioxide does not only cause acid rain, but also forms sulfate through chemical conversion in the long range transportation thus causing fine particle pollution in a regional scope. Research result shows that contribution of sulfate radicals and nitrate radicals to inhalable motes have reached to 15μg/m^3 in some regions of China. Fine particles or motes are harmful to human health and also lead to low visibility.

3.2.4 SO_2 POLLUTION IN CITIES SHOWS A SERIOUS SITUATION

In 2005, air quality monitoring result in 341 cities shows that annual average SO_2 concentration in the air of 22.6% of the cities exceeded Class 2 standard of the state and that of 6.5% of the cities exceeded Class 3 standard of the state, about 1/3 of the city population live in the environment with SO_2 concentration in the air out of standard [30].

4 NO_x POLLUTION AND PHOTOCHEMICAL SMOG

With the importance attached to acid rain pollution, SO_2 emission has obtained significant control in the world. In the first three years of the "11_{th} Five-Year-Plan" period, total SO_2 emission quantity has been reduced by 8.95% in China, nearly 90% of emission reduction task is fulfilled in the three years with notable achievements. However, NO_x emission is increasing continuously and rapidly. At the present time, NO_x emission in China is closing to 16 million tons, of which 67% originates from direct burning of coal. According to relevant research, NO_x emission, if remaining uncontrolled, will reach 30.94 million tons through 2015 [29][30]. It is estimated that the total NO_X emission will exceed that of SO_2 through 2015~2020 and become the first largest quantity of acid pollution gas in the emission in electric power industry.

The harm of NO_x had been reported at the beginning of the 40s of last century. NO_X was formally determined as one of the main air pollutants in the 60s of last century. The nitrogen oxide (NO_X) commonly referred to includes NO and NO_2, of which NO accounts for 95% of the NO_X in typical coal burning gas and NO_2 accounts for the rest percentage. NO can combine hemoglobin in blood causing degradation of oxygen carrying capability of the blood, hence oxygen deficit. In addition, NO has carcinogenic action and cause undesirable impact to cell division and genetic information. NO in air is slowly oxidized into

NO_2 under the action of O_2 which can enter man's respiratory system and contact the wet surface of lung causing lung illness and bronchial disease or leading death in serious case. NO_X can promote the formation of acid rain. NO_2 is the precursor of nitric acid and nitrous acid in acid rain. It will react with hydrocarbons in air under UV-irradiation to increase concentration of ozone in the near surface atmosphere causing poisonous light-blue photochemical smog affecting visibility in air. The acid rain and photochemical smog thus generated will cause large areas of crops and forests to be withered. Acid rain can also cause corrosion of buildings and equipment. Photochemical smog has strong irritation and harm action to human's eye, nose, heart, lung and hematopoietic tissues and obvious carcinogenicity. Ozone in the near surface atmosphere has extremely serious harm to nervus centralis. In addition, NO_x will cause ozone depletion in stratosphere by circulating reaction (1-5) and (1-6) with ozone in stratosphere causing ozone hole. NO_x has also some contribution to PM2.5. In a word, nitrogen oxide will bring serious harm to human health and destruction to ecological environment and national economy [31]-[32].

$$O_3+NO \longrightarrow O_2+NO_2$$

$$2NO_2+hv \longrightarrow 2NO+O_2$$

NO_2 concentration in air in big cities of Europe, North America and part regions of China is very high. In Los Angeles of U.S.A., photochemical smog pollution has appeared for several times. China has become the harder-hit area by NO_x emission. The data provided by the state environmental monitoring station also shows that NO_x pollution in China is very serious. The NO_x concentration in some cities and regions is out of standard and photochemical smog has appeared in several cities [12],[27]. Since the "10_{th} Five-Year-Plan ", the annual mean concentration of NO_2 in air of the 113 key cities for air pollution control has been exhibiting an upward trend on the whole. The concentration of NO_2 in air in the big cities of Beijing, Guangzhou, Shanghai, Hangzhou, Ningbo, Nanjing, Chengdu and Wuhan is relatively higher. Ozone concentration in air in the big cities of Beijing, Guangzhou and Shenzhen is sometimes out of standard. Viewing from the world map of NO_2 pollution in Fig.8, NO_X pollution in each country of the world is very serious.

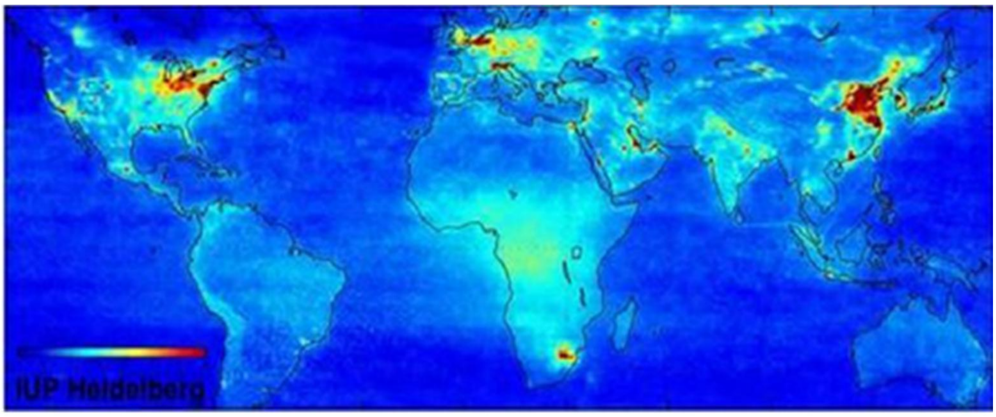

Fig. 8. World Map of NO_2 Concentration in Air

(Sourced from European Space Agency's Envisat Photo from Jan. 2003 to June, 2004)

5 PARTICLES POLLUTION AND HAZARD

About 1/3 of the particles in the environment of China comes from coal burning process. Solids suspended in air or fluids, no matter for long or short period, will cause harm to living creatures and human health, hence referred to as particulate pollution. Particles have many varieties, normally refer to dust particle, dust, fog dust, smoke, chemical smoke and soot with size between 0.1~75μm. Particles in size less than 1μm settle very slowly and spread far and widely.

Particles whether coming from nature or caused by human activities will bring up harm to animals and plants as well as human health. Particles dropped on plant leaves can cause mechanical burn and reduce photosynthetic intensity of leaves causing harm to plants.

Particles dissolved in water enter plant tissues with water causing damage. Heavy metal particles deposited on vegetables or forage plants enter the bodies of humans and animals through food chain. Particles in air have scattering and absorbing action to light, which will lead to appearance of obvious haze and reduction of visibility. What is more serious is that it will influence thermal balance of the earth. Increase of particles in air will cause more solar light to scatter and cause reduction of solar radiation absorption on earth surface. The main heat in troposphere comes from radiation of earth surface. Contrary to greenhouse effect, the increase of particles in air will cause decrease of global air temperature. In addition, increase of particles in air will lead to increase of condensation nucleus near the earth surface providing favorable conditions for condensation of moisture forming foggy weather. Therefore, particles in air are also a factor causing major problems of low air visibility, acid rain, global climatic change, smog event, and damage to ozone layer.

According to statistics, the air volume inhaled by a person every day is far in excess of the water drunk and the food taken in. The air inhaled often carries large amount of particles, which becomes the main reason leading to rise of mortality of humans [28],[30]. The inhalable motes refer to the generic term of particles that can enter human's respiratory track through nose and mouth and is expressed as PM_{10} , the finer ones of which expressed as $PM_{2.5}$ are also referred as lung-entering particles that can enter alveolus or even the blood system, directly leading to cardiovascular disease. Although the fume dust control technology can reach very high level in the world, the capture rate of particles below PM_{10} (especially $PM_{2.5}$) is very low, thus causing huge quantity of inhalable motes entering ambient media. Inhalable motes are currently the principal pollutant of urban air environment. The pollution problem of $PM_{2.5}$ is especially serious. The harm of inhalable motes to human health exhibits mainly in the "three-causing" action aspect: causing cancer, causing malformation and causing mutation. The main reason is that the inhalable motes often are enriched by heavy metals (e.g. As, Se, Pb, Cr) and organic pollutant like PAHs (polycyclic aromatic hydrocarbon), PCDD/Fs (Dioxins). These are most of carcinogenic substance and poisonous gene mutagen having extreme hazards. If PM_{10} in air increases by 10μg /m^3 each time, the clinic patients of hospital will increase proportionally. PM_{10} exhibits expressive positive correlation with cough and bronchitis when people catch a cold. Pulmonary function of children degrades when air pollution becomes more serious. Occurrence of expectoration and cough symptoms of children exhibits a linear increase. The death rate of lung cancer in the urban areas of cities exhibits a positive correlation with the total suspended particles in air in recent years. The disease rate of congenital malformation of new born children in the residential district located in the downwind side of the stack of a certain electric power plant in China is obviously higher than that in the clean zone and the closer to the power plant, the higher the disease rate of congenital malformation is, on which the particles emitted play an important toxic role.

6 OTHER ENVIRONMENTAL PROBLEMS CAUSED BY COAL COMBUSTION

6.1 CO_2 AND GREENHOUSE EFFECT

Greenhouse effect caused by carbon dioxide has attracted wide attention of the international society. China is now the second largest country in emission of CO_2 and Control of CO_2 emission is imperative.

In the greenhouse gases, the gas having the most significant influence on the global climatic change is CO_2 emitted by burning fossil fuels rich in carbon content – coal, petroleum, natural gas. The contribution of concentration increase of CO_2 to greenhouse effect is about 55%. Calculation suggests that surface temperature will rise 1.5℃~4.5℃ with increase of CO_2 concentration in air by one time. Hazards brought by the rapid growth of CO_2 emission include: rigorous weather types, changing ecological system function, species extinction and loss of biodiversity, reduction of drinking water, reduction of land caused by sea level rise and rise of average air temperature. During the past 50 years, China's average air temperature has risen by 0.5℃~0.8℃, slightly higher than the average global temperature rise value in the same period. The annual average sea level rise rate along the coast is 2.5mm, again slightly higher than the average level of the world. Therefore, control of CO_2 emission is imperative [32].

In order to effectively control CO_2 emission, Kyoto Protocol came into force formally on February 16, 2005. According to the provisions of the protocol, the 39 industrially developed countries of U.S.A., U.K. and others must reduce the total greenhouse gas reduction by another 5.2% on the emission basis of 1990 within the 5 years from 2008 to 2013 [31]-[32]. The developing countries including China and India will set emission reduction target of greenhouse gases on a voluntary basis according to the principle of "Common but Different Responsibilities". China as a developing country will not undertake CO_2 emission reduction liability in the first stage. But this does not mean China has no pressure in the CO_2 emission reduction aspect.

According to relevant data, total global CO_2 emission in 2005 was 27,136 Mt while CO_2 emission produced through energy consumption in China reached 5,101 Mt, accounting for 18.8% of the total global emission. Thus China became the second largest country after U.S.A. in the world in CO_2 emission [33]. As a developing country, China must put great efforts in the preparatory work in technical, economic and policies, laws and regulations aspects according to the actual conditions of its own and take an active stance to utter in the "Post Kyoto Protocol Era".

6.2 POLLUTION OF HAZARDOUS TRACE ELEMENTS

Almost all the elements shown in the periodic table of elements are present in the coal. Quite a lot of elements though in existing in micro amount, have high toxicity and will cause a great impact to ecological environment and human health.

These toxic trace elements include mercury, scandium (Sc), antimony (Sb), Arsenic (As), cadmium, lead, terbium, barium, beryllium, chromium, nickel, manganese, silver, cobalt as well as radioactive elements like cesium (Cs), strontium, thorium (Th). Most of these elements are emitted in the air with soot dust in the burning process, causing serious pollution to the environment. Research has shown that individual elements like mercury and arsenic are the main man-made pollution causing ecological damage and coal burning takes up an important ratio.

The endemic fluorosis occurred in Guizhou Province of China has been proved through multi-years study to be caused by soot carrying fluorine pollution. This endemic fluorosis induced by coal burning pollution is a kind of chronic intoxication caused by fluorine pollution in indoor air and grain and other foods that is caused by long term burning of high fluorine-containing coal in coal piling or in open furnace manner for heating, food cooking or roasting by the residents. Another example also in Guizhou is the event that the use of high arsenic coal in some districts caused more than 3,000 cases of arsenic poisoning and the population affected reached over 10,000 people. The annual arsenic emission of China has exceeded 10000t and the impact is outlasting [31],[34].

6.3 Organic Pollutants

The hydrocarbons in coal, if not thoroughly broken down and burnt completely in the combustion process, will form organic pollutant with considerable concentration, for example, polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene, and xylene (BTEX), alicyclic hydrocarbon and straight chain hydrocarbon, dioxins, etc. Though the emission of organic pollutants is less than SO_2 and NO_x, due to its high toxicity and slow degradation in environment, especially the carcinogenic and malformation character of PAHs have been receiving more and more attention of the public.

Viewing from China, the annual concentration of SO_2, inhalable motes and NO_2 in the urban air of the whole country in 2008 has been reduced by 28.5%, 33.3% and 31.5% respectively as compared with 2000. Environmental protection has achieved big progress. However, 23.2% of the urban air quality of the whole country has still not reached Class 2 standard of the state. In the 113 key cities, the air quality of 48 cities has not reached Class 2 standard. The inhalable motes and SO_2 concentration in urban air still maintain on a relatively high level [17],[33]. Therefore, energy conservation and reduction of consumption and pollution are still an important issue for mankind.

Conclusion

Pollutions due to coal consumption become very serious problems in the world, and power plant is the biggest consumer of coal. The control of air pollutions from coal-fired power plant is the key to solve environment problems caused by coal burning. In 2007, energy consumption reached 16.73billion tons of standard coal all over the world, in which the consumption of coal accounts for 4.849 billion tons of standard coal, just lower than the consumption of petrol (5.923billion tons of standard coal) ranking the top second. Since the 18th century, coal is the main energy for the society, and it will be one of the non-replaceable energy in the production and life of mankind. However, utilization of coal brings us serious ecological environment problems, the main pollutants in atmosphere: SO_2, NO_x, CO, dust, particulates, organic pollutants, heavy metal are mainly coming from coal combustion which damaged irreversibly the health of human and the ecological environment.

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