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Solid waste treatment and sustainable development of human society

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Abstract. Industrial revolution has enabled humans to move into industrial society from agricultural society, and big machine manufacture has greatly improved the social productive forces, and brought abundant convenience to our life, such as industrial products that we cannot live without. However, we should see through the appearance to perceive the essence, and figure out the negative effects of industrialization on our daily life, as well as the corresponding solutions. In this paper, the significance of solid waste treatment to human sustainable development will be discussed from the perspective of solid waste treatment in iron and steel plants.

As Shakespeare mentioned, "To be or not to be, that is a question!" We should make a decision on sustainable development or unsustainable development. In the 18th century, human beings initiated the industrial revolution, which made human society move forward to industrial society from agricultural society. The industrialization greatly improved the social productive forces, and qualitatively promoted the improvement of human living standards. Industry brings us great convenience, and also severe challenges, such as air pollution, water pollution, and soil pollution. Global climate change has become an urgent problem for mankind. The accumulation of unreasonable processed industrial wastes in nature will have a lasting impact on the environment. Therefore, it is an important task for scientific researchers to process such wastes in an appropriate way.

1. Pollution from industrialization in Western countries

In the second half of the 18th century, European countries, including the United Kingdom, took the lead in realizing the industrial revolution, followed by the United States and Japan, as shown in Figure 1. Industrial revolution has greatly improved the social productive forces, unprecedentedly developed the science and technology and changed social life, thus promoting the establishment of an industrialization system based on coal, metallurgy and chemical engineering [1]. The first Industrial Revolution was promoted based on the improvement of the steam engine. The widespread application of steam engines exploited and utilized underground coal reserves. Since coal was taken as the main energy source at the beginning of industrialization, coal output rose dramatically in various countries. In 1900, the total output of coal in the United Kingdom, United States, Germany, France and Japan reached 664.1 million tons [2]. The large-scale exploitation and use of coal improved the productivity and reduced the intensity of workers, but also emitted lots of pollutants to the atmosphere, including CO, CO_2, NOx, SO_2, and dust. While emitting pollution gases such as SO_2, metallurgy and other heavy industries would also discharge multiple heavy metals such as lead, zinc, cadmium, copper and arsenic, which would pollute the atmosphere, soil and water resources, thus seriously endangering human health. In the United Kingdom, as the first country realizing the industrial revolution, hundreds of people died from air and water pollution in the 19th century, and London was known as "The City of Fog". In 1873, 1880 and 1892, the great London fog killed 1,800 people. From 1832 to 1886, the severe water pollution of the Thames River caused four cholera epidemics in London, and only in 1849, 14,000 people were killed [3].

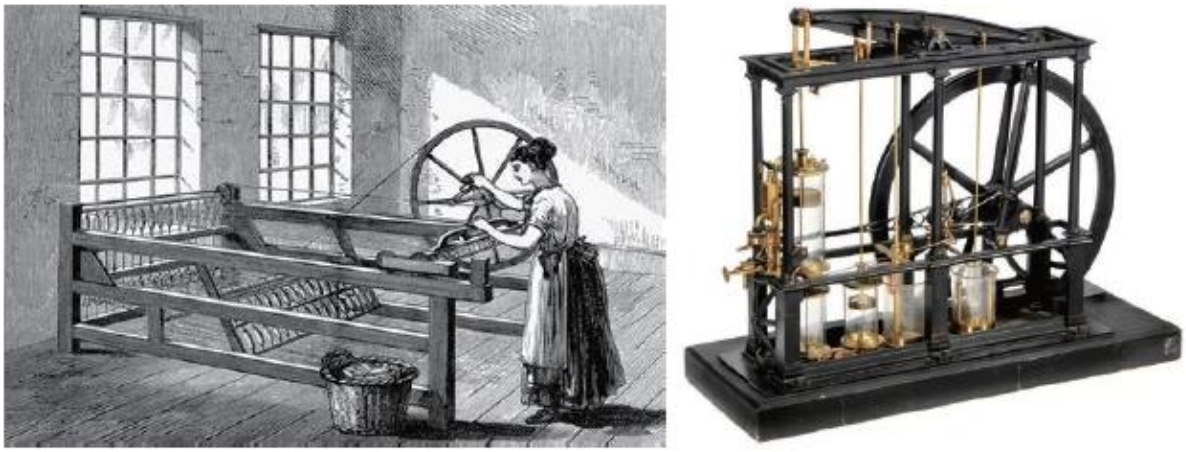

Figure 1. The First Industrial Revolution

In the late 19th century and early 20th century, the Second Industrial Revolution (Figure 2) was started in many countries around the world, which, centered on the later capitalist countries, the United States and Germany, made technological innovations in the fields of electric power, radio, internal combustion technology, metallurgy, and chemical engineering, creating a profound impact on economy, politics, culture, military, science and technology of human society [4]. With the progress of the industrial revolution, severe air pollution attacked the industrial cities in the

United States, including Chicago, Pittsburgh, St. Louis, and Cincinnati. In addition, the industrial heartland in Germany was also covered by the gray yellow haze. The Japanese people had “itai-itai disease” due to the taking of rice planted with wastewater containing cadmium from zinc and lead smelters, and “minamata disease” due to the taking of aquatic products affected by industrial wastewater containing methyl mercury [1]. Therefore, the industrial revolution was a double-edged sword: It can greatly improve the production efficiency and convenience of life, but may also bring a huge impact on people’s life, and even endanger their lives.

Figure 2. The Second Industrial Revolution

Electric power was mainly generated by thermal power plants, steam engines were gradually replaced with internal combustion engines, which promoted the rapid development in the automobile and aerospace fields, and put forward new requirements for other fields such as metallurgy. However, the development of these technologies generally relied on the consumption of coal, oil and other fossil fuels, which means the release of inactive carbon fixed by plants hundreds of millions of years ago. Then, atmospheric CO2 rose in an exponential manner [5]. With the continuous rise of CO2 and other greenhouse gases, the greenhouse effect would cause global warming and climate change. As predicted by the Intergovernmental Panel on Climate Change (IPCC), if the temperature rises by 2 ℃, the Earth and mankind will face irreversible climate disasters. Figure 3 shows global melting of ice and snow due to the greenhouse effect.

Figure 3. Global warming due to the greenhouse effect

So far, although new power generation patterns such as power generation with wind, hydro, nuclear, solar, and natural gas, and clean energy such as natural gas and combustible ice, have been developed, they could still not completely replace traditional fossil fuels due to the limitations in technology, production efficiency, and environmental risks. The mining of coal, oil and other traditional resources would inevitably cut down trees, and destroy forests, grasslands and other vegetation, thus continuously weakening the carbon sequestration capacity of the biosphere. These lessons after the industrial revolution in Western countries are like the warnings issued by nature to human beings. The industrial revolution opened the Pandora's box, and with the pursuit of industrialization, urbanization, and modernization in developing countries, the earth’s environment cannot bear the consequences of copying the blind development of Western countries.

2. Solid waste hazards and disposal

In view of the contradiction between the severe environmental situation and modernization, we should adhere to the

notion that "lucid waters and lush mountains are invaluable assets", which expounds the dialectical and unified relationship between economic development and ecological protection [6]. We are fully aware that we cannot copy the modernization experience of Western countries, and cannot follow the old path of "treatment after pollution", but in the process of modernization in China, various pollutants are still being produced, which must be processed in an effective and harmless manner. The aware of a problem is the beginning of solving it. After putting forward a goal, we should find out the right path to achieve the established goal. "We must not only propose a task, but also a method to accomplish the task. Our task is to cross the river, but we cannot accomplish it without a bridge or a boat. Without solving the problem of providing a bridge or a boat, river crossing will be just empty talk. No task can be accomplished without a method" [7]. We should not indulge in empty talk, but propose a method for solving the problem.

For example, solid wastes generally include urban solid wastes and industrial solid wastes, in which, urban solid wastes have increased by 8%-9% each year, with the per capita annual production of household waste of 450-500 kg [8]. With the growth of population and the progress of urbanization, the pressure of municipal waste disposal has been increasing. At present, 80% of urban wastes in China are still treated by landfilling, and the comprehensive utilization rate of urban construction waste resources is less than 30%, which is far lower than that in Japan, South Korea and the European Union (90%) [9]. In addition, early waste landfill is just simple landfill, without considering the severe environment contamination sue to gas and liquid in such wastes. Since the 21st century, with the technological progress in China, for solving the problem of landfill seepage prevention, newly built sanitary landfills in cities such as Guangzhou and Shenzhen have adopted the advanced HDPE geomembrane technology [10]. In addition to landfill treatment, incineration is another major treatment method. The incineration of urban solid wastes can effectively reduce the volume and weight, but Dioxin produced in the process of incineration will produce irreversible harm to the human body. With the development of incineration technologies and improvement of incineration equipment, the emission of Dioxin has been effectively controlled. No single treatment process can make urban solid wastes fully reach the standard, but due to the cost of multi-process collaborative processing, there were still a considerable number of landfills failing to meet the seepage control requirements even in 2011. In recent years, with the emphasis on environmental protection and the improvement of technologies, the measures such as waste classification pilots have been implemented, which would resolve the treatment of urban solid wastes in China. Figure 4 shows the current situation of urban solid wastes.

Figure 4. Urban solid wastes

Compared with urban solid wastes, industrial solid wastes are greater in yield and stronger in pollution, with more heavy metal elements. Without proper processing, they would cause profound negative effects. Industrial solid wastes are mainly composed of dust, slag, waste and other wastes generated during industrial production, such as mining, chemical engineering, non-metallic mineral processing, electric gas production, and ferrous and non-ferrous metallurgy [11]. In terms of ferrous metallurgy alone, the output of crude steel in China reached 1.053 billion tons in 2020, and the output of iron and steel ranked the first in the world. With the increase of the output of iron and steel, the pollution of various wastes to the environment has been increasingly deepened. In general, dust production in iron and steel enterprises is 8%-15% of the iron and steel output [12], based on which, it could be calculated that the annual dust production in China's iron and steel enterprises would be 100 million tons. The necessity and urgency of metallurgical dust treatment has put forward high requirements for scientific researchers. The main components of dust in iron and steel enterprises are shown in Table 1.

Table 1. Main components of dust in iron and steel enterprises (mass fraction, %)

Type	C	Zn	TFe	SiO_2	CaO	Al_2O_3	MgO
Raw fly ash	0.2	0.01	40-70	4.00	2.8	3.4	1.5
Sintered ash	0.3	0.20	40-60	6.20	10.7	2.4	2.4
Gas ash	20-35	0.20	28-60	4.18	2.1	2.7	0.9
Converter ash	20-35	2-4	20-60	3.78	1.9	0.5	0.7
Converter mud	0.8	1-4	40-58	0.23	8.7	0.1	3.3
Electric furnace ash	0.9	2-28	48-58	0.50	7.4	1.3	4.0

At present, the utilization rate of dust is less than 20%. Due to the small particle size, large surface area and difficulty in humidification [13], most iron and steel enterprises take the dust as a raw material for blast furnace ironmaking or sintering, but the direct addition of metallurgical dust without treatment into the sintering machine or blast furnace would directly affect the quality of sinter due to the presence of zinc or alkali metals, or cause thickening or nodulation of the blast furnace, and damage the lining. The uneven distribution of gas in tuyere would harm the cooling wall, thus affecting the metallurgical process and service life of the blast furnace, and reducing the enterprise revenue [14]. Metallurgical dust can mainly be processed by landfilling, physical processing, pyrogenic processing, wet processing and integrated processing. Direct landfilling would cause serious pollution, and occupy a large area of land. High-temperature curing treatment before landfill can reduce the pollution, but the valuable elements cannot be recycled. Landfill is equivalent to the burying of all the valuable elements, resulting in a waste of resources. Physical processing is limited in capacity, and it can only be taken as the pretreatment process for pyrogenic and wet processing. Pyrogenic processing, with the disadvantages of complex operation, multiple processes, high energy consumption and low recovery rate, could only recover mixed elements, and could not realize accurate separation and recovery. Wet processing could only treat medium and high zinc dust, and low zinc dust should be enriched in advance. In contrast, the pyrogenic-wet processing has a wide application prospect, with a satisfactory comprehensive recovery benefit and less environmental pollution. It can be used to recover metal elements that cannot be recovered by pyrogenic or wet processing alone. The pyrogenic-wet combined cascade separation and recovery technology could recover the valuable elements in metallurgical dust as much as possible, and the recycling of raw materials used in the recycling process would not cause secondary environmental pollution, but ensure the production efficiency, and separate and purify all kinds of elements, maximizing enterprise benefits. The specific recycling process is shown in Figure 5.

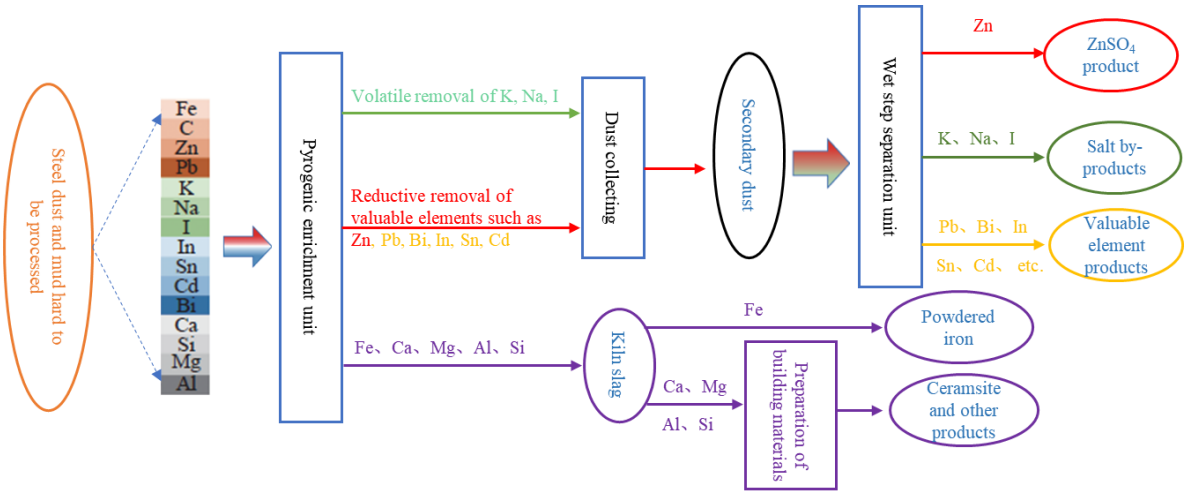

Figure 5. Schematic diagram of combined fire-wet treatment process

The pyrogenic-wet processing could effectively overcome the disadvantages of high energy consumption, low recovery rate and failure in accurate separation of elements. The pyrogenic enrichment can enlarge the range of the wet processing, which can also make use of the landfill dust in addition to the treatment of medium and high zinc dust. The stepwise recovery of elements in metallurgical dust is just like the sorting of urban solid wastes, which collects different valuable elements with appropriate processes, so as to effectively solve the problem of accumulation and pollution of metallurgical dust.

3. Future prospect for solid waste treatment

"China would increase independent contribution and take more effective policies and measures, to peak carbon dioxide emission by 2030, and realize carbon neutrality by 2060" [15]. As the only country in the world with all the industrial categories listed in United Nations Industrial Classification, China has an independent and complete modern industrial system, covering 666 minor industrial categories, 207 intermediate industrial categories and 41 major industrial categories [16]. China is exploring an industrialization path that is different from the path of "treatment after pollution" adopted in Western countries with the unique wisdom and efforts. As a developing country, China is trying to reach the goal of "carbon neutrality and carbon peaking", which reflects the responsibility and responsibility of a major power.

The increase in annual output of steel has increased the solid wastes such as metallurgical dust. The pyrogenic-wet processing provides a feasible technical solution for improving the current situation, which is expected to solve or alleviate the problem of metallurgical dust accumulation and pollution. Metallurgical dust treatment is only a part of solid waste treatment. Following the concept of "wastes are misplaced resources", full recovery of urban and industrial solid wastes will greatly reduce the impact of environmental pollution. Solid waste treatment is also only a small step in environmental protection, which can reduce the negative effects of industrialization and urbanization to a certain extent, serve the national "ecological civilization" strategy and assist in building a beautiful modern country. In China, the largest developing country, sustainable development of human society may no longer be a question based on the

dialectical unity theory of economic development and ecological protection. China has attached more attention to environmental protection, and increased scientific research input, based on which, people's awareness of environmental protection has been strengthened, the level of science and technology has been improved, significantly reducing air pollutants and effectively controlling water pollution.

References

[1] MEI Xue-qin. A Historical Survey of Environmental Pollution and its Treatment in Major Western Countries after the Industrial Revolution. World History, 2000(6):20

[2] LI Jing-wen, FANG Han-zhong. International Technical and Economic Comparison - Past, Present and Future of Great Powers. Beijing: China Society Press, 1990

[3] MEI Xue-qin. Primary Exploration on Environmental Problems of Cities in the United Kingdom in the 19th Century. Journal of Liaoning Normal University, 2000(3):105

[4] XU Wei. On the Second Industrial Revolution in the United States. World History, 1989(6):20

[5] YANG Hong-xiao, WU Bo, ZHANG Jin-tun, et al. Progress of Research into Carbon Fixation and Storage of Forest Ecosystems. Journal of Beijing Normal University (Natural Science Edition), 2005(2):172

[6] WANG Jin-nan, SU Jie-qiong, WAN Jun. Theoretical Connotation and its Realization Mechanism Innovation of "Lucid Waters and Lush Mountains are Invaluable Assets". Environmental Protection, 2017, 45(11):13

[7] Selected Works of Mao Zedong: Volume 1. Beijing: People's Publishing House, 1991

[8] JI Tao. Current Situation and Application Prospect of Urban Waste Compost. Tianjin Science & Technology, 2008(5):46

[9] WANG Xu-qian, GUO Bin, SU Hong-jian, et al. Analysis on Treatment and Comprehensive Utilization of Urban Solid Waste. Resources Economization & Environmental Protection, 2021(7):135

[10] ZHANG Ying-min, SHANG Xiao-bo, LI Kai-ming, et al. Technologies Status and Management Strategies of Municipal Solid Waste Disposal in China. Ecology and Environmental Sciences, 2011, 20(2):389

[11] WANG Wen-xing, TONG Li, Hai Re-ti. The Sources and Forward Problems of Soil Pollutants. Ecology and Environmnet, 2005(1):1

[12] SHE Xue-feng, XUE Qing-guo, DONG Jie-ji, et al. Study on Basic Properties of Typical Industrial Dust from Iron and Steel Plant and Analysis of Its Utilization. The Chinese Journal of Process Engineering, 2009, 9(S1):7

[13] HAO Yue-jun, JIANG Wu-feng, HAO Su-ju, et al. Research Progress on Comprehensive Treatment of Zinc-Containing Dust//The Chinese Society for Metals, Baosteel Group. Symposia II, The 10th China Iron and Steel Annual Conference & The 6th Baosteel Academic Conference. Shanghai, 2015:5

[14] WANG Qiong. Study on the Reduction and Dezinization Process of Iron-Bearing Dust and Mud [Dissertation]. Tangshan: Hebei United University, 2014

[15] XI Jin-ping. Address to the General Debate of the Seventy-fifth Session of the United Nations General Assembly. People's Daily, 2020-09-22(003)[2021-12-10] https://baijiahao.baidu.com/s?id=1678548552858080177&wfr=spider&for=pc

[16] MIAO Wei. Remarkable Achievements and Unceasing Development. People's Daily, 2019-09-21(004)[2021-12-10] http://www.xinhuanet.com/politics/2019-09/21/c_1125021490.htm