Take Shanghai as Example, Analyzing the Environmental Effect and Sustainability of Chinese Medical Waste Disposal during Covid-19

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Abstract. This thesis analyzes the amount carbon dioxide emissions from medical waste disposal as well as the sustainability of this method, by taking Shanghai as an example, which suffered from outbreak of Omicron mutant strain virus in 2022. This thesis involves three perspectives: the chemical reaction of the waste, the consumption of coal to burn the waste and the daily totally cost for treating medical waste. Conclusions were reached: Although it is not economical, high temperature incineration is probably the most environmentally friendly way of treatment. Medical waste, such as nucleic acid swabs and tubes, is mainly made of polyethylene, and only generated carbon dioxide and water when burned. After comparing the total amount of carbon dioxide daily produced in Shanghai with the amount from burning medical waste, it is found that the latter represents a limited percentage of the former. However, the daily cost of disposing of medical waste in Shanghai remains high, which puts pressure on the city's environmental department. The daily requirement of 11 dedicated incineration plants may be burden on both waste treatment and economic field in long run, so reducing the demand for medical plastics or increasing the combustion efficiency is necessary in the future.

Keywords: Covid-19, Medical Waste, Carbon Dioxide, Sustainable Economic, China.

1. Introduction

In the afternoon of March 1, 2022, Shanghai held a press conference on the prevention and control of the epidemic, where it was announced that there was one new local case in the Shanghai. This case can be seen as the beginning of the outbreak. Beginning on March 28, Shanghai started lockdown and under full martial law-- this regulation continued for a long time until June 1.

In these two months, according to data from the Shanghai epidemic press conference, in Shanghai, generally every 200,000 people nucleic acid testing can generate 1 ton of medical waste. The cumulative collection and disposal of medical waste is about 68,500 tons, an average of more than 2 kg of medical waste per resident. "The peak reached a daily output of more than 1,400 tons." Shanghai Ecological Environment Bureau inspector Ren Juping introduced, "Medical waste is collected by the sampling agency and brought back to the medical and health institutions or testing agencies, and then arranged by the city's centralized medical waste collection and disposal department to transport to centralized incineration and disposal facilities [1]."

Obviously, whether the disposal of medical waste causes air pollution became the primary controversial issue in the environmental field during the Covid-19 New Crown outbreak containment period in China. These wastes are forced to be professionally disposed of within two to three days of generation, with high-temperature incineration as the main method, in order to avoid secondary infections due to exposure to the public. This article simplifies the types of medical waste by considering only plastic products, such as nucleic acid swabs and nucleic acid swab tubes (in fact, these products account for most of the weight of the plastic products that need to be incinerated.) Even without considering the small amounts of dioxins, VOCs (volatile organic compounds), nitrogen oxides, and other harmful gases produced by burning polyethylene as the main raw material for medical waste, the large amounts of carbon dioxide produced during the process may contribute to the urban heat island effect in the local area.

This article aims to determine whether the pollution to the air as well as greenhouse effect in Shanghai will be intensified by burning waste.

2. The Reason Why Shanghai is Chosen as the Example City

China, unlike the vast majority of countries worldwide, has been adhering to a strict prevention and control policy since the outbreak of the novel coronavirus in 2020, requiring each city to strive to clear the number of infections. As a major city for the 2022 novel coronavirus outbreak, Shanghai has taken on enormous public pressure. The city government has introduced a series of controlling policies that have caused widespread controversy, especially for the daily nucleic acid testing requirement ----The discussion about its rationality has been repeatedly mentioned among the public, since it is quite inconvenient and wasting.

The reasons for choosing Shanghai as the subject of discussion in this article are mainly for three reasons.

2.1. Shanghai Owns a Higher International Status than Other Chinese Cities

Shanghai, a provincial-level administrative region of the People's Republic of China, is the national central city and likewise the international economic, financial, trade, shipping, and science and technology innovation center of China [2]. As of 2019, the city has 16 districts under its jurisdiction, with a total area of 6340.5 km2 built-up area of 1237.85 km2 [3]. At the end of 2021, the city's resident population is 24,894,300. The large population base will generate a large amount of medical waste daily as well as carbon dioxide gas after incineration, and the improper disposal of garbage may be able to change the local greenhouse effect; at the same time, the large urban area ensures that the number of garbage incineration stations (which will be discussed next) can reach a reference value, allowing the generalizability of the study to be basically guaranteed.

2.2. Policies of Epidemic Regulation in Shanghai has Matured during the Lockdown Period

Shanghai is the second first-tier city in China which has experienced long period lockdown. Until this outbreak of novel coronavirus in Shanghai, it has been two years and two months since the first lockdown of Wuhan in 2020, and relevant policies have been repeatedly improved, while technologies such as nucleic acid testing have become pervade and matured, generating more plastic waste.

2.3. The Case of Shanghai is Representative

As a cosmopolitan city and the core of the national economic system, we can somewhat anticipate future policy trends in China from Shanghai's performance during the epidemic. The fact that the Shanghai government maintained its policy during the containment period, even though it spent heavily on the construction of mobile cabin hospitals and the provision of free nucleic acid testing services, proves that the priority of epidemic prevention is of high importance in the national approach.

3. Disposal Method

3.1. Analysis of Medical Waste Ingredients and Sources

The main component of mass-produced nucleic acid pharyngeal swab tubes in China is polyethylene [4].

Polystyrene is a plastic. It is made up of many styrene. Styrene is a small organic compound (its skeletal formula is shown in Fig 1) with the chemical formula C6H5CH=CH2. Just like Fig 2 shows, it has a vinyl (-CH=CH2) functional group attached to a benzene ring (C6H6) [5].

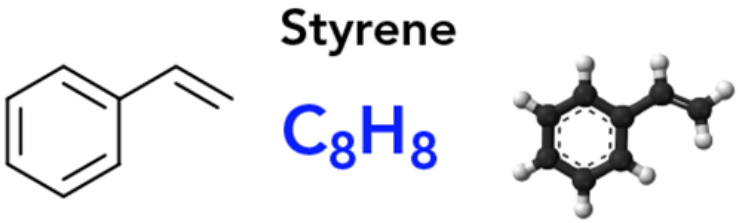


Fig. 1 Skeletal formula, molecular formula and space filling model of styrene

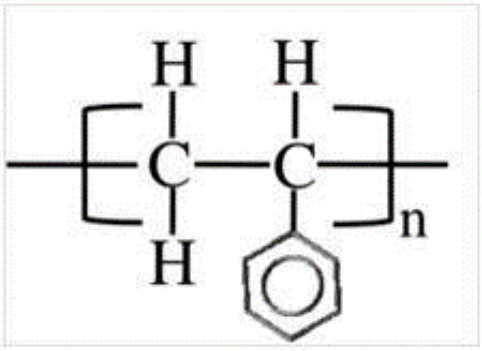


Fig. 2 Structural formula for polystyrene

Source: Sander de Jong via Wikimedia Commons and Ben Mills via Wikimedia Commons

The melting point of polystyrene is between 210℃ and 249℃. Polystyrene is most commonly disposed of by burial or incineration. If done properly, incineration is an effective method of disposal.

$$(C2H4)n+3nO2\rightarrow 2nCO2+2nH2O \quad (1)$$

The only waste by-products are carbon dioxide, water and a small amount of soot, which is the same waste produced when a car engine burns gasoline.

Carbon dioxide is also non-toxic and stable, but it also leads to climate change. The production of 1 kg of polyethylene, requires the equivalent of 2 kg of oil for energy and raw material. If we assume burning 1 kg of oil creates about 3 kg of carbon dioxide, then 6 kg carbon dioxide can be taken approximately is created during production and incineration per kg of polyethylene [6].

3.2. Method of Disposal

Although plastic products can be disposed of in a variety of ways, such as landfill, recycling, and incineration. However, because the medical waste generated over this period of time had risk of carrying the coronavirus, and secondary contact may cause the spread of an epidemic. Chinese government had established a policy that forced the waste to be incinerated only.

On the other hand, the incinerating method seems a much better way. Because if we bury them in the trash, they will end up as solid waste in the landfill. Polystyrene doesn't like chemical reactions. This means the waste will remain stable in landfills for hundreds or thousands of years.

4. The Amount of Carbon Dioxide Emission from Medical Waste

4.1. The Amount of Carbon Dioxide Emission from Chemcial Reaction

Here are two key data, 8,400 tons and 547,945 tons. As mentioned above, the amount of medical waste generated in Shanghai during the epidemic amounts to 1,400 tons a day, which will produce：

1400*6=8400 tons of carbon dioxide

When fully incinerated, though this number sometimes floats depended on different policies and epidemic condition.

Currently, Shanghai emits 200 million tonnes of carbon a year. Emissions from industry, transportation and buildings account for around 45%, 30% and 25% of the total respectively, according to research by the World Resources Institute [7]. Assuming there are 365 days in a year, that would equate to

$$200000000/365=547,945 \text{ tons of } CO_2 \text{ per day}$$

Then we can calculate the percentage:

$$8400/547945= 0.01533=1.533\%$$

From the contrast of these two numbers, the amount of carbon dioxide produced by combustion of medical waste accounts for small percentage in the planned daily emission amount, only about 1.533%, which will not lead a significant change in the greenhouse effect.

The polypropylene used in the production of nucleic acid swabs and nucleic acid swab tubes is produced with a small amount of catalyst added during the production process. Such catalysts will produce dioxins after incinerating, which are class I carcinogens and may cause significant health effects to the residents around the incineration plants. Therefore, in order to prevent environmental hazards during the process and to truly realize the harmlessness of disposal, the incineration plant in Shanghai has introduced advanced machinery and treatment methods ---- After the waste enters the incinerator and burns, the resulting flue gas stays for more than two seconds at a temperature of more than 850°C, allowing the irreversible decomposition of dioxins. The flue gas generated by incineration passes through the dry reactor, in which the active carbon can fully absorb dioxins and heavy metals. Therefore, except for carbon dioxide, other pollution from burning medical waste cannot cause damage to the atmosphere [8].

4.2. The Amount of Carbon Dioxide Emission from the Burning Coal

The plastic in medical waste has a melting point of over 200 degrees Celsius, which requires the incineration plant to burn coal to reach this temperature. However, coal is mainly composed of carbon, and burning it produces large amounts of carbon dioxide. Shanghai now owns 27 domestic waste incineration plants, and 11 of them specifically dedicated to the treatment of medical waste and a professional medical waste collection and disposal system. The people in charge said that medical waste disposal is now running smoothly at well below the limit [9]. Shanghai are also one of the few cities in the world where waste incineration plants are extensively located in the city center, which partly avoids disparity in CO_2 pollution from one region to another.

Waste incineration plants take coal as the main fuel and air as the combustion aid. For every ton of standard coal burned in an industrial boiler, 2.66-2.72 tons of carbon dioxide, 8.5 kg of sulfur dioxide, 7.4 kg of nitrogen oxides, about 2% to 3% of fly ash and 20% of slag are produced. Through the electrostatic precipitator process, SNCR (selective non-catalytic reduction) denitrification + SCR (selective catalytic reduction) technology, dry plus wet flue gas purification and treatment system to remove particulate matter, nitrogen oxides, acid gases, heavy metals and other harmful substances in the flue gas, the emission index is controlled to 1/10 of the EU 2010 standard. The fly ash is transported to landfill for sanitary landfill; the residue is handed over to qualified third-party processing organizations to be used as raw materials for building materials. So, the only product left from the coal is carbon dioxide.

Next, the coal used in the incineration station is divided into three grades, with the calorific value of each unit of coal as the differentiation standard.

In general, the calorific value of coal is 3000~5000 per kilogram, the thermal efficiency of coal-fired boilers is 70%~80%, the rated capacity of a waste incinerator is 20.8t/h, i.e., 20800kg/h [10], while the calorific value of coal-fired boilers is 1400kcal/kg [11] for one hour to maintain waste incineration.

$$1400*20800=29,120,000 \text{ kcal}$$

The calorific value required to maintain the combustion temperature in a boiler for one hour is 29,120,000 calories. Then we can calculate the amount of coal required for one hour of combustion in a boiler separately:

1. If high quality coal is used, the calorific value of coal is 4500 calories, 29120000 calories ÷ 4500 calories (calorific value of coal) ÷ 75% (boiler thermal efficiency) = 8628.15 kg coal;
2. If you choose medium coal, the calorific value of coal is 4000 calories, 29120000 calories ÷ 4000 calories (calorific value of coal) ÷ 75% (boiler thermal efficiency) = 9706.67 kg coal;
3. If you choose inferior coal, the calorific value of coal is 3500 calories, 29120000 calories ÷ 3500 calories (calorific value of coal) ÷ 75% (boiler thermal efficiency) = 11093.33 kg coal;

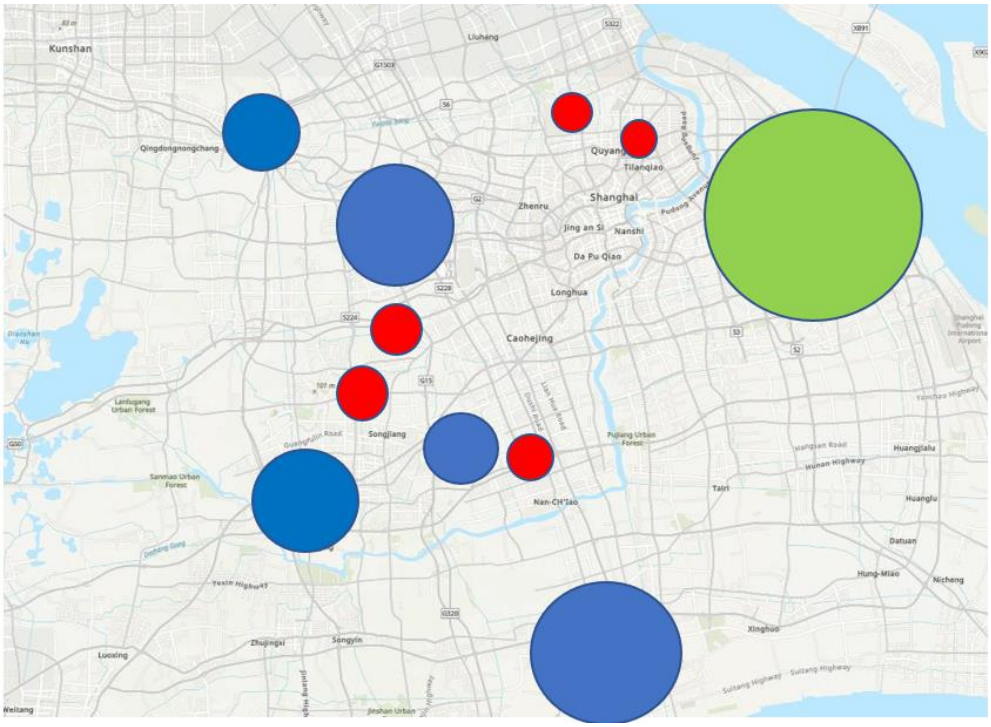


Fig. 3 Shanghai waste incineration plant for medical distribution map
(Green for large, blue for medium, red for small, eleven in total)
Source: Google map

Assume that large incineration plants use high quality coals, medium incineration plants use medium coals, and small incineration plants use inferior coals. Assume that there are three industrial boilers in each large incineration plant, two industrial boilers in medium incineration plant and one industrial boilers in small incineration plant. Then the large incineration plant consumes:

8628.15 kg * 3= 25884.45 (kilograms per hour)

The medium incineration plant consumes:

9706.67 kg * 2=19413.34 (kilograms per hour)

And the small incineration plant consumes:

11093.33 kg * 1=11093.33 (kilograms per hour)

It is known that the number of these three types of incineration plants in 11 plants are respectively one, five, five (the position is shown in Fig 3), then it can be deduced that the total weight of coal required per hour for the city-wide boilers burning medical waste is:

25884.45*1 + 19413.34*5 + 11093.33*5 = 178418 (kg)

A typical ton of standard coal, with 90% carbon content, is estimated to emit: 2.66-2.72 tons of carbon dioxide, which is approximated here as 2.72 tons. Then the total hourly CO2 emissions from boilers burning medical waste citywide are:

178418*2.72=485296 (kg)

Also, according to the Chinese Evaluation Standards for Domestic Waste Incineration Plants, which stipulate that the annual operating time of each incinerator should not be less than 8000 hours,

it can be roughly deduced that the daily operating time of each waste incineration station is 21.91 hours [12]. In other words, the waste incineration plants in Shanghai operate almost non-stop, and such a treatment mode can effectively reduce emissions, because interruption of heating and then reheating will add additional emissions.

485296*21.91=10632844(kg)= 10632.844 (tons)

The total daily CO2 emission in Shanghai under normal conditions is 547,945 tons, and the gas from medical waste incineration accounts for:

10632.844/547945=1.9405%

It isn't a percentage that represents a significant burden for the waste treatment system.

5. The Expenditure Required to Treat Medical Waste by High-temperature Incineration

Shanghai is the financial center of China and the seventh highest urban GDP (in terms of PPP) in the world [13], which indicates that the city's urban development focus is mainly on economic development. In the next analysis, the cost of high-temperature incineration of medical waste is calculated and used to analyze the sustainability of this approach.

5.1. Cost of Coal Procurement

As a port city, Shanghai has continued the tradition of importing coal from overseas since the Qing Dynasty [14], and in the 21st century (before the epidemic period), a portion of Shanghai's coal demand was also from Asian countries such as Japan. After the outbreak of the epidemic in Shanghai, the ports were almost shut down and overseas cargoes were detained and inspected for a long time before they could be put into production, which largely increased the demand for domestic coal in Shanghai and other coastal cities. Shanghai was used to buying coal from Qinhuangdao port, and according to China Coal Market, up to July 21, 2021, Qinhuangdao coal is trading at a price well above historical averages (the curve is shown in Fig 4), while the trend for 2022 is expected to continue to grow.

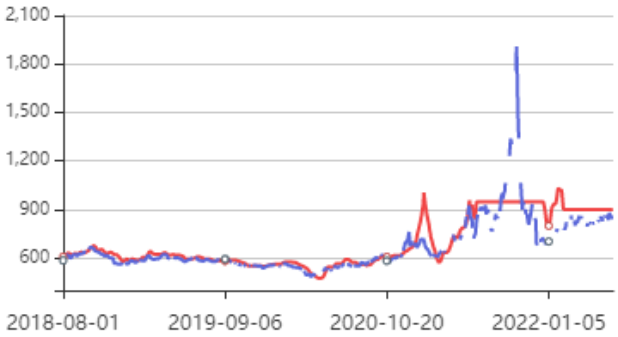


Fig. 4 Qinhuangdao historical coal price growth curves

(Red curve: Qinhuangdao coal price index chart, unit: yuan/ton)

(Blue curve: Qinhuangdao coal futures settlement price, unit: yuan/ton)

Source: CCTD China Coal Market Website

Up to October 21, 2022, the prices of the three coals are [15]:

1. High-quality coal (the calorific value of coal is 4500 calories) is 786 yuan/ton, approximate to 108.5 dollar/tons.

2. Medium-quality coal (the calorific value of coal is 4000 calories) is 715 yuan/ton, approximate to 98.70 dollar/tons.

3. Low-quality coal (the calorific value of coal is 3500 calories) is 635 yuan/ton, approximate to 87.66 dollar/tons.

Therefore, the total daily cost of coal for incinerating medical waste in Shanghai can be calculated by combining the consumption of each type of coal as shown above.

1.if high-quality coal is used, the amount of coal used on every day is

8628.15*3*1*21.91= 567128.30 kg=567.128 tons

So, the daily cost of high-quality coal is

567.128*108.5=61533.3 dollar

2. if medium-quality coal is used, the amount of coal used on every day is

9706.67*2*5*21.91= 2126731.40 kg=2126.731 tons

So, the daily cost of high-quality coal is

2126.731*98.70=209908.35 dollar

3. if low-quality coal is used, the amount of coal used on every day is

11093.33*1*5*21.91= 1215274.30 kg=1215.274 tons

So, the daily cost of high-quality coal is

1215.274 *87.66=106530.91 dollar

Thus, the total spending on the purchase of coal in Shanghai is about:

61533.3+209908.35+106530.91=377972.56 dollar

The result turns out that about 0.37 million of dollar will be spent every day. This can be a non-negligible economic burden for the environmental authorities in Shanghai.

5.2. The Revenue of Electricity Generation from Medical Waste Incineration

Burning waste does not only cost money, but with modern improvements in the process, waste burning can generate excess electricity. In Shanghai, the process steps for waste-to-energy generation are:

1. Burning the waste to produce heat
2. Use the heat to boil water to produce steam
3. Convert the steam to power through a piston
4. convert the power into electricity through a generator [16]

It is estimated that the power generation capacity of the domestic waste incineration power plant is about 305-420 kWh/ton, and the feed-in electricity is about 250-350 kWh/ton after deducting its own energy lost in the waste incineration power generation process [17]; since plastic waste and wood discussed in this paper are listed as the two waste types with the highest power generation capacity, author take 350 kWh/ton as the final feed-in electricity.

The total amount of waste incinerated per day was used as a reference quantity ----1,400 tons of plastic medical waste.

1400*350=490,000 kWh

The current standard price of electricity in China is roughly between 0.5 and 0.62 RMB per kWh, while industrial electricity is between 0.8 and 1.8 RMB per kWh [18]. If author assume that the price of electricity generated per unit of incinerated waste is 1.5 yuan, then the total price of electricity generated per day comes to another 735000 yuan, which is equal to a value of about $101466

This provides a portion of the reporting, but is still not enough to generate a profit for the 0.37 million of dollar needed to purchase coal each day. Finally, the daily cost of burning waste in Shanghai is roughly:

377972.56 - 101466 = 276507 dollar

6. Conclusions

Shanghai's waste disposal policy during the city closure had been successful in the environmental field and had not contributed excess CO2 to the local atmosphere, and it also hadn’t exacerbated the greenhouse effect or the urban heat island effect. However, from an economic aspect, the daily cost of disposing of medical waste in Shanghai remains significant, which puts pressure on the city's environmental department, which is not sustainable enough.

6.1. Evalutation About Environmental Aspect

During the epidemic lockdown period, domestic and industrial waste decreased and most incineration plants were not working, so the incineration plants were below their limits and medical waste did not increase the treatment burden or exceed the previous average CO2 emissions in short run. But after these two months, residential life, commercial activities, and industrial production will gradually recover, and medical waste will require additional man-hours to process compared to the original pre-epidemic norm, which may also produce excess carbon pollution. Increasing the combustion efficiency by developing technology or introducing advanced installations is necessary in the future.

6.2. Evalutation About Economic Aspect

In the sixth panel of the text (The expenditure required to treat medical waste by high-temperature incineration), author only considers the two conditions of purchasing coal and incineration to generate electricity, but in reality, some factors like waste transportation costs, storage site rent, even the salary of the incineration plant staff, will increase the cost of incinerating waste. Because incineration of waste is highly environmentally friendly, it is not reasonable to drastically change the treatment method. Shanghai and even Chinese officials should consider relaxing nucleic acid sampling regulations and policies to reduce the production of plastic waste in order to reduce the economic burden.

References

[1] Jingyen D. How to properly dispose of medical waste in Shanghai, which has increased sixfold since March? 2022-06-21. https://baijiahao.baidu.com/s?id=1736249865658788417&wfr=spider&for=pc

[2] Chinese State Council. Approval of Shanghai Urban Master Plan by the State Council. [F] Column on government information disclosure.2017 000014349/2017-00225.

[3] Shanghai Municipal Bureau of Statistics. Shanghai Statistical Bulletin on National Economic and Social Development in 2019. [R] China Statistical Bulletin 2020.

[4] Yan Z. Shanghai Petrochemical fully produces polyethylene special material for nucleic acid sampling tube. [J] Engineering Science and Technology I Series, 2022,47(03):78.

[5] Gilchrist S& Let's Talk Science. Polystyrene: The Pros, the Cons, the Chemistry. 2019-01-06. https://letstalkscience.ca/educational-resources/stem-in-context/polystyrene-pros-cons-chemistry

[6] Juerg J. Plastic bags and plastic bottles - CO2 emissions during their lifetime. 2009-04-11. https://timeforchange.org/plastic-bags-and-plastic-bottles-co2-emissions-during-their-lifetime/

[7] Yi S. China Dialogue, Shanghai leads way in China's carbon transition. 2021. https://chinadialogue.net/en/cities/shanghai-leads-way-in-chinas-carbon-transition/#:~:text=Currently%2C%20Shanghai%20emits%20200%20million,major%20cities%20in%20developed%20nations.

[8] Jinhui Z. Burning 1 ton of garbage can "spit out" 560 kWh of electricity. 2021. https://www.sohu.com/a/457062257_362042

[9] Yinpu Q. Shangguan, Shanghai's daily medical waste disposal volume surges 367% during epidemic, more than 1,400 tons of epidemic-related waste disappear every day. 2022. https://export.shobserver.com/baijiahao/html/478974.html

[10] Leling W. Waste incinerator capacity and design parameters. 2021. https://wenku.baidu.com/view/a955c30af321dd36a32d7375a417866fb94ac077.html

[11] Xinyue H. Waste incineration technology. 2022. https://baijiahao.baidu.com/s?id=1722810224907895077&wfr=spider&for=pc

[12] Zhongrui Y. Performance evaluation report on the waste disposal and fly ash transportation and disposal fee project of Yuqiao incineration plant in Pudong New Area in 2020. 2021.

[13] Wikipedia. List of cities by GDP. 2021. https://en.wikipedia.org/wiki/List_of_cities_by_GDP

[14] Jun Z. Modern Sino-Japanese Coal Trade - Centered on Shanghai's Imports of Japanese Coal. [J] Historical Study of the Qing Dynasty. 2021, (02):118-129.

[15] China Coal. Qinhuangdao Power Coal Price. 2022. https://www.cctd.com.cn/

[16] Kaiying B.Organic waste generation, how many kilowatt-hours of electricity can be produced from 1 ton of waste in general? Or what is the general range of how many degrees. 2021. https://zhidao.baidu.com/question/881054646521126892.html

[17] Anwei S. How much electricity can be generated from one ton of waste? How much CO2 emissions can be reduced? 2019. https://www.sohu.com/a/286358684_161058

[18] Yunzhang C. No price increase for 30 years, what is China's electricity price ranking in the world? 2022. https://baijiahao.baidu.com/s?id=1743400168220156438&wfr=spider&for=pc