Treatment of waste gas from electronic dismantling workshop

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Abstract. At present, due to China's electronic waste treatment technology is not mature enough. In the market, a large number of electronic wastes into the household dismantling workshop and through simple, inefficient, extensive way to recycle. After the extraction of valuable resources, the remaining toxic and harmful substances are discharged at will, resulting in a high level of toxic and harmful pollutants in the air of the region. The deposition of harmful and harmful pollutants in the air also further leads to the deterioration of the local soil, water and other ecological environment, threatening the health and survival of local residents. The paper takes the exhaust gas from electronic waste dismantling process based on family workshop of Guiyu town as the experimental object. Water absorption and activated carbon adsorption were applied to treat exhaust gas. And the ferriete precipitation was used to treat the recirculated wastewater after spray system. The experiment results indicate that the lead cadmium, tin and its compounds and benzene series could be removed above 95% after water absorption and active carbon adsorption. The lead, cadmium and copper in recirculated wastewater respectively could be removed 96.69%, 79.76% and 90.82% after ferrite precipitation process.

1. The significance and necessity of the project

With the progress of science and technology and the improvement of social living standards, the service cycle of electronic and electrical products is getting shorter and shorter. In recent years, with the increasing number of discarded electronic and electrical abbreviations in China, the recycling and utilization of electronic and electrical products is gradually attracting attention. In 2010, the Conference of the World Chemical Management Agency released the report "Recycling-Turning Electronic Waste into Resource", which predicted the quantity of developing countries in the future. Among them, the forecast quantity of China's main discarded electronic and electrical products is shown in the table 1, whose total volume will surge from 9099,190,000 in 2015 to 137,502,400 in 2020.
Table 1. Forecast of major electronic and electrical waste in China in the future

| Year | television | refrigerator | washer | conditioner | computer | total  |
|------|------------|--------------|--------|-------------|----------|--------|
| 2015 | 1131       | 1529         | 276    | 346         | 3509     | 9099   |
| 2016 | 1223       | 1617         | 305    | 3824        | 3706     | 10677  |
| 2017 | 1315       | 1705         | 334    | 4185        | 3904     | 11445  |
| 2018 | 1407       | 1973         | 363    | 4102        | 4547     | 12213  |
| 2019 | 1449       | 1881         | 391    | 1449        | 4909     | 12982  |
| 2020 | 1591       | 1969         | 420    | 1591        | 5270     | 13750  |

In 2012 alone, 70 million mobile phones were eliminated, resulting in about 500,000 tons of electronic waste. According to a report issued by the UN environment programme, over the next five years, the world all kinds of electronic garbage output will be more than 60 million tons per year on average, about the electronic waste will be transferred to developing countries, by 2020, only because of the old computer out, India produces electronic waste will than growth of 500%, while 400% of South Africa and China can also.

With the increase of the quantity of discarded electronic and electrical products, the harm it brings is being paid more and more attention. The scale of electronic demolition has brought huge economic benefits to Guiyu, but it has also turned the rural town into a high risk area for e-waste. The dioxin content in the atmosphere is 30 to 40 times that of Guangzhou, making Guiyu the "most toxic place in the world". Local residents are exposed to persistent organic pollutants (POPs), including dioxins, in their daily lives through breathing, skin, drinking water and eating. Their metabolites will be combined with DNA in the human body and may cause genetic mutations or cancer depending on the physical differences of the exposed individuals. A report from Shantou University shows that the incidence of cancer and abortion in Guiyu town due to dioxin is the highest in the world. The waste gas from burning board produced in the electronic dismantling process of a large number of scattered and difficult to control effectively is one of the important reasons for the deterioration of air quality and the threat of ecological environment in Guiyu area.

2. Research on the exhaust gas from burning board

2.1. Present situation of treatment technology of burning board waste gas

The tail gas treatment technology of electronic disassembly industry mainly includes activated carbon adsorption, low temperature plasma, photocatalysis, low temperature plasma synergistic photocatalysis and water film treatment.[1-3] At present, the most widely used exhaust gas treatment technology in the electronic disassembly industry is activated carbon treatment, which is mainly due to the wide use range of activated carbon adsorption method, simple equipment, early investment and low management and maintenance costs, so it occupies a certain position in the market application. The treatment efficiencies of activated carbon adsorption and low-temperature plasma synergistic photocatalysis showed no significant difference, but were significantly higher than that of low-temperature plasma and photocatalysis, and the treatment efficiencies were 38.2% and 41.1%, respectively. There was no significant difference in the treatment efficiency of VOCs by low temperature plasma and photocatalysis, which were 31.4 % and 23.8 %, respectively. Low-temperature plasma and photocatalytic technology have the advantages of high efficiency and energy saving, simple process and less secondary pollution[4-5] in the field of waste gas treatment, so they are widely used in the field of waste gas treatment. However, it is found from the survey results that low temperature plasma and photocatalytic technology are less efficient in the treatment of VOCs in the plastics industry. This may be because low temperature plasma technology is generally suitable for low concentration VOCs exhaust gas (generally less than 300 mg/m3), and when dealing with high concentration VOCs exhaust gas, many intermediate by-products may be generated, making VOCs composition more complex, resulting in low processing efficiency.
2.2. The treatment technology is selected according to the characteristics of Guiyu industry
A large number of toxic pollutants, metal particles and their compounds, such as benzene, toluene, odor, lead and its compounds, tin and its compounds, are carried in the waste gas of PCB burning[6]. In order to solve the pollution caused by waste gas from plate burning in Guiyu area, it is necessary to design a feasible process and treatment equipment which is easy to manage, low in operation cost and suitable for the small scale and scattered characteristics of family workshops in Guiyu area.

At present, water film absorption, photocatalytic oxidation and other processes are effective measures to solve the organic pollutants, metals and their compounds produced in the disassembly process. Photocatalytic oxidation process can remove persistent pollutants in waste gas more effectively than water film absorption method, and the harm of treated tail gas is lower. However, the operation management and control of the equipment are more complex and the technical level is higher than water film absorption treatment. There are some problems in the operation management of the home-based disassembly workshop with local farmers and migrant workers. Therefore, the activated carbon adsorption process was added to enhance the adsorption of persistent organic pollutants such as benzene, toluene, xylene and so on. In the treatment equipment, water film absorption and activated carbon adsorption were used in series, so that the purification and treatment effect of waste gas can be further guaranteed. At the same time, it also makes the treatment technology simple and easy to operate, meeting the requirements of local workshop production.

2.3. Discussion on the results of absorption-adsorption treatment
Lead and its compounds, cadmium and its compounds, tin and its compounds were analyzed by 3012H-C ultraminiaturized soot and gas rapid tester and TY-ULTIMA2 inductively coupled plasma emission spectrometer. HP HP5890II gas chromatograph and 3012H-C ultra-small dust gas rapid tester were used to analyze benzene, toluene and xylene. The odor was analyzed by the three point comparative smelly bag method for determination of odor in air quality.

In the experiment, the waste gas generated in the process of electronic disassembly is collected by the air collection hood, and then sent to the self-made water film absorption activated carbon adsorption treatment device (as shown in Figure 1) for two-stage series purification.

The waste gas from plate burning enters the spray system from the bottom of the water film spray equipment. A water film plate is set in the system to make the spray water evenly distributed on its surface, increase the gas-liquid contact area, and improve the absorption of the harmful gas components in the waste gas by the water. Particles, metals and their compounds in the waste gas, and harmful pollutants easily soluble in water can be absorbed by clean water in this process, and then brought into the circulating liquid storage tank to precipitate the solid impurities in the waste gas. The tail gas after absorption treatment enters the activated carbon adsorption tank, and after activated carbon adsorption treatment, the waste gas pollutants of insoluble water are adsorbed on the activated carbon, so that the waste gas of plate burning can be thoroughly purified.

| Table 2. Waste gas water film absorption - activated carbon adsorption treatment effect |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                 | Lead (mg/m³)    | Cadmium (mg/m³) | Tin (mg/m³)     | Benzene (mg/m³) | Xylene (mg/m³)  |
| Before treatment               | 0.45            | 0.30            | 5.00            | 50.46           | 0.56            |
| after processing               | 0.015           | 0.05            | 0.03            | 0.01            | 0.02            |
| Place                          | To rate         | 96.67           | 99.17           | 99.52           | 97.87           |
|                                |                 | 98.57           |                 |                 | 81.97           |

It can be seen from table 2 that after water film spraying and activated carbon adsorption treatment, the removal rate of lead, cadmium, tin and other metals, their compounds and benzene series can reach more than 95%, and the odor removal rate can reach 81.97%. The emission of waste gas meets the requirements of the secondary emission standard of Guangdong local standard Emission limits of air pollutants (DB 44 / 27-2001).
The deterioration of air quality in Guiyu area has led to the deposition of heavy metals in the ground soil and the threat to the health of residents, which is related to the fact that the electronic dismantling industry in this area is scattered, disordered and widely distributed in various areas of Guiyu, and it is difficult to achieve effective management. The use of simple operation, low investment costs of the plate burning waste gas purification equipment, can directly improve the air quality in the family workshop, improve the working environment, protect the health of production workers, for the current widespread rural household electronic dismantling workshop is an effective measure to achieve air pollution control, to prevent further deterioration of the atmospheric environment quality in Guiyu area. Therefore, the deterioration of ecological environment is of positive significance.

3. Sedimentation treatment of circulating waste liquid

In the process of circulating water membrane spray absorption-activated carbon adsorption treatment, most of the organic pollutants in the waste gas will be absorbed by activated carbon, while heavy metals and their compounds would be transferred to the circulating spray solution, resulting in the gradual accumulation of heavy metal pollutants in the spray solution during the process of circulating absorption adsorption treatment. Therefore, effective process measures must be taken to treat the circulating waste liquid to ensure the safety of receiving water and environment. The ferrite precipitation process is adopted to treat the circulating waste liquid, and the process flow is shown in Figure 1.

![Fig. 1 Process flow chart of ferrite precipitation process for recycling waste liquid treatment](image)

The circulating waste liquid is pumped into the self-made SBR equipment from the storage tank, so that the treatment of waste liquid is carried out in different stages of reaction treatment-precipitation-separation. In the reaction treatment stage, excess FeSO₄ is added firstly, which is fully mixed with the waste liquid, and then NaOH is used to adjust the pH value between 8.5 and 9.5, so that most of the heavy metal ions in the water are precipitated in the form of hydroxide. Finally, NaClO is added to oxidize Fe²⁺ to Fe³⁺, and stirring is used to accelerate the formation of ferrite. The formed ferrite condenses the metal hydroxide in the water into ferrite through adsorption or magnetic force Grain size. In the stage of the precipitation and separation, the gravity of ferrite crystal is used to settle freely under the static condition, and the pH value of water is controlled to be about 8.0, so that the excessive iron ions form hydroxide to precipitate together, so as to ensure that the concentration of iron ions in the effluent does not exceed the standard. As shown in Table 3, after the treatment of ferrite precipitation process, the metal pollutants and other impurities in the circulating waste liquid can be effectively removed, and the removal rates of SS, lead, cadmium and copper are 84.45%, 96.69%, 79.76% and 90.82% respectively. The treated effluent completely meets the requirements of the Discharge limit standard of water pollutants in Guangdong Province (DB 44 / 26-2001). The effect of ferrite precipitation treatment of circulating waste liquid is shown in Table 3.
Table 3. Treatment effect of circulating waste liquid ferrite precipitation

|                | Lead (mg/L) | Cadmium (mg/L) | Cuprum (mg/L) | SS (mg/L) |
|----------------|-------------|----------------|---------------|-----------|
| Before treatment| 3.23       | 0.08           | 2.34          | 431.00    |
| after processing| 0.11       | 0.08           | 0.22          | 67.00     |
| Place To rate  | 96.69      | 79.76          | 90.82         | 84.45     |

4. Conclusion
The process of water film spray absorption and activated carbon adsorption can effectively remove the pollutants from the electronic waste dismantling, and effectively purify the air of the disassembly workshop. The process is simple and easy to operate, but heavy metals and their compounds will be transferred to the spray circulating liquid; The use of ferrite process can effectively remove heavy metals and their compounds in the circulating waste liquid, and ensure the standard and safety of the discharged sewage; The combination of water film spray absorption, activated carbon adsorption and circulating waste liquid treatment process has low operation cost, which can effectively control the air pollution of rural household electronic dismantling workshops in Guiyu, and is one of the effective measures to prevent the further deterioration of the local ecological environment.

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References
[1] Andersson M, Knutson Wedel M, Forsgren C, Christéen J. Microwave assisted pyrolysis of residual fractions of waste electrical and electronics equipment[J]. Minerals Engineering. 2012 (29):105–11.
[2] An TC, Zhang DL, Li GY, Mai BX, Fu JM. On-site and off-site atmospheric PBDEs in an electronic dismantling workshop in south China: gas-particle partitioning and human exposure assessment[J]. Environmental Pollution. 2011, 12(159):3529–35.
[3] Blazso M, Czégény Z, Csoma C. Pyrolysis and debromination of flame retarded polymers of electronic scrap studied by analytical pyrolysis[J]. Journal of Analytical and Applied Pyrolysis. 2002, 2(64):249–61.
[4] Vasile C, Brebu MA, Karayildirim T, Yanik J, Darie H. Feedstock recycling from plastic and thermoset fractions of used computers (I): pyrolysis[J]. Journal Mater Cycles Waste Manage. 2006, 4(86):99–108.
[5] Zhang ML, An TC, Hu XH, Wang C, Sheng GY, Fu JM. Preparation and photocatalytic properties of a nanometer ZnO–SnO2 coupled oxide[J]. Applied Catalysis A: General.2004, 2(260):215–22.
[6] Taicheng An, Yong Huang, Guiying Li. Pollution profiles and health risk assessment of VOCs emitted during e-waste dismantling processes associated with different dismantling methods[J]. Environment International. 2014 (73):186–194.