Experimental Study on Combustion Characteristics of High Concentration Organic Liquid Waste

Yu Jin1, Xianbin Xiao1, Yumengqiu Zhou1 and Jin Zhao2

1National Engineering Laboratory of Biomass Power Generation Equipment, North China Electric Power University, Beijing 102206, China
2State Grid Energy Conservation Services CO. Ltd. Beijing 100000, China

E-mail: 1079804738@qq.com

Abstract. With the increasing in energy demand in social development, the organic waste liquid produced in industrial production and daily life is gradually increasing, and its pollution is also becoming increasingly serious. Concentrated on high concentration organic waste liquid incineration, the paper makes a study on the incineration characteristics of different simulation waste liquid in laboratory-scale horizontal incinerator and pilot-scale vertical incinerator was made in this paper. Especially, a key analysis was made on the incineration stability of the simulated wastewater under the different conditions and had a further analysis is of the secondary pollutants in the flue gas. As the calorific value of organic waste liquid increases, the auxiliary fuel required for combustion is gradually reduced. At the same time, in order to ensure the complete combustion of organic waste liquid and reduce the consumption of auxiliary fuel, it gives the quantitative relationship between the calorific value of organic waste liquid and auxiliary fuel.

1. Introduction

In the industrial production, the discharged water is generally referred to as the industrial wastewater containing toxic and harmful substances, and it is extremely wide range. Generally, when the wastewater contains higher organics and it is suitable to incineration, it is just regard as organic waste liquid. If it contains Biochemical Oxygen Demand 5 (BOD5) >100mg/l [1] and Chemical Oxygen Demand (COD) >2000mg/l [2] in the organic waste liquid, the liquid is often referred to be as high concentration organic wastewater.

The composition, morphology, properties and the concentration of pollutants in the organic waste liquid vary widely. It often contains a lot of suspended particles, colloid, dissolved solid and other impurities. And most of the organic waste liquid always carries with some pathogenic microorganisms. If the wastewater is discharged without treated, it not only causes seriously environmental pollution and destruction of ecological environment, but also damages people's health and affects the sustainable development of the society. Thus, taking a study and treatment on high concentration organic wastewater has the very broad economic prospects and practical significance.

At present, incineration is considered as the most effective and easiest method to realize more reasonable, industrialized and economical technology in disposing of high concentration organic waste liquid by countries around the world [3, 4]. With being mature gradually, this technology is known for fast processing speed, high degree of reduction and effective energy recycling. In addition, it has other characters, such as shorter processing time, investment savings and smaller using land. These benefits
have led this technology to be the mainstream of dealing with high concentration organic wastewater and receive more and more attention.

However, incineration method has also occurred secondary pollution problems caused by the harmful gas, such as NO\textsubscript{x}, HCl, SO\textsubscript{2} and Dioxin [5]. Once the wastewater contains alkaline inorganic, the process of incineration will involve the recycling issues of salt and alkali [6]. Thus, the emission characteristics and control measures of these harmful substances must be studied in order to meet the state environmental protection standards. This paper respectively studied specific wastewater incineration conditions in different scale incinerators.

2. Experiment part
The experiments are divided into Laboratory-scale and Pilot-scale.

2.1. Laboratory-scale experiment part

2.1.1. Simulated wastewater. According to the experimental scheme, the 1,4-butanediol (BDO) and Polytetramethylene ether glycol (PTMEG) were confected to simulate wastewater. In the simulated wastewater BDO and PTMEG components are shown in table 1, the heat value of them are 11876kJ/kg and 20151kJ/kg respectively.

| Name                  | Molecular Formula | BDO Content (wt%) | PTMEG Content (wt%) |
|-----------------------|-------------------|-------------------|---------------------|
| tetrahydrofuran (THF) | C\textsubscript{4}H\textsubscript{8}O         | 0.37              | 3.22                |
| sodium formate        | CHNaO\textsubscript{2}       | 6.53              | 0                   |
| 1,4-butanediol (BDO)  | C\textsubscript{4}H\textsubscript{10}O\textsubscript{2} | 39.44             | 4.95                |
| butanol               | C\textsubscript{4}H\textsubscript{10}O          | 0.14              | 0                   |
| methanal              | CH\textsubscript{2}O       | 1.65              | 0                   |
| methanol              | CH\textsubscript{4}OH      | 14.24             | 17.40               |
| methylal              | C\textsubscript{3}H\textsubscript{8}O\textsubscript{2} | 1.02              | 0                   |
| methyl acetate (MeAC) | C\textsubscript{3}H\textsubscript{6}O\textsubscript{2} | 0                 | 72.98               |
| sodium hydroxide      | NaOH               | 0.15              | 0                   |
| sodium sulfate        | Na\textsubscript{2}SO\textsubscript{4}      | 0                 | 0.48                |
| butenediol            | C\textsubscript{4}H\textsubscript{8}O\textsubscript{2} | 0.26              | 0                   |
| water                 | H\textsubscript{2}O       | 36.20             | 0.97                |
2.1.2. Experimental device. Laboratory-scale experiment platform adopts horizontal incinerator. The process flow diagram was as shown in figure 1. The device mainly comprises liquefied petroleum gas tank, waste liquid preheating device, gas burner (RLS28 MB412 type), furnace (The inner wall was a 2520 refractory metal material ), flue, spray tower, ash collection box, gas analysis apparatus and so on.

2.2. Pilot-scale experimental part

2.2.1. Simulated wastewater. According to the experimental scheme, there were respectively provided with three kinds of simulated wastewater. The components of simulated wastewater 1, 2, 3 were shown in table 2, and the heat value of them were 7306kJ/kg, 4037kJ/kg and 12208kJ/kg respectively.

| Component          | Heat Value (kJ/kg) |
|--------------------|--------------------|
| Methyl acetate (MeAC) | 13.65              |
| Water              | 58.60              |
| Total              | 29.85              |

2.2.2. Experimental device. The pilot-scale experiment platform adopts vertical incinerator and the process diagram was shown in figure 2. The experimental platform mainly includes auxiliary gas system (liquefied petroleum gas tank), the compressed air system, air and gas system (includes blowing machine, suction fan), wastewater pretreatment device (mainly for mixing, heating), burner, furnace (insulating and no heating), flue, flue gas cooling system (mainly contain water-cooled jacket, chiller, spray system), gas analysis apparatus and so on.

Figure 1. Laboratory-scale wastewater atomization combustion system diagram
3. Results and discussion

Before the combustion experiment, the simulated wastewater was preheated to 40 °C in order to ensure that the organic components were dissolved in the wastewater which was homogeneous solution. When the auxiliary fuel (LPG) was lighted alone, the furnace temperature would be risen to 1000°C. According to the above conditions, the simulated wastewater was used to do the atomization combustion experiment in the furnace.

The flow rate of laboratory-scale incineration experiment wastewater was 25kg/h and the flow rate of pilot-scale wastewater was changed by the working condition.

3.1. The result of laboratory-scale simulated wastewater BDO incineration experiments

As shown in figure 3, the data of left column was the parameters without spraying and the curve was the parameters of the wastewater spraying. Seen from the figure 3, with the auxiliary fuel (LPG) reducing, the furnace temperature dropped, and the CO concentration was always 0 ppm. This could explain that wastewater was completely combusted in the course of the experiment. NOx gradually decreased from 85 ppm to 0 ppm and SO2 was always 0 ppm. It was mainly due to the simulated wastewater not containing S element. When the flow rate of auxiliary fuel changed from 9.0 Nm³/h to 4.0 Nm³/h, the furnace temperature always kept at 1000°C, it meant that the combustion station was always stable; as the flow rate continued to decrease, the combustion station started to be instable; especially, when the flow rate decreased to 2.0 Nm³/h, the fire extinguishing phenomenon would appear.
We can see from figure 4 that the content of O₂ increased with the decreasing of LPG flow rate, it meant that the waste liquid was completely burned. The flow rate was between 4-9 Nm³/h, the O₂ concentration and the furnace temperature both increased slowly; as the flow rate continued to decrease, the furnace temperature increased rapidly from 400-950 °C when LPG flow rate decreased from 4.0 Nm³/h to 1 Nm³/h, and at the same time the O₂ concentration changed from 5.5% to 11Nm³/h. This was because that the combustion was complete and it need no more O₂.

3.2. The results of laboratory-scale simulated wastewater PTMEG incineration experiments

As shown in figure 5, the independent data of left column was the parameters without spray and the curve was the parameters of wastewater sprayed. As the auxiliary fuel (LPG) reduced, the furnace temperature dropped and the content of O₂ was stable at a certain value after increasing. What is more, if the content of CO was always 0 ppm, this showed that wastewater was always completely combusted in the experiment course. NOₓ gradually decreased from 85 ppm to 10 ppm and SO₂ was always 0 ppm. When the flow rate of auxiliary fuel decreased to 0 Nm³/h, the incineration would be still stable.

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**Figure 4.** the relationship between O₂ and LPG flow rate of burning simulated wastewater BDO

**Figure 5.** the results of simulated wastewater PTMEG incineration experiments

**Figure 6.** the relationship between O₂ and LPG flow rate of burning simulated wastewater PTMEG
We can see from figure 6 that when LPG flow rate changed from 12.0 Nm\(^3\)/h to 2.0 Nm\(^3\)/h, the content of O\(_2\) increased. And in this range the furnace temperature increased from 250°C to 920°C, it meant that the waste liquid was completely burned. As the LPG flow rate continued to decrease, the O\(_2\) concentration and the furnace temperature both dropped. It was because that the other components need O\(_2\) when burned, and it resulted in the decreasing of O\(_2\) concentration. The heat value was lower so the furnace temperature was lower than 920°C.

3.3. The results of pilot-scale wastewater incineration experiment

As shown in figure 7, when the heat value (wastewater 1) is 7306kJ/kg, the LPG-wastewater ratio (the ratio of the LPG and wastewater flow rate) was 41.67 at least. When the heat value (wastewater 2) was 4037kJ/kg, the LPG-wastewater ratio was over 43.28. While the experimental conditions and repeat times were limited, especially the heat value (wastewater 3) was 12208kJ/kg and the LPG-wastewater ratio was more than 117.65 which value was far from the minimum LPG-wastewater ratio. But the two foregoing groups still had a certain value. In order to ensure the stable incineration and reduce the cost of auxiliary fuel, the LPG-wastewater ratio should choose 50-250 Nm\(^3\)/kg if the heat value was between 4000kJ/kg and 12000kJ/kg.

![Figure 7](image)

**Figure 7.** the comparison between different waste heat value and LPG-wastewater ratio

![Figure 8](image)

**Figure 8.** the comparison of different waste heat value and NO\(_x\) concentration

As shown in figure 8, NO\(_x\) concentration varied with the change of the wastewater heat value, but it was very low and in line with the national emission standard all the time.

4. Conclusion

As the working condition of laboratory-scale incineration device could be controlled accurately, the auxiliary fuel was consumed less in the same condition.

When the heat value of wastewater was 4037kJ/kg, it needed more auxiliary fuel to make the incineration stable and when the heat value was 11876kJ/kg, it needed less auxiliary fuel and when the heat value was 20151kJ/kg, the wastewater could burn stably single.
When the heat value was between 4000 kJ/kg and 12000 kJ/kg, the ratio of auxiliary fuel to waste liquid should be between 50 Nm$^3$/kg and 250 Nm$^3$/kg in order to ensure the stable combustion of the waste liquid and reduce the cost of the auxiliary fuel.

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References
[1] Gulyas H 1997 Water Science and Technology 36(2-3) 9-16
[2] Zhao Y, Zhu F, Pang G and Liu F 2003 Electric Power Environmental Protection 03 46-48
[3] Roos A C, Verschuur R J, Schreurs B and Jansens P J 2003 Chemical Engineering Research and Design 81(8) 881-92
[4] Lu H and Guo H 2005 China Environmental Protection Industry 12 36-38
[5] Bie R, Pan Q, Liang Z, Liu Z and Zhou D 2003 Power Engineering 05 2716-20
[6] Xu G and Zhang G 2002 Industrial Water Treatment 04 56-57