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How Ozone Can Affect Volatile Organic Compounds

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Abstract: This Article studies the removal of Volatile Organic Compounds (VOC) from polluted air, by using ozone on platina catalyst. Among volatile compounds, toluene a strong and well-known pollutant has been chosen for this study. The oxidation process of VOC on platina depends on different elements such as flow rate of polluted air, concentration of toluene before oxidation, flow rate of ozone, temperature and platina surface area. In this study the flow rate of polluted air and ozone were 100 cc/min and 50 cc/min, respectively. Impacts of temperature changes and ozone concentration on the amount of removed toluene have been studied. The test results show that when ozone is used, much more toluene is removed than when ozone is not used. Considering that the perfect removal of ozone at lower temperatures is achievable, removal of volatile compounds in existence of ozone due to its high oxidation ability has a considerable importance in terms of the process, and is more economical.

Key words: VOC Compounds, Platina, Toluene, Ozone, Oxidation

INTRODUCTION

It is in fact useless to think about industrial development without taking account of its environmental impacts. Industrial pollutions fall into three categories: solid, liquid and gas. The waste products of petrochemical industries and oil refineries are listed as solid pollutants. Aromatic compounds such as benzene, toluene and other organic compounds entering the environment through industrial sewage are among liquid pollutants. The third group is gas pollutants, products of different parts of petrochemical industries, refineries and other chemical/non-chemical industries (Beychok, 1967; Ergas and McGrath, 1997).

Since volatile organic compounds fall into the category of gas industrial pollutants, this study is mainly focused on this group of pollutants. There exist different methods for removing VOC and other pollutants produced from sewage of industrial and petrochemical industries. These methods can be used according to the situation, capacity and present facilities. The most important methods for omitting volatile organic compounds are biological decomposition, liquid adsorption, surface absorption, filtration, thermal oxidation and catalytic oxidation (Conti *et al.,* 1999; Chang 1996). Oxidation is one of the most common methods for removing VOC from polluted gas (Ruddy and Carroll, 1993; Leso and Smith, 1997). In order to run the process with high efficiency, catalytic oxidation needs high temperature, and consumes a huge amount of energy. Ozone attacks stable compounds such as multi ring aromatics and chlorine hydrocarbons and then oxidizes them at low temperature. Moreover, there is no need for its post-process decontamination since it automatically turns into oxygen. One of the advantages of using ozone is reduction of heat during the process which is environmental friendly and a tremendous energy-saver. Different kinds of catalysts are used to achieve thorough combustion of volatile organic compounds among which pt/pd on ceramic and chrome oxide on zeolith can be mentioned. Metals of platina group are extremely resistant to halogen pollutions, and that is why using platina as a catalyst plays an important role (Saracco and Specchia, 2000). In order to remove toluene (which has been chosen as a pilot, well-known compound) from polluted air, platina has used as a catalyst and ozone as an oxidizer.

MATERIALS AND METHODS

In order to test the functionality of oxidation process by using ozone the pilot device as shown in fig 1. was used to examine different parameters during the process. These tests study the impact of parameters such as reactor temperature and ozone concentration on the toluene removal. At the first stage of the test, the air

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that contains 800 ppm toluene will be oxidized by oxygen and ozone in the reactor at different temperatures. Each time, the outgoing air will be sent to GC device to measure the concentration of toluene. Analyzing the results of GC device shows a diagram on computer screen. The lower part of diagram represents concentration of toluene. The following equation is used to determine the exact amount of toluene concentration:

$$C_{toluene} = 0.0066759A \quad (1)$$

C shows the concentration of toluene (ppm), and A is the surface area below the graph according to the GC device. This equation is derived from linearization of data outputs resulted from calibration of device with different standard solutions. In each test flow rate of the air that contains toluene is 25 ml/min, flow rate of clean air is 75 ml/min and flow rate of ozone is 50 ml/min. Toluene concentration is analyzed by GC accurately before and after the reactor. For reproducibility of the results each experiment is repeated at least 3 times. The amount of removed toluene is measured at temperatures varying between 50-400 °c, on a surface of 50 m^2 platina (the absorbent surface is measured by a device using BET equation). In each test, the starting temperature is 400 °c and decreases to 50 °c. This is for burning of the coke remains from the previous tests and stopping toluene discharge. According to the fact that at high temperatures toluene will be absorbed and will be discharged at low temperatures, running the tests with an ascending temperature degree would result in toluene discharge from absorbent surface at high temperature and a subsequent severe decline in accuracy of the tests.

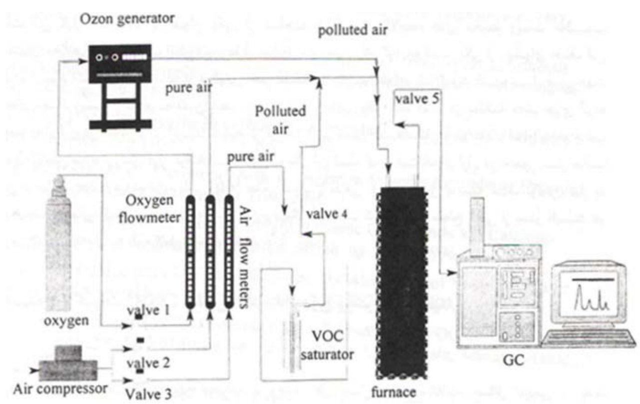

Fig. 1: schematic diagram of ozonization pilot plant

RESULTS AND DISCUSSIONS

As it shows in Table 1, the amount of removed toluene by using ozone is much more than when oxygen is used as an oxidizer in the absence of ozone. At high temperatures, regardless of using ozone or oxygen, the amount of removed toluene will be increased. While concentration of ozone is 36 ppm, the suitable temperature limit for total toluene removal is between 200-400 °c, which is the same if oxygen is used as well.

Table 1: The amount of unremoved toluene with using 36 ppm ozone and without ozone

Temperature (°c)	Toluene out with ozone (ppm)	Toluene out without ozone (ppm)
400	0	0
300	0	0
200	0	0
100	56	300
50	100	270

As it shows in Table 2, concentration of ozone is 56ppm, and the test is done at 50, 100, 200, 300 and 400 °c using ozone and oxygen in order. At temperatures between 300-400 °c, using oxygen has also desirable results, but at temperatures between 100-300 °c it is necessary to use ozone for complete removal of toluene. The amount of removed toluene at different temperatures by using ozone is much more than when oxygen is used as an oxidizer in the absence of ozone.

Table 2: The amount of unremoved toluene with using 56 ppm ozone and without ozone

Temperature (°c)	Toluene out with ozone (ppm)	Toluene out without ozone (ppm)
400	0	0
300	0	0
200	0	74
100	0	400
50	69	450

In Table 3 it is apparent that the best temperature for removing toluene is between 100-400 °c, when ozone concentration is 67 ppm. The suitable temperature for removing toluene by using oxygen is approximately between 200-400 °c.

Table 3: The amount of unremoved toluene with using 67 ppm ozone and without ozone

Temperature (°c)	Toluene out with ozone (ppm)	Toluene out without ozone (ppm)
400	0	0
300	0	0
200	0	0
100	0	350
50	50	380

At 200, 300 and 400 °c, with an ozone concentration of 36, 56 and 67 ppm the results show that at these temperatures, the toluene will be completely removed, with three different concentrations of ozone. However at 100 °c, when ozone concentration is 56 or 67 ppm, toluene will be totally removed, but when the given ozone concentration decreases to 36 ppm, complete removal of toluene is not achievable. At the same temperature, by using oxygen, the remained toluene concentration will be approximately between 300-400 ppm. Also, at 50 °c, by using ozone, the concentration of outgoing toluene, ranging from 50 to 100 ppm, but ranging from 270 to 450 ppm if oxygen is used.

Conclusions:

According to the data and the results of the tests, using ozone as an oxidizer optimizes the removal of toluene more efficiently than oxygen. At temperatures between 100-400 °c toluene will be totally vanished, by using platina as a catalyst and ozone as an oxidizer. At the temperature limit from 50 to 100 °c, depending on ozone concentration, total removal of toluene is not achievable. At temperatures between 100-400 °c, by using platina and oxygen, the rate of toluene's removal will grow by increasing the temperature. At temperatures higher than 200 °c, the amount of ozone concentration is not influential on the rate of removed toluene (which is 100% at high temperatures), but at temperatures between 50-200 °c, the more ozone concentration is, the more toluene will be removed. Ozone with higher concentration will expand its effective surface and increase the possibility of effective reaction between ozone and toluene and thus more amount of toluene removal. At temperatures below 50 °c with given amounts of ozone concentration (36, 56 and 67 ppm), it is impossible to remove toluene completely. According to the above-mentioned tests, and the fact that platina is both economical and accessible; also, effectiveness of ozone-platina system compared to oxygen-platina system, industrial pollutions (containing VOC) can be removed more efficiently, and with less price by using ozone-platina system.

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