INVESTIGATION OF OZONE DECAY HALF-LIFE IN DEPENDENCE OF TEMPERATURE AND HUMIDITY AS WELL AS H_2S AND NH_3 OXIDATION MECHANISM

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In the present research, a measurement method of ozone decay half-life τ (h) in air depending on the temperature and humidity is proposed. This method allows simulating the conditions of ozone generation during sanitizing of various premises. The ozone generation was carried out in a closed volume of 0.125 m^3 by ozonator based on dielectric barrier discharge. Through measurement ozone decay at temperatures of 10, 24 and 40 °C and humidity φ ~ 10, 50, 80 % was calculated. The ozone decay was found to change depending on temperature and humidity. The productivity of ARAO-1 type generator has been determined at various conditions. The H_2S and NH_3 oxidation mechanism has been studied. It was revealed that 8.6 mg of O_3 is required for of 1 mg of H_2S oxidized and 1.8 mg of ozone is required for 1 mg NH_3 oxidation.

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INTRODUCTION

Ozone is one of the strongest known oxidants having strong bactericidal action. It destroys microorganisms, fungi, toxins and microalgae even at low concentrations [1-3]. However, the effectiveness of ozone treatment depends on the ability to maintain the required ozone concentration for a long enough period of time. This study was focused on ozone half-life decay period in the air depending on the temperature and relative humidity. Ozone half-life is the time necessary the initial ozone concentration decreased by a half. The half-life depends on the temperature, relative humidity, degree of interaction with the walls of the material, dust from air pollution, leak and other parameters [4]. The experiments have been carried out in specially created ideal conditions to estimate the ozone decay half-life period.

Hydrogen sulfide is an important atmospheric pollutant. It reacts rapidly with ozone at room temperature and their kinetics is of great interest. Nevertheless, there are few reported studies of the oxidation kinetics. Therefore, the oxidation mechanism of H_2S and NH_3 has also been investigated.

1. EXPERIMENTAL SETUP AND METHOD

The experiments were carried out in a sealed thermal insulation volume of 0.125 m^3 made of organic glass and equipped with a humidity/temperature sensor. The block diagram of the experiment is shown in Fig.1. The ozone concentration from the reactor was measured using M454 DIN (USA) ozone monitor. Ozone concentration inside the reaction chamber was determined by monochromatic device MDR-2 and photoelectric counter (FEU).

The temperature and humidity was kept stable during measurements. Ozone was generated in a volume of ozonator until the predetermined concentration of O_3 was reached.

2. OZONE DECAY HALF-LIFE

The experiments of ozone half-life measuring have been carried out in the reaction chamber at temperatures of 10…40^{0}C and at a humidity of φ ~ 10…80 %.

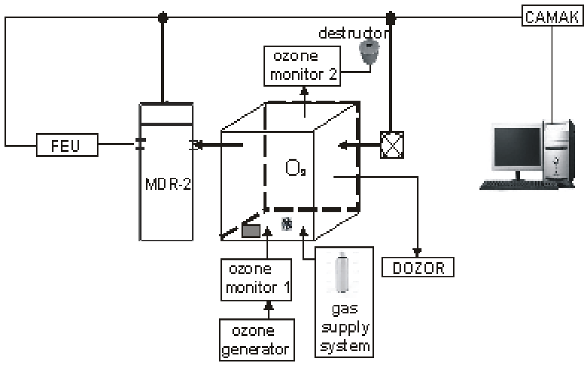

Fig. 1. Block diagram of the experiment

Each measurement was repeated 3…4 times and the results were averaged. It was determined, that increasing the temperature, the ozone half-life decreases exponentially.

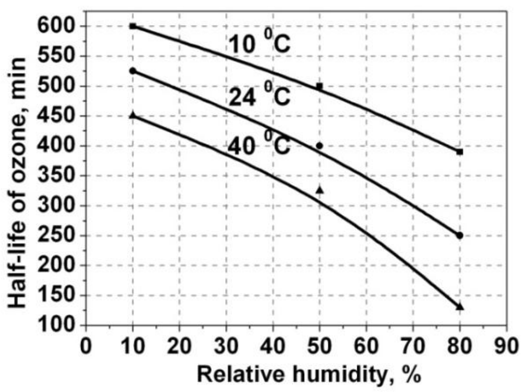

Fig. 2. Dependence of ozone half-life on relative humidity at fixed temperature

It was revealed that in the chamber filled with air, the ozone half-life decreases by 13 % with increasing the temperature from 10 to 24^{0}C. Next, an increase from 24 to 40^{0}C decreases the half-life by 16 %. In the presence of ammonia vapor and during temperature growth from 10 to 40^{0}C, the ozone half-life is decreased by 40 at 10 % humidity. At above mentioned conditions, the half-life of ozone is reduced by 50 and 59 % at a humidity of 50 and 80 %, respectively.

Ozone decay half-life dependent on temperature and relative humidity

Temperature, ⁰C	*Relative humidity, %*	*Ozone Half-life , min*
24	10	525
24	50	400
24	80	250
10	10	600
40	10	450

Fig. 2 shows the ozone decay half-life period at relative humidity and at fixed temperature. The ozone half-life reaches minimum values at 40 ^{0}C and at a relative humidity of 80 %.

3. ARAO-1 OZONATOR PRODUCTIVITY

Ozone generator of ARAO-1 type has been used as a testing device in order to determine productivity of the device depending on the temperature conditions and humidity. Fig. 3 shows the dependence of productivity of ozone generator on fixed relative humidity (a) and temperature (b). As it can be seen from the figure the productivity decreases with increasing the temperature and humidity.

4. H_2S AND NH_3 OXIDATION MECHANIZM

To study the kinetics of oxidation of hydrogen sulfide by ozone, the following experiment was carried out: hydrogen sulfide was injected into the reaction chamber using a gas supply system. The gas concentration was measured by gas analyzer "Dozor C-P_V" and it comprised 3.4 mg (see Fig. 1). Ozone was generated by dielectric barrier discharge.

Fig. 4 shows the oxidation process of hydrogen sulfide by ozone. As a result it was revealed that 8.6 mg of O_3 is required for 1 mg of H_2S oxidized.

The oxidation reaction of hydrogen sulfide starts with sulfur formation with the following transition directly to H_2SO_4:

$$H_2S + O_3 = S + O_2 + H_2O,$$
$$3H_2S + 4O_3 = 3H_2SO_4.$$

These reactions start at the same time, but the second one prevails with an excess of ozone. Ammonia is oxidized by ozone transforming into ammonium nitrate. Ozone converts oxidation of nitrogen from -3 oxidation state directly to +5 leading to the formation of ammonium nitrate:

$$6NH_3 + 4O_3 = 3NH_4NO_3 + 3H_2O.$$

Fig. 5 shows the process of ozone oxidation of ammonia. The experiments have shown that 1.8 mg of O_3 required for 1 mg of NH_3 oxidized.

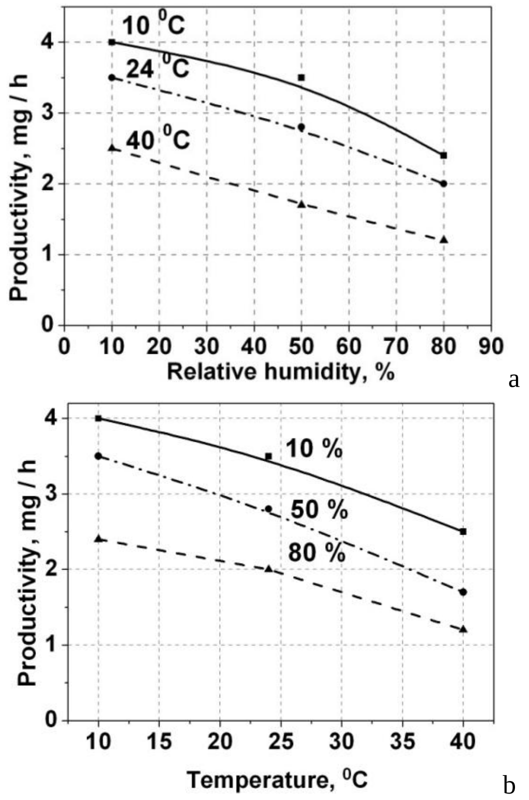

Fig. 3. Dependence of productivity of ozone generator on fixed relative humidity (a), and temperature (b)

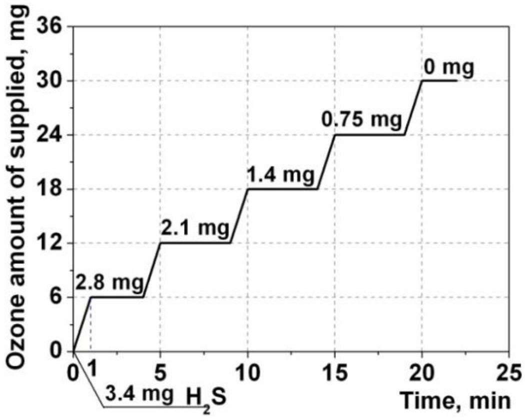

Fig. 4. H_2S oxidation kinetics

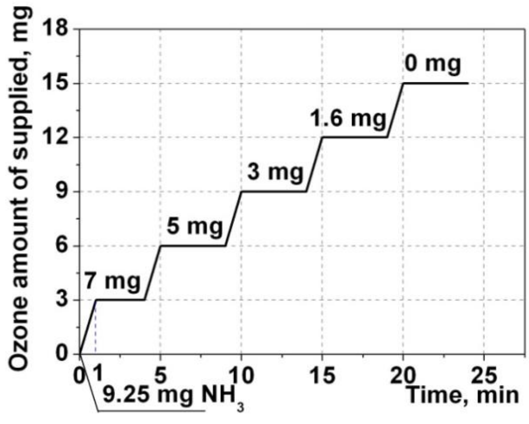

Fig. 5. NH_3 oxidation mechanism by ozone

CONCLUSIONS

1. A measuring method of ozone decay half-life τ (h) in air depending on the temperature and humidity has been proposed. The results of measuring of ozone half-life were obtained at 10, 24 and 40 ^{0}C and humidity – φ ~ 10, 50, 80 %. It was shown that ozone decay half-life decreases by 13 % with increasing the temperature from 10 to 24 ^{0}C. The half-life decreases by 16 % at increasing of temperature from 24 to 40 ^{0}C. In the presence of ammonia vapor and at temperature growth from 10 to 40 ^{0}C, the ozone half-life is decreased by 40 at 10 % humidity.

2. It was found that the productivity of ARAO-1 type ozone generator decreases with increasing the temperature and humidity.

3. The H_2S and NH_3 oxidation mechanism has been studied. It was revealed that 8.6 mg of O_3 is required for of 1 mg of H_2S oxidized and 1.8 mg of ozone is required for 1 mg NH_3 oxidation.

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ИССЛЕДОВАНИЕ ПЕРИОДА ПОЛУРАСПАДА ОЗОНА В ЗАВИСИМОСТИ ОТ ТЕМПЕРАТУРЫ И ВЛАЖНОСТИ, А ТАКЖЕ МЕХАНИЗМА ОКИСЛЕНИЯ H_2S И NH_3

В.С. Таран, В.В. Красный, А.С. Лозина, О.Г. Чечельницкий, А.В. Щебетун

Предложен метод измерения полураспада озона τ (ч) в воздухе в зависимости от температуры и влажности. Метод позволяет моделировать условия генерации озона во время санитарной обработки различных помещений. Генерирование озона проводилось в замкнутом объёме 0,125 м^3 с помощью озонатора на основе диэлектрического барьерного разряда. Измерения полураспада озона проводились при температурах 10, 24 и 40 ^{0}С и влажности φ ~10, 50, 80 %. Установлена зависимость периода полураспада озона от температуры и влажности. Определена производительность генератора озона АРАО-1 при различных условиях. Изучен механизм окисления соединений H_2S и NH_3. Было установлено, что 8,6 мг O_3 требуется для окисления 1 мг H_2S и 1,8 мг озона требуется для окисления 1 мг NH_3.

ДОСЛІДЖЕННЯ ПЕРІОДУ НАПІВРОЗПАДУ ОЗОНУ ЗАЛЕЖНО ВІД ТЕМПЕРАТУРИ І ВОЛОГОСТІ, А ТАКОЖ МЕХАНІЗМУ ОКИСЛЕННЯ H_2S і NH_3

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Запропоновано метод вимірювання напіврозпаду озону τ (год) в повітрі в залежності від температури і вологості. Метод дозволяє моделювати умови генерації озону під час санітарної обробки різних приміщень. Генерування озону проводилося в замкнутому просторі 0,125 м^3 за допомогою озонатора на основі діелектричного бар'єрного розряду. Вимірювання напіврозпаду озону проводилося при температурах 10, 24 і 40 ^{0}С і вологості φ ~ 10, 50, 80 %. Встановлено залежність періоду напіврозпаду озону від температури і вологості. Визначено продуктивність генератора озону АРАО-1 при різних умовах. Вивчено механізм окислення сполук H_2S і NH_3. Було встановлено, що 8,6 мг O_3 потрібно для окислення 1 мг H_2S і 1,8 мг озону потрібно для окислення 1 мг NH_3.