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Experimental Research on Water Curtain Scavenging Ammonia Dispersion in Confined Space

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Abstract

Ammonia (NH_3) is a typical toxic and hazardous gas that is easy to cause explosion, poisoning and pollution due to accidental release. This paper studies the water curtains scavenging the dispersion of ammonia by conducting experiments in confined space. The time profile of NH_3 concentration in air was analysed. Firstly, the free dispersion experiments for NH_3 in confined space were conducted to study the scavenging effectiveness of the water curtain. Secondly, a series of experiments were carried out to explore the factors affecting the scavenging efficiency of water curtains. The results showed that the water curtains can scavenge most ammonia gas and reduce the sustained time of ammonia gas dispersion. The scavenging efficiency of a water curtain can reach 90%. The scavenging efficiency of fan spray nozzles was similar to that of cone nozzles. When the water pressure increased from 0.05 MPa to 0.2 MPa, the scavenging efficiency would increase from 83-88% to 92-94%.

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Keywords: water curtains, ammonia dispersion, confined space, scavenging efficiency, small-scaled experiments.

Nomenclature

η_0	scavenging efficiency of the water curtain
φ	volume fraction of NH_3(ppm)

1 Introduction

With the rapid development of chemical industries, toxic and hazardous gases have been widely used. Ammonia, a typical toxic and hazardous gas, is an important industrial raw material. Liquid ammonia is widely used as a refrigerant. In large poultry slaughterhouses, the slaughtering and cutting workshops are all low temperature environments, using a liquid ammonia refrigeration system. Generally, a few tons of liquid ammonia are present in the slaughtering houses. Liquid ammonia is corrosive and volatile, and may explode within a certain concentration range in air. Moreover, it is toxic for humans and may cause environmental damage when leaking.

Liquid ammonia is stored in pressure cylinders or steel tanks. A water curtain, as a clean and effective technique to control and mitigate toxic and hazardous gases, has been used in many accidental releases[1]. Therefore, in a liquid ammonia

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warehouse, it has become an important safety measure to install water curtain systems. Mohamed and Ryozo[3], and Hanseno et al.[4] proposed a mechanism of water curtain scavenging gas dispersion by simulations and experiments.

Factors of water curtain scavenging toxic and hazardous gases in open space were explored in previous research[5]. Olewski[8] carried out medium scale LNG-related experiments and CFD simulations of a water curtain to test the ability of water curtains to hold up or disperse gases. Other workers[9][10],[11] evaluated the effectiveness of water spray curtains mitigating heavy gas in confined spaces. Dandrieux et al.[12] compared the effectiveness between two different release rates of ammonia in the presence of peacock tail water curtains.

In this paper, small-scale field experiments were carried out to research the factors affecting the scavenging efficiency of water curtains for ammonia.

2 Experimental system

The experimental system was composed of a gas discharge system, a small-scaled confined space, a water curtain system and a NH_3 concentration detection system. The gas discharge system included a gas cylinder, a reducing valve, a rotor flow meter and pipings. The reducing valve was connected between the cylinder and the rotor flow meter. The outlet diameter of the pipe was 6mm. The size of the space was 5 m×1.6 m×2.5 m (length × width ×height). There were some tiny cracks at the corner and edge of the space, so the pressure of the indoor space was equal to that of the outside. The water curtain system was composed of a water supply system, nozzles, pressure gauge, valves and flow meters. Two types of nozzles (fan spray nozzle and cone nozzle) were adopted in the experiments. The range of the flow meter was 300~3000m3/h. The models of the fan spray nozzles and cone nozzles were ZSTM15A and ZSTWB34/60, respectively. The flow coefficient of both nozzles was 38. The NH_3 concentration detection system was composed of six NH3 concentration sensors and a transmitter. The data was collected using a data acquisition system

The atmospheric pressure was 0.1 MPa. The ambient temperature was 25 ℃. The height of the release source was 0.8m. The release rate of NH_3 was 160 L/h. Two water nozzles, 1.5m away from the release source, were installed on a movable pipe with the spacing of 0.6m at the height of 2.0m. The water pressure was 0.15 MPa. Water sprayed vertically down from the nozzles. Six ammonia concentration sensors were placed further downstream from the ammonia release point (as seen in Fig.1). The scavenging efficiency of the water curtain was determined as follows:

$$\eta = (\varphi_0 - \varphi_1)/\varphi_0 \tag{1}$$

where φ_0 and φ_1 represent the volume fraction of NH_3 before and after using the water curtain, respectively.

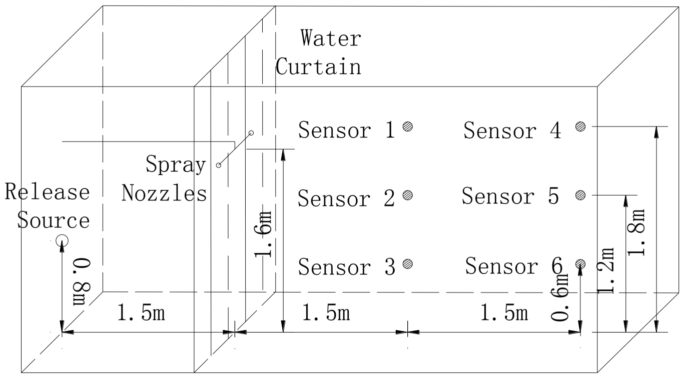

Fig. 1. Position of NH_3 concentration sensors

3 Experiments

3.1 Water spray nozzles

With the same ammonia flow, the effect of different spray nozzles on the ammonia scavenging efficiency was investigated. Fig.2 shows the variation of NH_3 concentration with time for two different nozzles. Table 1 shows the ammonia scavenging efficiencies of the different water curtains. Sensors 4 to 6 did not detect ammonia and hence these curves are not shown.

As can be seen from Table 1, water curtains can significantly reduce NH_3 concentration. The solubility of ammonia in the water was very high, so absorption played a leading role in water curtains scavenging NH_3 dispersion.