Effect of plasma activated water on reducing ammonia emission from agriculture and livestock

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Abstract: At present, a large amount of ammonia loss from agriculture and livestock has caused serious environmental pollution and energy waste. Existing studies have shown that ammonia emission can be effectively reduced by acidifying animal slurry. In this study, the inhibition effect of plasma activated water (PAW) on ammonia volatilization was investigated. The PAW was produced by a needle-water discharge in air with different discharge time and the ammonia source was simulated by using ammonia water. The results show that PAW can effectively inhibit the NH_3 volatilization from ammonia water, and the inhibition effect incearses with the PAW producing time.

Keywords: Plasma activated water; atmospheric pressure air plasma; ammonia volatilization; inhibition effect

1. Introduction

In recent years, nitrogen use efficiency (NUE) of crops worldwide has been estimated at 35%, and the nitrogen loss rate can be as high as 50% of the nitrogen application amount[1–3], which not only causes a waste of resources, but also brings an increasingly serious ammonia pollution problem. Although automobile and industrial production also produce NH_3, about 80% of NH_3 entering the air comes from agriculture and livestock[4,5], which is mainly caused by the overused and low utilization rate of nitrogen fertilizer in agriculture and the improper disposal of animal slurry accumulation in livestock[4,6,7]. Existing studies show that acidizing animal slurry is a feasible method to reduce ammonia volatilization. It is based on acid or other substances to reduce the pH value of animal slurry in order to reduce ammonia volatilization[8–11].

The PAW produced by atmospheric pressure air discharge has rich discharge products, containing a large number of H^+ and reactive oxygen and nitrogen species (RONSs)[12,13]. PAW is acidic, and usually has the characteristics of high energy utilization rate, easy arraying, high activity, no pollution, and relatively convenient preparation[12,14–16]. Acidifying animal slurry or fertilizer by PAW may reduce the pH and inhibit the NH_3 volatilization, while adding more N elements in the form of NO_3^- to the products.

In this study, we investigated the inhibition effect on ammonia volatilization by using ammonia water with the mass fraction of 1% which simulates the volatile ammonia source in agriculture and livestock. PAW was first generated by needle-water discharge in air under different discharge time and then mixed with ammonia water. The inhibition effect was evaluated by the results of Fourier Transform Infrared Spectrum (FTIR) and the influence of the PAW producing time was analysed and compared.

2. Method

Fig.1 shows the schematic of the experiment setup. A DC high voltage power supply was used to drive the needle-water discharge in a closed cavity with the inner dimension of 8 cm × 8 cm × 8 cm. A stainless steel needle was used as the anode and 10 mL of deionized water (DIW) was placed in a glass dish (with the inner diameter ⌀ 55 mm × 15 mm) as the water electrode, which was connected to the ground. When discharge, the distance between the needle tip and the water surface was fixed at 5 mm. The discharge was continuous for 5 min and 10 min to generate PAW in the atmospheric pressure and room temperature. In the following text, PAW-5 and PAW-10 represents the experimental group of discharging for 5 min and 10 min, respectively.

After discharge, the PAW and 1% ammonia water were mixed at 9:1 ratio, and 2 mL of the mixed solution was taken into a closed cavity (with inner dimension of 19 cm × 14 cm × 33 cm and equipped with ZnSe detection window) for gas phase products detection by using fourier transform infrared spectrometer (VERTEX 70, Bruker). The concentration of the volatile NH_3 can be calculated according to the FTIR results[17]. In addition, DIW mixed with ammonia water was used as control for the same detection. Each group of experiments was repeated three times.

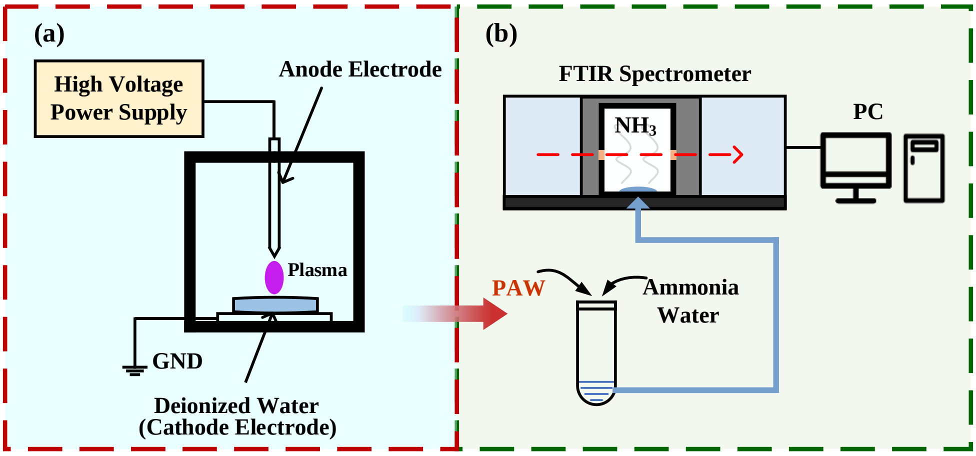

Fig. 1. The schematic of the experiment setup.
(a) Generation of PAW and (b) ammonia volatilization and detection.

3. Results

Fig.2 shows the revolution of gas-phase products volatilizing from the mixed solution. The considerable infrared absorption peak of NH_3 in the range of 900 to 1000 cm^{-1} can be seen from Fig.2 (a). With the increase of time, the absorbance of NH_3 gradually increases, which also reflects the gradual increase in the NH_3 concentration. The concentration of NH_3 volatilizing from the mixted solution *vs.* time was obtained according to the calibration results, as shown in Fig.2 (b). It can be seen that the PAW has obvious inhibition effect on NH_3 volatilization. The inhibitory effect of PAW-10 is significantly better than that of PAW-5. At 300 s, the NH_3 concentration from the mixed solution decreases from ~317 ppm in the control group to ~136 ppm in the PAW-10 group.

One of the main reasons why PAW can inhibit ammonia volatilization may be that the RONSs produced during the discharge react with water and form large amounts of H^+. When PAW containing a large amount of H^+ was added to the ammonia water, it can convert more free ammonia into NH_4^+, thus reducing the NH_3 volatilization. The longer the discharge time, the more RONS will be produced which leads to better inhibition effect on ammonia volatilization.

4. Conclusion

In this study, we evaluated the inhibition effect of PAW on ammononia volatilization by using ammonia water to simulate volatile ammonia sources in agriculture and livestock. Obvious inhibition effect of PAW on ammonia volatilization was observed. It proposed a new prospect for reducing ammonia emission and controlling ammonia pollution in agriculture and livestock by PAW which is convenient, clean and cheap.

5. Acknowledgement

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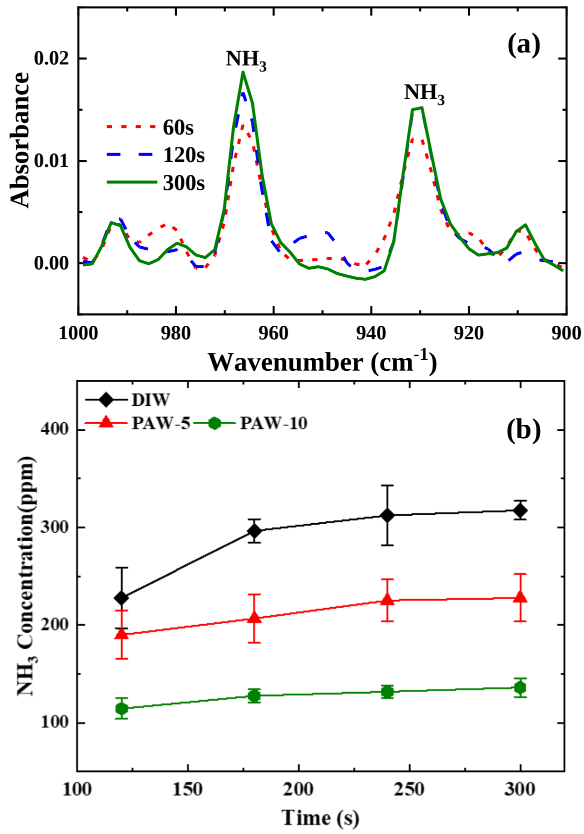

Fig. 2. Revolution of gas-phase products volatilized from the mixed solution. (a) Typical FTIR spectrum, (b)volatile NH_3 concentration from PAW and ammonia water mixture

6. References

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