

# The international research progress of Ammonia(NH<sub>3</sub>) emissions and emissions reduction technology in farmland ecosystem

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**Abstract.** NH<sub>3</sub> is the important factor leading to the grey haze, and one of the main causes of environmental problems of serious ecological imbalance, such as acid rain and air quality deterioration. The fertilizer excessive application of the current farmland results NH<sub>3</sub> emissions intensity greatly. In order to clear the farmland NH<sub>3</sub> emissions research status and achievements, the literature of farmland NH<sub>3</sub> emission related were retrieved by the SCI journals and Chinese science citation database. Some factors of NH<sub>3</sub> emission were analyzed such as soil factors, climate factors and farmland management measures. The research progress was inducted on farmland NH<sub>3</sub> emission reduction technology. The results will help to clarify farmland NH<sub>3</sub> emissions research progress. The theoretical guidance was provided on the future of farmland NH<sub>3</sub> emissions research.

## 1. Introduction

NH<sub>3</sub> emissions is the largest in the gas of containing N<sup>[1]</sup>. NH<sub>3</sub> is the only source of particulate NH<sub>4</sub><sup>+</sup> and alkaline gaseous substance in the gas. The NH<sub>3</sub> 90 percent was converted to NH<sub>4</sub><sup>+</sup>, which was reacted with the acid in the atmosphere. There are NH<sub>4</sub><sup>+</sup> 84 percent photochemical reactions. NH<sub>3</sub> exists in aerosol particles with NH<sub>4</sub>NO<sub>3</sub>, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and NH<sub>4</sub>Cl binding mode(such as PM<sub>2.5</sub>)<sup>[2,3]</sup>. especially the haze formation process, they accounted for 30 percent to 70 percent of PM<sub>2.5</sub> mass concentration<sup>[4]</sup>. Simultaneously, the NH<sub>3</sub> accumulating in the atmosphere will be oxidized into N<sub>2</sub>O and NO, etc. The N<sub>2</sub>O is not only an important greenhouse gas, but also participate in the stratospheric optical process, destroy the ozone layer, enhance ultraviolet radiation to the earth's surface, causing environmental pollution and huge economic losses<sup>[5]</sup>. The increase of NH<sub>3</sub> concentration in atmosphere is closely related to the change of agricultural production mode. Agricultural production is an important source of NH<sub>3</sub> emissions<sup>[6]</sup>.

## 2. NH<sub>3</sub> emissions research progress at home and abroad

In recent years, a lot of field data have been accumulated at home and abroad on the NH<sub>3</sub> emissions. Some researchers have done a lot of quantitative research on the NH<sub>3</sub> emission rate and influencing factors under field conditions. There are 3 main factors affecting the NH<sub>3</sub>-N loss of nitrogenous fertilizer, such as soil properties, meteorological conditions and agricultural technical measures<sup>[7,8]</sup>.

### 2.1. Soil factors

Soil pH is one of the important factors affecting NH<sub>3</sub> emissions. The NH<sub>3</sub> emissions increase with the



increase of soil pH value<sup>[9]</sup>. Urea applied into the soil, the soil pH increase after a short period of time, and reach maximum on the second day after fertigation, then fell rapidly, and maintain between 7.6-8.0. Some is absorbed by crops in the hydrolysis product  $\text{NH}_4^+$ , part are transformed into  $\text{NO}_3^-$ -N, part are adsorbed by soil, the rest are released into atmosphere in the form of  $\text{NH}_3$  emission loss. The soil cation exchange capacity (CEC) changes  $\text{H}^+$  concentration in soil solution, adsorb  $\text{NH}_4^+$  and  $\text{NH}_3$  strongly, decrease the concentration of  $\text{NH}_3$ , inhibit  $\text{NH}_3$  emission, reduce  $\text{NH}_3$  emission<sup>[10]</sup>. Xiao(2016) studied soil's clay content was much and organic matter content was high in winter wheat field, and cumulative  $\text{NH}_3$  emissions is 3.40-5.06 kg N/hm<sup>2</sup> in different fertilization treatment. The reason is that the texture of clay soil has a strong adsorption capacity of  $\text{NH}_4^+$  generally, reduce the  $\text{NH}_4^+$  content in the soil liquid phase effectively, thus reduce the loss of  $\text{NH}_3$  emission<sup>[11,12]</sup>.  $\text{CaCO}_3$  content and total salt content in soil were closely related to the  $\text{NH}_3$  emission of nitrogen fertilizer. Zhu(1989) researched that urea is in calcareous soil contained more calcium carbonate,  $\text{NH}_3$  emission was more than that in acid paddy soil. Dry land, especially, on calcareous soil,  $\text{NH}_3$  emissions is a great loss on application of urea and ammonium bicarbonate<sup>[13]</sup>.

## 2.2. Meteorological factors

Soil temperature directly affects the  $\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$  reaction equilibrium constant and  $\text{NH}_3$  diffusion rate from the soil to the atmosphere. Temperatures elevated accelerate the emission rate of  $\text{NH}_3$ . On the one hand, Temperature increased the proportion of the liquid  $\text{NH}_4^+$ -N in the total ammonia significantly and promotes  $\text{NH}_4^+$  conversion to  $\text{NH}_3$ . On the other hand, the soil urease activity increased with the increase of temperature<sup>[15]</sup>.

There is a close relationship between the  $\text{NH}_3$  emission and precipitation and other environmental factors in the field of nitrogen fertilizer. Nastr(2000) studied that fertilizer was brought into the deep soil with the rain infiltration, thereby reducing the loss of  $\text{NH}_3$  emissions<sup>[16]</sup>. The rainfall reduced  $\text{NH}_3$  emissions a week after fertilization significantly. Rainfall duration affects  $\text{NH}_3$  emission<sup>[17]</sup>. However, a small amount of rain affected  $\text{NH}_3$  emissions under irrigation conditions<sup>[18,19]</sup>.

## 2.3. Agricultural management measures

It is difficult that the researchers realize the  $\text{NH}_3$  emission reduction in agricultural production practice by changing the physical and chemical properties of soil and climate environment. How to reduce the  $\text{NH}_3$  emission losses in agricultural production, it is the key for adjustment of agricultural management measures. Agricultural management practices influence  $\text{NH}_3$  emissions significantly.

**2.3.1. Fertilizer amount.**  $\text{NH}_3$  emissions were positively correlated with the amount of nitrogen application<sup>[20]</sup>. Zhang(2007) studied that  $\text{NH}_3$  emissions were 8.2-28.7kg/hm<sup>2</sup> and 21.8-62.1kg/hm<sup>2</sup> on different fertilizer levels of rice season.  $\text{NH}_3$  emissions accounted for 3.7%-8.8% and 10.0%-18.9% of urea application rate<sup>[21]</sup>. Wang(2006) show that increasing N application rate significantly increased soil  $\text{NH}_3$  emission rate<sup>[22]</sup>. The peak of  $\text{NH}_3$  emission rate in different nitrogen application treatments appeared at third days (N 140~165 g/hm<sup>2</sup>h) and fifth days (N 100~400g/hm<sup>2</sup>h). The effective way to reduce the loss of nitrogen fertilizer was to control nitrogen fertilizer application amount<sup>[4,23]</sup>.

**2.3.2. Tillage and fertilization methods.** A variety of N fertilizer deep application technology to reduce the effect of  $\text{NH}_3$  emission is better by reducing the time of  $\text{NH}_4^+$ -N fertilizer exposed to the air than surface application.  $\text{NH}_3$  emission is the strongest in the case of surface application of N fertilizer,  $\text{NH}_3$  emissions on a mixed mode of surface and deep application fertilization are less than that of surface application, and that is weakest on deep application.

**2.3.3. Fertilization application period.** Fertilizer application period significantly affected  $\text{NH}_3$  emission losses.  $\text{NH}_3$  emission rate was the highest in tillering fertilizer, and panicle fertilizer was the lowest. Wang Xiubin studied the total amount of  $\text{NH}_3$  emission in different fertilization application period. The results showed that the method of reducing the amount of nitrogen application and nitrogen fertilizer application delayed backwards in time can reduce the loss of  $\text{NH}_3$  emission and

increase the yield<sup>[24,25,26]</sup>.  $\text{NO}_3^-$ -N and  $\text{NH}_4^+$ -N seasonal dynamic changes are different on different nitrogen treatment of soil, and mainly depends on the different nitrogen fertilizer N release characteristics, fertilizer use time and Fertilizer use by several times, etc<sup>[27]</sup>.

### 3. Conclusions

In fact, to take effective control measures, this problem is not confined to China, but worldwide. To strengthen the following several aspects:

In recent years, the domestic scientific research workers studied more  $\text{NH}_3$  emission factors, however, most of the existing research focused on paddy and corn field ecosystem.  $\text{NH}_3$  emissions vary for the planting patterns and soil environment. To achieve accurate quantitative evaluation model of  $\text{NH}_3$  emissions, it is necessary for  $\text{NH}_3$  emissions affecting factors and mechanism research on different ecological conditions, different planting patterns and different types of farmland soil.

Previous studies have a lot of potted plants and greenhouse cultivation on  $\text{NH}_3$  emissions research work. Their environmental factors control is different on field crops compared in situ observation study, such as moisture and temperature. To strengthen the wild farmland  $\text{NH}_3$  emission research, measures of  $\text{NH}_3$  emission reduction can help farmland the practical application.

Temperature effect on  $\text{NH}_3$  emissions research results are inconsistent. Some think temperature and  $\text{NH}_3$  emissions have significant positive correlation, however, some studies suggest temperature is not  $\text{NH}_3$  emissions limits. the following work need study temperature to influence the  $\text{NH}_3$  emission, to clear temperature influence mechanism of  $\text{NH}_3$  emissions on different ecological environment.

To agricultural sustainable development, future research direction must adhere to the general principle of "high-yield, high-quality, high efficiency" and "low consumption, no pollution", actively research the effective and easy technology to reduce  $\text{NH}_3$  emission loss.

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