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Ammonia emissions from paddy fields are underestimated in China ☆

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A B S T R A C T

Excessive nitrogen (N) fertilizers are often used in China, and a large proportion of the N can be lost as ammonia (NH_3). However, quantifying the NH_3 emission from paddy fields is always affected by large uncertainties due to different measuring methods and other factors such as climate. In this study, using a standardized method, we measured the NH_3 emissions in three typical annual rice cropping systems: single rice, double rice and rotation with other crops. The measurements were conducted for 2 years with a total of 3131 observations across China. Results showed that NH_3 emissions accounted for 17.7% (14.4−21.0%) of the N applied under current farm practice, which was 33.1% (10.6−52.6%) higher than previous estimates. Nitrogen application rate was the dominant factor influencing NH_3 emission rate, which exponentially increased with the N fertilizer rate ($p < .001$). Total NH_3 emissions from paddy fields were estimated at 1.7 Tg N yr^{-1} in 2013 in China, several times the amount of N lost through leaching or runoff. This suggests that mitigation measures for non-point source pollution from cropland should take into account not only the N lost to water, but also to air, thereby improving air quality.

1. Introduction

China produced 208.2 million tons of rice in 2014, accounting for 28.1% of global production (FAO, 2017). However, excessive amounts of nitrogen (N) fertilizers are being used in paddy fields, with an average N fertilizer rate of over 300 kg N ha^{-1} yr^{-1} (Deng et al., 2011), and over 50% of this input N is lost to the environment through multiple pathways. Ammonia volatilization is one of the dominant pathways of N loss in paddy fields (Yan et al., 2011; Soares et al., 2012; Xu et al., 2012). NH_3 volatilization increases farmers' production costs and causes environmental degradation (Xu et al., 2015). NH_3 is a major atmospheric pollutant that plays an important role in the formation of secondary inorganic aerosols, leading to poor air quality and adverse impacts on human health (Behera et al., 2013; Gu et al., 2014). The emitted NH_3 can also return to land and surface water through deposition, resulting in soil and water acidification, eutrophication and biodiversity loss (Hellsten et al., 2008; Guo et al., 2010).

NH_3 emission is affected by a number of factors, such as fertilizer application rate (Dattamudi et al., 2016; Huang et al., 2016; Jiang et al., 2017), climate conditions (e.g. temperature, wind speed) (Fan et al., 2011; Louro et al., 2013), and soil properties (e.g. pH, soil type) (Fan et al., 2011; Zhang et al., 2013; Webb et al., 2014). Inventories of NH_3 emissions from paddy soils in China have been conducted (Zhang et al., 2011; Chen et al., 2014). However, large uncertainties exist in these inventories due to the variations in emission factors derived from different measuring methods (Hayashi et al., 2011; Zhao et al., 2012). For example, Chen et al. (2014) calculated that NH_3 lost from paddy fields accounted for

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