Research progress on the influence of irrigation methods on ammonia volatilization in farmland

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Abstract. Ammonia volatilization is an important way to lose nitrogen fertilizer in Agricultural Ecosystems, and the main source of ammonia volatilization in the world comes from ammonia volatilization in agriculture. Ammonia volatilization not only reduces the utilization rate of nitrogen fertilizer in farmland, leading to the waste of resources, but also leads to environmental problems such as air quality decline, soil acidification and water eutrophication. The paper reviews the characteristics of furrow irrigation, drip irrigation and sprinkler irrigation and the research results of soil ammonia volatilization under several irrigation methods. It provides a theoretical basis for selecting suitable irrigation management measures to reduce the emission of ammonia volatilization in farmland system.

1. Introduction
Ammonia (NH₃) volatilization is an important pathway for nitrogen loss in agricultural cropping systems [1], and the emission of ammonia from agriculture reaches 41 million tons per year [2]. Across the globe, an average of 18% of nitrogen fertilizer is being lost through ammonial emission [3], and ammonia volatilization from nitrogen application accounts for about 14% of NH₃-N annual emissions [1]. Ammonia is a vital alkaline air pollutant. On the one hand, ammonia volatilized into the atmosphere reacts with sulfur dioxide and nitrogen oxides in the atmosphere to produce precursors of atmospheric particulates (PM2.5) such as ammonium sulfate and ammonium nitrate [4], which is a key factor to promote the formation of haze [5]. On the other hand, ammonia is also the main component of atmospheric dry and wet deposition, and excessive ammonia deposition can cause a series of environmental problems such as soil acidification, water eutrophication and biodiversity reduction [6]. In addition, ammonia settling to the ground will also become a secondary source of indirect emissions of greenhouse gases such as nitrous oxide [7]. According to statistics, China is one of the largest nitrogen fertilizer application countries in the world [8]. In 2018, the the usage of nitrogen fertilizer application amount in China reached 20.65 million tons [6], but the utilization rate of nitrogen fertilizer was only 20%–40%[9], among which the loss of ammonia volatilization accounted for 1% ~ 47% of the total usage of nitrogen[10-11]. In some favorable environmental conditions, the loss of NH₃ volatilization may reach 60% of the input of nitrogen [12]. Therefore, it is one of the key problems in environmental field to improve the utilization rate of nitrogen fertilizer,
reduce ammonia volatilization, reduce environmental pollution and establish reasonable farmland management measures.

Irrigation is an important farmland management measure, including furrow irrigation, drip irrigation and sprinkler irrigation. The changes of soil structure and physicochemical properties under different irrigation methods are different, which affect the rate and process of NH$_3$ volatilization [13-14]. China is a country with poor water resources. However, in arid and semi-arid areas, water shortage and the low efficient usage of irrigation water are common[15-16]. At the same time, the rate of nitrogen loss caused by unreasonable irrigation was about 50% ~ 70%, which aggravated the of ammonia volatilization[17]. Many previous studies have shown that water-saving irrigation can effectively reduce ammonia volatilization and improve the utilization rate of water and fertilizer[18-19]. Therefore, water-saving irrigation has become the only way for the sustainable development of agricultural system. By comparing the similarities and differences between different irrigation methods and their effects on soil state, this paper is aimed to provide theoretical guidance and reference for the selection of appropriate farmland irrigation management for ammonia volatilization and emission reduction in China’s farmland system.

2. Mechanism of ammonia volatilization

Ammonia volatilization refers to the process of ammonia gas escaping from soil surface (dry land) or field water surface (paddy field) to atmosphere during the conversion of nitrogen in soil. Ammonia volatilization occurs when the partial pressure of ammonia (atmospheric concentration of ammonia) on the surface of soil or field water is greater than that of atmospheric concentration of ammonia (atmospheric concentration of ammonia) [20]. The process of ammonia volatilization in farmland is reversible, and there is a dynamic balance between NH$_4^+$ and ammonia in soil. Therefore, the conditions that promote ammonia volatilization vice versa inhibit ammonia emission[4]. The ammonia volatilization process in dry fields is shown in Figure 1[4]:

![Figure 1. The process of ammonia volatilization in dry soil](image)

3. Irrigation schemes

3.1. Furrow irrigation

Furrow irrigation, also known as diffuse irrigation, adopts the "concentrated irrigation" of large water [17]. Furrow irrigation as the most traditional and routine irrigation method has the advantages of simple operation, low technical requirements, money and energy saving. But water consumption of furrow irrigation is large and the utilization rate of water resources is low [21]. At present, irrigation methods in most areas of China are still dominated by irrigation with large water furrows. Although furrow irrigation increases the yield of grain crops to a certain extent, the irrigation method has a large and uneven amount of water per irrigation, strong impact on the land, resulting in a large of water decline [17], strong evaporation, easy to cause soil consolidation, Reduce soil permeability, promote soil nutrient decomposition and transformation, resulting in low plant water and
fertilizer absorption and utilization. At the same time, the soil of furrow irrigation has a high degree of salt return, the salt accumulation in the root area is large, the nitrification is strongly inhibited, which leads to the accumulation of ammonium nitrogen in the surface soil, which increases the volatilization of ammonia and causes serious pollution to the environment[22].

Wang et al.[23] determined ammonia volatilization in field soil of winter wheat and summer maize rotation system in northern China under conventional irrigation. It was found that the nitrogen emitted from ammonia volatilization to the atmosphere every year was equivalent to 2.1% ~ 9.5% of nitrogen fertilizer input.

3.2 Drip irrigation
Drip irrigation is one of the efficient water-saving irrigation technologies, and the irrigation method adopts "low intensity and high frequency ", which has been widely used in China [17,24]. Drip irrigation slowly irrigates water in the root of crops through pipes and dripper systems, spreading around the radial direction with the center of drip head and showing a decreasing trend. Only wetting the soil near the root has little damage to soil structure, and most of the soil is dry under drip irrigation. It can reduce the loss of soil evaporation between crops and avoid surface runoff and deep leakage [25]. The integration of drip irrigation water and fertilizer can dissolve fertilizer in water and realize the simultaneous supply of water and fertilizer in crop root area by using pressure irrigation system. According to the soil condition and the characteristics of different growth stages of crops, the irrigation and fertilization method can effectively control the quantity and proportion of water and nutrient supply, make soil nitrogen supply and crop nitrogen demand synchronize in time and space, gives full play to the coupling effect of water and fertilizer, reduces the time and loss of nitrogen fertilizer conversion in soil, and improves the of water and fertilizer utilization [15,17]. Many studies have shown that the transport and distribution of soil water and nitrogen under drip irrigation are mainly affected by soil characteristics, irrigation flow rate, fertilizer concentration and irrigation amount[5]. Under the condition of drip irrigation and fertilization, the inorganic nitrogen content of soil decreased gradually from the surface to 60 cm and stabilized at 60~100 cm.[26], drip irrigation and fertilization in North China can make the nitrogen fertilizer utilization rate reach 51.21% [27].

Submembrane drip irrigation is a water-saving irrigation technology formed by the combination of drip irrigation technology and film mulching technology. It has obvious advantages of saving water and fertilizer, inhibiting evaporation and conserving moisture, and it is more conducive to the improvement of crop yield and water utilization rate. In recent years, this technology has been widely adopted in all agricultural areas of Xinjiang[17].

Li et al. [28] studied the corn field under drip irrigation and found that the ammonia volatilization rate reached its maximum on the second day, and the volatilization period was short. The net loss rate of ammonia volatilization during the whole growth period was 1.93%~3.52%, and the nitrogen fertilizer utilization rate reached the maximum of 82.14%.

3.3 Sprinkler irrigation
Sprinkler irrigation technology is a common water-saving irrigation technology, which uses machinery and power equipment to spray water with certain pressure into the air through the sprinkler head and drop it into the field in the form of raindrops. Sprinkler irrigation does not cause erosion or other damage to the soil. It can reduce the breakdown of soil aggregates caused by soaking soil structure, which makes irrigation water penetrate into the soil evenly and slowly, and enhance the water retention effect of surface soil [29]. Sprinkler irrigation has strong adaptability and obvious water-saving effect. Generally, it can save 30%~50% of water compared with furrow irrigation, making the water utilization rate reach 80% [30]. Sprinkler irrigation can effectively reduce air temperature and increase air humidity, which can regulate farmland temperature and humidity, thus reducing ammonia volatile [31]. Moreover, the amount of sprinkler irrigation water is generally not more than 60 mm, and the depth of wet soil layer is about 50 cm, which can wash the nitrate of topsoil
to 10-20 cm dense layers of crop roots, which is beneficial to crop absorption and utilization, and does not produce deep leakage loss [32].

Yang et al. [14] found in their study that the cumulative volatilization amount of ammonia under sprinkler irrigation decreased by 43.55%–58.15% compared with trench irrigation under the same amount of nitrogen application. Zhang et al. [33] studied winter wheat and summer corn fields and showed that the nitrogen loss rate of ammonia volatilization under sprinkler irrigation was 6.5%–8.3% and 5.3%–8.0%, respectively.

4. Conclusion
Different irrigation methods have different effects on soil physical and chemical properties and the hydrolysis and migration of nitrogen fertilizer, which is an important factor affecting ammonia volatilization. Therefore, irrigation method plays an important role in the study of ammonia volatilization in farmland. Water-saving irrigation can not only increase crop yield, but also improve the utilization rate of water and fertilizer, save resources, reduce ammonia volatilization and reduce environmental pollution. According to different crops, soil and environmental conditions, the choice of appropriate irrigation management measures is an important means of sustainable development of agriculture.

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