A review of N$_2$O emissions affected in farmland ecosystem

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Abstract. N$_2$O is an important greenhouse gas in the atmosphere. Agricultural production is the largest source of N$_2$O emissions. The influencing factors of N$_2$O emission from farmland ecosystem, such as soil moisture, soil temperature, soil oxidation-reduction potential, pH of soil, fertilization management and soil texture are summarized, which are closely related to irrigation management. The soil moisture content of drip irrigation, sprinkler irrigation and other water-saving irrigation methods is different. The research on N$_2$O emission from the world's water-saving irrigation mode has great potential for reducing greenhouse gas emissions. Future work on N$_2$O emissions should carry out the studies on the regulation of greenhouse gas emission by water saving irrigation in different ecological conditions.

1. Introduction

N$_2$O is an important greenhouse gas in the atmosphere, which global warming potential is about 298 times more than that of CO$_2$[1]. N$_2$O is the largest substance that consumes the stratospheric ozone [2]. Since the era of the industrial revolution, the content of N$_2$O in the global atmosphere increased from 270 ppbv to 319 ppbv in 2007, which in the atmosphere increased by 16% [3]. Therefore, the studies of N$_2$O emissions have attracted the attention of governments and researchers. At present, the main sources of anthropogenic N$_2$O emissions are agriculture, industry, fossil fuel combustion, active nitrogen leaching and indirect emission from atmospheric deposition. Among them, agricultural production is the largest source of N$_2$O emissions, accounting for about 80% of anthropogenic emissions [4]. With the increase of the human population and the consequent demand for more grain production, the N$_2$O emissions of agriculture are expected to increase in the next ten years [5]. Therefore, the influencing factors of N$_2$O emissions from farmland ecosystem are summarized, which is of great significance for defining the research direction of N$_2$O emissions.

2. The factors of affecting N2O emissions

2.1. Soil moisture

Soil moisture affects the processes of nitrification and denitrification by changing the content of oxygen in soil, thus affecting generation of N$_2$O [6]. Under the condition of low soil moisture, the higher oxygen partial pressure in the soil is beneficial to the nitrification of microorganisms. When soil moisture is high, soil aeration is poor and oxygen partial pressure is low, so it is easy to form anaerobic environment in soil, which is beneficial to denitrification. In the 45% of water filled pore
space(WFPS), the N₂O content in ammonia oxidation process accounts for 88% of the total amount of N₂O produced in the soil [6]. When soil WFPS is 70%, N₂O produces the highest amount, 35%-57% of which comes from the process of ammonia oxidation, and 44%-58% comes from the process of denitrification of nitrifying bacteria. Only 2%-9% comes from the process of heterotrophic denitrification [7]. Under the WFPS of 30%-70%, N₂O was mainly produced by nitrification [8]. When WFPS is greater than 80%-90%, denitrification is the main process of N₂O production in soil [9].

2.2. Soil temperature
Soil temperature regulates the release of soil N₂O by controlling enzyme activities in soil microbial metabolism and decomposition of soil organic matter. The denitrification can occur at the temperature range of 0-75 °C, and the low temperature can lead to the decrease of soil water use, and the high temperature can lead to the death of microbes [10]. N₂O emission flux is positively correlated with temperature. The soil environment above 5 °C is suitable for nitrification and denitrification. The optimum temperature for nitrification is 25 °C-35 °C, the maximum N₂O emission fluxes is at this temperature, and the optimum temperature for denitrification is 30 °C-37 °C [11]. At 40 °C, N₂O emissions from denitrification are about 88% of the total N₂O emissions [12]. When the temperature is low, the N₂O emissions will also decrease due to the decrease of microbial activity and the decrease of N₂O solubility and diffusivity.

2.3. Soil oxidation-reduction potential
Soil oxidation-reduction potential (Eh) is an important indicator of redox state of soil solution, and is closely related to the process of oxygen supply and consumption in the soil, and is one of the important indicators to reflect the condition of soil ventilation [13]. The redox state of soil has a wide influence on soil, such as the redox reaction of soil mineral components, soil stability, absorption of plant roots to active ions, soil microbial population composition and enzyme activity, and so on [14]. Soil moisture will directly affect Eh through affecting soil oxygen content and efficiency utilized of nutrient [15]. When soil moisture increases, Eh will also decrease with the change of soil environment from aerobic state to anaerobic state [16]. The enhanced activity of facultative anaerobe and obligate anaerobe in anaerobic condition is the main reason leading to the reduction of soil redox potential. These factors are affected by soil moisture, and then affect N₂O emissions [17].

2.4. pH of soil
Soil pH is an important factor affecting soil nitrification and denitrification [18]. N₂O/ (N₂+N₂O) ratio was negatively correlated with soil pH (5<pH<8). Lower pH of soil can significantly promote N₂O emissions [19]. The reason is that acid soils will inhibit the activity of N₂O reductase or affect microbial processes and increase N₂O emissions [19]. Nitrate reduction process, nitrite reduction process and nitric oxide reduction process are more active under acidic conditions. When pH>7, the activity of Nitrous Oxide reductase in soil increased. The activity of the reductase in pH<7 decreased while the activities of other denitrifying enzymes increased, which resulted in more N₂O production during denitrification [20]. Yang et al. found that the rate of ammonia oxidation increased when the soil pH increased, which resulted in a decrease in the content of the inorganic nitrogen source (NH₄⁺) in the processes of N₂O formation, thus reducing the emission of N₂O [21].

2.5. Fertilization management
Soil N₂O emission is restricted by the content of reaction substrate [22]. When organic fertilizer or nitrogen fertilizer is applied to farmland, the decomposition of exogenous C and N provides energy for the microorganisms of nitrification and denitrification, thus enhancing soil microbial activity and nitrification and denitrification, which promotes the production and emission of N₂O [23]. Research of Kelliher et al. found that using urea to set up 8 nitrogen levels (0-1500 kg N / ha⁻¹) gradient, N₂O emission flux was significantly positively correlated with nitrogen application rate [24]. Some
researchers have studied the effects of different kinds of organic manure on N$_2$O emissions in paddy field. It is found that the effects of application of organic fertilizer on N$_2$O emissions in paddy field are more complex. There is no linear relationship between N$_2$O emission and the content of C and N in organic fertilizer. The emission of N$_2$O in paddy field is related to the type of organic fertilizer and the degree of maturity. However, the application of organic fertilizer after heavy rain can reduce the N$_2$O emission of soil, mainly because the mineralization of organic matter will consume O$_2$ in the soil, and then inhibit the nitrification, but the denitrification of soil is not affected, and the N$_2$O is reduced to N$_2$, thus reducing the N$_2$O emission of soil [25].

2.6. Soil texture
Soil texture will affect soil water holding capacity, aeration and redox potential, and then influence the process of N$_2$O emission in nitrification and denitrification. Because of low aeration porosity and high oxygen diffusion resistance in fine soil, it has higher N$_2$O potential, but N$_2$O is easier to release from coarse soil [26]. Beare et al. found that the N$_2$O emission of sandy soil is significantly higher than that of loam and clay due to the rapid diffusion of gas in sandy soil, weak buffer to redox potential and large supply of organic matter in N$_2$O microorganism. Anthropogenic compaction can change the volume, aeration and water content of soil, and further affect the process of soil carbon and nitrogen transformation. Because compaction can enhance soil denitrification potential, the N$_2$O emission from compacted soil is often higher than that of uncompacted soil [27].

3. Conclusions
The factors of affecting N$_2$O emission from farmland, such as soil moisture, temperature, oxidation-reduction potential, pH, fertilization management and soil texture are closely related to irrigation management. However, there is still less research on N$_2$O emissions from irrigation of farmland. The area of farmland is enlarged and the consumption of irrigation water is increased. In order to save water resources, the area of water-saving irrigation has been increasing. The soil moisture of drip irrigation, sprinkler irrigation and other water-saving irrigation modes is different. Soil moisture affects soil temperature, oxidation-reduction potential, pH and fertilizer, and then controls N$_2$O emission in soil. The research on N$_2$O emission from the world's water-saving irrigation modes has great potential for reducing greenhouse gas emissions. Future work should carry out the studies of water-saving irrigation on N$_2$O emission in different ecological conditions.

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