

ESTIMATION OF NITRIC ACID GAS DRY DEPOSITION IN VIET NAM

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Abstract: *This article uses dry deposition calculating method to estimate Nitric acid (HNO_3) gas dry deposition and analyze, evaluate trend of HNO_3 gas dry deposition in recent years. The results present that HNO_3 gas concentration is from 0.02 to 0.83 ppb and Yen Bai site has the highest HNO_3 gas emission in 2020 and 2021. High HNO_3 gas emission focuses on summer and spring at Northern's sites. HNO_3 gas emission at Southern sites is lower than that of Northern ones. HNO_3 gas dry deposition is from 6.63 kg/ha/year to 10.26 kg/ha/year and the highest HNO_3 gas dry deposition value is in 2021. Ha Noi site has the highest HNO_3 gas dry deposition value in 2019, 2020, and 2022 while Yen Bai site is in 2021 and 2023. HNO_3 gas dry deposition value at Southern sites is lower than Northern sites. The highest monthly HNO_3 gas dry deposition is from June to August at Yen Bai site in 2021 and May in 2020. Annual average HNO_3 gas dry deposition of 2021 is higher than other years. HNO_3 gas dry deposition in recent years has an increasing trend.*

Keywords: *Nitric acid gas, dry deposition, HNO_3 deposition trend.*

1. Introduction

Dry deposition process controls the transfer of pollutants from the atmosphere to the surface [1] and it is an important environmental problem because acid substances in dry deposition process is existed in the form of gas particles. They are blown by wind and fall down ground, trees and enter rivers [2]. Moreover, dry deposition normally is represented by strong acids, which can dissolve metal oxides and dust in the air and soil leading to reduction of the pH water when raining. This acid deposition causes crop damage and productivity decline, threatening animal and plant living, affecting to human health.

Nitric acid (HNO_3) is a strong acid and it is widely used by a number of industries. In the chemical industry, it is used for the manufacture of metallic nitrates, nitrous acid and nitrites, oxalic acid, phthalic acid, and so on [3]. As one of the major atmospheric pollutants, nitric acid not only can play crucial roles in the important

chemistry of the troposphere, but also can be considered as one of the plentiful substances of polar stratospheric clouds, which contribute to polar ozone loss [4]. Furthermore, most of NO and NO_2 emitted to the atmosphere from air pollution sources (particularly fossil fuel combustion and agricultural activities) and is converted to nitric acid [3], [5] through action of NO_2 and OH during the day, and N_2O_5 and H_2O at night [6], [7]. As nitric acid is an important atmospheric trace gas that influences ozone, cloud formation and thereby may have an indirect influence on climate [5]. Its measure is not easily determined and Gil et al (2020) used the parallel plate diffusion scrubber-chromatograph system to measure the nitric acid concentrations in the atmosphere [8]. Viet Nam is supported by Acid Deposition Monitoring Network in East Asia. 5 stations was installed from North to South in Viet Nam to monitor nitric acid concentration. Nitric acid is collected frequently on weekly basis and original data is sent to EANET yearly. This article mentions 1) analyzing nitric acid concentration changing from 2019 to 2023 year; 2) estimating nitric acid dry deposition bases on its emitting

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concentration of 5 stations in Viet Nam; 3) evaluating nitric acid trend during 5 recent years in order to enhance understand about acid deposition and monitor nitric acid gas emission.

2. Methodology

Data of HNO₃ gas concentration is collected from dry monitoring stations in Northern and Southern of Viet Nam and is analyzed at laboratory of Viet Nam Institute of Meteorology Hydrology and Climate change (IMHEN). Then it is used inferential method to calculate acid nitric gas dry deposition basing on equation [9; 10] as following:

$$F_i = V_d^i \times C_i$$

Whereas: F_i is the dry deposition of HNO₃ gas type; V_d is the deposition velocity of HNO₃ gas type; C_i is the atmospheric concentration of HNO₃ gas type.

V_d Deposition velocity is applied by resistance model [11] and considering meteorological factors, deposition surface and land-use [9] to estimate deposition velocity. It is presented by following equation:

$$V_d = \frac{1}{r_a + r_b + r_c}$$

Whereas: V_d is the deposition velocity; R_a is the aerodynamic resistance; R_b is the quasi-laminar layer resistance; R_c is the surface resistance.

Wind speed, temperature, relative humidity, solar radiation and precipitation are collected at the monitoring stations and used to calculate V_d . R_a and R_b parameters are calculated by parameterizations of Erisman and Draaijers (1995) [12]. R_c is estimated by equation of Wesely (1989) [10] including stomal parameter, mesophyll and surface resistances parameters.

3. Results and discussion

After HNO₃ gas concentration is collected and analyzed by filter net method in laboratory and estimated HNO₃ gas dry deposition for 5 stations in Viet Nam, trend of HNO₃ gas dry deposition is displayed in recently years as following:

3.1. Concentration of HNO₃ gas

Figure 1 indicates that HNO₃ gas concentration in 2019-2023 emitted from 0.02-0.83 ppb, in which 2021 has high emission of HNO₃ gas, especially at Yen Bai station. Next is 2020 year with high HNO₃ gas concentration and at Yen Bai station too. Thus, with high HNO₃ gas emission, except for Yen Bai station with the highest HNO₃ gas concentration, HNO₃ gas emission at Ha Noi station is gained high concentration as well after Yen Bai station. However, high HNO₃ gas emission at Ha Noi site occurs in different months. Particular in 2019, 2021, 2023 year focus on spring and summer season. 2022 year has higher HNO₃ gas concentration on winter. Contrast, with Yen Bai station in 2021, high HNO₃ gas concentration focusses on last month of summer and autumn season with 0.7-0.85 ppb. However, at Yen Bai station still appears high HNO₃ gas concentration in the spring and summer season, which is other year as 2020 year. Stations at Southern of Viet Nam have lower HNO₃ gas concentration and not much changing monthly while HNO₃ gas concentration at stations of Northern have big fluctuation. Particular is Hoa Binh station in 2019 year, Yen Bai station in 2020 and 2021 year, Ha Noi station in 2022 and 2023 year. When considering annual average HNO₃ gas concentration at stations shows that HNO₃ gas concentration in 2021 year is emitter than other years and gains higher HNO₃ gas concentration (Figure 1).

3.2. Dry deposition of HNO₃ gas

HNO₃ gas dry deposition results and is presented in Table 1. It indicates that total HNO₃ dry deposition in 5 years as 6.63 kg/ha/2019 year; 8.71 kg/ha/2020 year; 10.26 kg/ha/2021 year; 7.7 kg/ha/2022 year; and 8.34 kg/ha/2023 year. 2021 has the highest HNO₃ dry deposition while 2019 has the lowest HNO₃ dry deposition (Table 1).

Moreover, Ha Noi site has the highest HNO₃ gas dry deposition in 2022 (3.26 kg/ha/ year) while Yen Bai site reveals the highest HNO₃ gas dry deposition in 2023 (4.24 kg/ha/year). HNO₃ gas dry deposition in Hoa Binh site ranges from

1.13-1.94 kg/ha/year during 2019-2023. Ho Chi Minh site presents HNO_3 gas dry deposition from 1.01-1.49 kg/ha/year with small changing gap in 5 years. Can Tho site indicate the lowest HNO_3 gas dry deposition versus remaining sites with 0.3-0.55 kg/ha/year. Thus, HNO_3 gas dry deposition at Southern sites are lower than Northern sites and the sites, which have the highest HNO_3 gas dry deposition as Yen Bai and Ha Noi sites during 5 recently years.

Monthly HNO_3 gas dry deposition is displayed in Figure 2. The highest HNO_3 gas dry deposition is in 2021 at Yen Bai site with high HNO_3 gas dry deposition in June, July, and August (0.55-0.7 kg/ha/month) and 2020 has high HNO_3 gas dry deposition in May with 0.55 kg/ha/month.

However, in 2019; 2022; and 2023-year, Ha Noi site presents higher HNO_3 gas dry deposition value than Yen Bai site in April of 2019 year with 0.36 kg/ha/month; in June of 2022 year with 0.32 kg/ha/month; and in March of 2023 year with 0.28 kg/ha/month while Yen Bai site has HNO_3 gas dry deposition from 0.05-0.28 kg/ha/month in these years. Moreover, it is not much changing of HNO_3 gas dry deposition at Can Tho and Ho Chi Minh sites; HNO_3 gas dry deposition at Hoa Binh site is decreased deeply in February and October of 2023 year as well as in December of 2022. When considering annual average HNO_3 gas dry deposition during 5 years, HNO_3 gas dry deposition in 2021 is higher than other years (Figure 2).

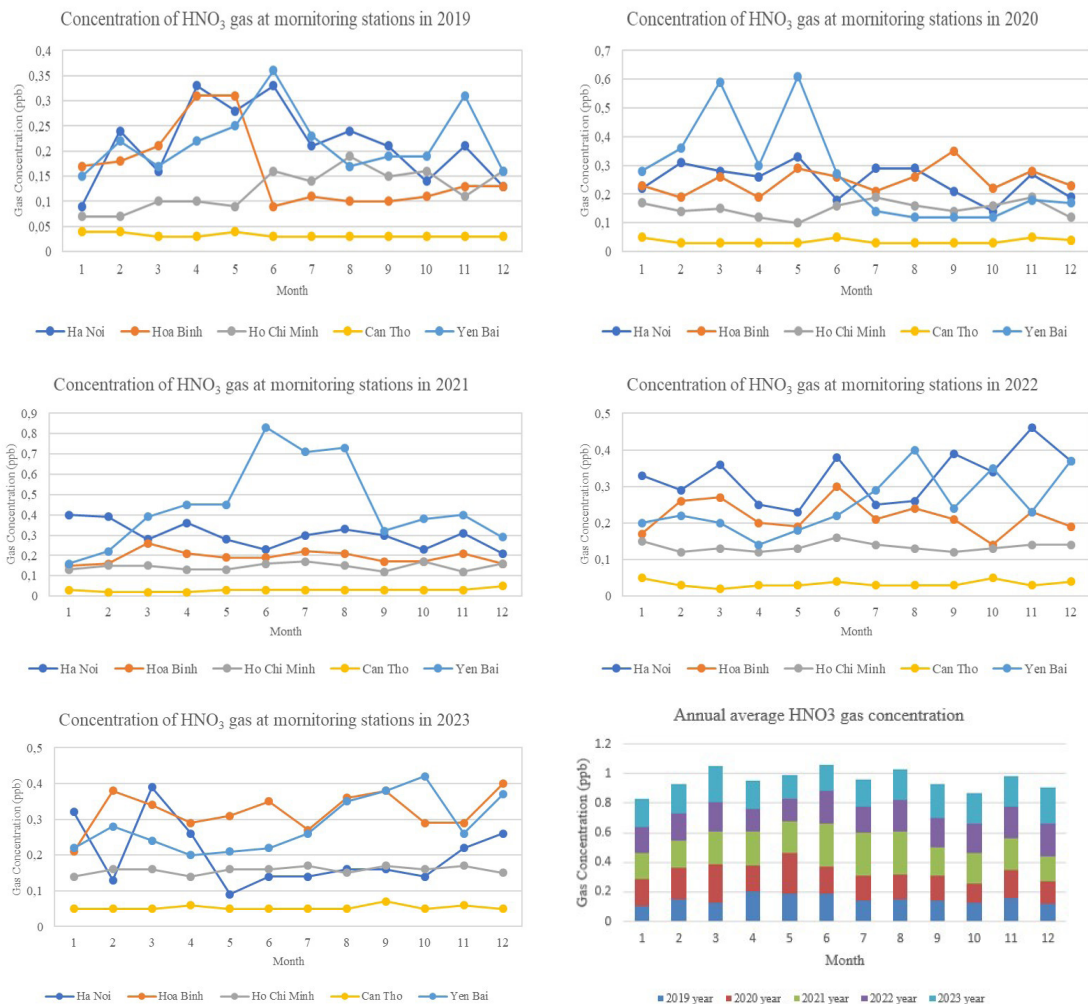


Fig 1. HNO_3 gas concentration at monitoring stations in Viet Nam

Table 1. Dry deposition of HNO_3 gas at stations in Viet Nam

Station/ month	1	2	3	4	5	6	7	8	9	10	11	12	Sum 2019
Ha Noi	0.08	0.26	0.15	0.36	0.26	0.3	0.17	0.19	0.16	0.12	0.16	0.1	2.31
Hoa Binh	0.11	0.11	0.13	0.19	0.19	0.06	0.07	0.13	0.06	0.07	0.08	0.08	1.25
Ho Chi Minh	0.05	0.05	0.07	0.07	0.05	0.11	0.1	0.12	0.1	0.1	0.07	0.11	1.01
Can Tho	0.03	0.03	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.3
Yen Bai	0.05	0.1	0.08	0.13	0.17	0.28	0.19	0.14	0.14	0.14	0.22	0.12	1.76
Station/ month	1	2	3	4	5	6	7	8	9	10	11	12	Sum 2020
Ha Noi	0.22	0.2	0.26	0.23	0.36	0.2	0.23	0.35	0.17	0.15	0.21	0.19	2.77
Hoa Binh	0.14	0.11	0.16	0.12	0.17	0.16	0.13	0.16	0.21	0.13	0.17	0.14	1.8
Ho Chi Minh	0.14	0.11	0.11	0.08	0.07	0.13	0.14	0.1	0.1	0.11	0.13	0.08	1.29
Can Tho	0.04	0.02	0.03	0.02	0.03	0.04	0.02	0.02	0.03	0.02	0.04	0.04	0.35
Yen Bai	0.17	0.22	0.36	0.27	0.55	0.25	0.08	0.07	0.11	0.11	0.11	0.21	2.5
Station/ month	1	2	3	4	5	6	7	8	9	10	11	12	Sum 2021
Ha Noi	0.31	0.35	0.28	0.44	0.3	0.19	0.29	0.26	0.22	0.21	0.24	0.17	3.26
Hoa Binh	0.09	0.1	0	0.12	0.12	0.11	0.13	0.12	0.1	0.1	0.12	0	1.13
Ho Chi Minh	0.12	0.12	0.12	0.1	0.11	0.12	0.13	0.11	0.1	0.13	0.08	0.1	1.33
Can Tho	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.05	0.3
Yen Bai	0.11	0.16	0.23	0.41	0.4	0.7	0.55	0.61	0.21	0.35	0.27	0.24	4.24
Station/ month	1	2	3	4	5	6	7	8	9	10	11	12	Sum 2022
Ha Noi	0.2	0.17	0.22	0.15	0.14	0.32	0.17	0.2	0.21	0.2	0.28	0.22	2.49
Hoa Binh	0.11	0.16	0.16	0.12	0.11	0.18	0.13	0.15	0.13	0.08	0.14	0	1.47
Ho Chi Minh	0.13	0.1	0.1	0.1	0.12	0.12	0.11	0.12	0.09	0.1	0.1	0.1	1.29
Can Tho	0.04	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.04	0.35
Yen Bai	0.12	0.17	0.11	0.1	0.11	0.15	0.21	0.29	0.15	0.27	0.15	0.27	2.1
Station/ month	1	2	3	4	5	6	7	8	9	10	11	12	Sum 2023
Ha Noi	0.25	0.1	0.28	0.15	0.08	0.15	0.15	0.08	0.14	0.16	0.17	0.27	1.99
Hoa Binh	0.12	0	0.2	0.18	0.19	0.21	0.16	0.22	0.23	0	0.18	0.24	1.94
Ho Chi Minh	0.14	0.11	0.13	0.12	0.12	0.12	0.12	0.12	0.14	0.14	0.13	0.12	1.49
Can Tho	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.55
Yen Bai	0.14	0.2	0.17	0.14	0.14	0.17	0.24	0.26	0.25	0.28	0.18	0.2	2.37

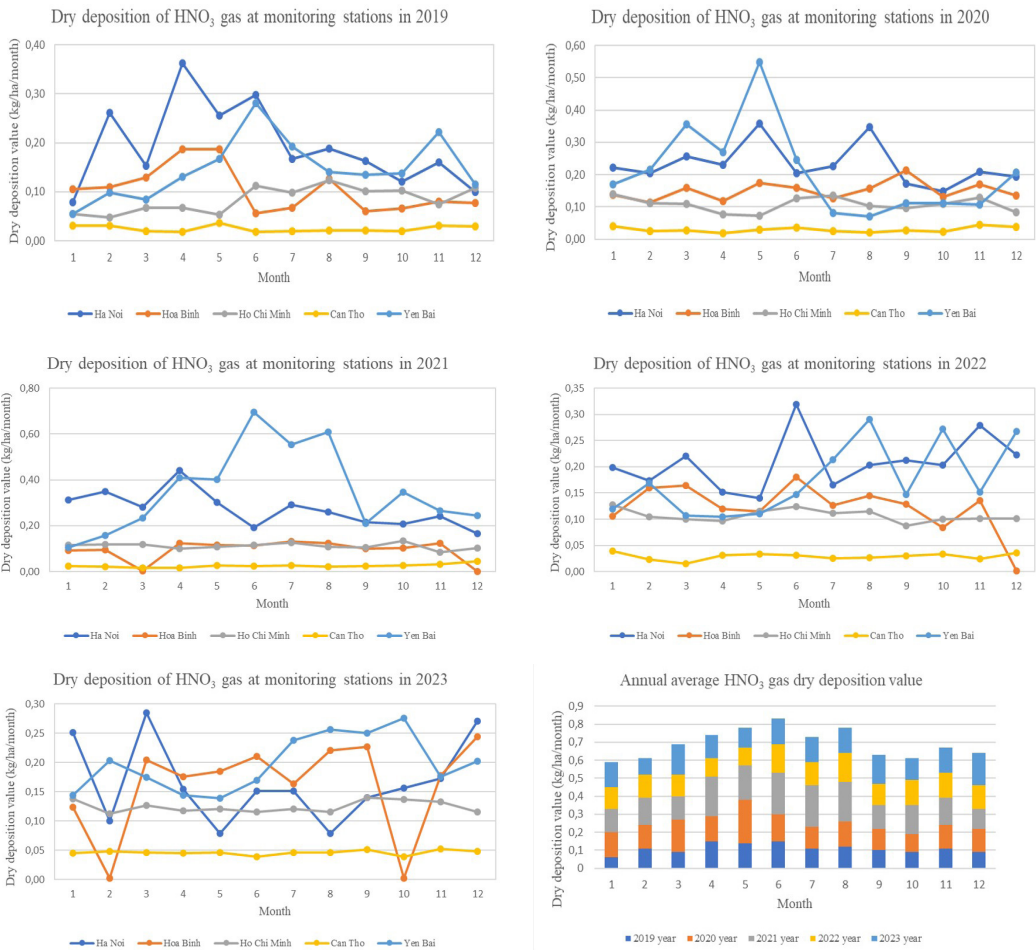


Fig 2. HNO₃ gas dry deposition at stations in Viet Nam

3.3. Trend of HNO₃ gas

Figure 3 displays an increasing trend of HNO₃ gas dry deposition in 5 recent years.

This significant will be holding environmental manager to make plans in order to monitor and control air quality as well as mitigate NO_x emission in Viet Nam.

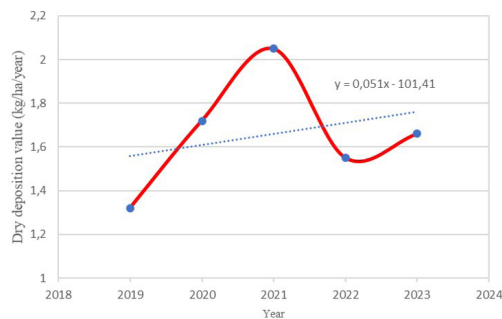


Fig.3 Trend of HNO₃ gas dry deposition in 1999-2023 year

4. Conclusion

Through analyzing HNO₃ gas concentration and estimating HNO₃ gas dry deposition in sites

of Viet Nam, this research concludes some points as below:

HNO₃ gas concentration ranges from 0.02 to

0.83 ppb and Yen Bai site has the highest HNO₃ gas emission in 2020 and 2021.

High HNO₃ gas emission is observed in summer and spring at Northern's sites

HNO₃ gas emission at Southern sites is lower than Northern ones.

HNO₃ gas dry deposition ranges from 6.63 kg/ha/year to 10.26 kg/ha/year and the highest HNO₃ gas dry deposition value is in 2021.

Ha Noi site has the high HNO₃ gas dry deposition value in 2019, 2020, and 2022 year

while Yen Bai site has high HNO₃ in 2021 and 2023 year.

HNO₃ gas dry deposition value at Southern sites is lower than Northern sites

The highest monthly HNO₃ gas dry deposition is from June to August at Yen Bai site in 2021 year and May in 2020

Annual average HNO₃ gas dry deposition of 2021 year is higher than other years.

HNO₃ gas dry deposition has an increasing trend in recent years.

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