National Assessment on Acid Deposition and Air Pollution ($PM_{2.5}$) in Myanmar

1. Basic Information on National Monitoring Activities

1.1 Outline of activities on acid deposition and Air Pollution (Particulate Matter - $PM_{2.5}$)

Myanmar has participated in the Acid Deposition Monitoring Network in East Asia (EANET) since November 2005. Following its participation in EANET, the Department of Meteorology and Hydrology (DMH) was designated as National Center for EANET in Myanmar.

DMH conducts regular monitoring of acid deposition on rain water across Myanmar as well as wet and dry deposition monitoring at the Kaba-aye station in Yangon. Myanmar also initiated $PM_{2.5}$ monitoring activities in Mandalay in 2015 under the Environmental Conservation Department (ECD) and in Yangon (Kaba-aye) in 2018 under DMH. Both monitoring systems were donated by the Asia Center for Air Pollution Research (ACAP) through the Asia Pacific Clean Air Partnership (APCAP).

In cooperation with the United Nations Environment Programme (UNEP) EANET Secretariat and with technical assistance from the Network Center (ACAP), DMH has implemented the following activities:

- Development of the National Monitoring Plan for EANET
- Preparation of Standard Operating Procedures (SOPs)
- Upgrading and improvement of laboratory facilities
- Capacity building and training of Myanmar staffs on acid deposition and air pollution monitoring
- Participation in inter-laboratory comparison programs for wet deposition analysis
- Public awareness and outreach activities on acid deposition and air pollution
- Provision and sharing of dry deposition, wet deposition, and $PM_{2.5}$ monitoring data

In addition, Myanmar regularly participates in EANET meetings and training programs, including Intergovernmental Meetings, Working Group Meetings, Scientific Advisory Committee Meetings, Quality Assurance/Quality Control (QA/QC) activities, Technical and Training (TNT) programs, and other capacity building initiatives. Myanmar also contributes monitoring results on wet and dry deposition, research findings to the EANET Science Bulletin, and national reports on acid deposition and air pollution activities.

1.2 Monitoring Program in 2010 to present

Since becoming a participating country of EANET, the National Center, the Department of Meteorology and Hydrology has been conducting wet deposition monitoring by measuring pH, electrical conductivity (EC), and the amount of precipitation. A Horiba pH/EC Conductivity Meter has been used to measure the pH and EC of collected rainwater samples.

In November 2011, a Filter Pack Method System for dry deposition monitoring and a Distilled Water Generator were installed at the Yangon (Kaba-Aye) monitoring station with the support of ACAP. Following the installation of these instruments, DMH began weekly analyses of wet and dry deposition samples to determine ion concentrations. The monitored cations include ammonium (NH_4^+), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) , while the monitored anions include sulphate (SO_4^{2-}), nitrate (NO_3^-), and chloride (Cl^-). Dry monitoring also includes four gaseous pollutants: Sulphur dioxide (SO_2), nitric acid (HNO_3), hydrogen chloride (HCl), and ammonia (NH_3).

To further strengthen laboratory capabilities, DMH installed water purification systems (RO-DI 30L(s) and RO-DI 15L(s) in March 2014, and vortex shakers in November 2014 using government funding.

Myanmar's air quality monitoring program commenced with the installation of an automatic $PM_{2.5}$ monitor at the Environmental Conservation Department (ECD) office in Mandalay in April, 2015. A second $PM_{2.5}$

monitoring station was established at Yangon (Kaba-aye) under DMH in March, 2018 and continues to operate. Both stations conduct continuous hourly monitoring of $PM_{2.5}$ concentrations.

The results of all analyses, including pH, EC, ionic composition, and $PM_{2.5}$ data are compiled and submitted annually to ACAP.

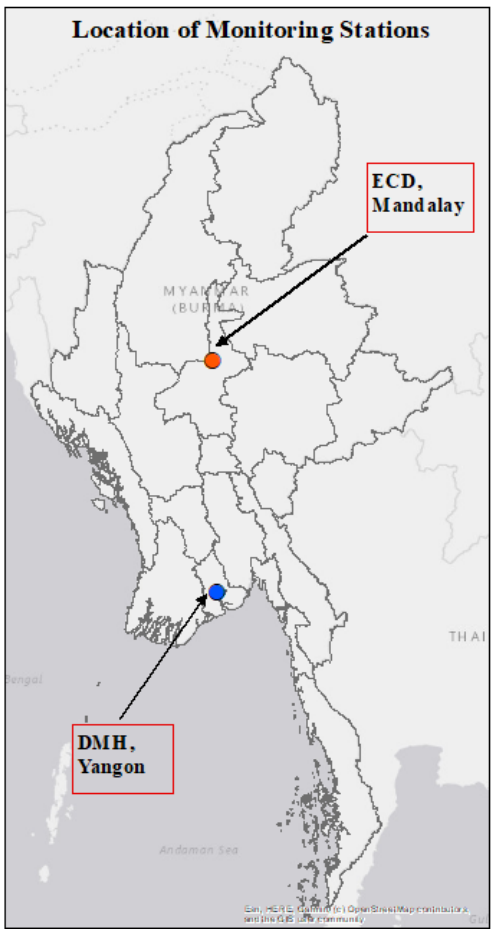
1.3 Monitoring Stations

In Myanmar, Yangon (Kaba-aye) monitoring station conducts wet deposition, dry deposition, and air pollution ($PM_{2.5}$) monitoring. A wet deposition sampler was installed in June 2007, followed by a filter pack system for dry deposition monitoring in November 2011 and an automatic $PM_{2.5}$ monitoring in March 2018. In addition, an automatic $PM_{2.5}$ air quality monitoring operated by the Environmental Conservation Department (ECD) was established in Mandalay in April 2015.

Table 1 presents the geographical locations and general information of the monitoring sites, while Figure 1 illustrates the spatial distribution of the monitoring stations across Myanmar.

Table 1. Geographical locations and general information of the monitoring sites in Myanmar.

Monitoring Sites	Site Classification	Location			Measured Parameters
		Latitude	Longitude	Altitude (m)	
Yangon (Kaba-aye)	Urban	16°51'53"N	96°09'13"E	21.7	Wet and Dry Deposition $PM_{2.5}$ monitoring
Mandalay (ECD)	Urban	21°54'46"N	96°03'51"E	70	$PM_{2.5}$ monitoring





$PM_{2.5}$ Monitoring at Mandalay







Wet and Dry Deposition, and $PM_{2.5}$ Monitoring at Yangon

Figure 1. Spatial distribution of the EANET monitoring stations across Myanmar

1.4 Sampling and Measurements

Rainwater samples for wet deposition monitoring have been collected daily using a wet-only sampler, with weekly composite analyses conducted since 2008. Dry deposition samples have been collected at bi-weekly intervals, with ion analysis performed since November 2011. Precipitation amounts, pH, and electrical conductivity (EC) are measured using a Horiba pH/COND meter. Ion concentrations are analyzed using an ion chromatograph, following the technical manual for wet and dry deposition monitoring analysis adopted by EANET, as summarized in Table 2.

Table 2. Monitoring parameters and method for wet deposition and dry deposition.

Monitoring Parameters		**Method**
Wet Deposition	**Dry Deposition**	
Electric Conductivity (EC)	-	Conductivity cell Method
pH	-	Glass electrode Method
Cl^-, NO_3^-, SO_4^{2-}	Cl^-, NO_3^-, SO_4^{2-}	Ion chromatography (preferably with suppressor)
NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}	NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_2, HNO_3, HCl, NH_3	Ion chromatography

2. Acid Deposition and Air Pollution in Myanmar and their Environmental Impacts

2.1 State of acid deposition and air pollution

Acid deposition and air pollution monitoring in Myanmar have been conducted following the methodologies outlined in the "Technical documents for wet and dry deposition monitoring in East Asia". Precipitation samples are collected daily on rainy days at Yangon (Kaba-Aye) monitoring station using a wet-only sampler. The collected samples are measured and analyzed in the laboratory following the procedures prescribed in the technical manual. All data presented in this report were obtained from the EANET data reports, except meteorological data, which were provided by the DMH. To ensure data quality and reliability, monthly datasets with less than 70% completeness were omitted from this report. For the annual analysis, the year 2020 for wet deposition, and the years 2020 and 2021 for dry deposition, fell less than 80% of data completeness. However, those years are used to interpret the long-term trend analysis.

2.1.1 State of wet deposition

Rainwater sampling at the Yangon (Kaba-Aye) station is used to assess long-term trends from 2015 to 2024 and shorter-term trends over the most recent five years to evaluate the current status. The assessment includes measurements of pH, EC, and cations (sodium, potassium, magnesium, calcium and ammonium), as well as anions (nitrate, sulphate and chloride).

2.1.1.1 Annual variations of pH and EC during 2015-2024

Annual rainfall at the Yangon (Kaba-Aye) monitoring station exhibited considerable variability during the study period 2015 to 2024, ranging from approximately 2,000 mm to 3,000 mm per year. Variations in rainfall were generally associated with changes in rainwater pH. Higher rainfall years tended to correspond with lower pH values, indicating slightly increased acidity. For example, in 2018 and 2019, relatively high precipitation levels were associated with pH values of approximately 6.5-6.6. In contrast, during 2022, when annual rainfall reached its lowest level within the study period, the pH increased to approximately 6.9.

This relationship suggests that increased rainfall may influence the chemical composition of precipitation through changes in the concentrations of acidic and alkaline constituents in the atmosphere. By 2024, annual

rainfall had recovered to nearly 3,000 mm, accompanied by a decrease in pH to approximately 6.65. The annual variations in precipitation and pH at the Yangon (Kaba-Aye) monitoring site from 2015 to 2024 are presented in Figure 2. The average rainwater pH observed at Kaba-Aye over the 10 years period was 6.7, indicating that precipitation remained near neutral and did not exhibit characteristics of acid rain. The observed pH values were also within the range generally considered acceptable for drinking water according to the guidelines of the World Health Organization (WHO).

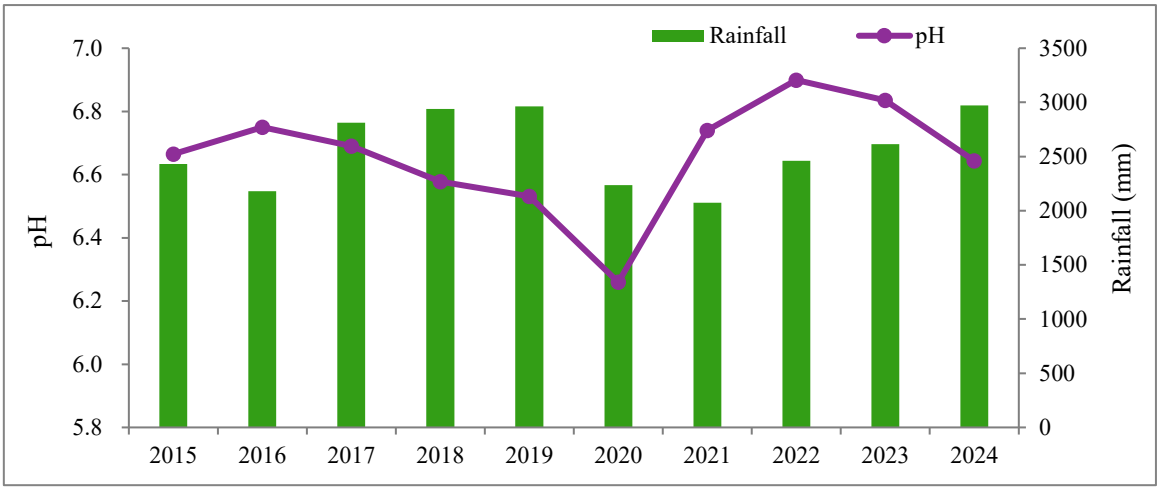


Figure 2. Annual variation of precipitation and pH during 2015 to 2024

Figure 3 illustrates the annual rainfall and rainwater EC revealed a clear inverse relationship during the period 2015-2024, indicating a clear atmospheric dilution effect. In years with exceptionally high rainfall amounts, such as 2017 and 2024 (approaching 3,000 mm), EC values decreased to their lowest levels, approximately 5.0 µS cm^{-1}. This reduction could be attributed to the dilution of dissolved ions by the large volume of precipitation. Conversely, in 2015, 2016, and 2023, when annual rainfall was comparatively lower, EC values increased to their highest levels, ranging from 13.5 to 15.0 µS cm^{-1}. These elevated conductivity vales suggest a higher concentration of dissolved ionic species in the rainwater due to reduced dilution.

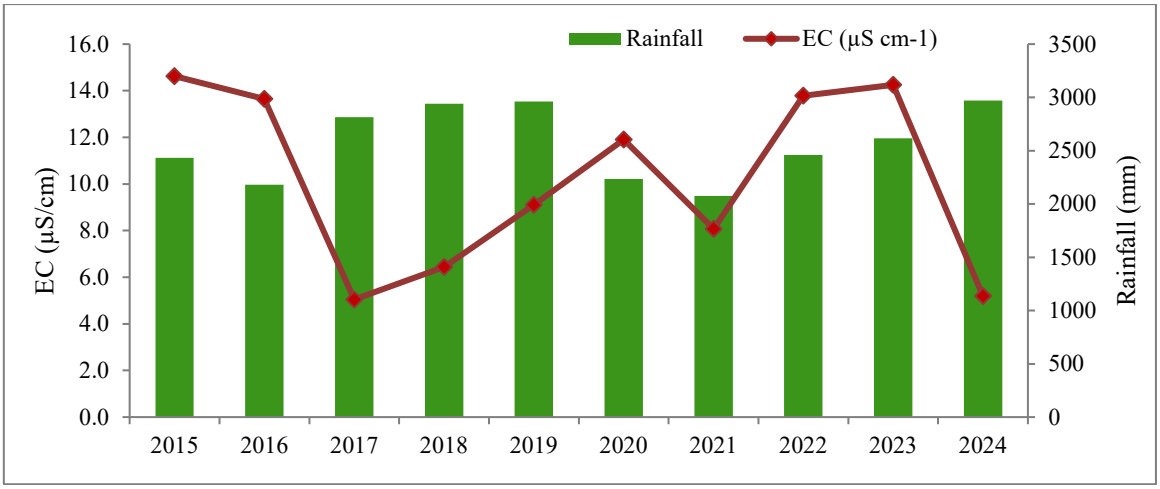


Figure 3. Annual variation of precipitation and Electric Conductivity (EC) during 2015 to 2024

In 2021, both rainfall and EC decreased simultaneously. This observation suggests that, although rainfall volume is a major factor influencing rainwater conductivity, other environmental factors such as seasonal wind patterns, variations in local air pollution levels, and dust transport events may also affect the concentration of conductive ions removed from the atmosphere by precipitation.

The annual maximum, minimum and mean values of pH, EC, and total precipitation recorded at the Yangon (Kaba-Aye) monitoring site during the period 2015-2024 are summarized in Table 3. During the period 2015-2024, the maximum and minimum electric conductivity (EC) values observed in rainwater samples at the site were 97.9 µS cm^{-1} and 2.84 µS cm^{-1}, respectively. The conductivity of precipitation is mainly determined by

the concentration of water-soluble ions, and its value is closely related to the total concentration of dissolved anions and cations in rainwater.

Table 3. Annual minimum, maximum and mean values of pH, EC and total precipitation at Yangon (Kaba-Aye)

Year	pH			EC (µS/cm)			Annual Total Precipitation (mm)
	Max	Min	Mean	Max	Min	Mean	
2015	7.0	6.5	6.66	97.9	10.8	14.63	2432
2016	6.9	6.6	6.75	39.0	4.2	13.65	2180
2017	7.0	6.6	6.69	11.0	3.4	5.04	2813
2018	6.8	6.5	6.58	22.4	2.8	6.44	2940
2019	6.8	5.5	6.53	50.0	6.4	9.10	2962
2020	6.4	6.0	6.27	16.6	9.2	11.9	1372
2021	7.1	6.7	6.74	35.5	4.5	8.07	2075
2022	7.4	6.7	6.90	33.7	8.6	13.78	2461
2023	7.0	6.5	6.83	39.8	6.3	14.25	2615
2024	6.9	6.5	6.64	26.3	3.6	5.19	2972

2.1.1.2 Temporal variations of major ions of wet deposition in 2015-2024

Figure 4 (a-h) illustrates the annual variation of major ions species concentrations from 2015 to 2024. Overall, most ions observed considerable inter-annual variability, while the linear trend analysis revealed generally weak long-term trends as indicated by the low coefficients of determination (R^2).

Sulphate (SO_4^{2-}) concentrations fluctuated between approximately 5 and 12 µmol L^{-1} throughout the study period. Although a slight decreasing trend was observed (slope = -0.0278), the very low R^2 value (0.0018) suggested that no significant long-term change occurred. Similarly, nitrate (NO_3^-) showed substantial year-to-year variability, with concentrations peak in 2019 before declining in subsequent years. The negative slope (-0.497) indicates a decreasing trend, however, the low R^2 value (0.0837) implies that the trend is weak.

Among the measured anions, chloride (Cl^-) exhibited the most evident decreasing tendency, with concentrations declining from approximately 30-35 µmol L^{-1} during the early years of the study to around 15-20 µmol L^{-1} in recent years. The trend line yielded a slope of −1.772 and an R^2 value of 0.5376, indicating a moderate negative relationship between concentration and time. This result suggests a possible reduction in chloride inputs over the study period.

Ammonium (NH_4^+) concentrations varied between approximately 10 and 22 µmol L^{-1} and displayed a weak decreasing trend (slope = -0.2825; R^2 = 0.0505). Sodium (Na^+) concentrations remained relatively stable throughout the study period. Although a slight increasing trend was observed (slope = 0.0611), the very low R^2 value (0.0029) indicates that no significant temporal change occurred.

Potassium (K^+) exhibited considerable annual fluctuations and a weak decline trend (slope = -0.582; R^2 = 0.2825). In contrast, calcium (Ca^{2+}) showed a slight increasing tendency (slope = 0.4243), although the low R^2 value (0.0535) suggests that the trend is not statistically strong. Magnesium (Mg^{2+}) also displayed a slight upward trend (slope = 0.2048), largely influenced by an elevated concentration observed in 2021. Nevertheless, the very low R^2 value (0.0059) indicates that no significant long-term increase could be confirmed.

Overall results demonstrate that the concentrations of major ionic species were characterized primarily by inter-annual variability rather than consistent long-term trends. Chloride was the only ion showing a relatively pronounced decreasing trend, whereas the trends observed for other ions were weak and may not be statistically significant. It should be noted that the annual data for 2020 did not meet the minimum data completeness criterion of 80%. Therefore, the calculated annual mean concentrations for this year may not fully represent actual annual conditions and should be interpreted cautiously in the trend analysis.

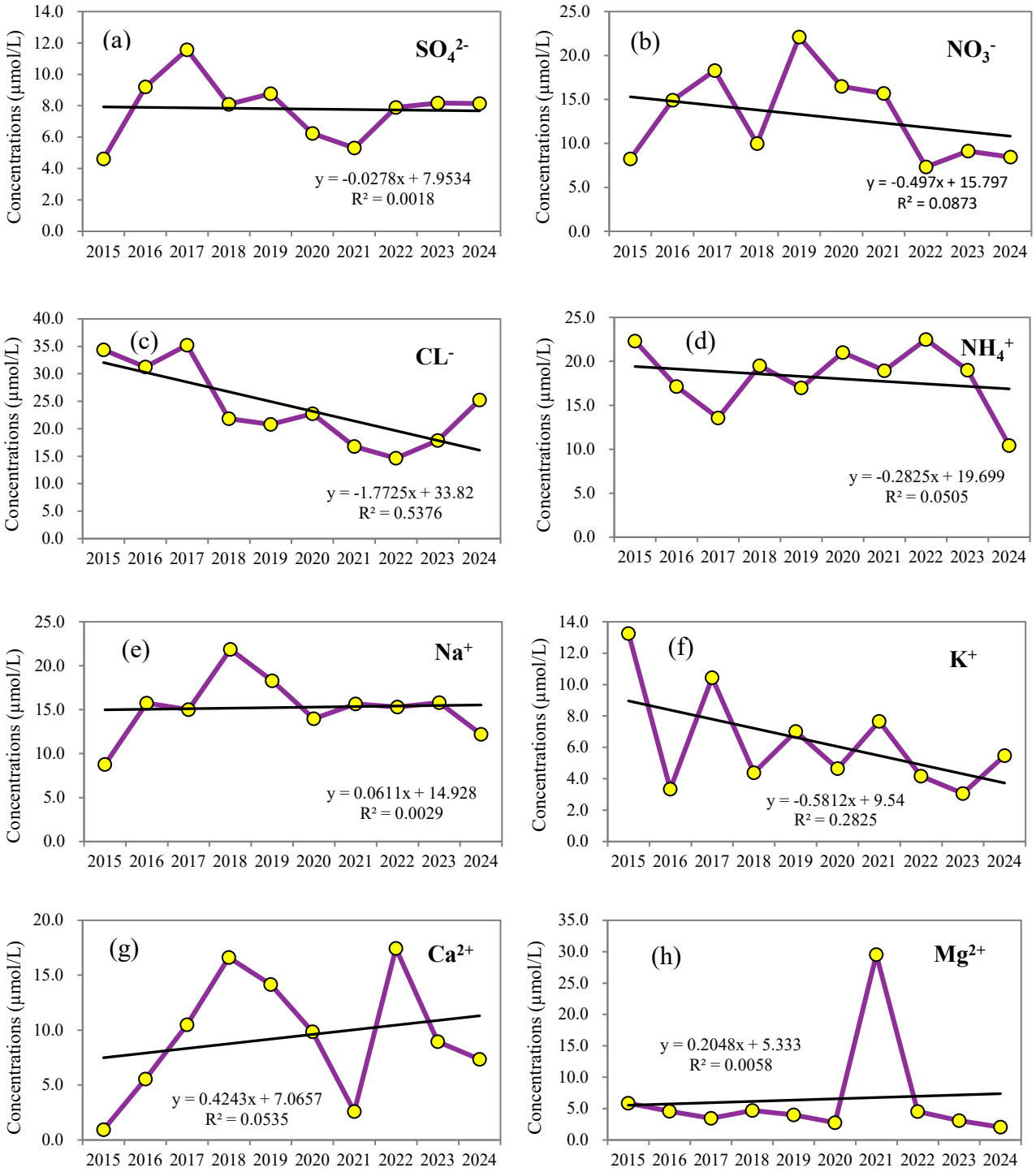


Figure 4 (a-h) Annual variation of major ions species concentrations (wet deposition) from 2015 to 2024

2.1.1.3 Comparative analysis of pH, EC over a decade

Figure 5 compares the monthly average precipitation, pH between the baseline periods (2015-2019) and the recent period (2020-2024). Overall precipitation, pH values during 2020-2024 were slightly higher than those observed during 2015-2019 for most months. The largest increased were observed in January and February, where pH values increased from approximately 6.05 to 6.8 and 7.0. In contrast, September and October showed slightly lower pH values during the recent period. Despite these variations, precipitation remained generally neutral to slightly alkaline (pH>6.0) throughout both periods. The overall increase in pH during 2020-2024 suggests a reduction in precipitation acidity compared with the baseline period.

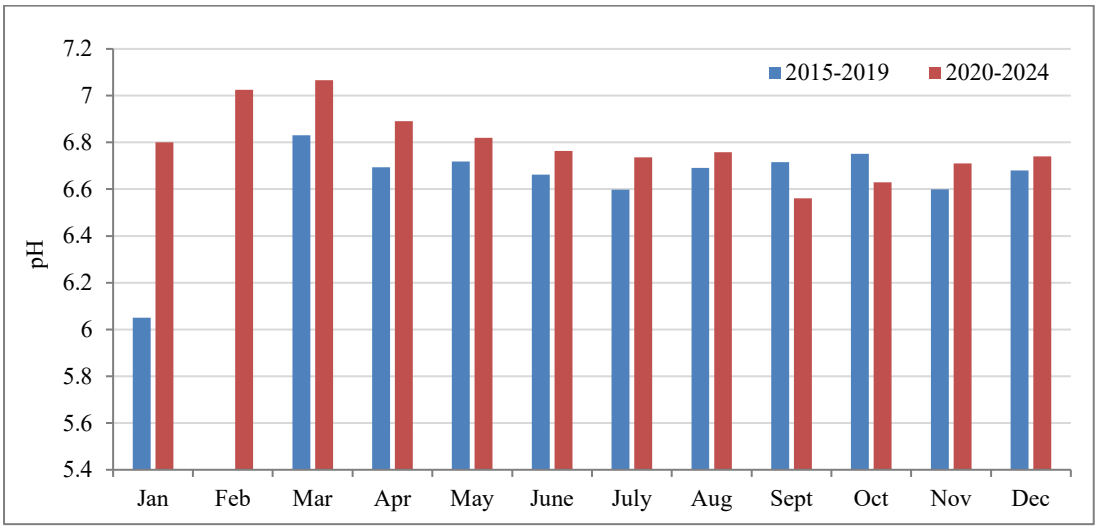


Figure 5. Comparison of precipitation pH for different 5-year periods

Figure 6 presents the comparison of monthly average electrical conductivity (EC) between the two periods. A notable reduction in EC was observed during 2020-2024, particularly in March and April. During the baseline period, EC reached approximately 97.9 µS cm^{-1} in March and 36.6 µS cm^{-1} in April, whereas corresponding values decreased to about 27.7 µS cm^{-1} and 24.8 µS cm^{-1}, respectively during the recent period. Monthly EC values during 2020-2024 exhibited less variability and remained relatively low throughout the year. The lower EC values indicate a decrease in the total dissolved ionic content of precipitation, suggesting reduced atmospheric loading of soluble pollutants and aerosols compared with the baseline period.

The comparison between the baseline (2015-2019) and recent (2020-2024) periods indicates an overall improvement in precipitation quality. The increase in precipitation pH and the decrease in electrical conductivity during 2020-2024 suggest reduced acidity and lower concentrations of dissolved ions in precipitation. These changes may reflect variations in emission sources, atmospheric transport patterns, or regional environmental conditions during the recent period. However, further investigation of individual ionic species and meteorological factors would be necessary to identify the specific cause of these observed differences.

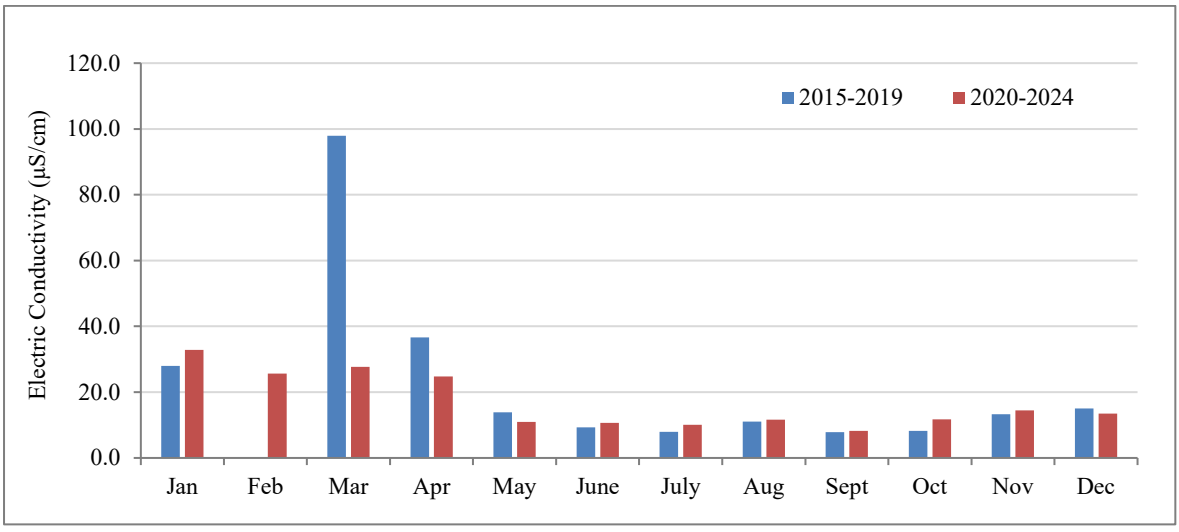


Figure 6. Comparison of EC for different 5-year periods.

2.1.1.4 Comparison of wet deposition over a decade

Figure 7 (a-j) compares the monthly wet deposition fluxes of major ionic species between the baseline period (2015-2019) and the recent period (2020-2024). Overall, most ions exhibited lower wet deposition during 2020-

2024 than during 2015-2019, particularly during the dry season months when the highest deposition fluxes were observed in the baseline period.

Chloride (Cl^-) deposition showed a substantial decrease during the recent period. The most pronounced reduction occurred in March, where deposition declined from approximately 130 µmol m^{-2} to less than 50 µmol m^{-2}. Lower deposition values were also observed in most other months, indicating a decrease in chloride input through precipitation.

A similar pattern was observed for nitrate (NO_3^-) and non-sea-salt sulfate (nss-SO_4^{2-}). Both species exhibited markedly lower deposition fluxes during 2020-2024, particularly in March and April. The sharp peaks observed during the baseline period were absent or considerably reduced in the recent period, suggesting a decline in atmospheric deposition of anthropogenic acidic components.

Sulphate (SO_4^{2-}) concentrations were generally lower during the recent period (2020-2024) compared with the baseline period (2015-2019), particularly during the dry season months. The highest concentration observed in March during 2015-2019 was substantially reduced in 2020-2024. During the wet season (May – October), sulphate concentrations remained relatively low and showed only minor differences between two periods.

For the major cations sodium (Na^+) and potassium (K^+) also showed lower deposition during 2020-2024. Sodium deposition decreased substantially during peak deposition months, while potassium exhibited a marked reduction in March. The potassium deposition in March during the baseline period was more than double that observed during the recent period. These results indicate a reduction in the transport and deposition of sea-salt and crustal aerosols.

Ammonium (NH_4^+) deposition displayed a different pattern. Although lower values were observed during some months, higher deposition was recorded during the recent period in April and May. This suggests that ammonium source remained active and may have partially offset reductions observed for acidic ions.

For crustal components, magnesium (Mg^{2+}), calcium (Ca^{2+}), and non-sea-salt calcium (nss-Ca^{2+}) generally showed lower deposition during the recent period, especially during the months with historically high deposition. However, several months exhibited comparable or slightly higher values during 2020-2024, indicating continued influence of soil dust and other crustal sources.

The overall comparison indicates that wet deposition fluxes of most major ions were lower during 2020-2024 than during 2015-2019. The reductions were particularly evident for Cl^-, NO_3^-, SO_4^{2-}, nss-SO_4^{2-}, Na^+, and K^+, suggest a decrease in atmospheric loading and subsequent removal of both anthropogenic and natural aerosol constituents. The observed decline in wet deposition is consistent with the increase in precipitation pH and decrease in electrical conductivity reported for the recent period, indicating an overall improvement in precipitation chemistry.

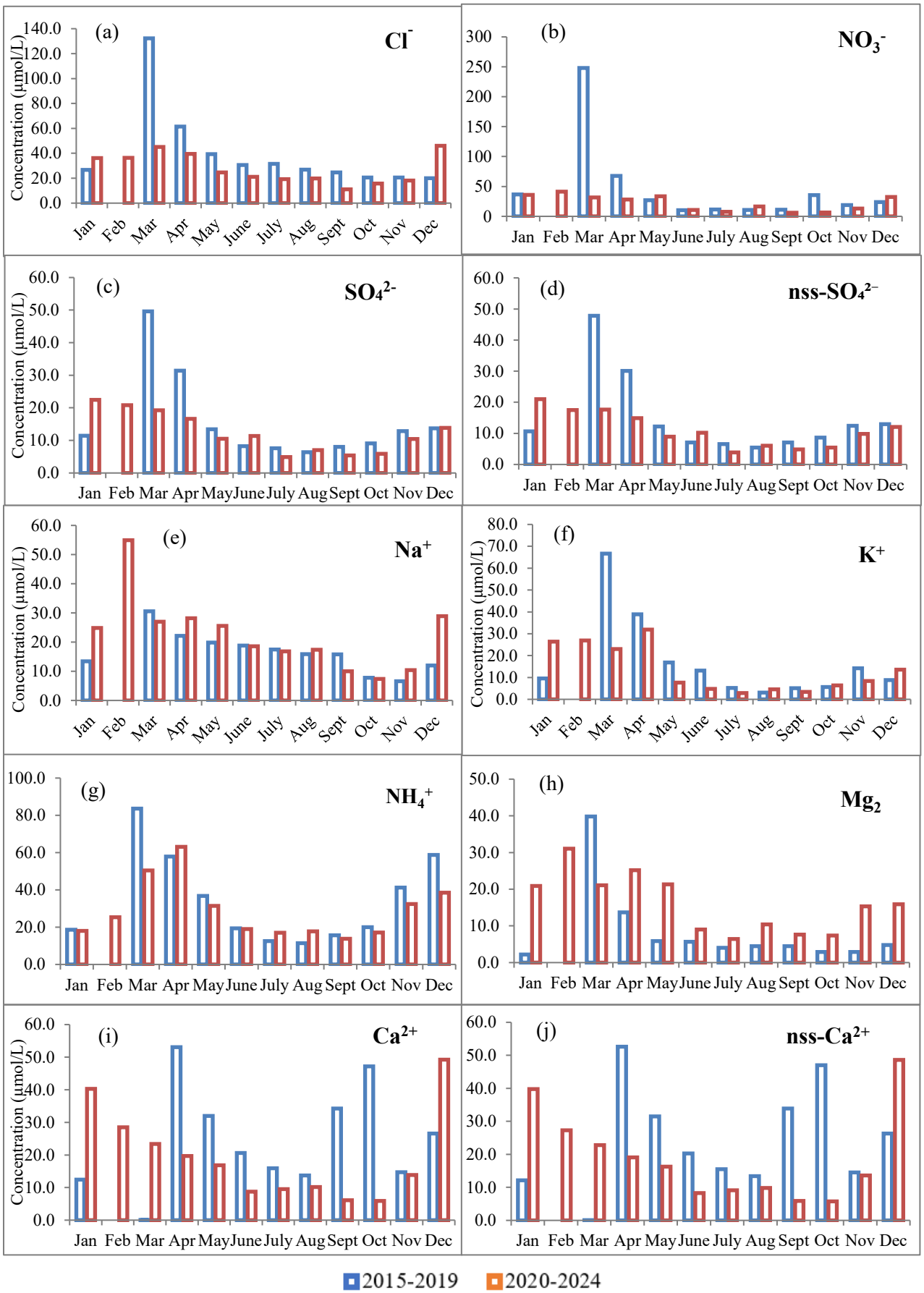


Figure 7 (a- j). Comparison of ion concentrations (wet deposition) for different 5-year period

2.1.2 State of dry deposition

Gaseous and major ions of dry deposition at the Yangon (Kaba-Aye) station is used to assess long-term trends from 2015 to 2024 and shorter-term trends over the most recent five years to evaluate the current status.

2.1.2.1 Annual variations of gaseous and major ions of dry deposition in 2015-2024

Figure 8 (a - l) shows the annual concentrations of gaseous species (SO_2, HNO_3, HCl, and NH_3) and particulate ionic species (Cl^-, SO_4^{2-}, NO_3^-, NH_4^+, Na^+, K^+, Mg^{2+}, and Ca^{2+}) during 2015–2024. Overall, most species exhibited considerable inter-annual variability, while long-term trends were generally weak, as indicated by the low R^2 value.

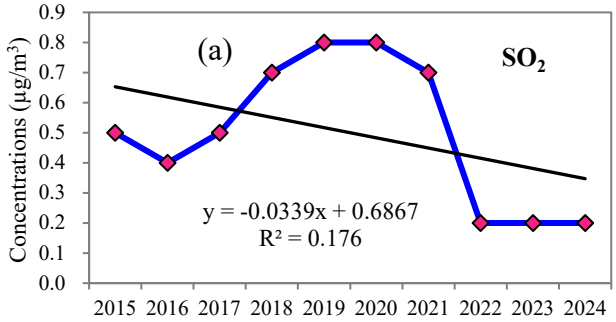
Among the gaseous species, SO_2 concentrations increased from 2016 to 2020, reaching maximum levels in 2019-2020, before declining sharply after 2021. The negative trend slope (-0.0339) indicates an overall decreasing tendency over the study period. HNO_3 concentrations remained relatively stable until 2018, increased substantially during 2019-2021, and then decreased notable in 2022, followed by slight recovery in subsequent years. However, the trend was weak (R^2 = 0.0224). HCl showed considerable year-to-year fluctuations, with the highest concentration recorded in 2020, followed by a decline during 2021-2023 and a slight increase in 2024. NH_3 exhibited the highest concentrations among the gaseous species but showed a pronounced decreasing trend (slope = −0.6829; R^2 = 0.6269), indicating a substantial reduction over the study period.

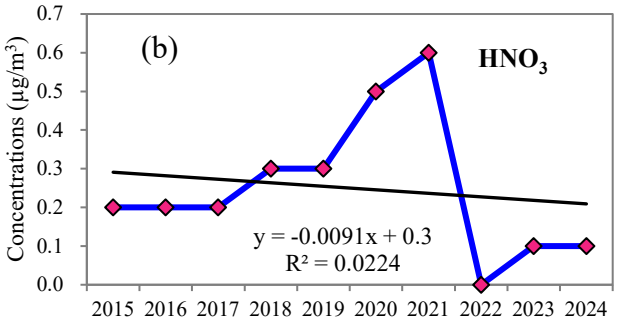
For particulate species, Cl^- concentrations fluctuated considerably, with elevated values observed in 2015, 2018, and 2020, followed by lower concentrations during recent years. SO_4^{2-} levels experienced significant annual fluctuations (R^2 = 0.1341), reaching a decade-high peak in 2020 before dropping sharply. Meanwhile, NO_3^- concentrations followed a more consistent downward path (R^2 = 0.2405), recorded highest concentration in 2017. Notably, both SO_4^{2-} and NO_3^- reached their lowest, most stable baselines between 2022 and 2024, maintaining minimal concentrations.

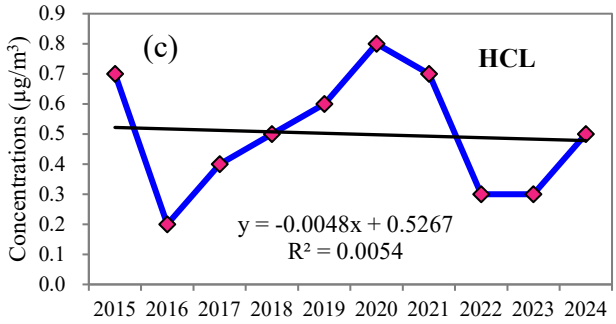
NH_4^+ also showed obvious variability, with a notable peak in 2021 before declining sharply in 2022 and gradually increasing thereafter. Na^+ concentrations remained relatively low throughout most years, except for a distinct peak in 2020. Similarly, K^+ exhibited substantial fluctuations, with elevated concentrations in 2019 and 2021 but lower levels during the remaining years.

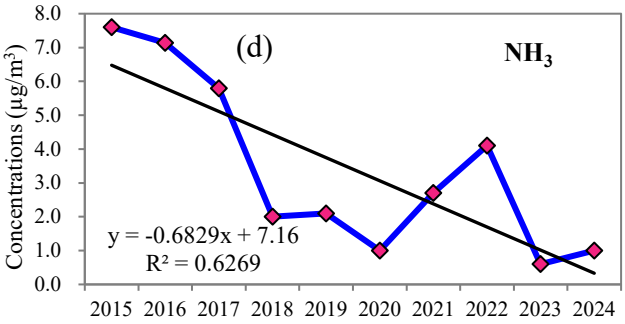
Among the crustal ions, Mg^{2+} concentrations remained low for most of the study period, except for an exceptionally high value observed in 2020. Ca^{2+} displayed a clear decreasing trend (slope = −0.2224; R^2 = 0.5033), with concentrations declining from relatively high levels in 2015–2016 to consistently lower values after 2017.

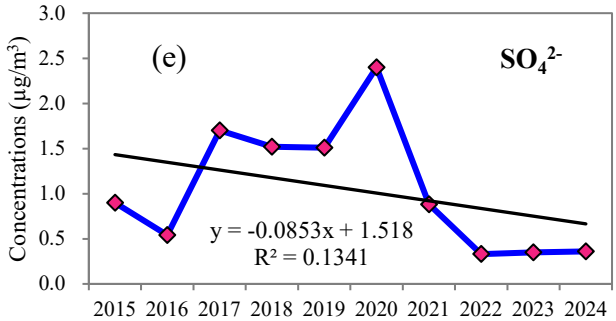
Overall, the results indicate decreasing trends for SO_2, NH_3, and Ca^{2+}, while other species were characterized primarily by interannual variability rather than consistent long-term changes. The relatively strong downward trends observed for NH_3 and Ca^{2+} could be suggested a reduction in emissions or atmospheric loading from their respective sources during the study period. It should be noted that the annual datasets for 2021 and 2022 did not meet the minimum data completeness criterion of 80%. Therefore, the annual mean concentrations reported for these years may be associated with greater uncertainty and should be interpreted with caution when assessing temporal variations and long-term trends.

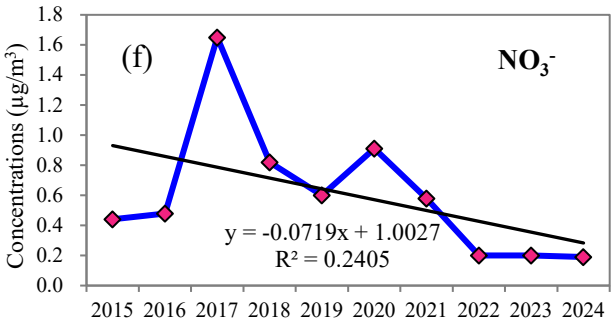

(a)
SO_2
y = -0.0339x + 0.6867
R² = 0.176
Concentrations (µg/m³)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

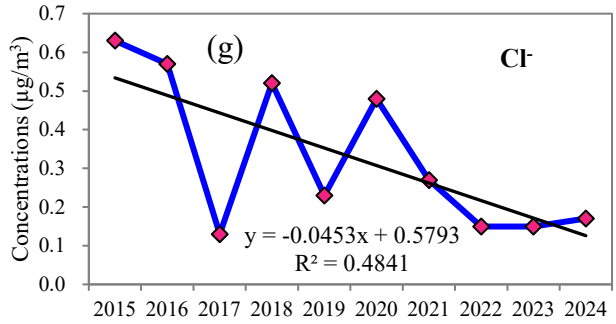

(b)
HNO_3
y = -0.0091x + 0.3
R² = 0.0224
Concentrations (µg/m³)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

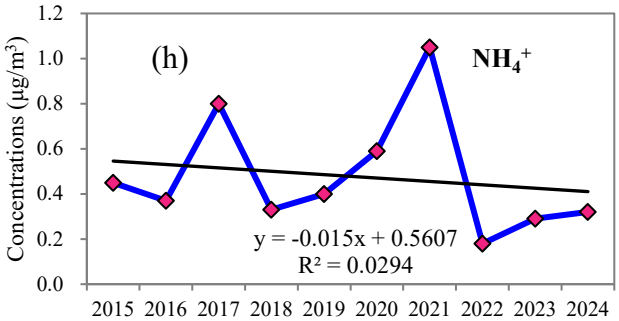

(c)
HCL
y = -0.0048x + 0.5267
R² = 0.0054
Concentrations (µg/m³)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

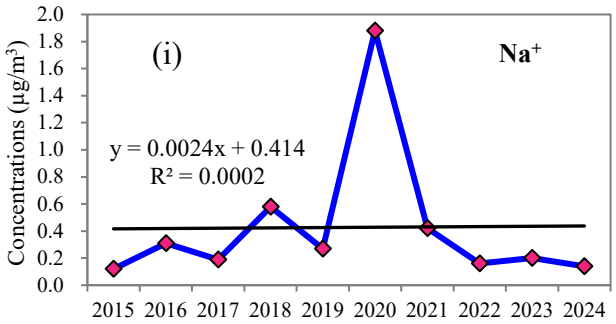

(d)
NH_3
y = -0.6829x + 7.16
R² = 0.6269
Concentrations (µg/m³)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

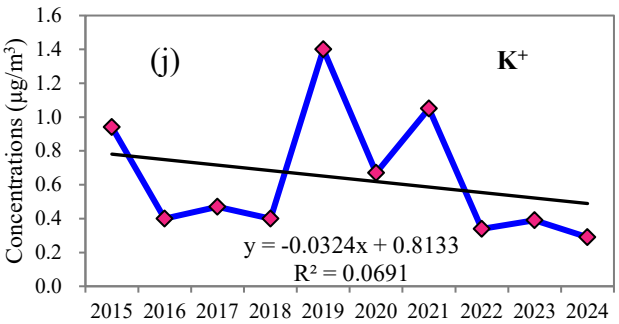

(e)
SO_4^{2-}
y = -0.0853x + 1.518
R² = 0.1341
Concentrations (µg/m³)
0.0 0.5 1.0 1.5 2.0 2.5 3.0
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024


(f)
NO_3^-
y = -0.0719x + 1.0027
R² = 0.2405
Concentrations (µg/m³)
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024


(g)
Cl^-
y = -0.0453x + 0.5793
R² = 0.4841
Concentrations (µg/m³)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024


(h)
NH_4^+
y = -0.015x + 0.5607
R² = 0.0294
Concentrations (µg/m³)
0.0 0.2 0.4 0.6 0.8 1.0 1.2
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024


(i)
Na^+
y = 0.0024x + 0.414
R² = 0.0002
Concentrations (µg/m³)
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024


(j)
K^+
y = -0.0324x + 0.8133
R² = 0.0691
Concentrations (µg/m³)
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

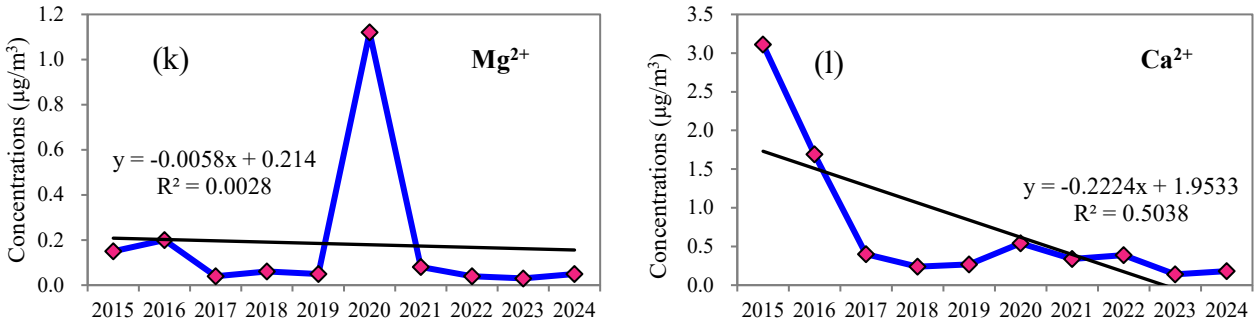


Figure 8 (a - l) Annual variations of gases and ions concentrations of dry deposition during 2015-2024

2.1.2.2 Comparative analysis of gaseous and major ions of dry deposition over a decade

Figure 9 (a - l) shows a comparison of monthly mean concentrations of atmospheric ionic species between the periods 2015–2019 and 2020–2024 reveals both similarities in seasonal patterns and differences in concentration levels. Among the acidic species, Hydrochloric acid (HCl) concentrations showed mixed trends between two periods. Higher concentrations during 2020-2024 were observed in February, March, May, and July, with the highest value occurring in May. In contrast, concentrations during 2015–2019 were greater in January, April, June, August, November, and December. The most notable increase in 2020–2024 occurred during May, when the concentration was more than twice that recorded during 2015–2019.

Nitric Acid (HNO_3) concentrations were generally low throughout the year in both periods; however, pronounced increases were observed during 2020–2024 in April and May. The highest monthly concentration occurred in May during 2020–2024, whereas concentrations remained below 0.5 µg m^{-3} during all months of 2015–2019. This indicates enhanced nitrate precursor oxidation or episodic atmospheric events during these months.

Ammonia (NH_3) exhibited the most distinct difference between the two periods. Concentrations during 2015–2019 were substantially higher in almost every month, particularly in January, March, April, May, October, November, and December. During 2020–2024, NH_3 concentrations remained below approximately 3 µg m^{-3} for most months, whereas values exceeded 5 µg m^{-3} during several months in 2015–2019. These results suggest a marked reduction in atmospheric ammonia levels during the later period.

For sulphur dioxide (SO_2), concentrations varied considerably among months. During 2020–2024, elevated concentrations were observed in January, February, and March, while 2015–2019 showed higher concentrations in all of the months except January, February, and March. The largest difference occurred in January, where concentrations during 2020–2024 were more than twice those recorded during 2015–2019.

Ammonium (NH_4^+) concentrations followed a pattern similar to NH_3. Higher concentrations were observed during 2015–2019 in January, March, June, August, and October, whereas 2020–2024 exhibited higher values in February, April, May, and November. A pronounced peak occurred in February during 2020–2024, while the highest concentration during 2015–2019 occurred in March. Despite these individual monthly increases, concentrations after June remained relatively low during both periods.

Sulphate ion (SO_4^{2-}) concentrations showed different monthly behavior. During 2020–2024, sulphate concentrations were markedly higher in February and slightly higher in October. In contrast, 2015–2019 recorded higher concentrations in January, March, April, September, and December. The most prominent peak was observed in February 2020–2024, reaching approximately 3.7 µg m^{-3}, which was substantially greater than the corresponding value during 2015–2019.

Nitrate ion (NO_3^-) concentrations varied considerably throughout the year in both periods. Concentrations during 2020–2024 were noticeably higher in February, May, July, and August, with the highest value occurring in February. In contrast, 2015–2019 showed higher concentrations during January, April, September, October, November, and December. Although individual monthly peaks differed between the two periods, no uniform increasing or decreasing trend was evident across the entire year.

Chloride ion (Cl^-) concentrations exhibited mixed monthly variations. During 2015–2019, elevated concentrations were observed in January, April, May, June, September, and December, with the maximum value occurring in May. Conversely, concentrations during 2020–2024 were higher in February, March, August, and November. The largest difference occurred in May, when Cl^- concentrations during 2015–2019 were approximately three times higher than those recorded during 2020–2024.

Calcium ion (Ca^{2+}) displayed the most pronounced temporal difference among all cations. Concentrations during 2015–2019 were substantially higher in April, May, November, and December, with major peaks observed in May and November. In contrast, 2020–2024 showed relatively low concentrations throughout most months, except for a moderate increase in February. These results indicate a marked reduction in calcium concentrations during the later period, suggesting lower contributions from crustal materials, soil dust, or resuspended particles.

Potassium ion (K^+) concentrations showed distinct differences between the two periods. During 2015–2019, high concentrations were observed in January, March, April, October, and November, with the highest value occurring in October. In contrast, 2020–2024 exhibited higher concentrations in February, July, and August. Despite these monthly variations, the magnitude and frequency of elevated K^+ concentrations were generally greater during 2015–2019.

Magnesium ion (Mg^{2+}) concentrations remained low during most months in both periods. However, a remarkable peak was observed in June during 2020–2024, reaching nearly 1.9 μg m^{-3}, whereas concentrations during the same month in 2015–2019 remained very low. Apart from this isolated event, Mg^{2+} concentrations showed only minor differences between the two periods.

Sodium ion (Na^+) concentrations were generally low to moderate throughout the year. The most significant feature was the exceptionally high concentration observed in June during 2020–2024, which was approximately three times higher than the corresponding value during 2015–2019. Higher concentrations during 2020–2024 were also observed in February, April, and August. In contrast, concentrations during 2015–2019 were slightly higher in January, March, September, and October.

Overall, the comparison between 2015–2019 and 2020–2024 revealed substantial species-specific variations in atmospheric ionic composition. NH_3 and Ca^{2+} exhibited the most pronounced decreases during 2020–2024, suggesting reduced contributions from ammonia-related emissions and crustal or dust-derived sources. In contrast, HNO_3 and SO_4^{2-} showed notable increases during specific months, particularly during April–May and January-February, respectively, while Mg^{2+} and Na^+ displayed distinct concentration peaks in June. HCl, SO_2, NH_4^+, NO_3^-, Cl^-, and K^+ exhibited considerable month-to-month variability, with both increases and decreases observed depending on the month, and therefore showed no consistent long-term trend between the two periods. These findings indicate that temporal changes in atmospheric ionic composition were species-dependent and were likely influenced by variations in emission sources, atmospheric chemical transformations, transport pathways, and meteorological conditions throughout the year.

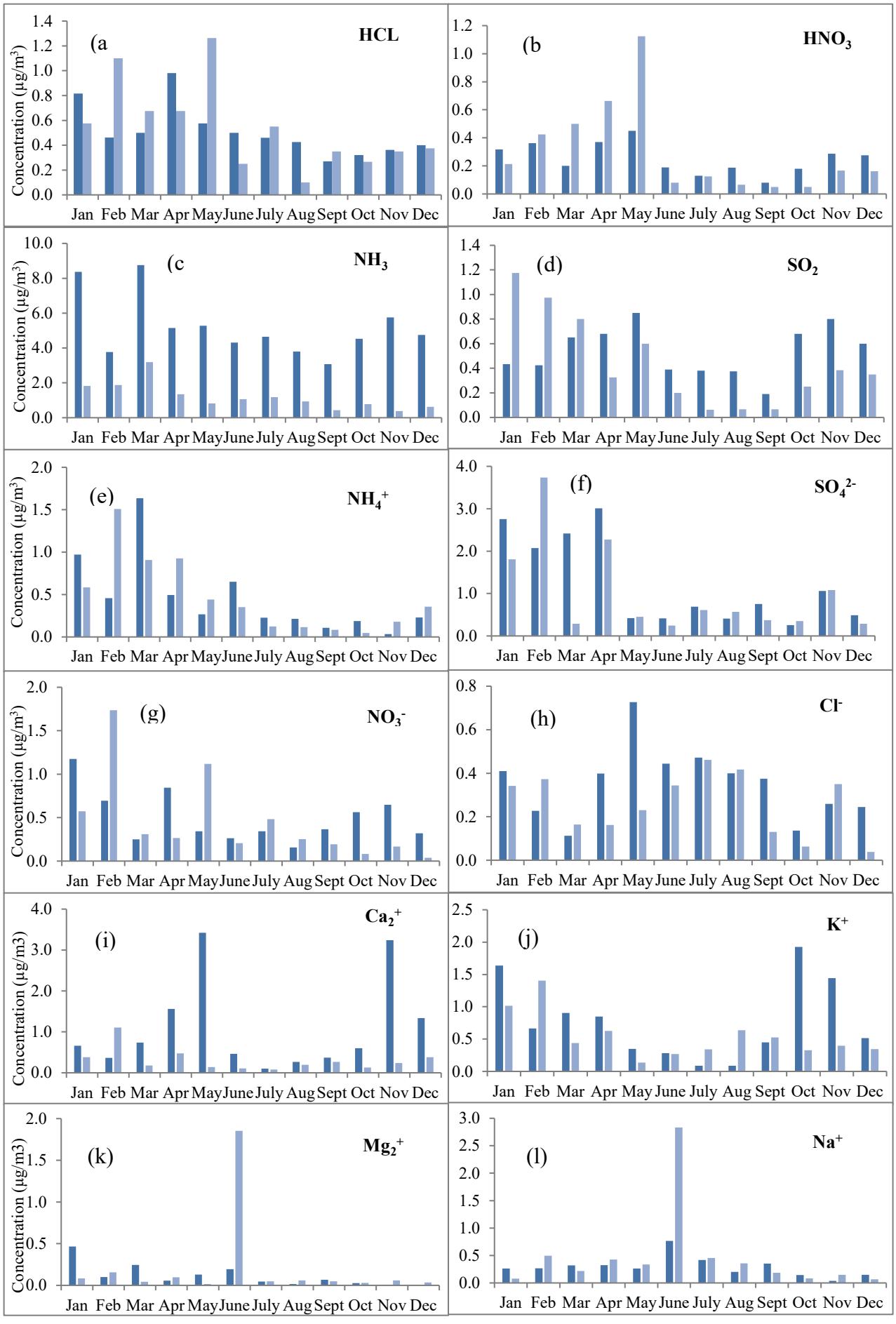


Figure 9 (a - l). Comparison of Five-year average of gaseous and ion concentration in dry

2.1.3 State of Particulate Matter ($PM_{2.5}$) concentration at Yangon (Kaba-aye)

Figure 10 presented the annual mean $PM_{2.5}$ concentration from 2018 to 2024 remained consistently above the WHO Air Quality Guideline (2005) annual standard value of 10 µg/m^3, indicating persistent particulate matter pollution in the monitored area, Yangon (Kaba-aye).

$PM_{2.5}$ concentrations showed a slight decreasing trend from 23.6 µg/m³ in 2018 to 21.3 µg/m³ in 2020. The reduction observed in 2020 could be attributed to the COVID-19 pandemic, during which many economic and social activities were significantly reduced. The implementation of lockdown measures, travel restrictions, and approximately 50 percent reductions in workforce attendance in various sectors contributed to lower emissions from transportation, industrial, and other anthropogenic sources.

However, $PM_{2.5}$ concentrations increased sharply to 29.8 µg/m³ in 2021, representing the highest annual mean value during the study period. This increase may be associated with the recovery of economic activities and other emission-generating sources after the COVID-19 lockdown period. Subsequently, the concentration decreased to 25.4 µg/m³ in 2022, slightly increased to 26.7 µg/m³ in 2023, and declined marginally to 25.2 µg/m³ in 2024.

Overall, $PM_{2.5}$ levels throughout the study period remained more than twice the WHO guideline value, highlighting the continued challenge of air pollution and the need for strengthened air quality management measures, including emission control, open burning reduction, and continuous monitoring to protect public health and the environment.

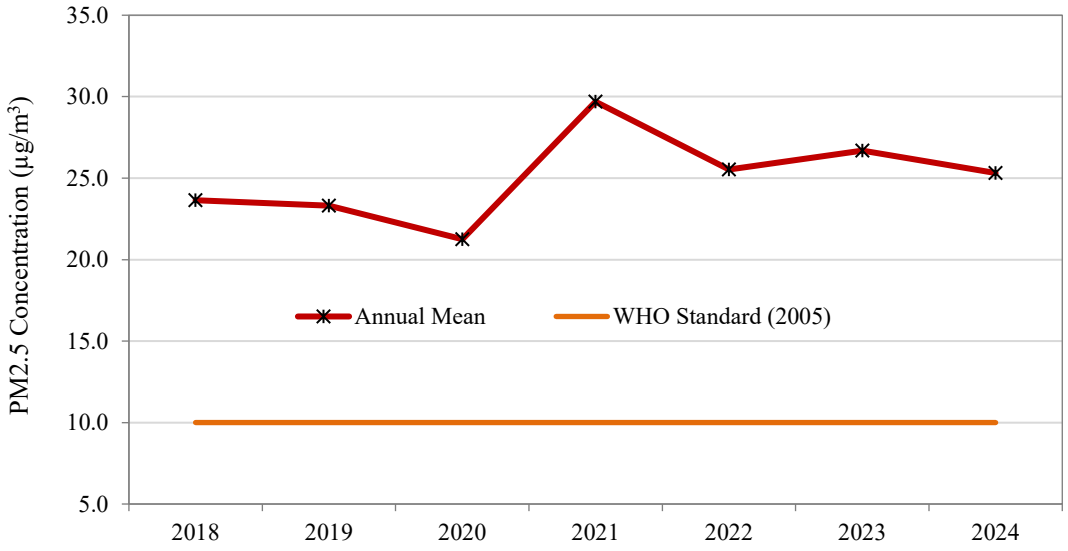


Figure 10. Annual mean $PM_{2.5}$ concentration during 2018-2024 at Yangon (Kaba-aye)

3. Review of National measure against acid deposition

Myanmar has adopted environmental laws and institutional frameworks for environmental and air quality management, including the Environmental Conservation Law, Environmental Conservation Rules, National Environmental Policy, Environmental Quality (Emission) Guideline, Myanmar Climate Change Strategy, Myanmar National Waste Management Strategy and Master Plan. However, Myanmar has not yet established a legally binding National Ambient Air Quality Standard. Therefore, the World Health Organization (WHO) Air Quality Guidelines (2005) are currently being used as the reference standard for air quality assessment and management in Myanmar.

To address this gap, the Ministry of Natural Resources and Environmental Conservation (MONREC), in collaboration with relevant government departments, academic institutions, development partners, and other stakeholders, has established a technical working group to develop Myanmar's National Ambient Air Quality

Standards. The working group is conducting technical assessments, reviewing international best practices, and carrying out stakeholder consultations to formulate nationally appropriate air quality standards.

The proposed National Air Quality Standards cover six major air pollutants: Particulate Matter ($PM_{2.5}$), (PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Ozone (O_3), and Carbon Monoxide (CO). Proposed standard values are being developed based on WHO Air Quality Guidelines and regional practices, taking into consideration Myanmar's environmental, social, and economic conditions.

At the same time, relevant departments and organizations are closely cooperating to develop strategies and action plans for air quality management in Myanmar, including air quality monitoring, emission source inventory development, open burning control, emission reduction measures, transboundary haze pollution management, and public awareness raising. These efforts contribute to sustainable development and the mainstreaming of environmental protection and management throughout the country.

4. Conclusion

Myanmar has been actively participating in the East Asian Acid Deposition Monitoring Network (EANET) since the end of 2005 as a National Focal Point, with technical support from the ACAP, EANET Network Center. Regular monitoring activities continue to be conducted at the Yangon (Kaba-Aye) monitoring site, including precipitation chemistry, wet and dry deposition, gaseous pollutants, and particulate matter ($PM_{2.5}$) measurements. Monitoring data are routinely submitted to the EANET Network Center and shared with participating countries and relevant national organizations to support regional assessments of acid deposition and air quality.

In recent years, Myanmar has continued its commitment to EANET activities through sustained monitoring, data reporting, and participation in regional meetings, technical workshops, and capacity-building programs. Efforts have also been made to strengthen technical expertise in air quality monitoring, data management, and atmospheric research. Public awareness activities on acid deposition and air pollution have been promoted through stakeholder engagement, educational outreach, and information dissemination. Furthermore, monitoring results have contributed to national environmental management and air quality assessment initiatives.

Looking ahead, Myanmar aims to further enhance its monitoring capabilities, strengthen research on atmospheric deposition and air pollution, expand cooperation with regional and international partners, and increase public awareness of environmental and air quality issues. These efforts will support evidence-based environmental policies and contribute to the long-term protection of ecosystems, human health, and environmental quality.

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