National Assessment on Acid Deposition in Cambodia

Chapter 1.Base Information on National Monitoring Activities

1.1 Outline of the activities on acid deposition and National Monitoring Plan

Acid deposition monitoring of EANET consist of five environmental items – wet deposition, dry deposition (air concentration), soil and vegetation, inland aquatic environment, and catchment-scale monitoring.
Monitoring for wet and dry deposition is implemented to measure atmospheric concentrations and to evaluate fluxes of acidic substances to the land surface, while monitoring for soil and vegetation, inland aquatic environment and catchment-scale is carried out to assess adverse impacts on terrestrial and aquatic ecosystems. These monitoring data are used to evaluate the state of air concentration and acid deposition as well as impacts on ecosystems.

Cambodia participated in East Asia Acid Deposition Network (EANET) in 2001 and implemented regular monitoring activities together with twelve other countries. The national monitoring plan developed in 2006 for wet deposition monitoring, dry deposition monitoring has started from February 2010 and the monitoring of inland aquatic environment has started from June 2011.

1.2 Monitoring Station

Sites	Characteristics	Latitude	Longitude	Altitude
Phnom Penh Dry Monitoring	Urban	11°33'17"944 N	104°56'19"168 E	15 m
Phnom Penh Wet Monitoring	Urban	11°33'17"944 N	104°56'19"168 E	15 m
Phnom Penh PM 2.5 Monitoring	Urban	11°33'17"944 N	104°56'19"168 E	15 m
Phnom Penh Ozone (O3) Monitoring	Urban	11°33'17"944 N	104°56'19"168 E	15 m
Sras Srang Kirirom Inland	Remote	11°19' 41.83" N	104°2 '13.30" E	800m

1.2.1 Wet Deposition Monitoring

Wet Monitoring use automatic rain sampler, (Sampling, pH analysis, Electric Conductivity, Ion Chromatography), samplingweekly, Measurement of parameters : pH, EC, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}. Sample amount, conductivity and pH should be measured as soon as possible after sample

arrival, and checking agreement of samples and sample list. After conductivity and pH measurement, all samples should be filtered with clean membrane filters (pore size: 0.45µm). Filters should be well washed and be free from contamination. After filtration, samples should be refrigerated at 4ºC . Effort should be made to start analysis of the other parameters within a week of sample arrival in the laboratory and to complete the data sets by measuring EC, pH and all other chemical parameters.

1.2.2 Dry Deposition Monitoring

Cambodia was installed dry deposition monitoring in February 2010 in Phnom Penh city (11^{o} 33' N, 104^{o} 55' E). Used the four-stage filter pack method ,Filter pack method is available for the measurement of SO_2, HNO_3, HCl, NH_3, and particulate component (SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{2+}, Mg^{2+}). The four-stage filter pack method can measure all of these parameters at the same time. Sampling intervals: sample is collected for every two weeks, 1. Preparation of filter pack, 2. Sampling, 3. Extraction and chemical analysis, 4. Calculation of results.

Stage	Reaction	Collected specie
1^{st}(F0)	Filtration	Aerosols SO_4^{2-},NO_3^-,Cl^-, Na^+, NH_4^+,K^+, Ca^{2+},Mg^{2+}
2^{nd}(F1)	Adsorption	HNO_3, partial SO_2, partial HCl SO_4^{2-},NO_3^-,Cl^-, NH_4^+
	Neutralization by collected acid gases	partialNH_3
3^{rd}(F2)	Neutralization by alkali impregnated cellulose filter	SO_2, HCl , SO_4^{2-},Cl^-
4^{th}(F3)	Neutralization by acid impregnated cellulose filter	NH_3 ,NH_4^+

Stage	Specification of filter	Collected species
1^{st} (F0)	PTFE filter (pore size: 0.8 µm, diameter: 47 mm)	Aerosols
2^{nd} (F1)	Polyamide filter (pore size: 0.45 µm, diameter: 47 mm)	HNO_3, SO_2, HCl, NH_3

3rd (F2)	Impregnated cellulose filter Solution: 6% K2CO3 + 2% glycerin	SO_2, HCl
4th (F3)	Impregnated cellulose filter Solution: 5% H3PO4 + 2% glycerin	NH_3

1.2.3 PM 2.5 and Ozone (O3) Monitoring

Cambodia has started monitoring PM2.5 from April 2017. and has started monitoring Ozone (O3) from August 2019



Figure1.2.3.1 Picture of PM2.5 Monitoring.



Figure 1.2.3.2. Picture of Ozone (O3) Monitor

1.2.4 Inland aquatic environment Monitoring

In general, inland bodies of water with low alkalinity and low electric conductivities are prone to be sensitive to acidification by acid deposition. Therefore, it is important to conduct continuous monitoring of water bodies and aquatic fauna and so on. Items specified in the technical manual (2000) include water temperature, pH, electric conductivity (EC), alkalinity and concentration of : SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{2+} and Mg^{2+} of targeted lakes/rivers at least four times a year (seasonally), and transparency, water color, DOC (if impossible, COD), NO_2^-, and PO_4^{3-} more than once a year while some other optional items are specified to be monitored. In near future, it is expected that some additional items (*i.e.* Chlorophyll a, T-P, T-N, DO) will be adopted as mandatory parameters according to the new manual (2010) at each laboratory.

Selection of Sampling Sites

According to the technical manual (2010), the lakes chosen for monitoring should be harmonic type lakes, preferably with depths of approximately 10 m or less, a water residence time of 1 year or less, an area of 1

ha or more, with low alkalinity and electric conductivity, minimal anthropogenic water pollution and no coverage of the surface with aquatic organisms. If appropriate lakes are not available, rivers (streams) that are potentially susceptible to acidification and have little artificial influence should be selected.
For the monitoring sites, it is desirable to locate in nature protection areas, and human activities such as deforestation, and cultivation should be few and far between in the upstream area.

Field Operation

Surface water is sampled at one location at the center of the lake or river. In principle, measurements of pH and electric conductivity (EC) are conducted at the site before a more precise measurement is taken in the laboratory. Water samples for further analyses are kept

Cambodia has started the monitoring of inland aquatic environment from June 2011 , named SRAS SRANG at KIRIRUM national Park, Kampong Speu province, about 110 km from Phnom Penh city (11° 19' N104° 03' E) , water sample take 2 times a year , monitoring items : Temperature, Alkalinity, pH, EC, SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{2+}, Mg^{2+}.

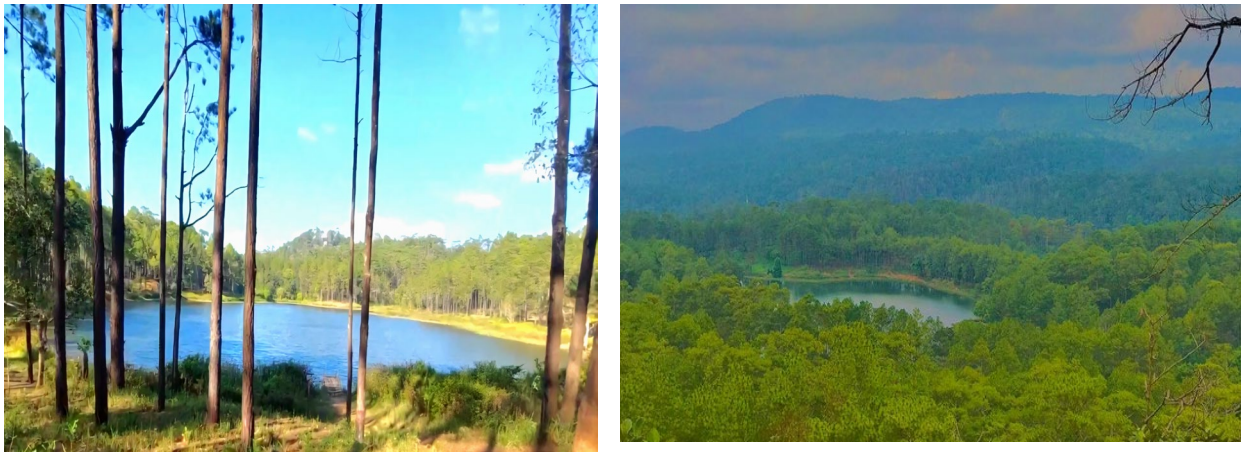


Figure 1.2.5.1. Picture of inland aquatic environment : Srash Srang Lake

Chapter 2. State of Acid Deposition in Cambodia

2.1 State of wet deposition

Acid deposition, more commonly known as acid rain, occurs when emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X) react in the atmosphere (with water, oxygen, and oxidants) to form various acidic compounds. These acidic compounds then fall to earth in either a wet form (rain, snow, and fog) or a dry form (gases, aerosols, and particles). Prevailing winds transport the acidic compounds hundreds of miles, often across state and national borders. At certain levels the acidic compounds, including small particles such as sulfates and nitrates can cause many negative human health and environmental effects.

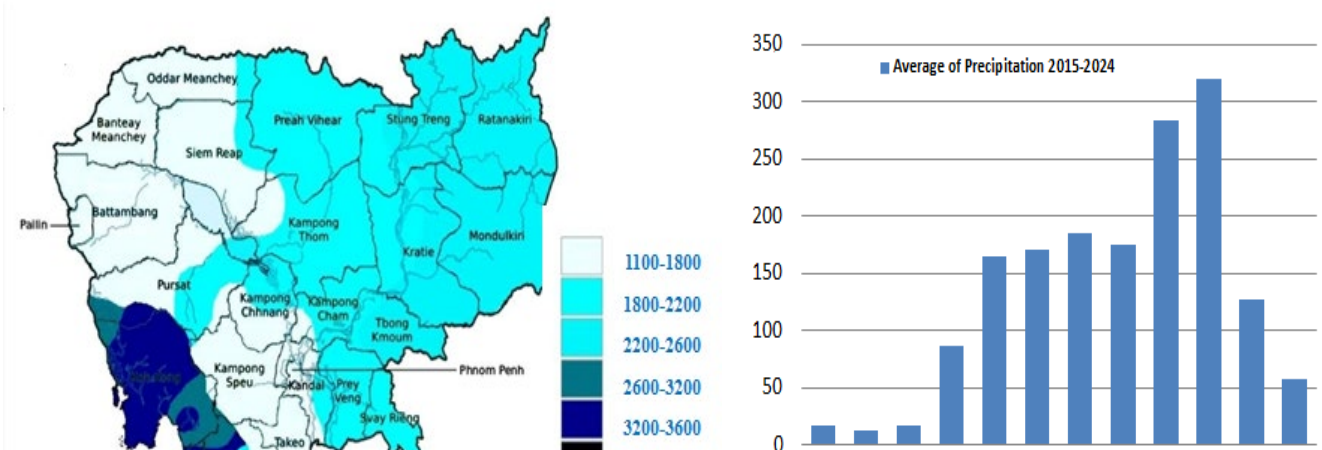


Figure 2.1.1. Picture of Precipitation by Provinces in mm (mm).

Figure 2.1.2. Average monthly precipitation in Phnom Penh 2015-2024

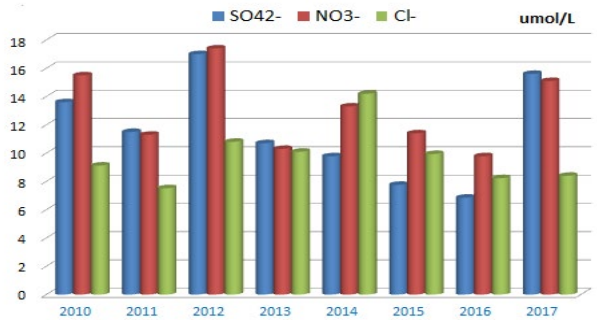
Figure 2.1.1: This image is a thematic map showing the annual precipitation (rainfall) levels by province in Cambodia. The rainfall is measured in millimeters (mm) and is color-coded from light to dark to represent different ranges.

1.The High Rainfall Zones (Dark Blue to Black): The coastal and southwestern mountainous areas of Cambodia receive the highest amount of rainfall by far. Highest Rainfall (>3600 mm): Indicated by the black patch at the southernmost tip, near Kampot and Preah Sihanouk. Very High Rainfall (3200-3600 mm): The deep dark blue color covers the coastal province of Koh Kong and parts of Preah Sihanouk and Kampot. This is due to the Cardamom Mountains trapping monsoon winds coming from the Gulf of Sea.

2. The Moderate to High Rainfall Zones (Teal and Cyan) : (2600-3200 mm) (Teal): Surrounds the ultra-wet coastal regions, touching parts of Pursat and Kampot. (1800-2600) mm (Bright Cyan/Light Blue): This covers the vast majority of northern, eastern, and northeastern Cambodia. Provinces like Preah Vihear, Stung Treng, Ratanakiri, Mondulkiri, Kratie, and Kampong Thom fall into this category, receiving a robust amount of seasonal rain.

3. The Low Rainfall Zones (White / Pale Blue) : The central plains and northwestern regions receive the least amount of rain in the country. Lowest Rainfall (1100-1800 mm): Represented by the white/pale areas. This spans across the central lowlands and parts of the northwest, including Banteay Meanchey, Battambang, Siem Reap, Oddar Meanchey, Kampong Speu, Takeo, Kandal, and Phnom Penh. These areas sit somewhat in a rain shadow or away from the immediate path of heavy coastal monsoon winds.

Figure 2.1.2 : The chart depicts the average monthly precipitation levels over a decade (2015–2024). It illustrates a strong seasonal weather pattern, characteristic of regions with distinct dry and wet seasons (such as tropical monsoon climates).



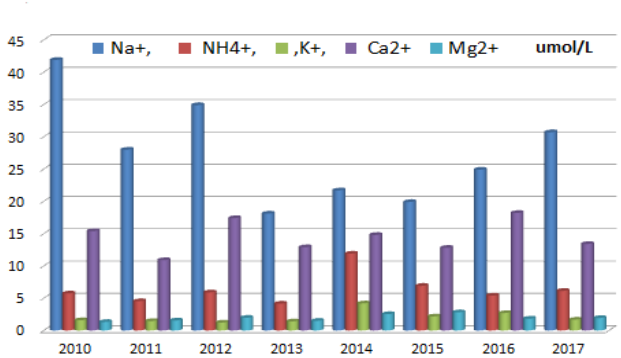


Figure 2.1.3. Average yearly concentration of Wet (Anion) .

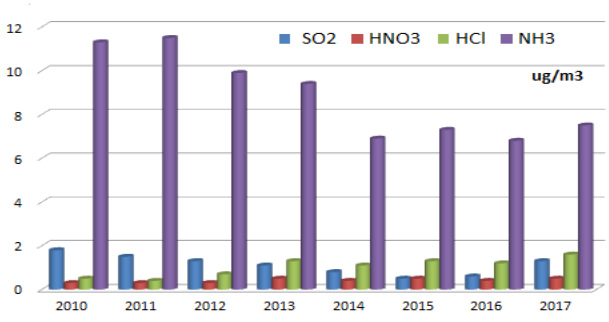


Figure 2.1.4. Average yearly concentration of Wet (Cation)

2.2 State of Dry Monitoring

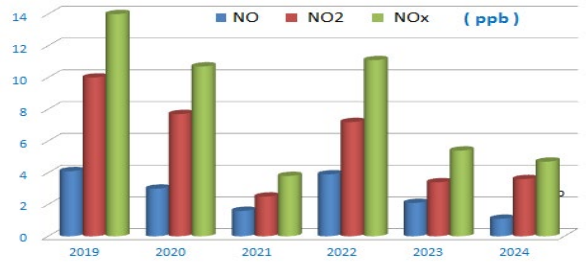


Figure 2.2.1. Average yearly concentration of dry (ug/m^3).

Figure 2.2.2. Average yearly concentration of dry (ug/m^3)

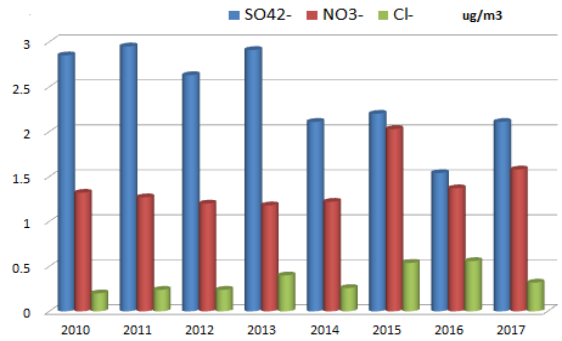


Figure 2.2.3. Average yearly concentration of dry (ug/m^3)

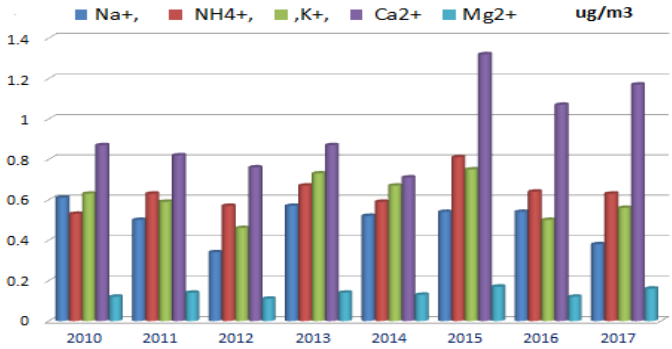


Figure 2.2.4. Average yearly concentration of dry (Cation) (ug/m^3)

2.3 State of inland aquatic environment Monitoring

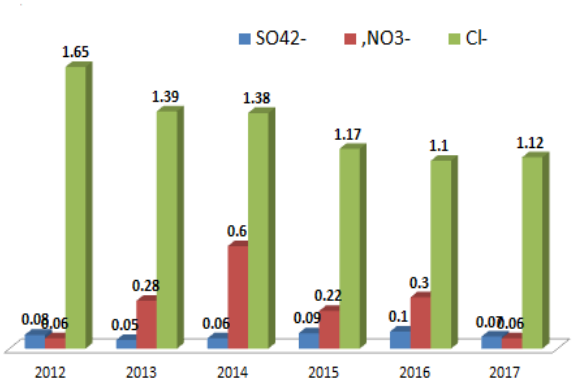


Figure 2.3.1. Average yearly concentration of inland (Anion)

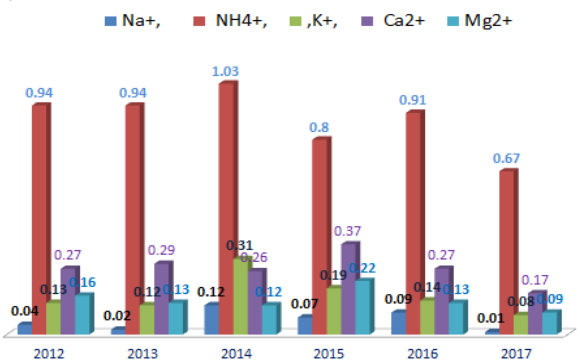
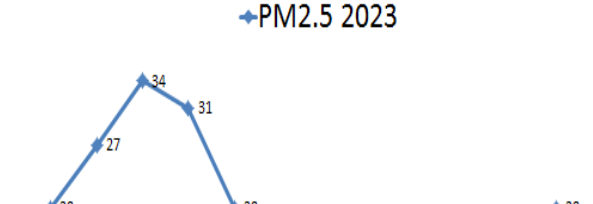


Figure 2.3.2. Average yearly concentration of inland (Srah Srang)

2.4 State of PM 2.5 Monitoring



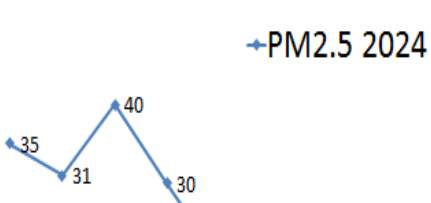


Figure 2.4.1. Monthly Concentrations of PM2.5 2024. Figure 2.4.2. Monthly Concentrations of PM2.5 2023.

Figure 2.4.1 and Figure 2.4.2 : This graph focuses specifically on the monthly PM 2.5 of air concentrations levels for the year 2023 and 2024, measured in micrograms per cubic meter ug/m^3).
In 2023 and 2024, the air quality followed a classic seasonal cycle: highly concentrations dry season months (averaging over 30 ug/m^3) followed by a highly stable, clean summer and early autumn (averaging around 12-13 ug/m^3).

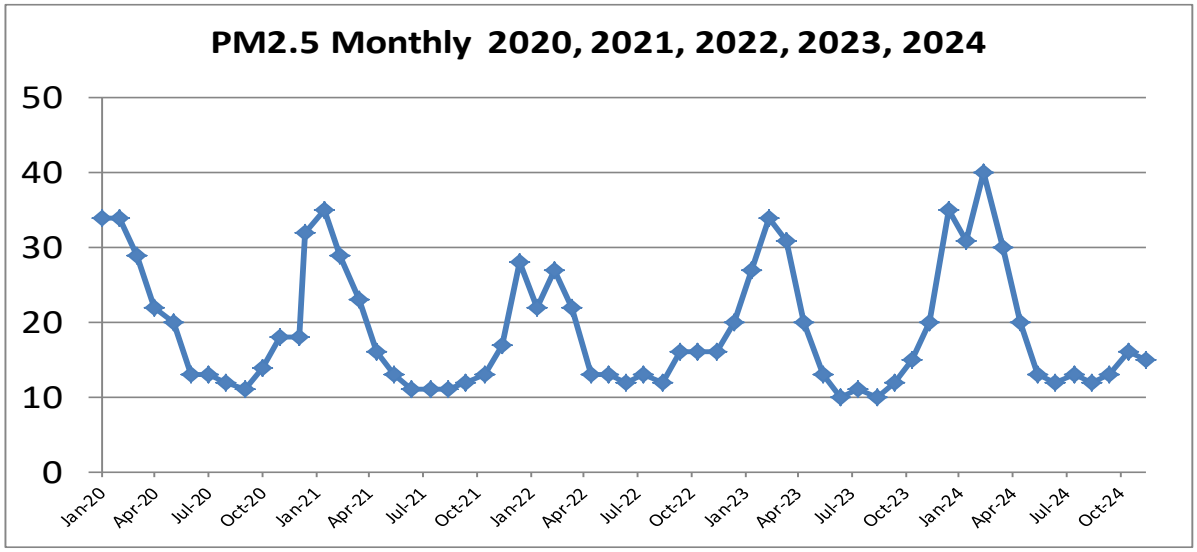


Figure 2.4.3. Monthly Concentrations of PM 2.5 2022-2024.

This timeline graph shows a continuous monthly tracking of PM 2.5 air pollution levels over a three-year period running from January 2022 through December 2024.

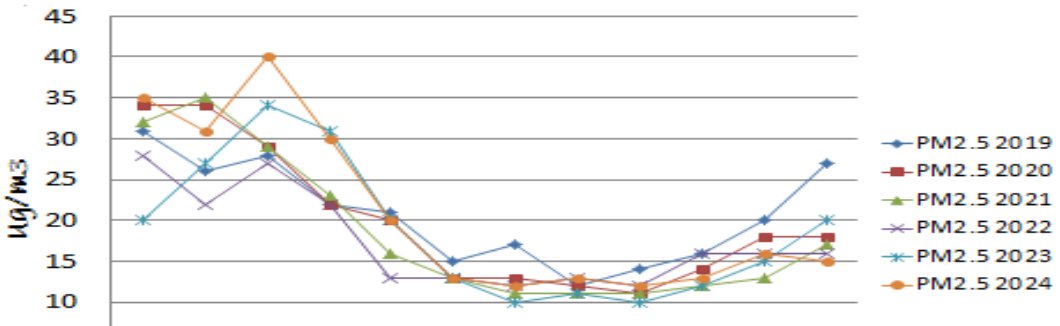


Figure 2.4.4. Monthly Concentrations of PM 2.5 2019-2024.

This line graph tracks monthly PM 2.5 air pollution levels (measured in micrograms per cubic meter, or ug/m^3) across six different years: 2019 through 2024.

High Concentrations (dry season): Concentrations levels are at their highest from January to April. During these months, values generally hover between 20 and 40 ug/m^3.

Low Concentrations (rainy season): Levels drop significantly starting in May and remain at their lowest from June to September, flattening out between 10 and 15 ug/m^3.

2.5 State of Ozone (O3) Monitoring

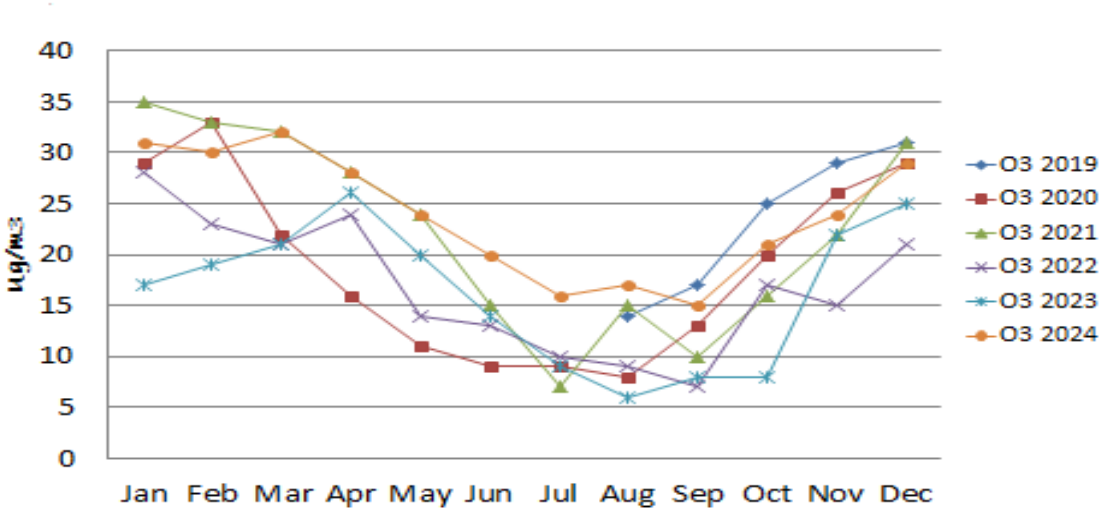


Figure 2.5.1. Monthly Concentrations of O_3 2019-2024

This graph tracks the monthly levels of Ozone (O_3) pollution, measured in micrograms per cubic meter (ug/m^3), from 2019 through 2024.

In short, this location experiences its worst ozone pollution during the cold months (December to February) and enjoys its cleanest air during the late summer (July to September). 2023 was the most unusual year due to its slow start, while 2024 was generally a "polluted" year where summer ozone didn't drop as low as usual.

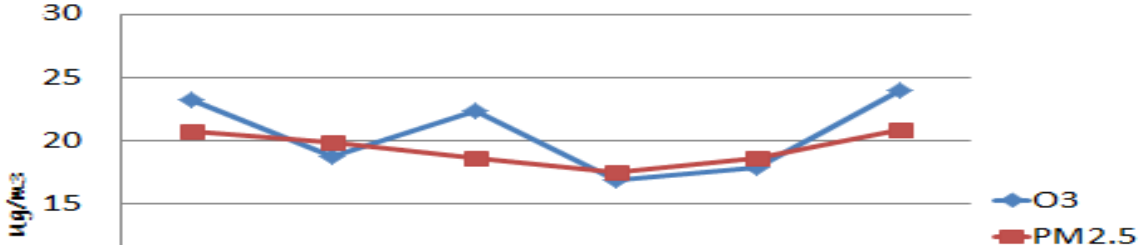


Figure 2.5.2. Yearly Concentrations of PM 2.5 and O_3 2019-2024

This line graph compares the annual average levels of two major air pollutants—Ozone (O^3) in blue and PM 2.5 in red—measured in micrograms per cubic meter (ug/m^3) over a six-year period from 2019 to 2024. Overall, this graph shows that after a period of general air quality improvement that bottomed out with very clean air in 2022, pollution levels for both PM 2.5 and Ozone have unfortunately rebounded sharply through 2023 and 2024.

Chapter 3. Conclusion & Executive Summary

1. Executive Overview

Since joining the Acid Deposition Monitoring Network in East Asia (EANET) in 2001, Cambodia has established a multi-parameter environmental monitoring framework across both urban (Phnom Penh) and baseline ecosystems (Sras Srang, Kirirom National Park).

While long-term observations indicate that Cambodia's ecosystems currently show no severe signs of ecological acidification, ambient air pollution in urban centers—specifically fine particulate matter PM 2.5 and surface ozone O^3 presents an emerging environmental and public health challenge that requires targeted policy interventions.

2. Core Findings

A. Ecosystem Resilience

- No Immediate Acidification Crisis: Multi-year chemical monitoring at the remote baseline site (Sras Srang Lake) indicates that direct, adverse ecological impacts—such as critical soil acidification or severe loss of aquatic alkalinity—have not yet manifested.

B. Strong Tropical Monsoon Influence

- Spatial Rainfall Variation: Precipitation amounts range drastically across regions, from extreme coastal monsoon zones (3,600 mm) to drier central plains (1,100 - 1,800 mm).
- Seasonal Pollutant Cycles: Atmospheric pollutant levels follow a distinct weather-driven cycle:
    - Dry Season (Jan–Apr / Dec–Feb): Concentrations peak sharply (PM 2.5 > 30 ug/m^3) due to agricultural biomass burning, transboundary atmospheric transport, and lower wet-deposition removal.
    - Wet Season (Jun–Sep): Pollutant levels drop to baseline levels (10 - 15 ug/m^3) due to heavy precipitation washout.

C. Recent Pollution Rebound (2022–2024)

- Post-2022 Surge: After achieving favorable air quality lows around 2022, annual concentrations of both PM 2.5 and surface O^3 rebounded significantly across 2023 and 2024.

- Primary Drivers: Rapid urbanization, increased motor vehicle density, industrial expansion, and seasonal open burning are offsetting prior air quality gains.

3. Executive Summary Matrix

Monitoring Area	Current Status	Primary Risk Factors	Strategic Priority
Wet & Dry Deposition	Stable baseline levels	Regional transboundary precursor gases (SO_2, NOx)	Continuous monitoring via upgraded laboratory standards
Inland Aquatic Systems	Healthy / Non-acidified	Catchment land-use changes	Expand monitoring to include biological indicators (e.g., chlorophyll *a*)
Ambient Air (PM 2.5 & O^3)	Rebounding / High seasonal risk	Vehicular emissions & seasonal agricultural open burning	Strict dry-season enforcement & updated emissions standards

4. Strategic Action Roadmap

Key Policy Priorities

1. Regulatory Frameworks: Modernize national ambient air quality regulations, set stricter industrial emission standards, and enforce higher fuel quality specifications.
2. Monitoring Infrastructure: Expand multi-parameter testing for inland aquatic systems and upgrade analytical laboratory capabilities in accordance with EANET's updated technical guidelines.
3. Targeted Seasonal Interventions: Establish cross-sectoral task forces to enforce strict bans on agricultural open burning and control high-emitting vehicles during high-risk dry season months (December through April).