2. Monitoring Data Quality

2.1. Introduction

EANET monitoring covers four environmental items – air concentration/dry deposition and wet deposition of atmospheric environment-related substances, soil and vegetation, and inland aquatic environment. Monitoring of air concentrations is implemented in order to evaluate the state of air pollution or air quality and that of wet and dry deposition is conducted to evaluate fluxes of atmospheric environment-related substances to the land surface through measuring gaseous pollutants, atmospheric aerosols, and chemical composition of precipitation, while monitoring for soil/vegetation and inland aquatic environment is carried out to assess adverse impacts on terrestrial and aquatic ecosystems.

In order to create a common understanding of the state of the atmospheric environment based on EANET monitoring data, it is essential that the reliability and comparability of the monitoring data be maintained. Such reliable and comparable monitoring data are also necessary to provide a sound basis for decision-making at the local, national, and regional levels aimed at preventing or reducing adverse environmental impacts caused by atmospheric environment-related substances. Furthermore, EANET monitoring data are also required to be comparable with those from leading monitoring networks worldwide and to meet the quality standards necessary for use in data analysis and model validation by researchers and experts around the world. This requires Quality Assurance (QA) and Quality Control (QC) to be implemented appropriately and on a continuous basis.

Against this background, the EANET produced four QA/QC programs (Wet Deposition, Air Concentration, Soil and Vegetation, Inland Aquatic Environment) in 2000. Then, the Technical Manuals for Wet Deposition Monitoring, Air Concentration Monitoring, Soil and Vegetation Monitoring, and Inland Aquatic Environment Monitoring described QA/QC matters (EANET, 2010a, 2010b, 2010c, 2010d, 2010e, 2013, and 2022). The QA/QC programs are composed of several procedure types: i) siting, ii) sampling procedures and sample handling, iii) chemical analysis, and iv) QA/QC for the measurement data at each site (EANET, 2016). These documents have been developed by EANET to guide receiving reliable data that can be comparable among the participating countries as well as with other monitoring networks outside of the East Asian region. The QA/QC programs cover activities for the components of the measurement/analysis system in a general way, i.e., in the field (sampling sites), laboratory, data management, and data reporting processes. Each National Center of the EANET participating countries needs to execute various QA/QC activities, including development of national QA/QC programs, standard operating procedures (SOPs) and satisfaction of the data quality objectives (DQOs). According to EANET documents, QA/QC activities are documented by each relevant entity. General procedures of QA/QC are described in Section 2.2.

Inter-laboratory comparisons are also an effective means of maintaining and improving the analytical performance of monitoring networks. The EANET is conducting the Inter-laboratory Comparison (ILC) Project among the analytical laboratories in participating countries based on the QA/QC program of the EANET for air concentration/dry deposition, wet deposition, soil, and inland aquatic environment monitoring. The purposes of this project are to evaluate the analytical systems through the evaluation of analytical results, analytical instruments and their operating condition and other relevant and appropriate practices. The ILC Projects of the EANET is introduced in Section 2.3.

Quality checks of monitoring data are, in principle, conducted under the leadership of the QA/QC Manager in each participating country. All monitoring data are collected at the Network Center (NC) of EANET and subject to a further verification process. The evaluation of the measurements is explained in Section 2.4.

Finally, conclusion and recommendations are summarized in Section 2.5.

2.2. General procedures of QA/QC

2.2.1 Preparation of National Monitoring Plan

National Monitoring Plan (NMP) includes information on monitoring sites, monitoring methods, monitoring frequency etc. in participating countries. The format of NMP consists of following items:
1) Information on established monitoring sites and their arrangement;
2) Measurement programs including sets of parameters and monitoring interval;
3) Metadata on participating laboratories for each field of monitoring activities, and;
4) Geoinformation on the respective monitoring sites with their scale maps.

This information is crucial for QA/QC activities in the EANET. First summarization of the NMP was prepared in November 2001. Every participating country of EANET has been required to prepare its NMP in accordance with the "Data Reporting Procedures and Formats for Acid Deposition Monitoring in East Asia". The NC has prepared the template for the NMP (https://www.eanet.asia/wp-content/uploads/2019/04/QAQC_Guidebook2016.pdf) as the part of the QA/QC Guidebook for Acid Deposition Monitoring Network in East Asia -2016 (EANET, 2016; https://www.eanet.asia/wp-content/uploads/2019/04/QAQC_Guidebook2016.pdf). The NMPs were prepared by participating countries after starting regular phase and have been reviewed every year with possible revision, if necessary.

The updating of information or making NMP actual to current national monitoring activities is under the responsibility of QA/QC Manager and NFP of country. All relevant information is prepared and discussed with the NC at the annual Senior Technical Managers' (STM) meeting. In addition, effective data management is essential for integrating monitoring data across the network, summarizing and aggregating the datasets, comparing them with those from other monitoring networks, and incorporating recommendations from the Scientific Advisory Committee (SAC).

2.2.2 Siting

EANET monitoring sites are classified into two basic categories according to types of measurement programs, namely, air concentration/acid deposition monitoring sites and ecological survey sites. Air concentration/acid deposition monitoring sites are operating bodies collecting fundamental data on air concentrations and wet acidified deposition to investigate its temporal and spatial distribution, They are classified into 3 sub-categories: remote sites, rural sites and urban sites with some differences in the objectives of the monitoring. Ecological survey sites are those that provide basic data for assessing the effects of air concentration and acidification on terrestrial ecosystems, and they are principally classified into 2 sub-categories: survey sites and ecosystem analysis sites. The criteria used for classification of the sites are listed in Table 2.2.1.

Table 2.2.1. Classification of monitoring sites.

Site Category	Site Classification	Main Purpose and Siting Criteria
Air concentration/ Acid Deposition Monitoring Site for wet deposition and dry deposition monitoring	Urban Site	- Assessment of the state of air concentration and acid deposition in urban areas - Data can be used for evaluation of air concentration and acid deposition effects on buildings and historical monuments or human health. - Urban and industrial areas, and the areas immediately outside the urban area
	Rural Site	- Assessment of the state of air concentration and acid deposition in rural areas and/or hinterlands - Data can be used for the evaluation of air concentration and acid deposition on agricultural crops, forests, etc. - More than 20 km away from large pollution sources like cities, power plants and highways.
	Remote Site	- Assessment of the state of air concentration and acid deposition in background areas - Data can be used for evaluation of long-range transport and deposition models. - More than 50 km away from large pollution sources like cities, power plants and highways - More than 500 m away from main roads (less than 500 vehicles per day)
Ecological Survey Site for soil and vegetation monitoring and Inland aquatic monitoring	Basic survey site	- Accumulation of basic data on soil, forest, and inland aquatic environment and disclose trends in their properties - In the vicinity of the air concentration and acid deposition monitoring site
	Ecosystem analysis site	- Assessment of air concentration and acid deposition impacts on whole ecosystem through application of terrestrial ecosystem analysis and/or catchment analysis - Sensitive areas to changes in atmospheric acidity and ecologically conserved area

Generally the siting criteria of atmospheric deposition monitoring correspond to those been recommended by WMO-GAW (WMO, 2004) and EMEP (EMEP, 2001) for their design of the measurement networks on precipitation chemistry.

2.2.3 Sampling and sample handling

The sampling has been carried out according to the monitoring manuals for each monitoring category. Especially for the collected wet deposition samples, dry monitoring samples using the filter pack method, and inland water samples, samples are stored in the refrigerator or added a biocide such as thymol to prevent deterioration or at least minimize possible conversion of the chemical species in the collected sample before chemical analysis. The collected soil samples are air-dried, sieved and then stored in cool and dark places before the analysis.

2.2.4 Chemical analysis

The major ions, hydronium ion (H^+, as pH), ammonium ion (NH_4^+), calcium ion (Ca^{2+}), potassium ion (K^+), magnesium ion (Mg^{2+}), sodium ion (Na^+), sulfate ion (SO_4^{2-}), nitrate ion (NO_3^-), chloride ion (Cl^-) in the collected water samples are analyzed. Alkalinity as an indicator for acid neutralizing capacity is also analyzed in the inland water samples, while exchangeable cations, including Ca^{2+}, Mg^{2+}, K^+, Na^+, H^+, and Al^{3+}, are analyzed in the soil samples. The operation manuals for each monitoring categories provide several acceptable analytical techniques to be applied in the laboratories of the participating countries.

2.2.5 QA/QC procedure prior to the data submission to the national and network center

The quality of the chemical analysis was evaluated in terms of ion balance and conductivity checks. The evaluation was quantified as R_1 and R_2 as defined below (WMO, 2004; EANET, 2010).

$$R_1 = \frac{(C - A)}{(C + A)} \times 100\ (\%) \qquad R_2 = \frac{(\Lambda_{obs} - \Lambda_{calc})}{(\Lambda_{obs} + \Lambda_{calc})} \times 100\ (\%)$$

where the symbols are defined as below and the symbols of the ion denote their concentration on an equivalent basis, and λ is the molar conductivity of the individual ion at infinite dilution at 25℃.

$$C = [H^+] + [NH_4^+] + [Ca^{2+}] + [K^+] + [Mg^{2+}] + [Na^+]$$
$$A = [SO_4^{2-}] + [NO_3^-] + [Cl^-]$$
$$\Lambda = \lambda_{H+}[H^+] + \lambda_{NH4+}[NH_4^+] + \lambda_{Ca2+}[Ca^{2+}] + \lambda_{K+}[K^+] + \lambda_{Mg2+}[Mg^{2+}] + \lambda_{Na+}[Na^+] + \lambda_{SO42-}[SO_4^{2-}] + \lambda_{NO3-}[NO_3^-] + \lambda_{Cl-}[Cl^-]$$

The acceptable ranges for R_1 and R_2 are defined as a function of the concentration sums of the analytical suites and presented in Table 2.2.2. Λ_{obs} indicates the measured value of the electrical conductivity of the sample. When the value of either R_1 or R_2 does not meet the criteria, the samples are supposed to be a subject of reanalysis as well as more detailed examination of all analytical procedures is involved. Then, it is also recommended that some ionic species including hydrogen carbonate, HCO_3^-, or organic acids should be added to the analytical suites or the criteria should be modified as a function of pH. The acceptable ranges are encouraged to be revised in consideration of the ionic composition and concentration levels as well as the present state of arts of the analytical laboratories.

Table 2.2.2. Required criteria of analysis quality by R_1 and R_2

(C + A), μeq L^{-1}	R_1, %	Λ_{obs}, mS m^{-1}	R_2, %
< 50	±30	< 0.5	±20
50–100	±15	0.5–3	±13
> 100	±8	> 3	±9

Figure 2.2.1 demonstrates the annual percentages of the data that satisfied with the criteria for ion balance (R_1) and conductivity (R_2) at each EANET monitoring site from 2020 to 2024. For R_1 values, some sites in China, Indonesia, Japan, Lao PDR, R. of Korea, Russia and Vietnam well satisfied the criteria. On the other hand, many sites in Southeast Asia did not meet these criteria for some reasons (e.g., equipment malfunction, unintentional contamination, unanalyzed ionic species such as organic acids may be included in precipitation samples). For R_2 values, some sites in China, Indonesia, Japan, Malaysia, R. of Korea, Russia, and Vietnam well satisfied the criteria. However, the data from other countries did not satisfy completely the criteria with the same reason as of R_1.

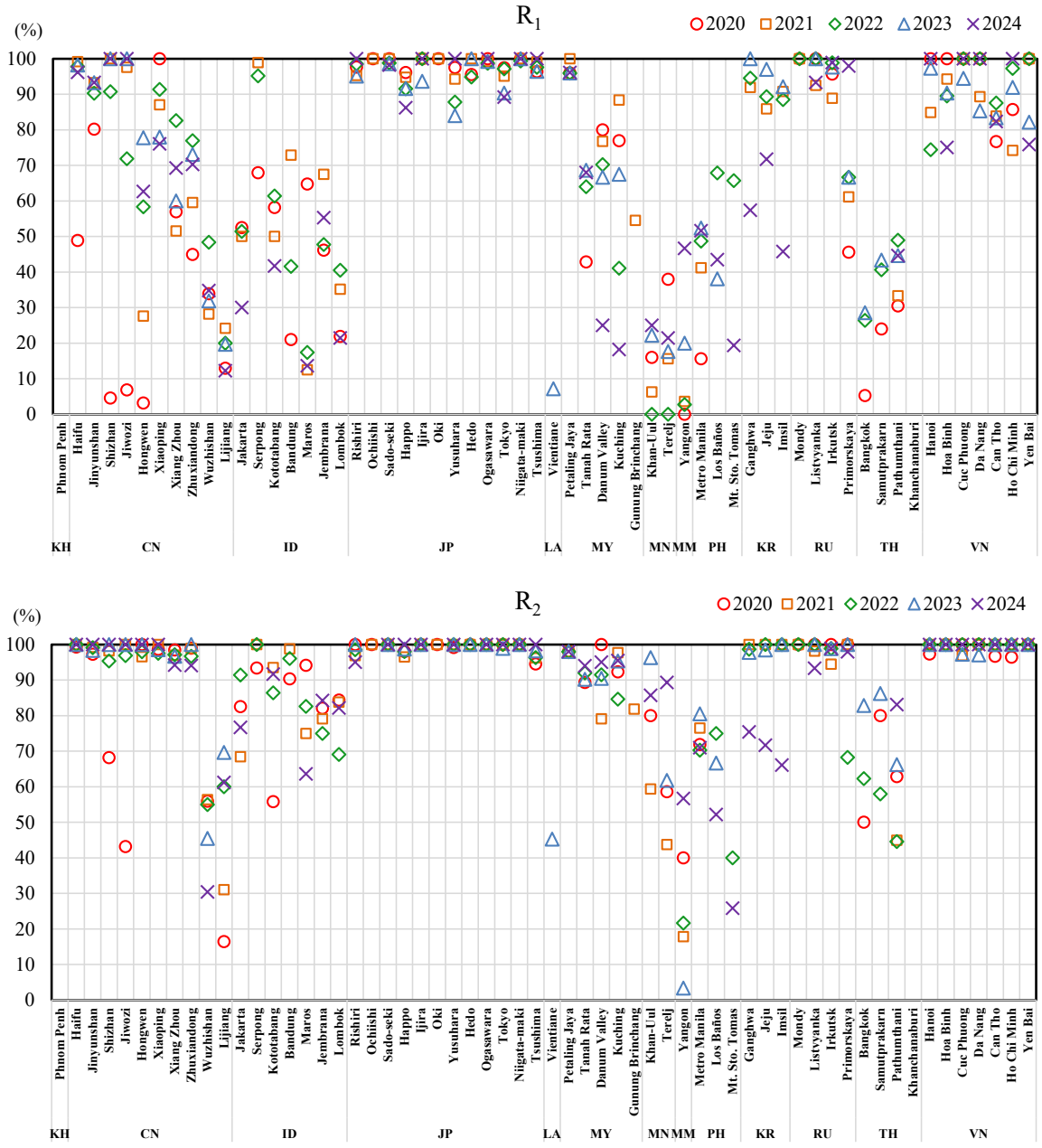


Figure 2.2.1. Annual percentage of the (precipitation chemistry) data that satisfied with the criteria for ion balance (R_1) and conductivity (R_2) from 2020 to 2024.

Note: The acronyms indicate each of the participating countries as follow: KH, Cambodia; CN, China; ID, Indonesia; JP, Japan; LA, Lao PDR; MY, Malaysia; MN, Mongolia; MM, Myanmar; PH, Philippines; KR, R. of Korea; RU, Russia; TH, Thailand; VN, Vietnam

2.3. Evaluation of the Inter-Laboratory Comparison Projects

Chemical analysis and evaluation of the analytical performance (as the part of QA/QC procedures) with help of ILC are very important for the data quality of EANET. It has being done annually since 1998 by starting on wet deposition (from the preparatory phase of the EANET) in order to improve the QA/QC of the network as a whole. There are different activities on analyzing media in the ILC Projects, i.e., on wet deposition, dry deposition, soil, and inland aquatic environment.

The ILC project of EANET is a well-designed world-wide approach of the round-robin test performed with a common sets of simulated water (artificial rainwater or surface water) or unified common samples in all analytical laboratories for the EANET monitoring. The purpose of this project is to evaluate the analytical systems through the evaluation of analytical accomplishments, analytical instruments and their operating condition and other relevant and appropriate practices. Particularly emphasis is placed on the issues: (i) to recognize the analytical precision and accuracy of the measurement of each laboratory, and provide an opportunity for the laboratories to improve the quality of the chemical analysis of wet deposition samples, and (ii) to improve reliability of analytical measurements through assessing the relevant techniques.

Throughout the ILC project, the outlier data and the actual procedure in each participating laboratory have been evaluated using artificial rainwater sample for wet deposition monitoring, artificial filter sample for the dry deposition monitoring with filter pack method, actual soil sample for soil monitoring and artificial inland water sample for the inland aquatic environment monitoring.

2.3.1 Wet deposition

The ILC surveys were conducted 27 times between 1998 and 2024. During this period, 21 to 37 laboratories from 13 countries participated. Figure 2.3.1 presents a summary of the number of participating laboratories and the available data for each survey.

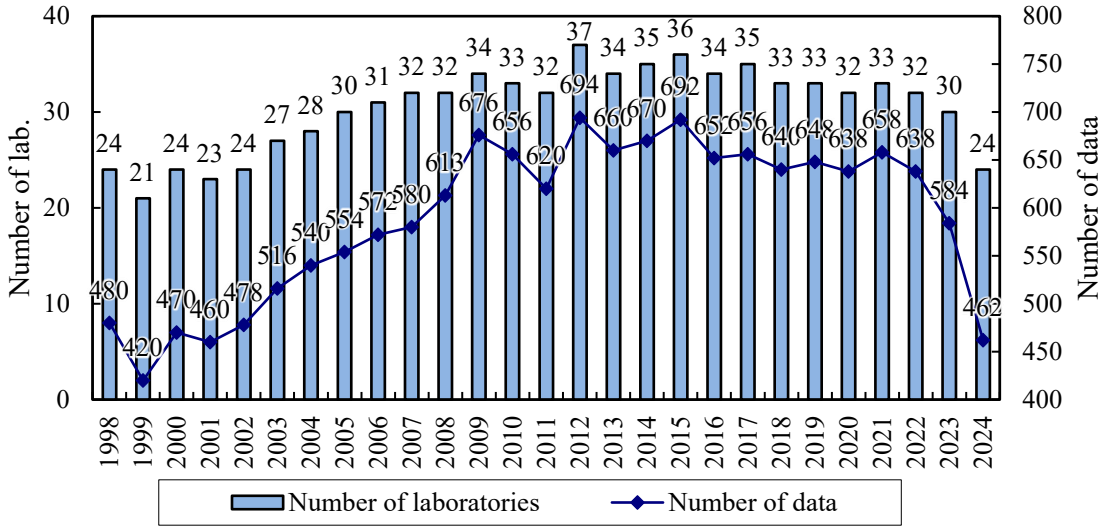


Figure 2.3.1. Number of participating laboratories and the number of data in the Inter-Laboratory Comparison Project on wet deposition for 1998-2024.

Two kinds of artificial rainwater samples of different levels of concentrations, higher and lower, were prepared by the NC to include all ions of analytical suites with the distribution of these samples to the participating laboratories at the end of every year.

The samples required to be diluted 100 times prior to analysis. Measurement of pH and electronic conductivity (EC), and determination of the concentrations of SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+. Analytical results were submitted to the NC to summarize and review the results by comparing to the prepared values and further by carrying out some statistical analysis. The well-established design and format of the annual "Report of the Inter-Laboratory Comparison Project" includes all received analytical results, laboratory codes and statistical descriptions together with the lists of the participating laboratories in countries (EANET, 2024). The values of concentrations in the artificial rainwater samples from the 1st attempt (1998) to the 27th attempt (2024) were summarized in Table 2.3.1.

Table 2.3.1. The prepared values of each parameter in artificial rainwater for Inter-Laboratory Comparison project of EANET.

year/sample #		pH	EC ($mS\ m^{-1}$)	SO_4^{2-}	NO_3^-	Cl^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+
				($\mu mol\ m^{-1}$)							
1998	No.1	4.05	7.94	83.5	93.3	129	95.8	11.1	41.1	13.1	84.8
	No.2	4.51	2.82	29.1	36.1	45.1	33.5	7.42	14.3	4.6	29.5
1999	No.1	4.14	6.38	67	75.0	104	77.0	8.9	33.0	11.0	68.0
	No.2	4.59	2.30	24.0	27.0	38.0	28.0	3.2	12.0	3.8	25.0
2000	No.1	4.10	6.23	59.7	63.3	101.3	51.3	9.9	29.4	11.7	60.5
	No.2	4.85	1.55	20.1	27.5	15.5	8.7	4.9	11.0	7.8	18.2
2001	No.1	4.10	7.45	85.0	93.3	108.4	68.4	15.8	41.1	18.7	87.8
	No.2	4.82	1.76	21.5	19.4	34.4	27.4	4.00	13.2	3.7	16.7
2002	No.1	4.30	3.75	40.3	51.0	33.7	13.7	6.92	19.1	7.02	42.4
	No.2	5.15	0.69	8.88	8.49	9.13	5.13	1.98	6.6	1.75	4.54
2003	No.031	4.52	3.44	44.7	30.9	66.0	46.1	6.9	20.5	7.0	48.3
	No.032	4.80	1.48	12.0	21.3	29.6	25.6	2.5	4.4	3.4	15.1
2004	No.041	4.60	3.93	58.5	41.4	76.6	66.6	7.0	38.9	9.7	39.3
	No.042	5.00	1.33	17.5	18.4	22.4	20.5	5.0	10.0	2.7	15.1
2005	No.051	4.66	3.32	43.7	40.3	68.5	56.5	6.9	23.2	11.7	40.9
	No.052	5.05	1.05	14.4	13.2	15.3	10.3	3.0	7.6	3.1	13.6
2006	No.061	4.72	3.10	45.8	36.3	57.5	44.5	6.9	23.8	11.7	43.9
	No.062	5.15	1.21	16.9	15.0	24.5	20.5	4.9	9.3	3.5	15.1
2007	No.071	4.64	3.72	54.9	43.6	69.0	53.4	8.3	28.6	14.0	52.7
	No.072	5.00	1.47	14.0	21.0	38.8	30.8	4.9	6.4	7.0	15.1
2008	No.081	4.49	3.97	49.5	47.4	75.8	56.8	9.1	25.7	12.6	47.5
	No.082	5.10	1.18	14.7	16.2	23.4	15.4	3.8	7.6	6.2	14.2
2009	No.091	4.52	4.23	57.8	46.7	81.9	59.9	9.1	29.0	14.8	57.5
	No.092	4.92	1.66	19.9	22.0	34.0	24.0	5.9	9.3	7.0	21.2
2010	No.101	4.54	3.97	52.0	47.0	77.0	60.0	8.9	26.0	13.0	52.1
	No.102	5.06	1.25	16.6	14.4	24.7	20.7	2.8	8.1	3.3	17.0
2011	No.111	5.52	3.52	76.4	37.8	56.7	53.7	10.4	47.6	13.7	57.5
	No.112	4.60	2.16	23.7	20.8	35.4	20.4	2.3	9.1	4.3	29.2
2012	No.121	4.60	3.25	37.1	32.9	78.7	58.7	6.3	18.6	10.8	37.1
	No.122	5.10	1.31	9.7	21.6	40.4	40.4	2.5	5.6	5.6	8.3
2013	No.131	4.60	3.19	46.2	36.4	49.4	34.4	7.1	22.0	9.7	48.4
	No.132	5.10	1.02	14.4	17.3	11.6	9.6	3.1	9.1	4.1	10.6
2014	No.141	4.70	3.20	49.0	37.1	54.8	44.8	6.9	24.7	10.1	48.6
	No.142	5.00	1.39	22.1	17.0	18.0	14.0	3.2	9.9	3.9	24.4
2015	No.151	4.74	3.05	44.1	38.9	56.8	48.8	7.8	22.2	10.5	43.9
	No.152	5.15	0.94	11.9	10.7	19.8	12.8	3.2	7.0	3.7	9.8
2016	No.161	4.85	2.39	44.5	21.0	32.3	18.3	6.9	28.8	7.0	31.5
	No.162	5.30	0.67	10.2	8.4	8.5	6.5	1.7	3.7	1.8	13.0
2017	No.171	4.85	2.98	60.0	30.9	33.2	26.2	4.8	33.9	9.5	52.1
	No.172	5.15	1.03	18.1	11.0	12.6	9.6	1.8	13.1	2.6	10.1
2018	No.181	4.92	2.44	50.7	33.6	14.3	11.3	4.4	27.1	10.1	47.1
	No.182	5.40	0.87	17.2	9.2	9.5	7.5	2.3	7.1	2.5	20.1
2019	No.191	4.89	2.80	42.9	25.9	65.2	55.2	5.3	23.4	8.8	38.9
	No.192	5.46	0.86	17.6	13.0	6.6	5.1	2.6	12.4	4.2	10.4
2020	No.201	4.70	2.76	35.8	29.8	58.1	48.1	4.0	16.8	7.9	38.0
	No.202	5.30	1.09	18.5	15.8	15.4	15.4	3.6	10.2	3.6	16.6
2021	No.211	4.70	3.08	48.7	38.0	44.2	34.2	6.9	21.5	10.5	54.5
	No.212	5.22	1.20	20.6	13.6	18.9	13.9	4.1	9.3	4.3	22.7
2022	No.221	4.70	2.98	45.3	32.1	52.8	42.8	4.9	30.2	8.6	30.3
	No.222	5.15	1.13	14.5	13.1	25.5	20.5	2.5	7.0	4.3	15.1
2023	No.231	4.77	2.49	34.1	31.1	47.1	41.1	4.5	17.4	7.8	33.3
	No.232	5.22	1.02	13.2	14.1	21.8	18.8	1.8	6.4	4.7	13.6
2024	No.241	4.70	2.72	34.2	40.4	47.8	42.8	5.9	16.8	9.8	34.8
	No.242	5.10	1.16	11.7	15.6	29.7	25.7	3.8	6.4	3.9	10.6

The results of the analysis in the project were evaluated in terms of the exceedance of the DQOs values which had been prescribed in the EANET QA/QC program as a deviation of ±15% from prepared value for each analytical suite. The flag "E" was put to the data that exceed DQOs by a factor of 2 (±15%~±30%), and the flag "X" to the data exceeding DQOs by a factor of over 2 (<-30% or >30%). A set of the data for each sample was evaluated with the data checking procedures.

However, the room for improvement may be identified in the comparison with established DQO for other international measurement networks. The high quality targets are presented in Table 2.3.2 by the reference to requirement of regional WMO-GAW Precipitation Chemistry network and EMEP.

Table 2.3.2. Data quality objectives for precipitation chemistry analysis (accuracy in single analysis in laboratory).

Analyzed component in laboratory	DQO established for:	
	GAW-PC network (WMO, 2004)	EMEP network (EMEP, 2001)
pH	0.07 units	0.1 units
conductivity	7%	15 %
acidity	25%	15 %
sulfate	7%	10 %
nitrate	7%	10 %
ammonium	7%	15 %
chloride	10%	15 %
sodium	10%	15 %
potassium	20%	15 %
calcium	15%	15 %
magnesium	10%	15 %

It should be noted that DQO for the most of analyzed constituent in regional WMO-GAW PC laboratories are less in range of value accuracy, than in EANET, especially for the most interested compounds like oxidized sulfur and oxidized nitrogen. The similar limits (as in the EANET) were established in EMEP, but the relevant documents on EMEP measurement strategy proposed the changes of those criteria (EMEP, 2009).

It is also useful to consider the comparison of approach being used by different international intercomparison projects for evaluation of analytical results and network laboratories performance as well as an application of some interesting tool like Yudgen plots (NIVA, 2011) and ring diagrams (WDCPC, 2011).

The ILC surveys were carried out 27 times, and the overall percentages of flagged data, “E” and “X” respectively, are shown in Figure 2.3.2. The percentage of data within the DQOs increased from 75.4-78.3% in 1998 to 89.6-95.0% in 2024. The percentage of the flagged data, which may be related to the concentration levels of the artificial rainwater, has been generally decreasing toward the 27th attempt.

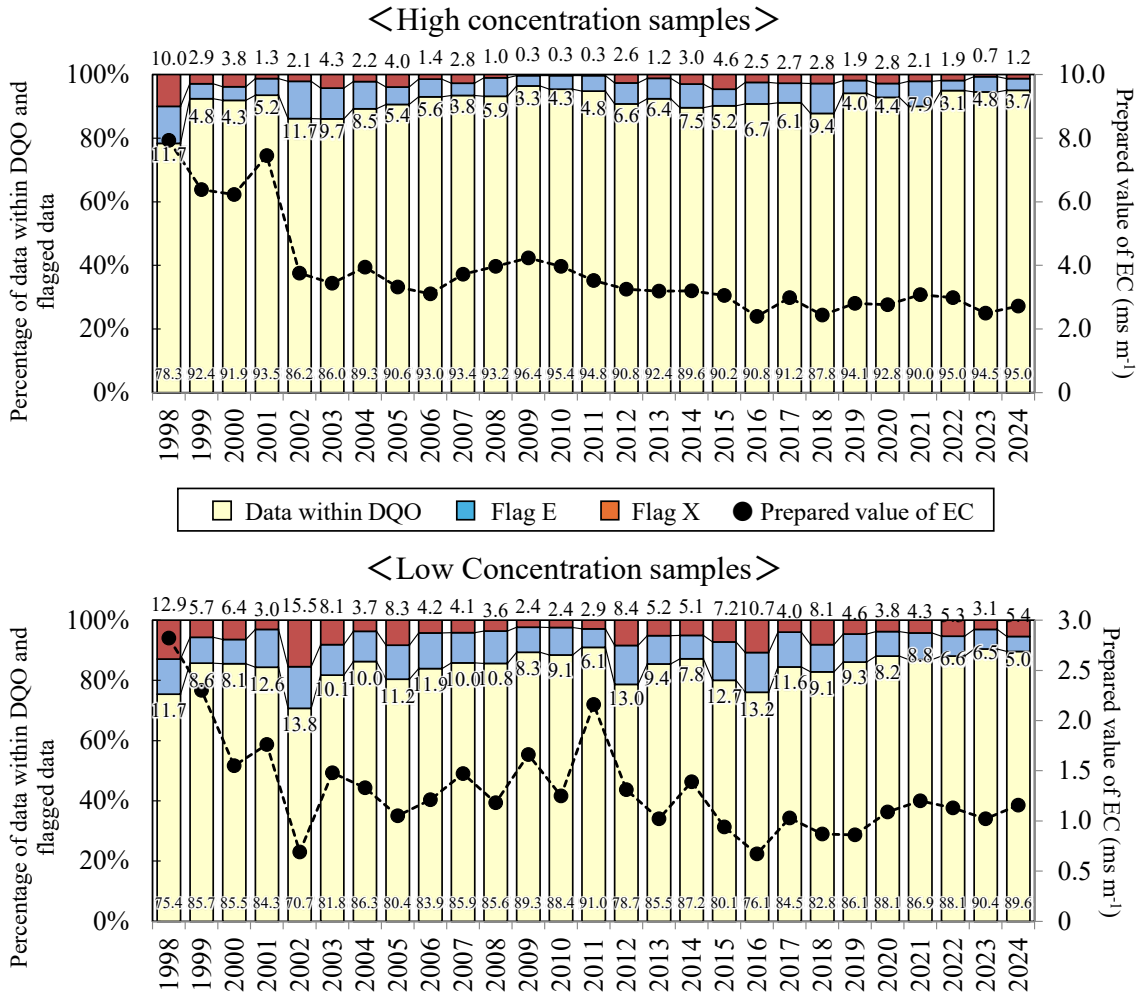


Figure 2.3.2. Overall comparisons of all Inter-Laboratory Comparison projects for wet deposition during 1998-2024.

2.3.2 Dry deposition

The ILC surveys on filter analysis were conducted 20 times between 2005 and 2024. The number of participating laboratories increased from 20 at the beginning of the program to a peak of 27 laboratories in 2015, and then gradually declined, reaching only 16 laboratories in 2024. Overall, participants from 13 countries have taken part in the surveys. s: Cambodia, China, Indonesia, Japan, Lao PDR, Malaysia, Mongolia, Myanmar, Philippines, Republic of Korea, Russia, Thailand and Vietnam. Figure 2.3.3 shows the number of participating laboratories in each year.

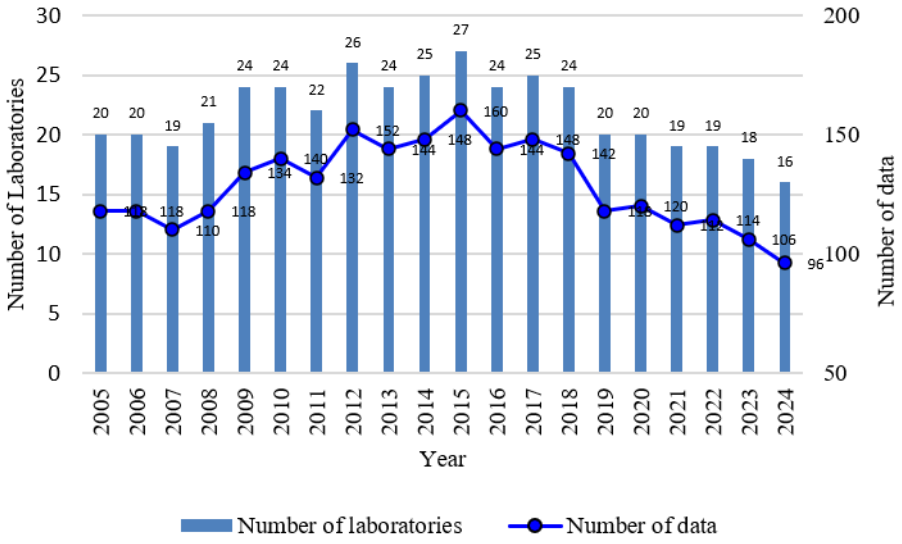


Figure 2.3.3. Number of participating laboratories the number of data in the Inter-Laboratory Comparison Project on dry deposition.

Two kinds of filter samples, one contained two ions ($SO_4^{2-}$and Cl^-), the other contained one ion (NH_4^+), were prepared and distributed to the laboratories. The blank filters, which were impregnated with K_2CO_3 or H_3PO_4 but did not contain any SO_4^{2-}, Cl^-, or NH_4^+, were also prepared and distributed these samples to the participating laboratories in October in each year. The preparation is correspondent to recommended procedure for the filter pack method described in "Technical Manual for Air Concentration Monitoring in East Asia" (EANET, 2013). Each filter sample was put in a centrifuge tube, a solvent was directly poured into the tube for extraction.

The prepared values of each parameter in the artificial filter samples from the 1st attempt in 2005 to the 20th attempt in 2024 are summarized in Table 2.3.3.

The DQOs of EANET are specified that determined values are expected for fall within ±15% deviation from the prepared values in *Technical Manual for Air Concentration Monitoring in East Asia* (EANET, 2013). Each laboratory analyzed each sample 3 times, and these average values are evaluated based on the deviation from the corresponding prepared values. A flag E indicates that its deviation exceeds ±15% but not ±30%, and a flag "X" indicates that its deviation exceeds ±30%.

The ILC surveys were carried out 20 times, and the overall percentages of flagged data, "E" and "X" respectively, are shown in Figure 2.3.4. The percentage of data within the DQOs slightly increased from 73.2% in 2005 to 75.0% in 2024 for small quantity samples and decreased from 80.4% in 2005) to 77.1% in 2024 for large quantity samples.

The relative standard deviations were varied. This variation was considered that the difference of the extraction procedure caused the variation of the results among the participating laboratories.

Table 2.3.3. The prepared values of each parameter in the artificial filter samples from the 1st attempt (2005) to the 20th attempt (2024) for Inter-Laboratory Comparison project of EANET.

year/sample #		SO_4^{2-}	Cl^-	NH_4^+
		(μg)		
2005	No.051	25	2.8	5.3
	No.052	70	30	20
2006	No.061	40	3.5	6.5
	No.062	140	40	50
2007	No.071	20	1.6	4.6
	No.072	80	25	30
2008	No.081	30	2.5	5.6
	No.082	110	32	35
2009	No.091	35	3.0	5.3
	No.092	120	38	40
2010	No.101	30	6.0	5.8
	No.102	90	27	45
2011	No.111	73	3.0	8.0
	No.112	110	32	26
2012	No.121	22	2.5	20
	No.122	170	11	70
2013	No.131	10	2.6	6.0
	No.132	70	13	40
2014	No.141	25	9.0	16
	No.142	65	21	43
2015	No.151	18	3.5	9.5
	No.152	74	14	51
2016	No.161	15	4.0	8.8
	No.162	54	15	46
2017	No.171	11	4.4	9.6
	No.172	61	13	54
2018*	No.181	30.0	3.61	12.0
	No.182	62.0	9.63	62.1
2019	No.191	7.02	3.02	9.45
	No.192	70.1	17.1	58.3
2020	No.201	8.25	3.42	8.82
	No.202	57.3	11.1	55.1
2021	No.211	9.55	2.83	11.1
	No.212	27.1	6.92	24.2
2022	No.221	11.8	6.82	24.4
	No.222	44.6	15.4	53.8
2023	No.231	10.0	5.02	18.1
	No.232	47.2	15.1	50.3
2024	No.241	16.0	7.61	26.0
	No.242	37.8	16.9	56.0

*Since Inter-laboratory Comparison Project 2018, the prepared values are officially disclosed 3 digits.

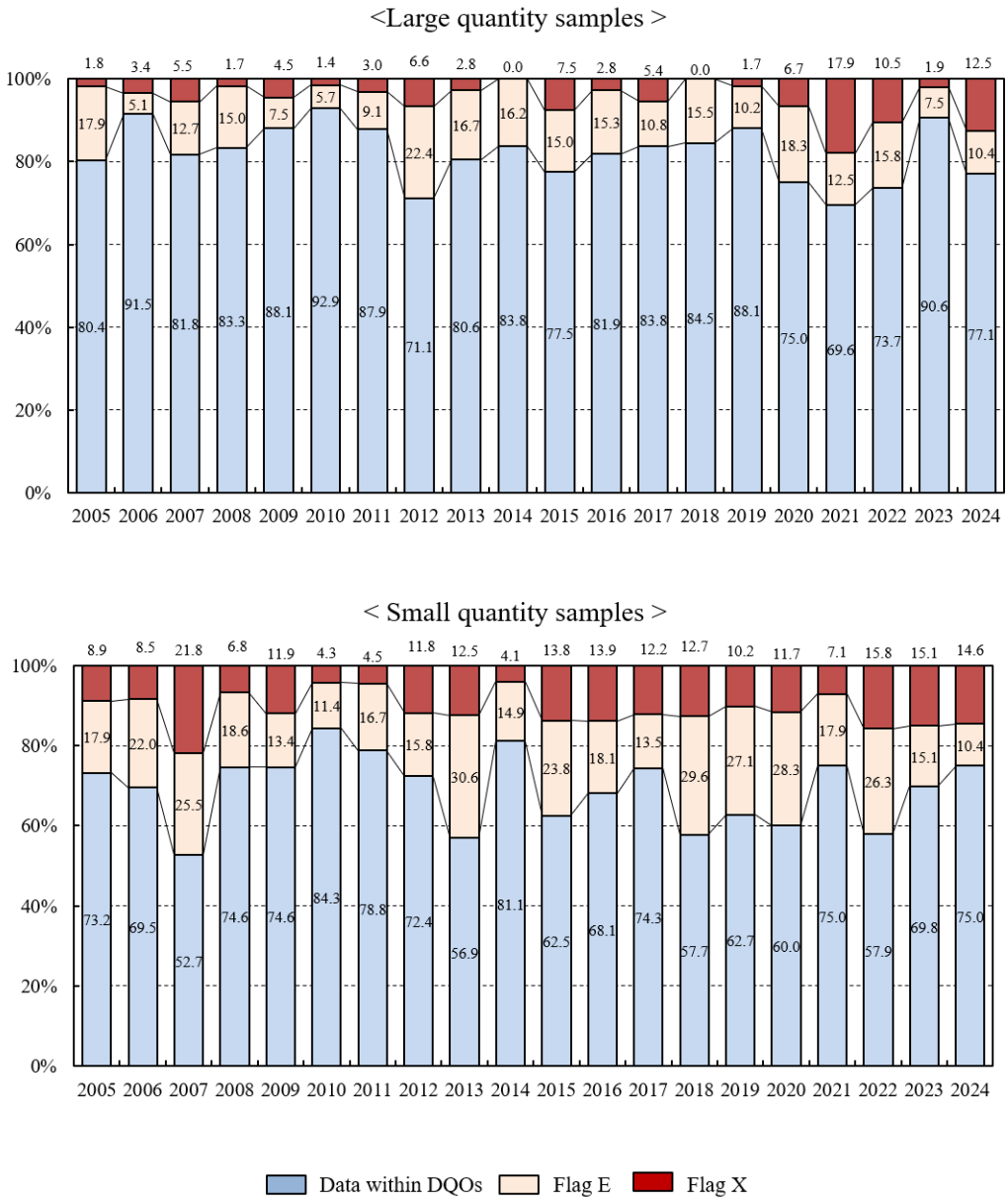


Figure 2.3.4. Overall comparisons of all Inter-Laboratory Comparison projects for dry deposition during 1998-2024.

2.3.3 Soil

The project on soil sample analysis started in 1999 as one of the activities within the QA/QC programs. Previously, twelve to sixteen laboratories participated from the following six to ten countries: China, Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Vietnam. However, the numbers of participating laboratories have reduced to six to eight laboratories from three to four countries in 2022-2024. Air-dried soil samples, which were prepared by the NC, were distributed to the laboratories every year except 2001. The laboratories carried out the whole procedures of the soil analysis including extraction, instrumental analysis or titration, and reporting. Performance at each step would be responsible for the inter-laboratory variations. In order to eliminate the differences in the sample preparation, therefore, samples of soil extract were also distributed in 2001 and 2002 to evaluate the procedures of respective steps. Distributed samples of the respective years and mandatory parameters to be measured for soil samples were listed in Tables 2.3.4 and 2.3.5, respectively.

Table 2.3.4. Distributed samples and their characteristics.

Year	Sample 1	Sample 2
1999 (1st)	No. 991: Acrisols (red soil)	No. 992: Gleysols (gley soil)
2000 (2nd)	No. 001: Cambisols (brown forest soil)	No. 002: Andosols (black soil: used for the 3rd and 4th Project)
2001 (3rd)	No. 011: Soil extract by CH_3COONH_4 solution (for exchangeable base cations)	No. 012: Soil extract by KCl solution (for exchangeable acidity, Al, and H)
2002 (4th)	No. 021: Andosols (black soil: soil sample)	No. 022: Soil extract by CH_3COONH_4 solution (for exchangeable base cations)
2003 (5th)	No. 031: Cambisols (brown forest soil)	No. 032: Arenosols (red soil)
2004 (6th)	No. 041: Andosols (black soil)	No. 042: Cambisols (brown forest soil)
2005 (7th)	No. 051: *Quercus serrata* (secondary forest)	No. 052: *Pinus densiflora* (secondary forest)
2006 (8th)	No. 061: Eutric Cambisol (brown forest soil)	No. 062: Dystric Cambisol (brown forest soil)
2007 (9th)	No. 071: Acrisols (red soil)	No. 072: Cambisols (brown forest soil)
2008 (10th)	No. 081: Cambisols (brown forest soil)	No. 082: Acrisols (red soil)
2009 (11th)	No. 091: Cambisols (brown forest soil)	No. 092: Acrisols (red soil)
2010 (12th)	No. 101: Cambisols	No. 102: Andosols
2011 (13th)	No. 111: Cambisols	No. 112: Cambisols
2012 (14th)	No. 121: Cambisols	No. 122: Cambisols
2013 (15th)	No. 131: Dydstric Cambisol	No. 132: Eutric Fluvisol
2014 (16th)	No. 141: Andisols	No. 142: Cambisols
2015 (17th)	No. 151: Acrisols	No. 152: Cambisols
2016 (18th)	No. 161: Cambisols	No. 162: Cambisols
2017 (19th)	No. 171: Acrisols	No. 172: Cambisols
2018 (20th)	No. 181: Cambisols	No. 182: Cambisols
2019 (21st)	No. 191: Andosols	No. 192: Cambisols
2020 (22nd)	No. 201: Cambisols	No. 202: Cambisols
2021 (23rd)	No. 211: Cambisols	No. 212: Alisols
2022 (24th)	No. 221: Andosols	No. 222: Cambisols
2023 (25th)	No. 231: Cambisols	No. 232: Cambisols
2024 (26th)	No. 241: Cambisols	No. 242: Cambisols

Table 2.3.5 Mandatory parameters to be measured for the soil samples.

Parameters	Unit
a) Moisture Content	wt %
b) pH(H_2O), pH(KCl)	
c) Ex- base cations, such as Ca^{2+}, Mg^{2+}, K^+, and Na^+	cmol(+) kg^{-1}
d) Ex- Acidity, Al^{3+}, and H^+	cmol(+) kg^{-1}

Note: Ex-, exchangeable

The laboratories analyzed each sample twice under the within-laboratory reproducibility condition (time, analysts, and/or instruments are different in a same laboratory). Moreover, triplicate analysis under the repeatability condition was carried out each time. Therefore, six datasets could be obtained for each sample. Precisions on inter-laboratory reproducibility, within-laboratory reproducibility, and repeatability were estimated by analysis of variance of the data, according to the method described in the "Technical Manual for Soil and Vegetation Monitoring in East Asia" (2nd ISAG, 2000).

Each parameter is statistically evaluated according to the several procedures described in the Technical Manual. One of the procedures is detection of outliers by Cochran and Grubbs method. Evenness of within-laboratory precision (variation in each laboratory) and inter-laboratory precision (variation between participant laboratories) are verified by this method. Figure 2.3.5 shows the change of outlier ratio in all properties and laboratories from 2002 to 2024. The ratio is calculated by {(N of entire dataset) – (N of verified dataset)} / (N of entire dataset)]. The number of participating laboratories peaked in the late 2000s to early 2010s, with up to 10 countries and 18 laboratories

involved. However, in 2024, the number of laboratories dropped to only three countries and six laboratories, reducing the project's scale to one-third of its peak. Although the outlier ratio has decreased since the initial experiment in 2002, it has remained relatively high (10-25%) between 2003 and 2024.Appropriate standard solution, extraction solution, dilution rate and calculation should be checked to reduce extremely different values considered as outliers.

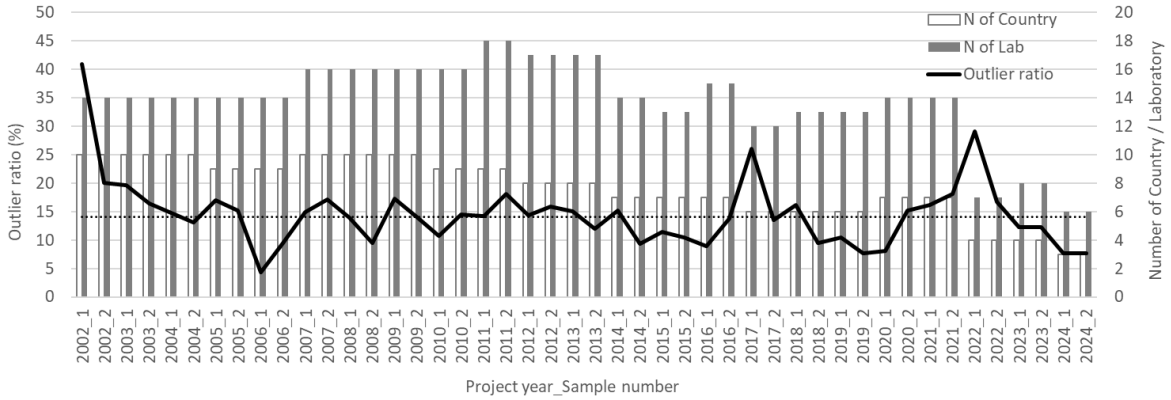


Figure 2.3.5. Change of the outlier ratio in all properties and laboratories from 2002 to 2024 Outlier ratio = {(N of entire dataset) – (N of verified dataset)} / (N of entire dataset). The suffixes '_1' and '_2' denote the two types of the samples analyzed each year (e.g., 241s and 242s). The dotted line indicates the average outlier ratio from 2003 to 2023.

Pretreatment procedures, such as extraction and dilution of the samples, and instrumental analysis may affect the inter-laboratory reproducibility. All the procedures should be checked step by step for improvement of the reproducibility. Moreover, all the distributed samples were collected in Japan, whose chemical and physical properties might be quite different from those monitored in the respective countries. This may also affect the inter-laboratory reproducibility. Thus, it was suggested that regional variation of exchangeable cations should carefully be evaluated taking uncertainties of the precision into consideration, while the pH values were enough comparable among the countries.

On the other hand, the high precisions of within-laboratory reproducibility and repeatability may allow to conclude that the analysis in the respective laboratories was conducted according to their standard procedures as appropriate. In the actual monitoring activities, soil samples collected from the permanent plots in the respective sites are analyzed periodically in the same laboratories. Temporal changes of soil chemical properties in the respective laboratories (respective sites) could be indicated and evaluated, although uncertainties of the actual values should still be taken into consideration.

2.3.4 Inland aquatic environment

The project on inland aquatic environment sample analysis started in 2000 as one of the activities within the QA/QC programs. Fourteen to sixteen laboratories participated from the following ten countries: China, Indonesia, Japan, Lao PDR, Malaysia, Mongolia, Philippines, Russia, Thailand, and Vietnam, participated in the projects. One artificial inland water sample, which contained all analyzed ions and was prepared by the NC, was distributed to the laboratories every year. The laboratories carried out the whole procedures of the inland water analysis including extraction, instrumental analysis or titration, and reporting. Performance at each step would be responsible for the inter-laboratory variations.

The ILC Projects of EANET have been carried out 25 times, and the results showing the percentage of flagged data and the percentage of data that satisfied the DQOs are shown in Figure 2.3.6.

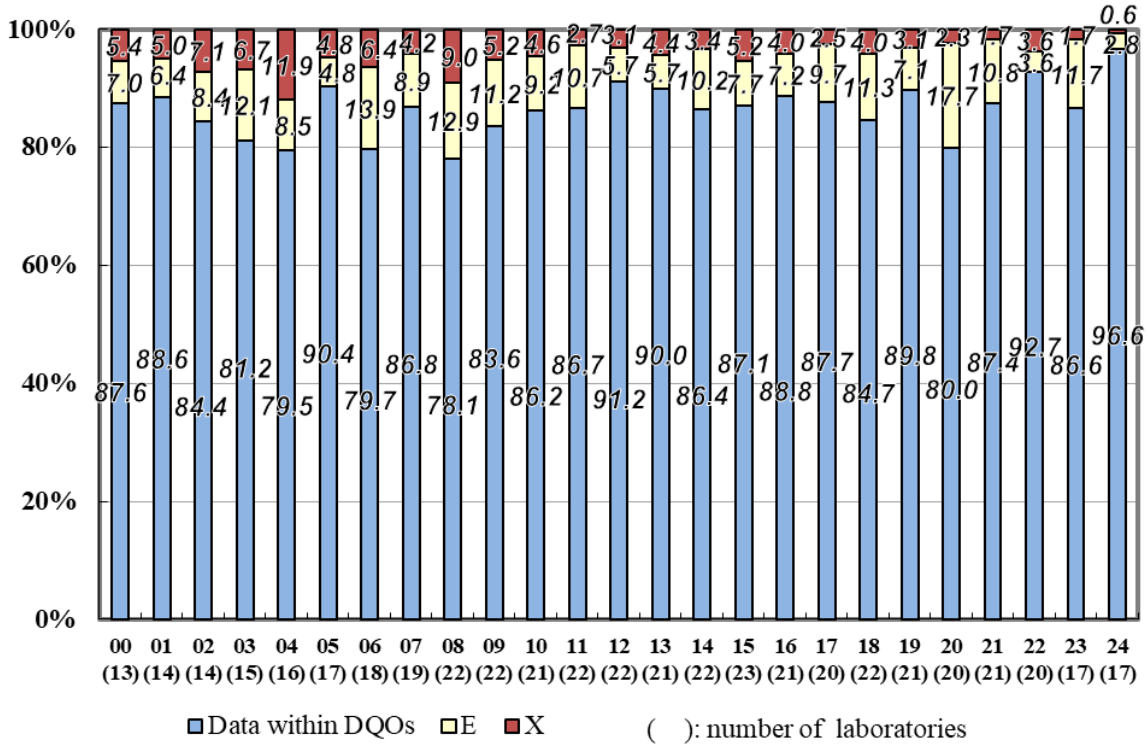
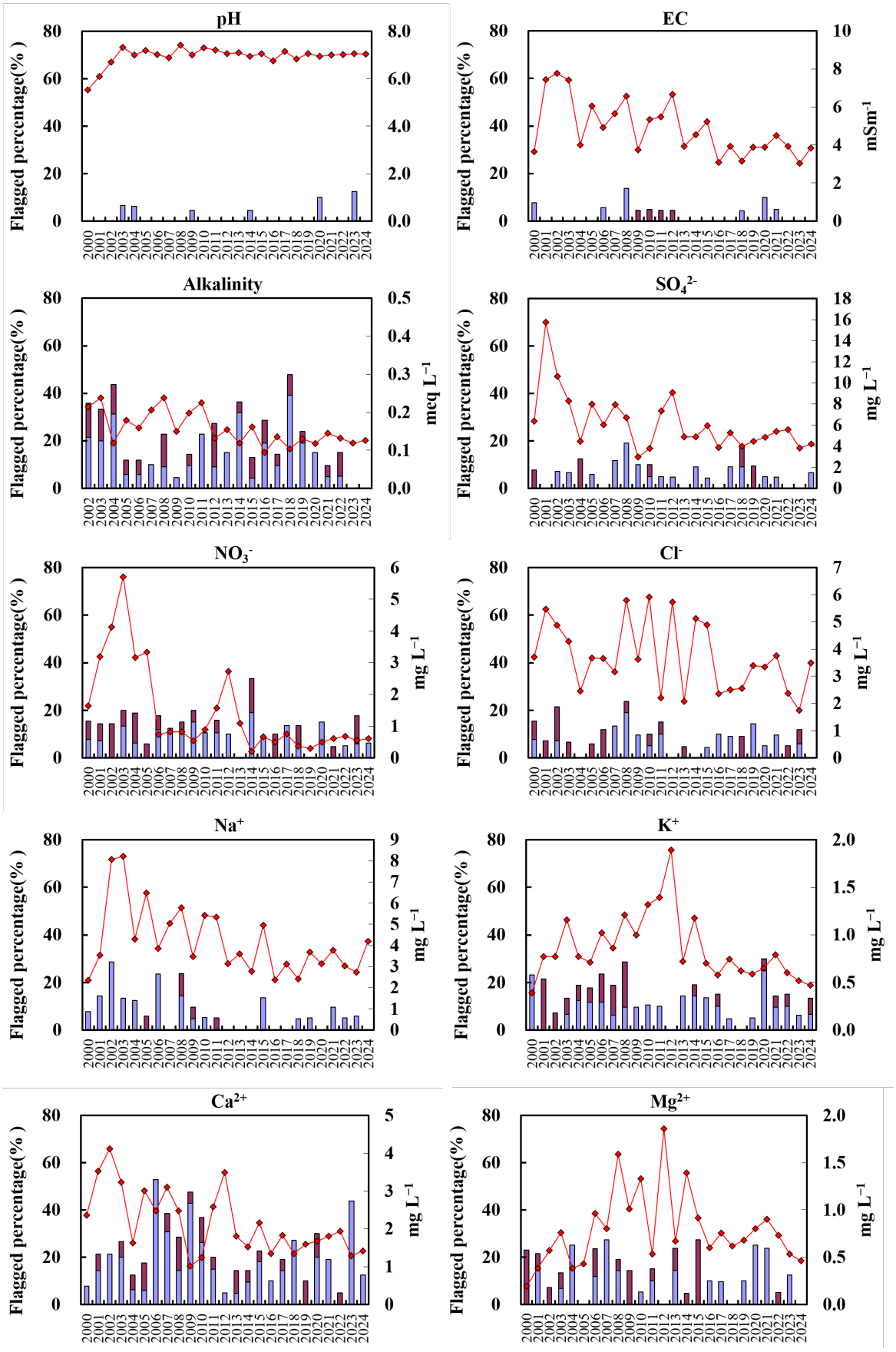


Figure 2.3.6. Comparison of the results from the Inter-Laboratory Comparison projects.

The percentage of data within DQOs showed some fluctuations in the early years, but remained at a high level in subsequent projects.

The comparison for each parameter from the 1st to 25th project with the percentage of flagged data is shown in Figure 2.3.7. There was no flagged data in pH, EC, Alkalinity, Cl^-, Na^+, Mg^{2+}, and NH_4^+ in this attempt. The analyses of NO_3^- and Ca^{2+} were improved, but slightly higher flagged percentages were observed for SO_4^{2-} and K^+ compared with the previous project.

Regarding NH_4^+, which had been a recurring issue in previous years, no flags were assigned this time. This is the first occurrence since the start of the project. The improvement is attributed to enhanced measurement skills in the participating countries, and further advancements in analytical methods are expected in the future.


pH
Flagged percentage(%)
EC
mSm-1
Alkalinity
meq L-1
SO4 2-
mg L-1
NO3-
mg L-1
Cl-
mg L-1
Na+
mg L-1
K+
mg L-1
Ca2+
mg L-1
Mg2+
mg L-1

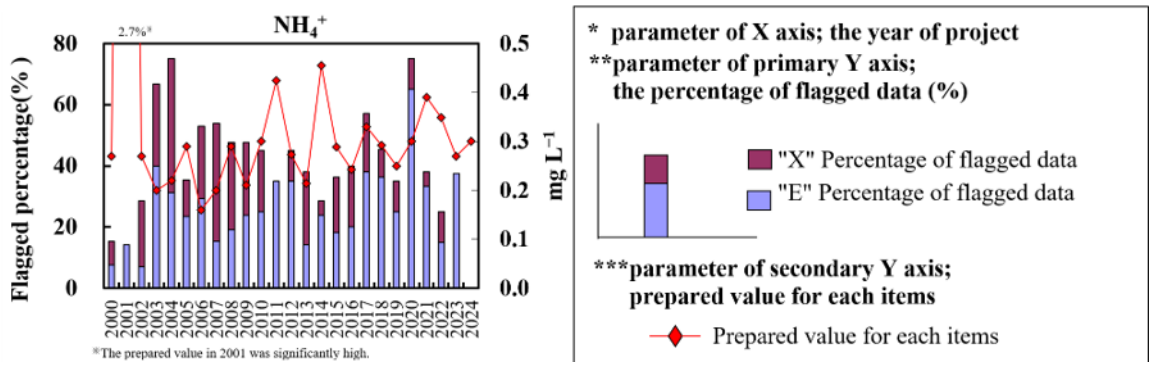


Figure 2.3.7. Comparison of the percentage of flagged data for each parameter in the Inter-Laboratory Comparison projects.

2.4 Evaluation of the regular measurements

The objectives of the QA/QC program are to obtain reliable data that can be comparable among the countries of the East Asian region, as well as with other networks by ensuring data accuracy, precision, representativeness and completeness in acid deposition monitoring. All activities of data management are directed to ensure acceptable quality assurance levels. This section describes data evaluation processes for QA/QC of the EANET monitoring. Evaluation of the datasets from the four viewpoints described below in Section 2.4.1-2.4.4 has ensured that a large proportion of the measurements, including those obtained during the early stage of the network, are of acceptable quality, while the quality of more recent datasets has further improved.

2.4.1 Flow for the data reporting and verification

Figure 2.4.1 shows the principal flow chart of reporting and verification for national monitoring data in EANET. The process illustrated in this flowchart is carried out annually. The compilation, verification, and subsequent processing of monitoring data collected by each participating country are, in principle, carried out by the respective National Center under the leadership of the country's QA/QC Manager of each participating country. The monitoring data are required to be submitted to the NC, where they are compiled and integrated. The NC conducts further data checking and verification under the leadership of the NC QA/QC Manager. If any issues are identified in the submitted data, including inconsistencies or other deficiencies, the NC requests confirmation from the QA/QC Manager and the National Center of the relevant country. Based on the results of the confirmation, the data are corrected or deleted, as appropriate. The monitoring data processed through the above procedures are then subjected to further verification by the Verification Group, comprising researchers and experts from outside EANET. This procedure is essential from the perspective of QA. Any issues raised by the Verification Group are also referred to the QA/QC Manager and the National Center of the relevant country for confirmation. Based on the outcome of the confirmation, the data are corrected or removed, as appropriate. Then, the NC prepares the Data Report based on the monitoring data verified through the above procedures. The Data Report is reviewed by the SAC, and its contents are finalized upon its adoption. However, if further comments are raised by SAC members, the Data Report may be adopted subject to revisions addressing those comments. If substantial revisions are required, an additional review by e-mail may also be conducted. The Data Report adopted by the SAC undergoes a final review at the Intergovernmental Meeting and is published after receiving its approval. The printed version of the Data Report is also made available in PDF format and can be downloaded from the EANET website (https://monitoring.eanet.asia/document/public/index). In addition, hourly, weekly, and bi-weekly monitoring data for air concentration and wet deposition are available from the EANET website. However, registration on the website (https://monitoring.eanet.asia/document/register/index) is required to access these data.

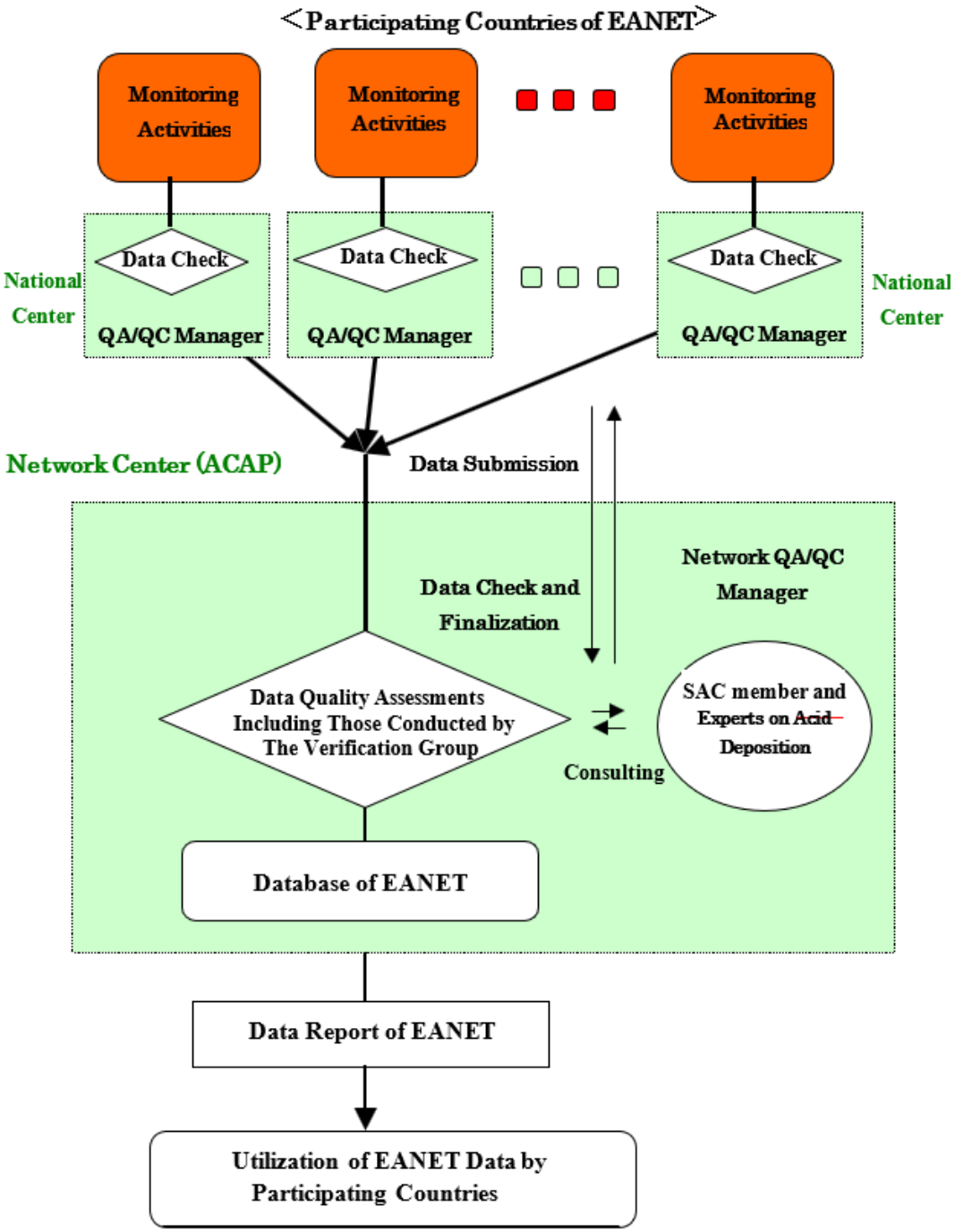


Figure 2.4.1. Flow chart of reporting and verification for EANET monitoring data.

2.4.2 Validation of the data for wet deposition

The annual wet deposition datasets include a set of quality flags to indicate values that fall outside defined criteria or raise concerns regarding sampling and chemical analysis. The most common issues involve missing values due to "insufficient sample volume" or "low analytical precision," for which corresponding flags are assigned to either the whole sample or individual measurements. A complete list of these flags is provided in the *Technical Manual for Wet Deposition Monitoring in East Asia* (EANET, 2010), and most of them are consistent with those recommended by other international monitoring frameworks such as EMEP and WMO (EMEP, 2001; WMO, 2004).

As part of routine quality assurance procedures, all wet deposition samples are evaluated using ion balance (R_1) and conductivity agreement (R_2), as described in Section 2.2.5. These criteria are defined across three concentration ranges to account for different chemical regimes. While this approach is widely adopted across monitoring networks, the specific threshold values for R_1 and R_2 may vary depending on network experience. The annual EANET Data Reports summarize the proportion of samples that meet these QA/QC criteria.

The results of the Mann–Kendall trend analysis of annual attainment rates for R_1, R_2, and their combination (R_1 & R_2) are presented in Table 2.4.1, while representative time series for selected sites are shown in Figure 2.4.2. Overall, 16 sites (31.4% of the 51 valid sites) exhibit increasing trends in data quality (i.e., higher attainment rates), whereas 9 sites (17.6% of the 51 valid sites) show decreasing data quality (i.e., increasing proportions of samples falling outside the acceptable ranges). In some countries, attainment rates have remained consistently high, with values close to 100% over extended periods.

Clear regional differences are evident. In China and Indonesia, many sites show marked improvements in both R_1 and R_2, indicating substantial enhancement in analytical performance. In contrast, Japan, Malaysia, and Vietnam exhibit mixed patterns, with some sites improving while others show stagnation or decline. In Japan, for example, Happo maintains consistently high attainment rates across all indicators, yet a statistically significant decreasing trend is observed over the long term. Meanwhile, in Mongolia, Myanmar, the Philippines, Russia, and Thailand, several sites demonstrate decreasing trends in either R_1 or R_2, suggesting deterioration in data quality at those locations.

Detailed examples of site-specific trends are illustrated in Figure 2.4.2. Sites such as Xiaoping (China), Petaling Jaya (Malaysia), and Ho Chi Minh (Vietnam) show pronounced improvements over time, with attainment rates approaching or reaching nearly 100% in recent years (e.g., 2024). In contrast, Kuching (Malaysia) and Yangon (Myanmar) exhibit clear declining trends, with some indicators falling below 50% in recent years. It should be noted that for sites where attainment rates are already consistently high, trend detection may not fully capture incremental improvements in performance.

The observed improvements or deteriorations are likely influenced by multiple factors, including laboratory practices, sample handling, and analytical capacity. Therefore, it is essential for participating countries to carefully assess these trends and take appropriate actions to improve laboratory management and maintain high standards of data quality.

Table 2.4.1. Results of the Mann–Kendall trend analysis of annual attainment rates of wet deposition QA/QC criteria (R_1, R_2, and both (R_1 & R_2)) at EANET sites, 2000–2024.

unit: %

Country	Site	N	R_1			R_2			R_1 & R_2		
			Z-score	Sen's slope	Trend	Z-score	Sen's slope	Trend	Z-score	Sen's slope	Trend
Cambodia	Phnom Penh	12	0.48	0.81	No trend	**1.99**	**4.19**	**Inc.**	0.41	0.31	No trend
China	Haifu	18	1.44	0.36	No trend	**3.29**	**0.19**	**Inc.**	1.59	0.46	No trend
	Jinyunshan	24	0.69	0.13	No trend	**3.00**	**0.15**	**Inc.**	0.97	0.13	No trend
	Shizhan	25	-0.21	-0.28	No trend	**2.34**	**1.37**	**Inc.**	0.23	0.11	No trend
	Jiwozi	24	0.35	0.49	No trend	**2.14**	**1.68**	**Inc.**	1.69	1.07	No trend
	Hongwen	25	1.64	0.91	No trend	**4.26**	**1.42**	**Inc.**	**2.10**	**1.26**	**Inc.**
	Xiaoping	25	**4.44**	**2.34**	**Inc.**	**4.19**	**1.86**	**Inc.**	**4.79**	**2.70**	**Inc.**
	Xiang Zhou	25	**2.03**	**1.18**	**Inc.**	**3.95**	**1.77**	**Inc.**	**2.87**	**1.91**	**Inc.**
	Zhuxiandong	21	**2.33**	**1.85**	**Inc.**	**4.02**	**2.13**	**Inc.**	**2.81**	**2.41**	**Inc.**
	Wuzhishan	6		*N/A*			*N/A*			*N/A*	
	Lijiang	6		*N/A*			*N/A*			*N/A*	
Indonesia	Jakarta	23	1.45	0.94	No trend	1.74	1.11	No trend	**2.06**	**1.29**	**Inc.**
	Serpong	22	-1.31	-0.89	No trend	0.40	0.03	No trend	-0.88	-0.56	No trend
	Kototabang	23	1.72	0.83	No trend	**2.35**	**1.68**	**Inc.**	**2.88**	**1.41**	**Inc.**
	Bandung	22	-0.99	-1.59	No trend	0.34	0.04	No trend	-0.79	-1.52	No trend
	Maros	16	-0.90	-0.91	No trend	0.18	0.20	No trend	-0.05	-0.19	No trend
	Jembrana	5		*N/A*			*N/A*			*N/A*	
	Lombok	5		*N/A*			*N/A*			*N/A*	
Japan	Rishiri	25	0.12	0.00	No trend	-0.73	0.00	No trend	-0.42	-0.04	No trend
	Ochiishi	19	0.59	0.00	No trend	1.20	0.00	No trend	0.72	0.00	No trend
	Sado-seki	25	0.64	0.00	No trend	0.83	0.00	No trend	0.67	0.00	No trend
	Happo	25	**-3.69**	**-0.25**	**Dec.**	**-3.13**	**-0.07**	**Dec.**	**-3.92**	**-0.31**	**Dec.**
	Ijira	25	0.00	0.00	No trend	0.00	0.00	No trend	0.00	0.00	No trend
	Oki	22	**3.09**	**0.09**	**Inc.**	**3.31**	**0.05**	**Inc.**	**3.83**	**0.15**	**Inc.**
	Yusuhara	25	-1.00	-0.10	No trend	0.63	0.00	No trend	-0.84	-0.15	No trend
	Hedo	24	0.84	0.02	No trend	1.00	0.00	No trend	0.75	0.04	No trend
	Ogasawara	25	**2.54**	**0.16**	**Inc.**	1.54	0.00	No trend	**2.69**	**0.15**	**Inc.**
	Tokyo	18	-0.49	-0.14	No trend	1.17	0.00	No trend	-0.42	-0.08	No trend
	Niigata-maki	6		*N/A*			*N/A*			*N/A*	
	Tsushima	6		*N/A*			*N/A*			*N/A*	
Lao PDR	*Vientiane*	7		*N/A*			*N/A*			*N/A*	
Malaysia	**Petaling Jaya**	24	**3.87**	**1.17**	**Inc.**	**3.07**	**0.26**	**Inc.**	**3.72**	**1.51**	**Inc.**
	Tanah Rata	23	0.66	0.27	No trend	1.27	0.38	No trend	0.92	0.45	No trend
	Danum Valley	19	-0.14	-0.11	No trend	1.30	0.35	No trend	0.21	0.11	No trend
	Kuching	16	**-2.61**	**-2.07**	**Dec.**	-1.76	-0.31	No trend	**-2.48**	**-2.43**	**Dec.**
	Gunung Brinchang	1		*N/A*			*N/A*			*N/A*	
Mongolia	*Khan-Uul*	4		*N/A*			*N/A*			*N/A*	
	Terelj	20	-0.03	-0.01	No trend	**-2.79**	**-2.27**	**Dec.**	-1.43	-0.64	No trend
Myanmar	Yangon	16	-0.99	-0.85	No trend	**-3.02**	**-4.17**	**Dec.**	**-2.17**	**-1.15**	**Dec.**
Philippines	Manila Observator	22	-0.17	-0.48	No trend	0.51	0.27	No trend	-0.34	-0.16	No trend
	Los Baños	19	0.28	0.40	No trend	-0.07	-0.08	No trend	0.67	0.83	No trend
	Mt. Sto. Tomas	13	-1.89	-6.31	No trend	-0.73	-0.75	No trend	**-2.14**	**-5.97**	**Dec.**
R of Korea	Ganghwa	23	0.87	0.15	No trend	0.00	0.00	No trend	0.51	0.26	No trend
	Jeju	23	1.70	0.89	No trend	0.30	0.00	No trend	1.48	1.02	No trend
	Imsil	22	1.44	1.01	No trend	1.23	0.17	No trend	1.55	1.21	No trend
Russia	Mondy	23	0.65	0.00	No trend	0.00	0.00	No trend	0.65	0.00	No trend
	Listvyanka	25	-0.71	0.00	No trend	-1.58	0.00	No trend	-0.76	0.00	No trend
	Irkutsk	25	-0.63	-0.01	No trend	**-2.35**	**-0.01**	**Dec.**	-0.98	-0.02	No trend
	Primorskaya	23	-1.07	0.00	No trend	0.48	0.00	No trend	-1.26	0.00	No trend
Thailand	Bangkok	23	**-2.75**	**-1.29**	**Dec.**	-0.63	-0.36	No trend	**-2.17**	**-0.85**	**Dec.**
	Samutprakarn	20	-0.68	-0.66	No trend	0.94	0.38	No trend	-0.42	-0.26	No trend
	Pathumthani	25	0.37	0.26	No trend	**-2.87**	**-0.76**	**Dec.**	0.16	0.05	No trend
	Khanchanaburi	20	0.23	0.10	No trend	-1.43	-0.95	No trend	-1.46	-1.03	No trend
Vietnam	Hanoi	25	-1.32	-0.21	No trend	-0.90	0.00	No trend	-1.43	-0.24	No trend
	Hoa Binh	25	**-2.09**	**-0.31**	**Dec.**	-0.62	0.00	No trend	**-2.09**	**-0.31**	**Dec.**
	Cuc Phuong	16	0.42	0.00	No trend	0.54	0.00	No trend	0.73	0.00	No trend
	Da Nang	16	0.39	0.00	No trend	1.45	0.00	No trend	1.09	0.16	No trend
	Can Tho	11	1.56	4.65	No trend	**2.82**	**1.11**	**Inc.**	1.71	5.21	No trend
	Ho Chi Minh	11	**2.49**	**4.86**	**Inc.**	**2.74**	**0.83**	**Inc.**	**2.80**	**5.00**	**Inc.**
	Yen Bai	10	-0.19	0.00	No trend	0.00	0.00	No trend	-0.19	0.00	No trend

Notes: A site was classified as *Increasing (Inc.)* when its Z-score exceeded ±1.96 and the Sen's slope was positive, or *Decreasing (Dec.)* when the slope was negative. If the Z-score fell within ±1.96, the site was categorized as *No trend*. Sites with sample sizes of seven or fewer observations were not included in the Mann–Kendall analysis. Shaded cells indicate sites where significant increasing (*Inc.*) or decreasing (*Dec.*) trends were detected for R_1, R_2, or both (R_1 & R_2).

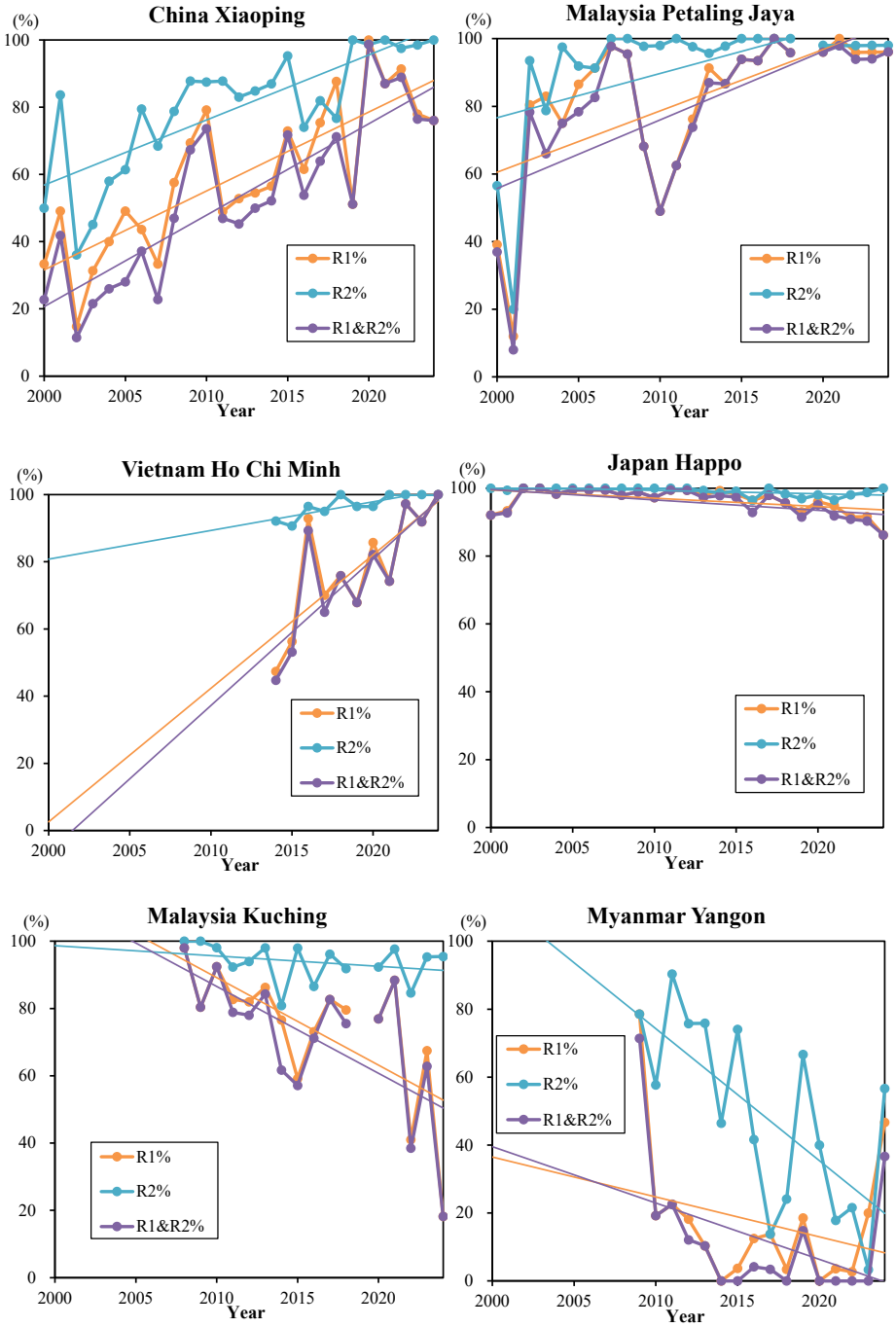


Figure 2.4.2. Time series of annual attainment rates and linear trend lines for selected EANET sites showing notable increases or decreases in wet deposition QA/QC criteria (R_1, R_2, and R_1 & R_2), 2000–2024.

2.4.3 Data completeness

Data Completeness is one of the data quality indicators when measurement data are summarized statistically in monthly, seasonally or annual periods. If large amounts of data are missing or regarded as invalid during the summary period, the summarized statistics (e.g., the mean, median, maximum and minimum values) can be highly misleading. Therefore, periodic reporting of summarized data should be based on the full operation measurements without any missing data, which would be actually inevitable in the long-term regional monitoring network activities.

For the wet deposition monitoring, two DQOs for data completeness are described in Technical Manual for Wet Deposition Monitoring in East Asia -2010, namely, Percent Precipitation Coverage Length (%PCL) and Percent Total Precipitation (%TP). %PCL is the percent of the summary period for which information on whether or not precipitation occurred is available. %TP is the percent of the total precipitation data measured during the summary period that is associated with valid samples. The requirement to be fulfilled in data is determined by the DQOs of %PCL and %TP are more than 80% (EANET, 2010).

For the dry deposition (air concentration) monitoring, the data completeness should be evaluated in terms of the flagged or invalid data for automatic monitoring and the filter pack and other manual method. Data completeness describes the fraction of valid data coverage length in a certain monitoring period. The definition of data completeness is expressed as follows;

(Data completeness for automatic monitor)
= (Number of valid hourly data) / (Number of total measured hourly data)
(Data completeness for filter pack and other manual methods)
= (Number of valid measurement days) / (Number of total measurement days)

In order to evaluate monthly and annual air concentrations and monthly and annual dry deposition fluxes, the data completeness should be no less than 70%.

Figure 2.4.3 shows the annual variations in %PCL for precipitation and %TP for pH, EC, and selected ions in precipitation from 2000 to 2024. The number of sites that satisfy the DQOs for wet deposition monitoring has remained consistently high and stable since around 2008.

Figure 2.4.4 shows annual variations of data completeness for SO_2, particulate SO_4^{2-}, O_3, NOx/NO_2, PM_{10} and $PM_{2.5}$ from 2000 to 2024. SO_2 measurements were obtained using automatic monitors (AUTO), the FP method, or both methods.(strictly speaking, the PS method in some cases). For the "Dry SO_2 (AUTO & FP) %" , the completeness of AUTO measurements was used preferentially when SO_2 was measured by an automatic monitor. If AUTO measurements were not available and SO_2 was measured using the FP method, the completeness of the FP measurements was used. In the initial period, the number of monitoring stations was lower, and the data completeness was lower than the DQO at many stations.

The major reasons of long-term missing data and nonattainment of the DQOs are power failure at the site due to lightning damage or unstable power supply, failure of the sampling inlet, malfunction of monitoring equipment due to deterioration over time or severe meteorological conditions, lack of financial and technical resources to repair the instruments, and so on. In order to improve data completeness, the alternative instruments for replacing the failed instruments should be kept in a laboratory, and lightning conductor, surge protector and/or uninterruptible power system (UPS) should be equipped in the station.

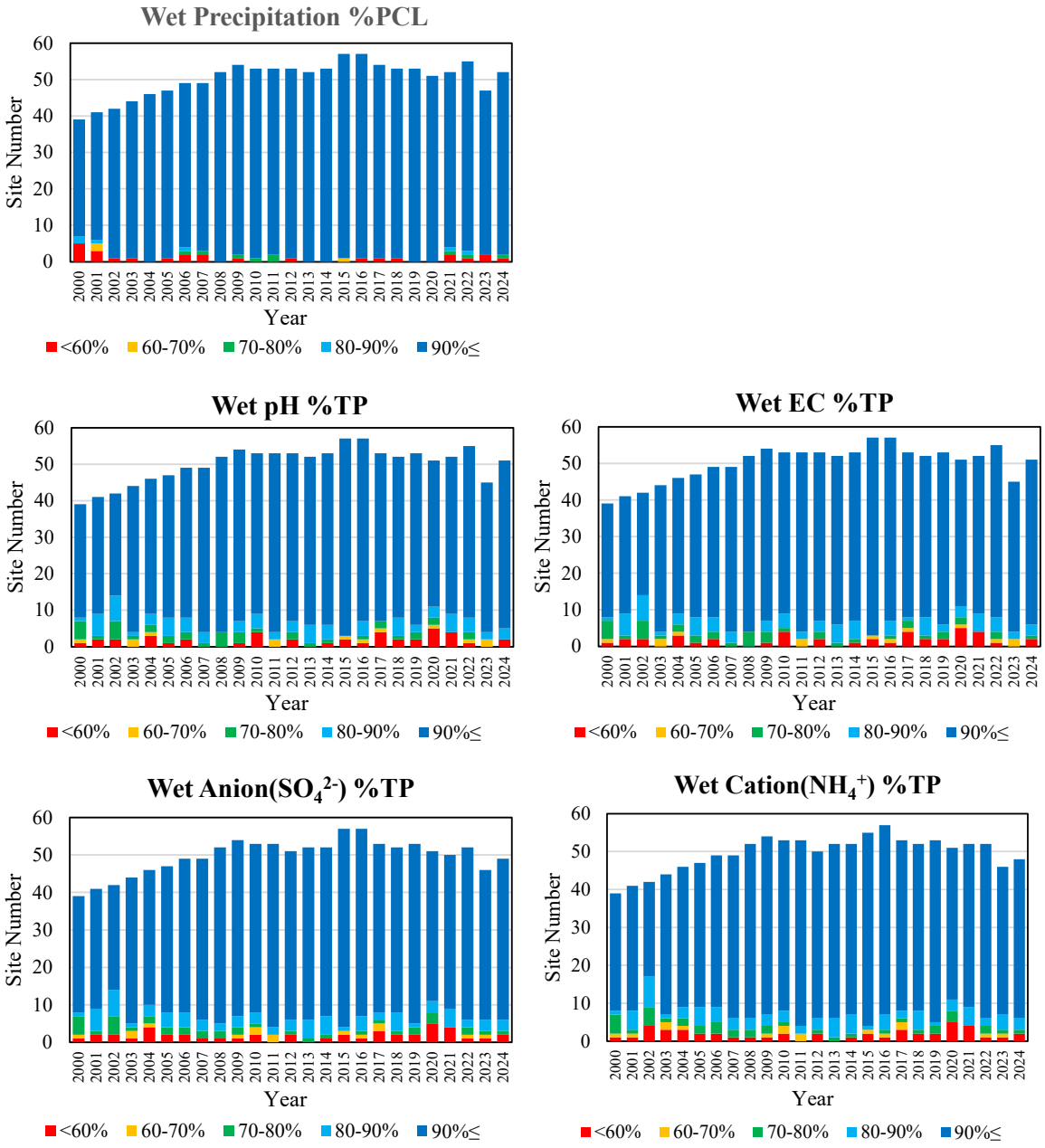


Figure 2.4.3. Annual variations of %PCL for precipitation and %TP for pH, EC, SO_4^{2-} and NH_4^+ in precipitation from 2000 to 2024.

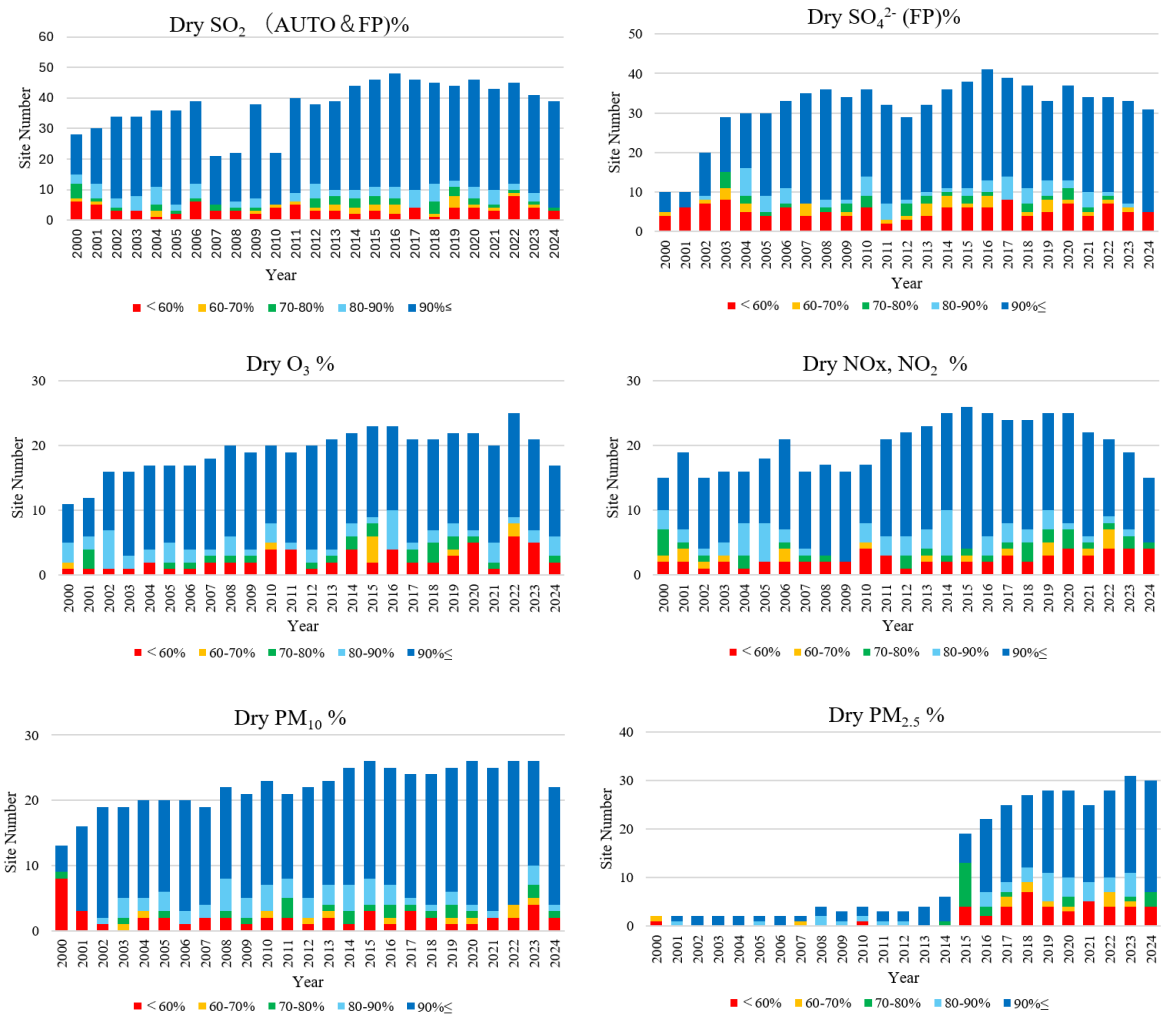


Figure 2.4.4. Annual variations of data completeness for SO_2 (measured by automatic monitor and filter-pack), particulate SO_4^{2-}, O_3, NOx/NO_2, PM_{10} and $PM_{2.5}$ from 2000 to 2024.

2.4.4 Site representativeness

The characteristics of the individual site were reported by the National Monitoring Plan of each EANET member country. It is important to consider the nature of the sites (e.g. urban, rural, remote, or ecological) for the evaluation of the monitoring data.

A specific feature of EANET monitoring is its integration of measurements across different environmental media, including the atmosphere, surface water, soil, and vegetation. The former are primarily characterized by the concentrations of pollutants in air and water, whereas the latter require consideration of ecosystem characteristics and their annual life cycles. When establishing monitoring sites, potential impacts of anthropogenic activities, such as emissions, wastewater discharges, and land use, should also be taken into account. Environmental conditions should further be considered to ensure that ecosystem changes attributable to the long-range transport of air pollutants can be effectively detected and evaluated.

EANET set up three categories for monitoring sites of air concentration and atmospheric deposition presented in the Guidelines and Technical Manuals (ADORC, 2000) with respect to the level of

impact on surrounded area: urban, rural and remote stations. The site criteria define the distance of possible air pollution sources with different intensity, land use in the vicinity of different spatial scale, etc. The specific information are required and collected on site condition in accordance with formats of National Monitoring Plan for the surrounded areas in a distance to 150 m, 0.15-10 km and 10-50 km from place of measurements.

For the rural and remote sites the applied requirements were established based on the experience gained from activities of other networks in the world. These criteria specifications are closely correspondent to the similar requirements of well-operated monitoring networks such as EMEP or regional GAW-PC network (EMEP, 2001; WMO, 2004). However, mentioned networks are not concerned urban atmospheric pollution which became a serious problem in East Asian megacities and other big cities especially in tropics. Those kinds of measurements are particularly related to a number of national networks as well as to specific international initiatives directed to urban pollution.

Taking into account the differences in atmospheric processes and emission impact in urban and non-urban conditions and evaluation of regional pollution has to be done separately for mentioned areas. And the nature of the sites (e.g. urban, rural, remote, or ecological) was kept in mind for the analyses. The characteristics of the individual site were reported by answers on series of questions and photos from four or more directions. For the practical purposes, the brief overview of site conditions could be observed at EANET site.

The site is evaluated from a perspective of available potential sources of sample contamination which could violate its representativeness of the area of interest on the three different spatial scales: on-site, local, and regional. Detailed examinations of the site by inspection and the related documents will evaluate the type of the site. Any changes of the site conditions on three different scales (on-site, local and regional) and relocation of the sampler may require a reevaluation of the type of the site (WMO, 2004).

The sites of fourth category have a focus on ecological monitoring of natural ecosystems which is also, might be referred to relevant conditions for the atmospheric deposition measurement. They are commonly stated as ecological sites being correspondent to one of these three mentioned above in terms of the location conditions, but its focus of measurement programs is on the data acquisition of the input to the ecological elements of interest.

Guideline for Acid Deposition Monitoring in East Asia (ADORC, 2000) recommended that ecological sites for soil and vegetation monitoring (basic survey program) and monitoring on inland aquatic environment have to be preferably established near the air concentration and deposition monitoring sites or in their vicinity. In particular for soil and vegetation monitoring, more detailed criterion was proposed for the distance from the air concentration and atmospheric deposition monitoring site as “within a radius of approximately 50 km”. Moreover, it was suggested that two forest plots with different soil types be selected in each area within 50 km from the deposition site.

The current situation on co-location of basic survey sites for ecological monitoring and the nearest air concentration and deposition monitoring sites was presented in Table 2.4.2. Most of ecological monitoring sites are corresponded to the air concentration and deposition monitoring sites, however, their classification could be different.

Table 2.4.2. Basic survey sites for ecological monitoring and the nearest deposition sites.

Country	Site for air concentration and deposition monitoring	Plot for soil and vegetation monitoring	Site for monitoring on inland aquatic environment
Cambodia	-	-	Sras Srang Lake
China	Chongqing - Jinyunshan	Jinyunshan	Jinyunshan Lake
	Xi'an - Jiwozi	Dabagou	Jiwozi River
	Xiamen - Xiaoping	Xiaoping	Xiaoping Dam
	Zhuhai - Zhuxiandong	Zhuxiandong	Zhuxiandong Stream
Indonesia	Serpong	Bogor Research Forest (Dramaga Experimental Forest)	-
	Bandung	-	Patengang Lake
	-	-	Gunung Lake
Japan	Happo	Sekido-san*2	Futago-ike Lake*2
		Horyu-zan*2	
	Ijira	Ijira	Ijira Lake
		Yamato	
Lao PDR	Vientiane	-	Nam Hum Lake
Malaysia	Petaling Jaya	Pasoh TEAM Plot 1 Pasoh TEAM Plot 8	
	Danum Valley		Baru River
	-	UPMKB Rehabilitated Forest Planted in 1991	-
		UPMKB Rehabilitated Forest Planted in 2008	
Mongolia	Ulaanbaatar	Bogdkhan Mountain	-
	Terelj	Terelj Mountain	Terelj River
Philippines	Manila Observatory	La Mesa Watershed	
	Los Baños	Mt. Makiling	Pandin Lake
		UP Quezon, Land Grant	
	Mt. Sto Tomas	Boneco Long Term Ecological Research Site	Ambulalakaw Lake
Republic of Korea	Imsil	Mt. Naejang	-
Russia	Irkutsk	Irkutsk	-
	Listvyanka	Bolshie Koty	
		Pereemnaya river catchment	Pereemnaya River
	Mondy	Ilchir Lake	-
		Okinskoe Lake	
		Solar Observatory	
	Primorskaya	Primorskaya	Komarovka River
Thailand	Khanchanaburi (Vajiralongkorn Dam)	Vajiralongkorn Dam	Vajiralongkorn Dam
		Vajiralongkorn Puye	
Vietnam	Hoa Binh	Cave of Heaven	Hoa Binh Reservoir
		Thang Ranh	

However, the conventional monitoring system seems could not provide evident information on implication between the ecological and air concentration/deposition data. Monitoring activities for ecosystems and atmospheric impact should be integrated more for discussion on both quantitative and qualitative relations. Catchment-scale monitoring may be one of approaches for this further investigation including some modeling. As shown in the Table 2.4.3, the catchment-scale monitoring has implemented currently in Japan and the Philippines. Japan submitted the data of the Lake Ijira Catchment, which was started in 2007. Moreover, the Philippines has just started the regular monitoring in 2019. Based on the catchment-scale dataset, the simulation model on biogeochemistry cycle is expected to be developed in near future.

Table 2.4.3. Site for catchment-scale monitoring

Country	Site for air concentration and depositio	Site for catchment-scale monitoring
	monitoring	
Japan	Ijira	Lake Ijira catchment
Philippines	Manila Observatory	La Messa Watershed

2.5 Conclusions and recommendations

One of the major objectives of EANET is to provide scientifically sound monitoring data on air concentrations and acid deposition in order to understand the status of air pollution and atmospheric deposition not only in the participating countries but also across the East Asian region, and to provide a scientific basis for policy development. To achieve this objective, it is essential that all monitoring data continuously maintain a high level of quality. Otherwise, it would be difficult to use the monitoring data to assess and discuss long-term trends, spatial distributions, and other characteristics of air pollution and atmospheric deposition. QA/QC activities are therefore essential for ensuring the quality and reliability of EANET monitoring data. This chapter introduces the QA/QC activities implemented under EANET and reports the results obtained to date.

Monitoring activities under EANET are implemented in accordance with the NMP prepared by each participating country. The NMP includes the National Center, implementation body, number of monitoring sites, measurement parameters and their monitoring interval, participating laboratories, information on each monitoring site such as outline of site situations, specific monitoring plans, methodologies of sample collection, status of monitoring equipment, and so on. The NMP needs to be re-confirmed periodically and is required to be sent to the NC, basically when the participating countries submit its annual monitoring data. Whenever the participating countries make some revisions, the revised NMP shall be submitted to the NC. It is very important to avoid misunderstanding between participating countries and NC.

EANET conducts the ILC Project among the analytical laboratories for wet deposition, dry deposition, soil, and inland aquatic environment in participating countries of the EANET based on the QA/QC program of the EANET. The objective of this project is to recognize the analytical precision and accuracy of the measurement in each participating laboratory, give further opportunities to improve the quality of the analysis, improve reliability of analytical data through the assessment of suitable analytical methods and techniques. This project has contributed significantly to improving and maintaining the capabilities of analytical laboratories in the EANET participating countries. Issues identified through the project have been reported at the STM and SAC meetings, where measures for improvement have been discussed. In particular, the STM provides an important opportunity for QA/QC Managers from the participating countries to meet and discuss these issues. The NC also communicates with relevant personnel in each participating country as needed through e-mail, web conferencing systems, and other means. However, it is preferable, where possible, to visit the countries and discuss issues directly with laboratory personnel on site. In this regard, the Technical Mission provides an important opportunity for such direct communication and technical

support. At the same time, given the limited budget available, the Technical Mission needs to be implemented strategically so that it can provide the greatest possible benefit to EANET as a whole.

To maintain and further improve the quality of EANET monitoring data, it is recommended that the following activities be promoted, taking into account the need to respond to the expanding scope of EANET activities and to adapt to new monitoring methods and target pollutants:

- Proper maintenance and management of monitoring sites: The site selection should be done in accordance with the technical manuals. All of the sites shall be prepared by their regional, local and on-site scale descriptions. And the sites shall represent the circumstances around the site in each classified region, such as remote, rural or urban sites. The existing monitoring sites should be reviewed their suitability to the requirements. Any changes in the location or conditions of a monitoring site should be promptly reported to the NC.
- Establishment of the common point of view to the methodology including sampling and measurement; For the monitoring activities that have been conducted under EANET to date, the methodologies and techniques have, in principle, already been well established. However, it is important to maintain these activities and ensure the transfer of the necessary knowledge and skills, including by securing sufficient financial and human resources. To this end, it is desirable that participating countries develop SOPs for each monitoring site and analytical laboratory.
- Implementation of technical support by the NC: Possible measures include ensuring the effective implementation of the ILC Project, strategically planning and implementing Technical Missions to maximize their effectiveness, and conducting capacity-building activities tailored to the needs of the participating countries. For the capacity-building, it is also important for participants in such activities to disseminate the knowledge and skills acquired to relevant personnel in their respective countries.
- Adaptation to new monitoring technologies and targets; In line with the expansion of the scope of EANET activities and the shift in its priorities, QA/QC activities for ozone and PM2.5 monitoring data need to be strengthened. In addition, information should be collected on emerging technologies and approaches, including low-cost sensors (LCSs), satellite observations, and the application of artificial intelligence (AI). It will also be increasingly important to consider how QA/QC activities should evolve in response to advances in monitoring technologies and changes in the monitoring environment.

2.6 References

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Box 1. Observational studies for sustainable monitoring in the EANET region

1. What observational studies have brought to the EANET region?

Long-term observational studies form the scientific foundation for understanding atmospheric pollution and its impacts in East Asia. Since commencing full-scale operation in 2001, EANET has established a region-wide monitoring network covering 13 Participating Countries and has generated harmonized datasets using common monitoring methodologies and QA/QC procedures. These observations have enabled countries to assess temporal trends in air pollutants and atmospheric deposition, understand transport of pollutants, and evaluate environmental responses across different ecosystems.

One of the most important achievements of EANET is the creation of a common scientific understanding of regional air pollution and acid deposition issues. Long-term observational records have revealed large geographical differences in pollution levels, deposition loads, and ecosystem sensitivity throughout East Asia. The accumulated evidence has supported national and regional policy development by providing objective information for emission reduction strategies and environmental management. Furthermore, EANET's monitoring data have served as valuable resources for scientific assessments, atmospheric modeling studies, and international cooperation on air pollution.

In addition, EANET observations have demonstrated the importance of maintaining continuous and comparable measurements over decades. Such long-term datasets are indispensable for distinguishing short-term fluctuations from genuine long-term environmental changes and for evaluating the effectiveness of air pollution control policies implemented by participating countries.

2. Key observational focuses under the MTP (2026–2030)

With the adoption of the expanded EANET scope in 2021, monitoring activities have evolved from a primary focus on acid deposition to a broader air quality management framework. Under the MTP 2026–2030, EANET is expected to continue emphasizing observations of PM2.5 and its chemical composition, surface ozone and its precursors, as well as nitrogen-related pollutants such as NOx and NH3. These pollutants are directly linked to adverse human health impacts, ecosystem degradation, and climate-related interactions.

Particulate matter, particularly PM2.5, remains one of the most significant environmental health concerns in East Asia. Observations of its chemical components provide critical information for source apportionment, identification of pollution sources, and assessment of emission control measures. Similarly, surface ozone monitoring is increasingly important because ozone concentrations continue to affect human health, crop productivity, and forest ecosystems across the region.

Nitrogen species represent another priority area. Nitrogen pollution has emerged as a cross-cutting issue that affects air quality, water quality, biodiversity, and climate. Monitoring atmospheric concentrations and deposition of reactive nitrogen compounds contributes to sustainable nitrogen management by improving understanding of nitrogen cycling and ecosystem impacts.

At the same time, EANET should continue to observe wet and dry deposition monitoring as well as ecological responses in forests and inland aquatic environments. These observations provide unique evidence of how atmospheric pollutants interact with ecosystems over long time scales and support assessments of environmental recovery or degradation.

3. Ensuring sustainable monitoring during MTP (2026–2030)

The sustainability of EANET's monitoring activities depends on the continuity and reliability of its observation network. Maintaining existing monitoring stations and upgrading monitoring instruments are necessary to preserve long-term data records and avoid discontinuities that would reduce the value of historical datasets. The continuation of monitoring sites is particularly important because many sites possess observation records covering more than two decades.

A second essential component is the consistent application of harmonized monitoring methodologies and QA/QC procedures throughout the network. Data comparability among countries is one of EANET's greatest strengths. Sustaining this comparability requires regular inter-laboratory comparison studies, monitoring site audit, instrument calibration, and updates of monitoring guidelines that reflect scientific advances while maintaining consistency with historical observations.

Capacity building also remains a key pillar of sustainable monitoring. Technical training workshops, expert exchanges, and support for emerging monitoring activities contribute to strengthening national capacities and ensuring that all participating countries can maintain high-quality observations. Enhanced data sharing and open access to monitoring results further promote transparency, scientific collaboration, and evidence-based policymaking throughout the region.

4. Towards sustainable monitoring in the EANET region

Looking to the future, sustainable monitoring will require the integration of traditional observation systems with innovative technologies. Ground-based monitoring should remain the backbone of EANET because it provides the high-quality reference data necessary for scientific assessments and policy applications. However, complementary information from satellite observations, low-cost sensors, and advanced analytical tools can significantly enhance monitoring capabilities.

Recent developments by organizations such as NASA illustrate the growing potential of data-fusion approaches that combine air quality models, satellite observations, regulatory monitoring stations, and sensor networks to visualize pollution distributions across space and time. Such approaches can help fill spatial gaps in monitoring networks, improve exposure assessments, and support urban and regional air quality management. Nevertheless, these technologies should be regarded as complementary tools rather than replacements for EANET's official monitoring observations.

The integration of artificial intelligence (AI) and advanced data analytics may further improve the interpretation of large environmental datasets, which facilitate early identification of pollution episodes, and support policy-relevant assessments. Combined with EANET's long-term observational records, these emerging approaches can contribute to assessments of health impacts, ecosystem risks, and sustainable nitrogen management.

By combining robust long-term observations, harmonized methodologies, strengthened regional cooperation, and carefully validated new technologies, EANET can continue to serve as the leading regional platform for sustainable monitoring in East Asia. Its observational studies will remain indispensable for understanding environmental change, supporting air quality policies, and protecting both ecosystems and human well-being in the decades ahead.