Guideline for Catchment-scale Monitoring in East Asia

Endorsed by

Scientific Advisory Committee of EANET at its tenth Session

October 2010

Network Center for EANET

Table of contents

List of Contributors

The Guideline for Catchment-scale Monitoring was developed by the members of Task Force on Soil and Vegetation Monitoring. The members, who worked for the guideline, are listed here.

Prof. Wilfredo M. Carandang (Chairperson of the Task Force)	University of the Philippines at Los Banos, the Philippines
Dr. Haijiang Liu	China National Environmental Monitoring Centre, China
Dr. Masamichi Takahashi	Forestry and Forest Products Research Institute, Japan
Dr. Hiroyuki Sase	Asia Center for Air Pollution Research, Japan
Prof. Nik Muhamad Majid	Universiti Putra Malaysia, Malaysia
Dr. Ahmad Makmom Abdullah	Universiti Putra Malaysia, Malaysia
Dr. Apolonio M. Ocampo	University of the Philippines at Los Banos, the Philippines
Dr. Hye-Jin Kim (from 2010)	National Institute of Environment Research, Republic of Korea
Ms. Hoe-Jung Noh (until 2009)	National Institute of Environment Research, Republic of Korea
Dr. Tatiana A. Mikhailova	Siberian Institute of Plant Physiology and Biochemistry, RAS/SB, Russia
Mr. Bopit Kietvuttinon (from 2010)	Royal Forest Department, Thailand
Dr. Jesada Luangjame (until 2009)	Royal Forest Department, Thailand

Secretariat:
Dr. Hiroyuki Sase
Dr. Naoyuki Yamashita
Mr. Ryo Kobayashi
Ecological Impact Research Department, Asia Center for Air Pollution Research

1. Introduction

Terrestrial ecosystems consist of many components, including atmosphere, plant, soil, and stream. So far, most monitoring activities on acid deposition have been promoted for each component independently, namely monitoring on wet deposition, dry deposition, soil and vegetation, and inland aquatic environment. This approach may be useful to accumulate baseline data for spatial and temporal trend analysis for each component. However, precise discussion on relationship between components may need more integrated approach for both qualitative and quantitative evaluation.

Therefore, integrated monitoring including atmospheric deposition, soil, vegetation, and inland water, is required to evaluate effects of acid deposition on ecosystems qualitatively and quantitatively. Catchment-scale analysis may be one of solutions for this requirement. The integrated approach taking biogeochemical processes into account should be promoted in a catchment scale.

The catchment-scale monitoring may allow more practical discussion on relationship between seasonal or annual changes in stream water chemistry (concentrations or material/elemental fluxes) and those in atmospheric deposition. Material/elemental input-output budget in the catchment can be calculated based on the atmospheric deposition chemistry, stream water chemistry, and water balance. Moreover, based on the catchment-scale dataset, the simulation model on biogeochemical cycles is expected to be developed.

Strategy Paper on Future Direction of Soil and Vegetation Monitoring of EANET (EANET, 2002) suggested promoting case studies of the catchment-scale analysis to develop monitoring methodologies applicable to the East Asian region. The case studies have been implemented by NC and scientists in the EANET countries in the Sakaerat Silvicultural Research Station (SRS) site in Thailand, the Danum Valley site in Malaysia, and the Kajikawa study site in Japan. Moreover, the regular catchment-scale monitoring has just started in the Lake Ijira catchment, Japan, where acidification of the catchment area was suggested. Acidification mechanisms in the Lake Ijira catchment are being clarified gradually by the catchment-scale analysis.

Preparation of the monitoring guideline for EANET was proposed as one of the specific activities in the *Strategy Paper on Future Direction of Soil, Vegetation and related Ecosystems Monitoring of EANET (2009-2014)*, which was adopted by Scientific Advisory Committee (SAC) at its 8th Session in 2008. This *Guideline for the Catchment-scale Monitoring in East Asia* was developed based on experience through the case studies above in the East Asian region and endorsed by SAC at its 10th Session in 2010. It is expected that additional case studies will start in some other countries or the current case studies will be continued as the catchment-scale monitoring on a regular basis according to the guideline.

2. Basic matters on the catchment-scale monitoring

2.1. Objectives

The catchment-scale monitoring should be implemented for the following final objective:

- To evaluate effects of atmospheric deposition on ecosystems qualitatively and quantitatively on a catchment scale.

  In detail, the following objectives can be proposed:

  - To interpret seasonal or annual changes in the stream water chemistry based on atmospheric deposition and possible biogeochemical processes in a catchment
  - To discuss impacts of atmospheric deposition based on the input-output budget of materials/elements on a catchment scale.
  - To provide necessary dataset to the catchment-scale simulation model for understanding the current status and making future projection of the material/elemental cycles in the catchment due to the changing environment.

2.2. Selection of monitoring sites

Sites for the catchment-scale monitoring should be selected taking the following recommendations into account:

1) A forest catchment with a stream should be selected, while the size of the catchment may depend on each situation.
2) The catchment, where the water budget has been estimated, is preferable.
3) Sensitivity of soil or bedrock geology to atmospheric deposition should be considered for site selection.
4) If possible, the site should be in vicinity of the EANET acid deposition site to estimate atmospheric deposition amounts precisely.
5) Other ecological information from nearby sites is valuable.

3. Monitoring items

3.1. Items to be monitored

Items to be monitored and recommended methods are shown in Table 1a) and 1b).

The total deposition as an input and the discharge from the stream as an output should be estimated as minimum requirements (Table 1a). Most of items have been measured or proposed for deposition monitoring or ecological monitoring. The following existing technical documents can be referred for the respective items or methods:

- *Technical Manual for Wet Deposition Monitoring in East Asia-2010*: wet-only sampling for wet deposition monitoring
- *Technical Documents for Filter Pack Method in East Asia:* filter pack method for measurement of air concentration
- *Quality Assurance/Quality Control Program for the Air Concentration Monitoring in East Asia:* automatic monitors for measurement of air concentration
- *Sub-Manual on Forest Vegetation Monitoring in EANET:* bulk sampling of rainwater in forest area, passive sampler method for measurement of air concentration in forest area, throughfall-stemflow method for estimate of total deposition in forest area
- *Technical Manual for Dry Deposition Flux Estimation*: inferential method for estimate of dry deposition flux
- *Technical Manual for Inland Aquatic Environment Monitoring in East Asia-2010*: measurement methods for stream water chemistry and water discharge

In addition to the input and output, items for biogeochemical processes should be monitored to discuss material/elemental cycles in the catchment. Possible items to be monitored for this purpose were shown in Table 1b, while other items may be considered depending on targets. Some of items have been measured or proposed for soil and vegetation monitoring. The following existing technical documents can be referred for the respective items or methods:

- *Technical Manual for Soil and Vegetation Monitoring*: analysis of soil chemical properties and soil physical properties, description of soil profile

Table 1 a) Items to be monitored for estimating input and output

Items to be monitored		Requisite	Recommended methods
Input (total deposition)	Precipitation amount	Mandatory	➢ Rain gauge: at least one gauge in an open space near the catchment If the catchment area is significantly large, spatial variability of the precipitation should be checked in different positions.
	Wet deposition	Mandatory	➢ **Wet-only sampling:** at least 1 sampler in an open space near the catchment (when the EANET site is located in the vicinity or a power supply is available) ➢ **Bulk sampling:** at least 1 or more samplers in an open space near the catchment (when electricity is not available)
	Dry deposition	Optional	➢ **Inferential method:** estimated based on the concentration data by Filter pack method and meteorological data at the EANET site or the nearest meteorological station ➢ **Automatic monitors:** an alternative method for the concentration, or especially for O_3 ➢ **Passive sampling method:** an alternative method for the concentration, or especially for O_3 and NO_2
	Total deposition	Mandatory	➢ Wet + Dry: Calculated as sum of wet and dry depositions above ➢ **Throughfall–Stemflow method:** at least several points under the forest canopy (when electricity is not available)
Output (discharge from the stream)	Water discharge	Mandatory	➢ Weir: runoff of the catchment ➢ **H-Q curve method:** at the outlet of stream in the catchment (when a weir is not available)
	Stream water chemistry	Mandatory	➢ **Periodical collection of stream water to a plastic bucket/bottle:** at the outlet of stream of the catchment
	Chemical discharge	Mandatory	➢ Calculation: based on the water flux and the chemical concentration

Note: Bold methods have already referred in the other EANET documents.

Table 1 b) Items to be monitored for biogeochemical processes

Items to be monitored		Requisite	Recommended methods
Soil	Soil chemical properties	Mandatory	➢ **Collection of soil from the permanent plots:** at least two plots (with five sub-plots, respectively)
	Soil solution	Optional	➢ Suction (porous) cup method ➢ Pan Lysimeter method ➢ Resin capsule method
	Soil moisture	Optional	➢ Time Domain Reflectometry (TDR) method ➢ Amplitude Domain Reflectometry (ADR) method
	Soil physical properties	Optional	➢ **Fine earth bulk density: Metal sampling cylinder method** ➢ **Penetration resistance: Pocket penetrometer method**
	Soil gas emission	Optional	➢ Chamber method
Vegetation	Plant growth	Mandatory	➢ **Measurement of tree size (description of trees):** DBH and height of trees at least one plot (with three coaxial circle sub-plots) ➢ Dendrometer ➢ Tree ring analysis
	Species composition	Optional	➢ **Understory vegetation survey**
	Elemental contents	Optional	➢ Litter trap ➢ Collection of living leaf
Water balance	Evapotranspiration	Optional	➢ Heat balance method by using canopy tower

Note: Bold methods have already referred in the other EANET documents.

Note. Based on the experience in the case study sites in the EANET countries (Luangjame et al., 2009), the following recommendations should be referred for implementation of the monitoring items:

Recommendations for the input items:

1) Spatial variability of the precipitation amount should be considered in mountainous area if the catchment area is relatively large.

2) The throughfall-stemflow (TF-SF) method is useful to estimate total (wet and dry) atmospheric deposition amounts for certain constituents, such as SO_4^{2-}, whose canopy interaction can be negligible.
3) Dry deposition flux should be estimated by appropriate methods other than the TF-SF method to estimate total deposition precisely, especially for nitrogen compounds, taking canopy interactions such as uptake or consumption into account.
4) The deposition and meteorological data collected in the nearest EANET station should be utilized if available. The total deposition can be estimated by using the data of the filter-pack method and the wet-only sampler at the EANET station.
5) In particular in tropical region, wet deposition of nitrogen should be estimated by appropriate methods since microbial consumption of nitrogen is large during the storage in the sampling field. The ion-exchange-resin sampler may be applicable in forest area for long-term collection (for several months).

Recommendations for the output items:

6) The water year should be decided based on hydrological cycle in each catchment taking precipitation and discharge patterns into account.
7) Evapotranspiration should be estimated if possible, for precise water balance, especially in tropical region.
8) Cooperation with hydrologists may be helpful to understand hydrological processes in the catchment in detail.

Recommendations for items of biogeochemical processes:

9) Plant growth should be measured in the catchment area. Tree ring analysis may be useful to estimate the previous growth rate for the long-term analysis. At least, some information on plant growth should be compiled through a literature study.
10) Soil samples should be collected for analysis taking a spatial variation of soil chemical properties in the catchment.

3.2. Chemical parameters to be measured

Major chemical parameters to be measured for the respective items are shown in Table 2.

Table 2 Chemical parameters for the respective items

Items	Requisite	Parameters to be measured
Rainwater samples	Mandatory	➢ Cations: NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, and K^+ ➢ Anions: SO_4^{2-}, NO_3^-, and Cl^- ➢ Electric conductivity (EC) ➢ pH
	Optional	➢ Total organic nitrogen (TON) ➢ Total organic carbon (TOC)
Stream water samples	Mandatory	➢ Cations: NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, and K^+ ➢ Anions: SO_4^{2-}, NO_3^-, and Cl^- ➢ EC ➢ pH ➢ Alkalinity (Gran's ANC and/or pH 4.8 endpoint)
	Optional	➢ SiO_2 ➢ TON ➢ TOC ➢ Total dissolved Al
Air concentrations (by filter pack method)	Mandatory	➢ Cations: NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, and K^+ ➢ Anions: SO_4^{2-}, NO_3^-, and Cl^- ➢ Gasses: SO_2, HNO_3, HCl, and NH_3
Soil chemical properties	Mandatory	➢ pH (H_2O) and pH (KCl) ➢ Exchangeable Base Cations (Ca, Mg, K and Na) ➢ Exchangeable Acidity, Al and H ➢ Effective Cation Exchangeable Capacity
	Optional	➢ Total carbon (T-C) ➢ Total nitrogen (T-N)
Soil solution	Optional	➢ Cations: NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, and K^+ ➢ Anions: SO_4^{2-}, NO_3^-, and Cl^- ➢ SiO_2 ➢ pH ➢ EC
Soil gasses	Optional	➢ N_2O ➢ CO_2
Litter and leaf samples	Optional	➢ T-C ➢ T-N ➢ Base cations: Ca, Mg, Na, and K ➢ Total Al

Note: The parameters should be elaborated taking the model simulation into account.

3.3. Measurement frequency

Proposed frequency for measurement of the respective items was shown in Table 3, while actual frequency can be decided depending on the situation of each site.

Table 3 Proposed frequencies for measurement of the respective items

Items to be monitored		Proposed frequency
Input (total deposition)	Precipitation amount	➢ Continuously or daily
	Wet deposition	➢ Daily or weekly: for wet only samplers ➢ Weekly or biweekly: for bulk sampling
	Dry deposition	➢ Weekly: for filter pack method ➢ Continuously: for automatic monitor ➢ Biweekly or monthly: for passive sampling method
	Total deposition	➢ Biweekly, or monthly: for calculation of wet+dry ➢ Biweekly: for throughfall-stemflow method
Output (discharge from the stream)	Water discharge	➢ Continuously or biweekly
	Stream water chemistry	➢ Weekly or biweekly ➢ Intensive sampling (1-2 hour interval) during heavy-rain or snow-melting events
	Chemical discharge	➢ Biweekly, monthly or annual: for calculation
Soil	Soil chemical properties	➢ Once for several years ➢ Twice a year in case of tropical seasonal forest
	Soil solution	➢ Monthly or four times a year
	Soil moisture	➢ Continuously
	Soil physical properties	➢ Once
	Soil gas emission	➢ Monthly or four times a year
Vegetation	Plant growth	➢ Once for several years: for description of trees ➢ Continuously: dendrometer or annual enumeration
	Species composition	➢ Once for several years:
	Elemental contents	➢ Biweekly or monthly: for litter trap ➢ Monthly or bimonthly: for leaf analysis

Note. Recommendations for the measurement frequency:

11) Stream water samples should be collected at the outlet of the catchment periodically, hopefully at 2-week interval (or twice a month).

12) Intensive sampling of the stream water should be conducted during heavy-rain or snow-melting events if possible.
13) Seasonal variation of soil chemical properties should also be considered for some parameters, such as pH (H_2O), especially in tropical seasonal forest.

4. Monitoring procedures

4.1. Sampling protocols

Field sampling of the mandatory items should be carried out in accordance with sampling protocols described in the existing EANET technical documents (see the section 3.1).

Field sampling of the optional items should also be done so if the existing EANET technical documents can be referred.

Sampling protocols for other optional items may have flexibility depending on the situation of each site but should follow the methods, which have been authorized as the standard method in the EANET countries or at least published in international journals.

4.2. Transportation and storage of samples

Water samples, such as rainwater and stream water, should be refrigerated at 4 °C before shipment to the analytical laboratory. At latest, the samples should be transported to the analytical laboratory weekly or biweekly.

Samples arriving at laboratory should be kept in refrigerator and used for analysis as soon as possible.

4.3. Analytical procedures

Chemical analysis of the mandatory parameters should be carried out in accordance with analytical procedures described in the existing EANET technical documents (see the section 3.1). Analysis of the optional parameters should also be done so if the existing EANET technical documents can be referred. Possible analytical equipments or methods for the representative mandatory parameters are shown in Table 4.

Chemical analysis for other optional parameters may have flexibility depending on the situation of each laboratory but should follow the methods, which have been authorized as the standard method in the EANET countries or at least published in international journals.

Table 4 Possible analytical equipments or methods for the mandatory parameters

Items	Parameters	Analytical equipments/methods
Water samples: rainwater or stream water	Electric Conductivity (EC)	➢ Conductivity Cell
	pH	➢ Glass electrode (preferably with the Electrode of non-leak inner cell)
	Cations: NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, and K	➢ Ion Chromatography
	Anions: SO_4^{2-}, NO_3^-, and Cl^-	➢ Ion Chromatography
	Alkalinity (only for stream water)	➢ Titration by Burette or Digital Burette with pH Meter
Soil	pH (H_2O) and pH (KCl)	➢ Glass electrode (1:2.5 soil-solution suspension)
	Exchangeable Base Cations (Ca, Mg, K and Na)	➢ AAS, ICP-AES or ICP-MS (CH_3COONH_4-Extraction)
	Exchangeable Acidity, Al and H	➢ Titration (KCl-Extraction)

5. Quality assurance/quality control (QA/QC)

Data quality should be controlled and assured according to the EANET QA/QC program. Basically, protocols on sampling and chemical analysis can be standardized referring the existing EANET technical documents. The following fundamental matters should also be noted in the catchment-scale monitoring.

- Clear assignment of responsibility (personnel in charge of each activity)
- Standard operating procedures (SOPs) for each activity
- Documentation of activities

6. Evaluation

The data should be evaluated on a catchment scale. The input- output budget should be calculated based on the atmospheric deposition chemistry, stream water chemistry, and water balance to outline the material/elemental cycles in the catchment. The standard units should be used for the input and output. Recommended basic units for evaluation is as follows:

- Water flux (precipitation amount and stream water discharge): mm
- Chemical concentration: $mol_c\ L^{-1}$ (ex. $\mu mol_c\ L^{-1}$ or $mmol_c\ L^{-1}$)
- Ion flux (deposition, discharge or soil/vegetation flux): $mol_c\ ha^{-1}$ or $mol_c\ m^{-2}$
- Elemental flux for N and S: $kg\ ha^{-1}\ y^{-1}$ or $g\ m^{-2}\ y^{-1}$

Based on the compiled data with the standard units on a water-year basis, initial evaluations should be done for the following items:

- Water balance on a catchment-scale: input, output and possible evapotranspiration
- Material/elemental balance on a catchment-scale: input-output budget

7. Data reporting

Dataset should be submitted to Network Center after an initial evaluation is done by the national center. Since the catchment-scale data should be evaluated based on the water year, the dataset should be compiled on a water-year basis of the respective catchment sites.

Existing reporting formats for monitoring on wet deposition, dry deposition, soil and vegetation, and inland aquatic environment can be referred for reporting of the mandatory items.

In addition to the data of the respective items, the following summary tables should be attached.

- Table showing the list of dataset obtained in the catchment site
- Table showing the estimated input-output for a water year

Reference:

Luangjame, J., Garivait, H., Sase, H., Yamashita, N., Ohta, S., Leong, C.P. & Takahashi, M. 2009. Recommendations for preparation of a guidelineon the future catchment monitoring in the EANET participating countries. Second Meeting for the Task Force on Soil and Vegetation Monitoring of EANET.