Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia

Data Report

September 2007

National Focal Points (NFP) and National Implementing Agencies (NIA)

Bangladesh	**India**	**Maldives**	**Pakistan**
NFP: Ministry of Environment & Forest NIA: Department of Environment, Dhaka	NFP: Ministry of Environment and Forest NIA: Central Pollution Control Board, New Delhi	NFP & NIA: Ministry of Environment, Energy and Water, Malé	NFP: Ministry of Environment NIA: Pakistan Environment Protection Agency, Islamabad
Bhutan NFP&NIA: National Environment Commission, Thimphu	**Iran** NFP & NIA: Department of Environment, Tehran	**Nepal** NFP: Ministry of Environment, Science and Technology NIA: International Center for Integrated Mountain Development, Kathmandu	**Sri Lanka** NFP: Ministry of Environment and Natural Resources NIA: Central Environment Authority, Colombo

Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia is being implemented by UNEP Regional Resource Center for Asia and the Pacific in collaboration with the National Implementing Agencies (NIAs), South Asia Cooperative Environment Program (SACEP) and Stockholm Environment Institute (SEI) with the financial support from Sida, the Swedish International Development Cooperation Agency.

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1.0 Introduction

The United Nations Conference on Environment and Development (UNCED) produced a major strategic outlook for the 21st century in the Agenda 21. In addition to the many important sectoral declarations, it made some important observations on vital cross-cutting issues. One of these vital issues is described in Chapter 40 on Information for Decision Making: the importance of improved availability of information on all aspects of environment and development for decision making towards sustainable development. Agenda 21 also emphasizes the need for improved collection as well as presentation of data and information.

Decision making for sustainable development should be based on sound, reliable and timely information. Environment is one of the three pillars (economic, environmental and social) of sustainable development and it needs regular assessment.

Land, air, water and biodiversity are the major components of the environment which need regular assessment. Malé Declaration provides the basic framework for assessment of transboundary air pollution in South Asia and its effects. Hence, it is very important for the Malé Declaration that the monitoring results be compiled in a systematic database. Information on outcomes of monitoring activities is known only through monitoring data.

Acid deposition is an environmental problem that transcends national boundaries. The Malé Network is dedicated to creating a common understanding of the status of acid deposition among member countries and collaborating organizations, and to providing useful inputs for the assessment of acid deposition in the region.

The transport of atmospheric gases and particulate matter (aerosols) and adsorption by the Earth's surface (land surfaces, plant surfaces, building surfaces, water surfaces), without the mediation of precipitation is known as dry deposition, while dissolution those species in clouds, fog, rain or snow and eventually rain out or wash out by the falling rain or snow is known as wet deposition.

The proportion of wet and dry deposition can vary with location and time. Wet deposition is responsible for 30-50% of deposition fluxes to ecosystems in South Asia. Precipitation chemistry measurements provide information on the exchange of trace materials between the atmosphere and the earth’s surface. Dry deposition accounts for 50-70% of total deposition fluxes to the ecosystem. It is therefore important to monitor dry and wet deposition to obtain a complete evaluation of total deposition in a region, which is necessary for assessment of the effects of acidic substances.

One of the goals of the Malé Network is to provide high-quality data and other information on wet and dry deposition and its composition in the Malé Declaration participating countries.

Based on the national baseline studies during Phase I of the Malé Declaration Implementation it was obvious that there were large differences in the monitoring status and the air pollution monitoring experience among the Malé Declaration countries. The

national baseline studies showed that none of the countries, except India, had any systematic monitoring activities. To be able to compare the results achieved, the Monitoring Committee (MoC) for Malé Declaration concluded at an early stage that the use of simple and easy-to-handle methods as a reference standard in all countries were of great importance.

A monitoring manual has been prepared that includes elaborated recommendations on appropriate sampling techniques and analytical methods. Within the Malé Declaration Phase II programme those equipments and consumables for sampling and analysis have been provided for all the Malé Network Monitoring Stations (one site in each country) and laboratories. A list of equipments is provided in Appendix 1.

Phase III Malé Declaration implementation is to promote the scientific base for prevention and control of Transboundary air pollution in South Asia and to encourage and facilitate coordinated interventions of all the stakeholders on Transboundary air pollution at the national and regional level. One of the focuses of Phase III is to enhance the analytical and impact assessment capabilities at the national level through integration of findings from the monitoring stations, local pollution prevention studies and by conducting impact assessment studies. The data from monitoring station are now being produced and the countries are starting to analyse them. It is expected that the capacities established in each country and the support of UNEP, SEI and Sida will lead to meaningful conclusions on the state of Transboundary air pollution in a few years time.

2.0 Monitoring Sites

The criteria for selecting monitoring stations are given in Appendix 2. Based on the available resources and manpower, it was agreed to establish one monitoring station in each of the participating countries during Phase II. Monitoring sites have been chosen in all 8 countries. The MoC had the opportunity to visit the monitoring sites in Bangladesh, Bhutan, Iran, Maldives, Nepal and Sri Lanka. The details of the monitoring site in each participating country are presented in Table 2.1.

Table 2.1: Details monitoring stations of Malé Declaration

Country: Bhutan; **Station**: Gelephu **Latitude and longitude:** 27°0'N; 90°30'E **Altitude**: ~ 350m above sea level **Site type:** Remote site, close to Jigme Singye Wangchuk National Park and Manas National park **Monitoring parameters:** Air quality: PM_{10} (particulate mass of particles with diameters <10µm) or Respirable Suspended Particulate Matter (RSPM) or, Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2). Wet deposition: pH, and Electric Conductivity (EC)	**Country**: Bangladesh; **Station**: Kulna **Latitude and longitude:** 22º 18.975' N; 89º 02.607'E **Site type:** Rural site, located about 30 km North to the Sundarbans forest. **Monitoring parameters:** Air quality: PM_{10} (particulate mass of particles with diameters <10µm) or Respirable Suspended Particulate Matter (RSPM), Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2). Wet deposition: pH, and Electric Conductivity (EC)

Country: Iran; **Station**: Chamsari **Latitude and longitude:** 32˚ 24'N, 47˚31˙E **Site type:** Rural site, 40 km south to the town of Dehlaran and about 200 km south to Ilam, the headquarters of the province. **Monitoring parameters:** Air quality: PM_{10} (particulate mass of particles with diameters <10µm) or Respirable Suspended Particulate Matter (RSPM), Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2). Wet deposition: pH, and Electric Conductivity (EC)	**Country**: India; **Station**: Port Canning **Average annual rainfall:** 1750 – 1800 mm **Dominant wind direction:** N/NE during winter and S/ SW in summer **Site type:** Rural site, close to Synderbans. **Monitoring parameters:** Air quality: PM_{10} (particulate mass of particles with diameters <10µm) or Respirable Suspended Particulate Matter (RSPM), Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2). Wet deposition: pH, and Electric Conductivity (EC)
Country: Maldives; **Station**: Hanimaadhu **Latitude and longitude:** **Altitude**: ~2 m **Site type:** Remote site, in the northernmost atoll of Maldives located about 400 km to the north of the country's capital, Malé. **Monitoring parameters:** Air quality: Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2).	**Country**: Nepal; **Station**: Rampur **Latitude and longitude:** 27º 38'N; 84º 20'E **Altitude**: 164.95 m **Site type:** Rural site, located about 15 km to the south of the Royal Chitawan national park. **Monitoring parameters:** Air quality: PM_{10} (particulate mass of particles with diameters <10µm) or Respirable Suspended Particulate Matter (RSPM), Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2). Wet deposition: pH, and Electric Conductivity (EC)
Country: Pakistan; **Station**: Bahawalnagar **Site type:** Rural site **Monitoring parameters:** Air quality: PM_{10} (particulate mass of particles with diameters <10µm) or Respirable Suspended Particulate Matter (RSPM),, Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2). Wet deposition: pH, Electric Conductivity (EC)	**Country**: Sri Lanka; **Station**: Dutuwewa **Latitude and longitude:** 08° 20.952' N; 80 45.751'E **Altitude**: ~ 100m **Site type:** Remote site, in a forest in the north-central part of Sri Lanka **Monitoring parameters:** Air quality: PM_{10} (particulate mass of particles with diameters <10µm) or Respirable Suspended Particulate Matter (RSPM), Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2). Wet deposition: pH, Electric Conductivity (EC), Na^+, K^+,

In order to ensure the ownership of the programme, National Implementation Agencies (NIAs) were given complete freedom on site selection with technical guidance from the MoC. The local communities and the village heads were also consulted during site selection in most of the countries.

To strengthen the monitoring network, there will be three more monitoring sites (Sri Lanka, Bhutan and Iran) under Phase III implementation are agreed to established and site selection is under process in these countries.

3.0 Monitoring Programme

The air quality measurements include daily observations of ambient concentrations of SO_2, NO_2 and PM_{10}. A High Volume Sampler (HVS) is used to sample particulate matter (PM) and this provides data on total suspended Particulate matter (TSPM) as well as PM_{10}. Ambient concentrations of SO_2 and NO_2 are measured using both active bubbler techniques (daily means) and diffusive (passive) samplers (monthly means). The diffusive samplers are used as the reference for quality control of the active samplers, and the analysis of those passive samplers is presently performed by IVL-Swedish Environmental Research Institute Ltd.

Ozone monitoring is included in Phase III implementation and it has been introduced to all the monitoring sites since April/May 2006 by IVL. Three countries have already received ozone analysis data.

3.1 Wet Deposition Monitoring

3.1.1 Method

To obtain the uniformity and high quality of monitoring data, each participating country carries out the wet deposition monitoring fundamentally using the common methodologies specified in the "Technical Document for Wet and Dry Deposition Monitoring for Malé Declaration" which was provided during the in-country training programmes. A flow chart for sampling and analysis of samples are shown in Fig.1.

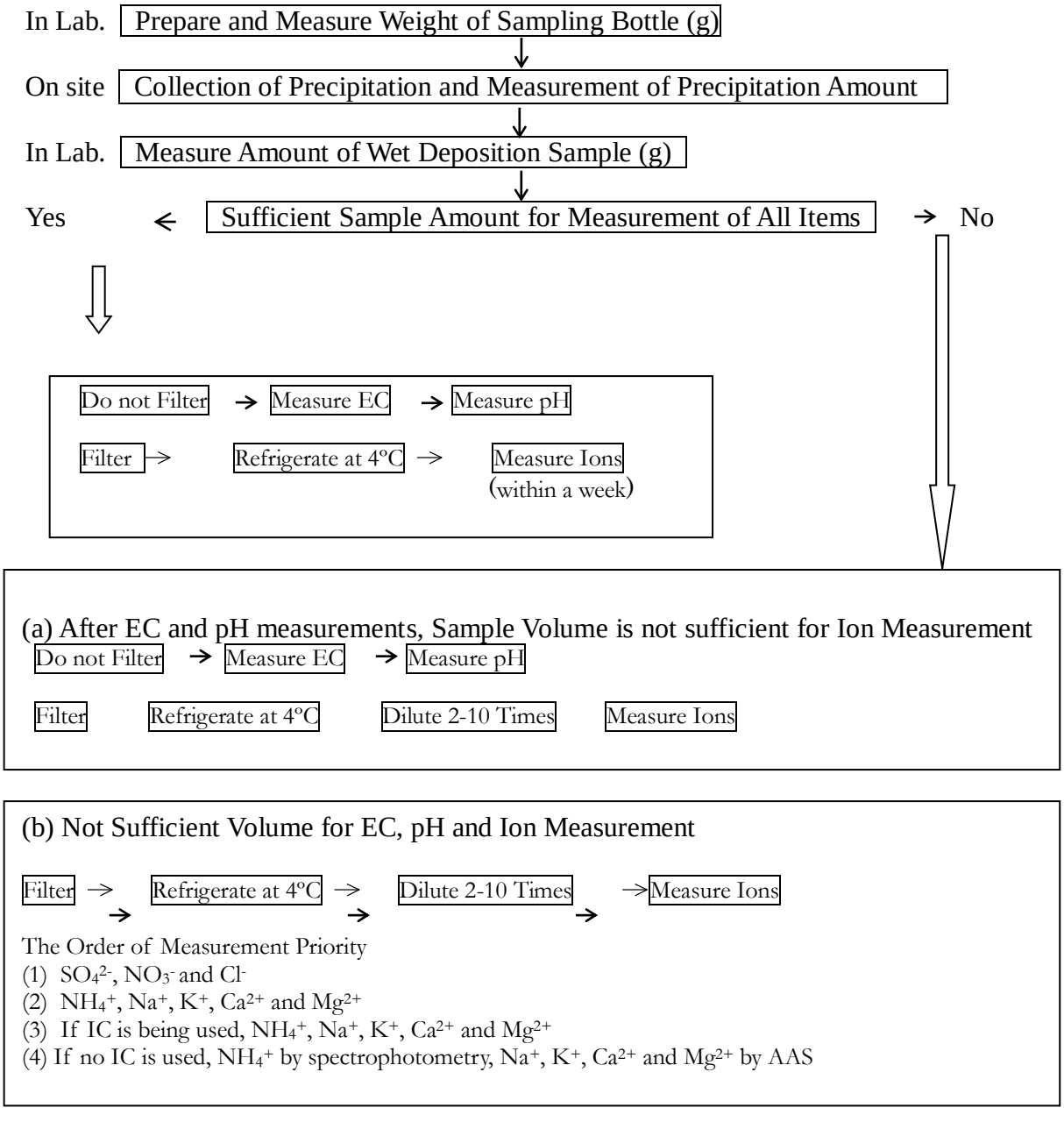

Fig 1 Flowchart of sampling and chemical analysis on wet deposition

1) Field Operation

Rainwater samples are collected with both an automated wet-only collector technique and a bulk simple collector technique. The wet-only and bulk samplers are recommended methods for sampling of precipitation. Precipitation samples are collected on a daily basis at two sites (Bhutan and Bangladesh), weekly collection is performed at the site in Sri Lanka, monthly collection and analysis at Nepal and random collection at

Pakistan site as shown in Table 3.1. For the wet deposition samples collected in a tropical region, a preservation of samples from microbial decomposition should be considered. Biocides such as Thymol are added for that purpose when a refrigerator is not available during sampling, shipping and storage. Samples without biocides are kept in cooling box to keep the sample temperature low enough to preserve the sample chemistry, and shipped to the laboratories in-charge of further chemical analysis.

Table 3.1 Sampling Method for Wet Deposition Monitoring using Wet only collector and Bulk collector

Country	**Name of site**	**Characteristics of sites**	**Sampling Interval**	**Sampling Months**
Bhutan	Bhur, Gelephu	Remote	Daily	2003: Jul, Aug, Sept,Dec 2004: Jan, Feb, Aug, Dec
Bangladesh	Kaikhali Forest station, Shamnagar, Satkhira	Remote	Daily	2004: Jul, Oct 2005: August, Sept, Oct 2006: April, Jun 2007: May, Jul, Aug
Iran	Chamsari, Ilam	Remote	Weekly	2004: Nov, Dec 2005: Jan, Nov, Dec 2006: Jan, Feb, Oct, Nov, Dec 2007: Jan, Feb
Sri Lanka	Dutuwewa	Remote	Weekly	2003: Nov, Dec 2004: Jan to Jul
Nepal	Rampur	Rural	Monthly	2006: Jul to Dec 2007: Jan to Aug
Pakistan	PBO Bahawal Nagar	Rural	Random	2007: Feb

2) Laboratory Operation

The procedures suggested for analysis of rainwater major constituents as described in the manual are shown in Table 3.2. Rainwater analysis for pH and electrical conductivity (EC) is recommended as well as the concentrations of anions (sulphate, nitrate, chloride) and cations (ammonium, calcium, magnesium, potassium and sodium). The analytical methods detailed here are typical for the analysis of precipitation samples with the instrumentation commonly available in many laboratories. Bangladesh, Bhutan, Iran, Nepal, Pakistan and Sri Lanka have submitted the rainwater analysis data from their monitoring site.

3) Data Management

Analytical data of precipitation samples were submitted from the participating laboratories to NIAs. Then each NIA submitted the data to UNEP RRC.AP. After that MoC members discuss with each NIAs at refresher course training which regularly held every year. After discussion, RRC.AP compiled and stored the monitoring data on the website. These data are accessible only for NIAs.

4) Meteorological Measurement

Meteorological parameters (wind direction/speed, temperature, relative humidity, precipitation and solar radiation) in relation to wet deposition should be measured at the site or at the nearest meteorological station in accordance with the measurement frequencies and methods of the meteorological monitoring system of each country. Bangladesh, Iran and Pakistan had sent their meteorological data from Metrological station near monitoring site.

Table 3.2: Techniques suggested for analysis of rainwater major constituents

Parameter	**Instrumental Method**
Electric Conductivity (EC)	Conductivity Cell
pH	Glass electrode
Chloride	Argentrometric method
Nitrate	Cadmium reduction method Spectrophotometry
Sulphate	Spectrophotometry
Ammonium	Spectrophotometry
Sodium	Flame photometry
Potassium	Flame photometry
Calcium	Titrimetry (EDTA method)
Magnesium	Titrimetry

3.1.2 Result of Monitoring

The wet deposition and meteorological data of each monitoring site are shown in the country data tables.

3.2 Air Concentration Monitoring

3.2.1 Method

High Volume Sampler (HVS) and Diffusive Samplers are used to monitor SO_2, NO_2 and PM_{10} in Malé Declaration Network. The samples from HVS were analyzed in their respective laboratories using suitable analytical methods such as ion chromatography (IC), atomic absorption spectroscopy (AAS), gas chromatography (GC) etc. for specific pollutants. For the analysis of samples colleted with diffusive samplers, they are repacked in their containers at the end of sampling interval and sent to IVL-Swedish Environmental Research Institute Ltd. for analysis. The start and end time of the sampling intervals are recorded.

3.2.2 Results of Monitoring

Nepal and Iran had sent continuous monitoring data on air concentration through HVS and there were one time data from Pakistan and India. For Diffusive sampler all the countries have send their samples to IVL for analysis and the data has been updated regularly. The results of monitoring data are presented in country data tables.

Appendix 1: List of Equipments and Consumables

1 Site Equipment

No.	Description	No. of Unit	Remark
1.1	PM_{10} air sampler	1	Envirotech model APM 460(NL)
1.2	pH meter	1	Hand held WTW model pH 300i (pH meter)
1.3	EC meter	1	Electrical conductivity meter, hand held WTW model COND 330i
1.4	Thermometer	1	Best Indian Make (-20 to 15degree C, least count 0.1 degree)
1.5	Diffusive samplers	2	For measurements at 1 site on a monthly basis during one year
1.6	Bulk sampler	2	
1.7	Wet only Collector	1	Included solar panels, solar shunt regulator

2 Laboratory - Equipment

2.1	Spectrophotometer	1	U/V and Visible Best Indian Make, Elico SL 171
2.2	Oven	1	Best Indian Make (50 to 250 degree range, 220-240V, 0.5KW)
2.3	Balance	1	Electronic Balance, Sartorius Make. Model BL210S Capacity 210g. Readability 0.1 mg
2.4	pH meter	1	Hand held WTW model pH 300i (pH meter)
2.5	Electrical conductivity meter	1	Electrical conductivity meter, hand held WTW model COND 330i
2.6	Desiccator	1	Mark 'Duran' Size 300mm
2.7	Distallation Unit	1	
2.8	Magnetic stirrer 1 L	1	Though listed as being reqd for soil qlty analysis, would be preparing for preparing solutions for DD/WD sample analysis
2.9	pH electrode for low ion concentration	1	
2.10	Calibrators		
	a) Soap Bubble Meter (manual type) (Calibrator for Rotameter)	1	
	b) Top loading Flow Calibrator	1	

3 Laboratory Consumables

A	***Glassware and other consumables***		
3.1	Washing bottle with ground glass stopper 500 ml	2	
3.2	Measuring cylinder 100 ml, 50ml, 25 ml. 10 ml	8	100 ml x 2 nos, 50ml x 2 nos, 25ml x 2 nos, 10ml x 2 nos
3.3	Glass tubes with ground-in stopper (Nessler's tubes)	12	

3.4	Volumetric flask 1000ml, 500 ml, 250 ml, 100 ml	7	1000ml x 2nos, 500 ml x 1 nos, 250 ml x 2 nos, 100 ml x 2 nos
3.5	Pipette 10 ml, 25 ml	4	10 ml x 2 nos, 25 ml x 2 nos
3.6	Filter paper Whatman 41, dia 47 mm	3	1 box = 100 nos
3.7	Bottle polypropylene 1 L, 500 ml	14	1 L x 6 nos, 500 ml x 8 nos
3.8	Beaker 100 ml, 250 ml	16	250 ml x 2 nos, 100ml x 12 nos
3.9	Regaent bottles 100ml	6	100ml x 6nos
3.10	Regaent bottles 250ml	6	250ml x 6 nos,
	Chemicals and other consumables		
3.11	2 monitoring kits		

4 Site Consumables

4.1	Filter paper Whatmans GF/A	2	Size 8"x10", in sealed pkt. Of 100 sheet
4.2	Impingers	4	35ml capacity, 4 will be supplied with hvs, 4 more are reqd as spare
4.3	Syringe 100 ml	2	5.00 each packet, in pkt. Of 10
4.4	Glass/inert plastic tubing	3	per meter, Silicon tube
4.5	Silicon grease	2	for 100 gm packet
4.6	Measuring cylinder 100 ml	2	each
4.7	Pipette 20 ml	3	10 ml x 2 nos, 20 ml x 1 nos
4.8	Polyethylene containers 20 ml	100	each - 60ml
4.90	Funnel	6	50 mm x 3 nos, 75 mm x 3 nos
4.10	Capped bottles 1 L	3	each (Tarson)
4.11	Ice box	2	each (medium size)
4.12	Power Cord 5 meter long	2	
4.13	Junction Box (Extension Board)	1	1 set
4.14	Burette (50 ml)	1	
4.15	Burette Stand	1	
4.16	Cleaning Brush for Glassware	2	
4.17	Printed paper envelopes to keep filters	1pkt	1 pkt. of 12 Nos.
4.18	Graph Pad	1 Pad.	
4.19	Iodine flask (250ml)	2	
4.20	Membrane Filtration Assembly	2	
4.21	Petridish	1	
4.22	Pipette (1 ml)	1	
4.23	Pipette (2 ml)	1	
4.24	Pipette stand	1	
4.25	Plier	1	
4.26	Pipetting Pump	1	
4.27	Silica gel (500 gm)	1	

4.28	Torch	1	
4.29	Tissue Roll	1	
4.30	Tweezer	1	
4.31	Sampling Bag	1	

5 Micro Meteoro Monitor Envirotech WM 251

5.1	Field Micrologger with Standard WS-15 Sensor		Assembly with Display facility for instantaneous values of wind speed, direction and temperature at two heights.
5.2	Software Packages for WM-251		for obtaining frequency distribution and stability wind rose diagrams.
5.3	Constant Voltage Transformer (CVT)		100 VA rating for providing stabilized mains voltage to the wind monitor.
5.4	Standard Magnetic Compass		to record North & South Poles.
	Optional Accessories:		
	Sensors for Relative Humidity	1	Operating Range: 0-100% RH; Accuracy:5% ; Resolution: 1oC
	Sensor for Rainfall	1	having resolution of 1mm and accuracy of 1%
	Power Pack with Solar Panel	1	A Power Pack where a battery has been provided with charging facility using 220V power supply.
	Central Data Processor	1	(Pentium IV Computer with a preloaded Wind Monitor WM251 Software, Suitable Dot Matrix Printer and a UPS)

Appendix 2 Site selection criteria for acidic gas deposition by the Malé Network

1. Two types of sites are required for monitoring transboundary air pollution—deposition monitoring sites for monitoring wet and dry deposition, and ecological monitoring sites where soils, vegetation, water bodies and aquatic ecology would be monitored. Deposition monitoring should not be done in forests, as vegetation will absorb a part of the pollutants, thus giving erroneous results.

2. The sites for monitoring the ecological parameters should be in a good natural forest which is likely to remain undisturbed in future. Ecological sites should also have a fresh water lake or stream that does not receive liquid or solid pollutants.

3. Monitoring of transboundary air pollutants should be done at remote sites as close as is practically feasible to the international border. The monitoring sites should be at least 25 km away from the nearest town/ large industry and 10 km away from the nearest highway/ small industry.

4. To the extent possible, there should be no human habitation/ activity or other emission sources close to the sites. Population density around the sites should be low and should be expected to remain low in future.

5. The site should be representative of other remote areas in its proximity.

6. The sites should be downwind of major emission sources in neighboring countries and upwind of major emission sources in the country in which the monitoring is being done.

7. Unless unavoidable, the sites should be sufficiently inland to avoid the influence of coastal breezes.

8. The terrain between the emission sources in the neighboring country and the monitoring sites should preferably be flat.

9. The sites should be secure. They should be accessible to sample collectors. They should have a power connection and be habitable for short periods, if necessary.

10. The sites should preferably have a meteorological station within about 50 km of them. The terrain between the monitoring site and the meteorological station should be flat.

11. The site should be within 12-15 hours travel time from the place where the samples (other than diffusive samplers) will be analysed.

12. A few of the ecological monitoring sites should be in areas which are at high risk to acidification impacts.

For best results, these criteria should be met to the extent possible. However, it is probable that all the above criteria will not be met at all the monitoring sites. A judicious choice must be made, and to the extent possible, the first six criteria should be met.