Report on the current monitoring methods for particulate matters

Working Group I for Joint Research on Dust and Sand Storms among China, Japan, Korea and Mongolia

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Appendix

1. Introduction

The main task of Working Group I (WG I) is the improvement of the early warning system. In order to achieve this, expansion of data sharing and improvement of data quality are necessary.

Under the WG I scheme, progress has been made in data sharing of particulate matter (PM) for typical dust events. Additionally, sharing of data from more monitoring stations with more parameters (visibility, PM2.5, etc.) is desirable. Especially the sharing of PM2.5 data is important, since PM2.5 concentration increased during DSS events, as did PM10 / SPM concentration as well, often exceeding the air quality standard. Therefore, sharing PM2.5 data, especially simultaneously monitored with PM10 / SPM at a certain location, is desirable.

Improvement of the quality of the shared data is another important issue to augment the early warning system. In order to improve the accuracy of the forecast, model calculation should be conducted using high-quality monitoring data. That is, the quality of monitoring data should be high and unity enough in a targeted area for the forecast.

Considering those issues, comparison of monitoring methods' particulate matters (such as PM2.5, PM10/SPM, TSP and so on) is necessary to improve the quality of the monitoring data. As the first step to achieve this, the monitoring methods for particulate matters in China, Korea, Mongolia and Japan are summarised respectively.

2. China

2.1. Monitoring target and air quality standard for PM

The definitions of particulate matter monitored in China are summarised in Table2-1. The air quality standard for PM is summarised in Table 2-2.

Table 2-1 Definition of PM in China

PM	Definition
TSP	TSP is defined as particulate matter with diameter smaller than or equal to 100 μm.
PM10	PM10 is defined as particulate matter with diameter smaller than or equal to 10 μm, and is collected by a cutter with a 50% cut off diameter for 10 μm.
PM2.5	PM2.5 is defined as particulate matter with diameter smaller than or equal to 2.5 μm, and is collected by a cutter with a 50% cut off diameter for 2.5 μm.

Table 2-2 Limit values of PM and air quality standards in China

Unit: μg m^{-3}

PM	**primary or secondary**	**Concentration**	**Averaging period**	**Notes**
TSP	primary	80	1 year	Annual mean should be less than or equal to 80 μg m^{-3} Annual 95 percentile values from 24-hour mean should be less than or equal to 120 μg m^{-3}
		120	24 hour	24-hour mean should be less than or equal to 120 μg m^{-3}
	secondary	200	1 year	Annual mean should be less than or equal to 200 μg m^{-3} Annual 95 percentile values from 24-hour mean should be less than or equal to 300 μg m^{-3}
		300	24 hour	The 24-hour mean should be less than or equal to 300 μg m^{-3}
PM10	primary	40	1 year	The annual mean should be less than or equal to 40 μg m^{-3} The annual 95 percentile values from 24-hour mean should be less than or equal to 50 μg m^{-3}

PM	primary or secondary	Concentration	Averaging period	Notes
		50	24 hour	24-hour mean should be less than or equal to 50 μg m^{-3}
	secondary	70	1 year	Annual mean should be less than or equal to 70 μg m^{-3} Annual 95 percentile values from 24-hour mean should be less than or equal to 150 μg m^{-3}
		150	24 hour	24-hour mean should be less than or equal to 150 μg m^{-3}
PM2.5	primary	15	1 year	Annual mean should be less than or equal to 15 μg m^{-3} Annual 95 percentile values from 24-hour mean should be less than or equal to 35 μg m^{-3}
		35	24 hour	24-hour mean should be less than or equal to 35 μg m^{-3}
	secondary	35	1 year	Annual mean should be less than or equal to 35 μg m^{-3} Annual 95 percentile values from 24-hour mean should be less than or equal to 75 μg m^{-3}
		75	24 hour	24-hour mean should be less than or equal to 75 μg m^{-3}

* Excerpted from Ambient air quality standard of China (GB3095-2012)

* The primary standard is for nature reserves, landscapes and famous sceneries, or other areas that need to be especially protected. The second standard is for residential areas, business, traffic and resident multiple areas, culture areas, industrial areas, and rural areas.

2.2. Monitoring method for PM2.5

2.2.1. Method regulations

According to the Ambient air quality standard (GB3095-2012), standard methods for monitoring PM2.5 mass concentration include a gravimetric method and two automatic methods. The automatic methods include beta ray attenuation method and Taper element oscillating

microbalance method (TEOM). Automatic analyzers must be approved using equivalency test before they can be used in a monitoring network.

Monitoring methods for mass concentration of PM2.5 are defined in some technical regulations released by the Ministry of Environmental Protection of China (Table 2-3).

Table 2-3 Standard monitoring methods for PM2.5

PM	method	Monitoring method regulations
PM2.5	gravimetric method；beta ray attenuation method; Taper element oscillating microbalance method (TEOM)	Determination of atmospheric articles PM10 and PM2.5 in ambient air by gravimetric method (HJ618-2011, you could get more information from http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/201109/t20110914_217272.htm) Technical specifications for gravimetric measurement method for PM2.5 in ambient air (HJ656-2013, you could get more information from http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/201308/t20130802_256857.htm)

2.2.2. Requirements of equivalent method instrument

Requirements for PM2.5 automatic analyser are listed in Table 2-4.

Table 2-4 Requirements for automatic analyser for PM2.5 monitoring

Item	Requirement.
Dynamic Measure range	0-1000 μg m^{-3} or 0-10000 μg m^{-3}
Cut off diameter	50% cut point diameter should be 2.5±0.2 μm,
Flow rate	Flow rate error should be less than 2%.
Foil Calibration repeatability	Deviation of Calibration Foil should be less than 2%.
Parallelism	Deviation among 3 analysers should be less than 15%.
Comparison test to the gravimetric method	Slope of regression equation:1±0.15 Intercept:0±10 μg m^{-3} Correlation coefficient: ≥0.93 n=23

2.2.3. Equivalency test

Equivalency tests on automatic samplers to the gravimetric method are conducted by the China national environmental monitoring center (CNEMC). The test method is described in a regulation (Specification and test procedure for ambient air quality continuous automated monitoring system for PM10 and PM2.5 HJ653-2013, you could get more information from http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/201308/t20130802_256852.htm）， the test lasts 23 days at least, and 23 pairs of data will be obtained. Then the regression equation between the candidate automatic value and gravimetric method value is obtained, according to the special parameter of the regression equation to assess candidate automatic instruments.

2.2.4. Approved instrument

By the year 2015, some automatic analysers will get approval from CNEMC. The analysers are listed in Table 2-5.

Table 2-5 List of the approved instrument of PM2.5 in China

Instrument model	Manufacturer	Technique
7201	Beijing Zhongsheng	Beta attenuation method
XHPM2000E	Hebei Sail Hero	Beta attenuation method
TH2000PM	Wuhan Yuhong	Beta attenuation method
YX-AQMS-PM2.5	Yu Xing	Beta attenuation method
LGH-01E	Anhui Landun	Beta attenuation method
APDA-375A	Horiba	Beta attenuation method
MP101M	Environment S.A.	Beta attenuation method
TEOM1405F	Thermo Fisher Scientific	TEOM method
BPM-200	Focused Photonic	Beta attenuation method
F-701	Durag	Beta attenuation method
LHPM-2012	Lihe	Beta attenuation method

EPM-2050	Jiangsu Tianrui	Beta attenuation method
FH62C14-5014i	Thermo Fisher Scientific	Beta attenuation method
SHARP5030	Thermo Fisher Scientific	Beta attenuation method
BAM 1020	Metone	Beta attenuation method
FPM-377	Hach	Beta attenuation method
TK-P25A	Wuhan Taiken	Beta attenuation method
TH-2000Z1(single channel)	Wuhan Tianhong	Beta attenuation method
TH-2000Z1(double channel)	Wuhan Tianhong	Beta attenuation method
FAS-5100	Hefei Futong	Beta attenuation method

2.2.5. QA/QC

Quality assurance and quality control (QA/QC) are essential to obtain accurate and traceable monitoring data. The necessary QA/QC activities are required in some regulations (Automated methods for ambient air quality monitoring HJ/T193-2005, you could get more information from http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/200601/t20060101_71675.htm and this regulation is being revised), QA/QC activities for the PM2.5 automatic analyser are summarised in Table 2-6.

Table 2-6 QA/QC activities are for PM2.5 automatic analyser

Activities	Frequency	Action Criteria
Clean sample inlet and cutter	1/2 month	
Check flow rate	Once change the tape or filter	
Calibrate flow rate	1/6 month	
Calibration of standard foil	Depending on the necessity	
Calibration of sensors for temperature and air pressure	1/6 month	

Equivalency test for new instrument	Once a new instrument is installed.	
Equivalency test for instrument in service	1/year	
Precision audit	1/3month	
Accuracy audit	1/year	

2.3. Monitoring method for PM10

2.3.1. Method regulations

According to Ambient air quality standard (GB3095-2012), the standard methods for monitoring PM10 mass concentration include a gravimetric method and two automatic methods. The automatic methods include beta ray attenuation method and taper element oscillating microbalance method (TEOM). Automatic analysers must be approved using an equivalent test before they can be used in a monitoring network.

Monitoring methods for mass concentration of PM10 are defined in some technical regulations released by the Ministry of the Environment protection of China (Table 2-7).

Table 2-7 the standard monitoring methods for PM10

PM	Method	Monitoring method regulations
PM10	Gravimetric method, beta ray attenuation method, taper element oscillating microbalance method (TEOM)	Determination of atmospheric articles PM10 and PM2.5 in ambient air by gravimetric method (HJ618-2011)

2.3.2. Requirements of equivalent method instrument

Requirements for PM10 automatic analysers are listed in Table 2-8.

Table 2-8 Requirements for automatic analysers for PM10 monitoring

Item	Requirement.
Dynamic Measure range	0-1000 μg m^{-3} or 0-10000 μg m^{-3}
Cut off diameter	50% cut point diameter should be 10±0.5 μm,
Flow rate	24h average flow rate error should be less than 5%.
Foil Calibration repeatability	Deviation of Calibration Foil should be less than 2%.
Parallelism	Deviation among 3 analysers should be less than 10%.

Comparison test to the gravimetric method	Slope of regression equation:1±0.15 Intercept:0±10 μg m^{-3} Correlation coefficient: ≥0.95 n=10

2.3.3. Equivalency test

The Equivalency test for automatic samplers to the gravimetric method is conducted by the China national environmental monitoring center (CNEMC). The test method is described in a regulation (Specification and test procedure for ambient air quality continuous automated monitoring system for PM10 and PM2.5HJ653-2013), the test will last 10 days at least, and 10 pairs of data are obtained. Then the regression equation between the candidate automatic value and gravimetric method value is obtained, and the candidate automatic instruments are assessed according to the special parameter of the regression equation.

2.3.4. Approved instrument

By the year 2015, some automatic analysers will obtain approval from CNEMC. The approved analysers are listed in Table 2-9.

Table 2-9 List of the Approved instrument of PM10 in China

Instrument model	Manufacturer	Technique
BPM-200	Focused Photonic	Beta attenuation method
BAM 1020(2013)	Metone	Beta attenuation method
TH2000PM	Wuhan Yuhong	Beta attenuation method
XHPM2000E	Hebei Sail Hero	Beta attenuation method
MP101M	Environment S.A.	Beta attenuation method
LGH-01B	Anhui Landun	Beta attenuation method
FH62C14-5014i	Thermo Fisher Scientific	Beta attenuation method
7201	Beijing Zhongsheng	Beta attenuation method

AQMS-900(PM10)	Beijing SDL	Beta attenuation method
BAM 1020(2015)	Metone	Beta attenuation method

2.3.5. QA/QC

Quality assurance and quality control (QA/QC) are essential to obtain accurate and traceable monitoring data. The necessary QA/QC activities are required in some regulations (Automated methods for ambient air quality monitoring HJ/T193-2005), QA/QC activities for PM10 automatic analyser are summarised in Table 2-10 (same as PM2.5).

Table 2-10 QA/QC activities are for PM10 automatic analyser

Activities	Frequency	Action Criteria
Clean sample inlet and cutter	1/2 month	
Check flow rate	Once change the tape or filter	
Calibrate flow rate	1/6 month	
Calibration of standard foil	Depending on necessity	
Calibration of sensors for temperature and air pressure	1/6 month	
Equivalency test for new instrument	Once new instrument is installed.	
Equivalency test for instrument in service	1/year	
Precision audit	1/3month	
Accuracy audit	1/year	

2.4. Monitoring method for TSP

According to the Ambient air quality standard (GB3095-2012), the standard method for monitoring TSP mass concentration is a gravimetric method.

In the gravimetric method, particulate is collected by filter using a proper sampler. The particulate on the filter is weighed using an analytical balance, then the PM mass concentration in ambient are is calculated according to the sample volume.

The monitoring methods for mass concentration of TSP are defined in some technical regulations released by the Ministry of the Environment protection of China (Table 2-11).

Table 2-11 Standard monitoring methods for TSP

PM	Method	Monitoring method regulations
TSP	Gravimetric method	Ambient air determination of total suspended particulates gravimetric method (GB/T-15432-1995)

3. Korea

3.1. Monitoring target, quality standard and manual

PM10 and PM2.5 have been measured simultaneously in Korea since 2015. The environmental standard for dust, PM10 and PM2.5, has been set up and managed. Definition of PM10 is particulate matter less than 10 microns. It is tiny solid and/or liquid particles of soot, dust, smoke, fumes, and aerosols. Definition of PM2.5 is Suspended Solid or liquid particulate matter in the air, with an aerodynamic equivalent diameter of 2.5 μm or less.

* Same definitions as those provided by US EPA

Table 3-1 shows the air quality limit values and set-up dates. The sampler should be set at 1.5m height to 30m height from grand surface.

Table 3-1 Air Quality Standard for Particulate Matter (average of year and 24 hours)

Item	'93	'01	'07	'12	'15
PM10(μg/㎥)	80/year 150/24hr	70/year 150/24hr	50/year 100/24hr	50/year 100/24hr	50/year 100/24hr
PM2.5 (μg/㎥)					25/year 50/24hr

Table 3-2 Availability of manuals on standard methods

PM	Monitoring	Chemical analysis
PM2.5	Standard methods for monitoring of air quality(2011.9, 2014.7)	Methods for sampling, analysis of ion components, inorganic elements, carbon (2011.9)
PM10	Standard methods for monitoring of air quality (2006)	None

3.2. Monitoring methods for PM2.5

Two kinds of methods are available. One is gravimetric method and the other is beta ray attenuation method.

Table 3-3. Requirement of automatic sampler for PM2.5 monitoring

Item	Requirement
Dynamic Measure range	0-1000 μg/m^3/hour

3.2.1. Equivalency test

Model-type approval is necessary via a comparative field test using NRM (National Reference Method). Here, equivalence of automatic monitoring to the primary method was assessed by the National Institute Environmental Research (NIER), KOREA. The method to demonstrate the equivalence was presented in the notice "Type approval and QA/QC for environmental measuring instrument (2014.12)" as a reference provided by NIER. Briefly, the test is conducted twice per 23 days at NRM (National Reference Method) operation sites, which means at least two tests are conducted for one candidate instrument. More than 46 values have to be obtained. Those values are compared to the NRM values, and then evaluated based on NIER criteria limits. The automatic continuous measuring instruments in monitoring stations must be operated with mass concentration measuring instruments in the same place at the same time, during 15 days, more than three times a month.

Main criteria for the equivalence tests are summarized in Table 3-4.

Table 3-4. Criteria for Equivalency tests of PM2.5 instruments

Item	Range
Accuracy	over 85%
Slope of linear regression	0.9~1.1
Intercept of linear regression	-2.25~2.25

3.2.2. Approved instruments

Model-type approval has been performed since 2014. Table 3-5 summarizes a list of approved samplers and continuous monitors.

Table 3-5. List of approved PM2.5 instrument

Instruments	Model	Month of Approval
PM2.5 Sampler	PMS-204	Sep. 2014
	PMS-104	Sep. 2014
	E-FRM-230	Sep. 2014
	KN-L25P1	Oct. 2014
	Partisol2000i	Oct. 2014

	LV-250R	Dec. 2014
	PQ200	Dec. 2014
	SEQ 47/50	Mar. 2015
	Partisol2025i	Mar. 2015
	BMW-4500	Jun. 2015
PM2.5 continuous monitor[1)]	BAM1020	Oct. 2014
	PM711	Oct. 2014
	MP101M	Jan. 2015
	E-BAM	Jan. 2015
	5014i	Aug. 2015
	BAM-1022	Aug. 2015

1) Method: Beta ray attenuation (TEOM method is not included)

3.2.3. QA/QC

In order to provide PM2.5 traceable data, NIER operates two NRM sites: in Seoul and Gwangju. Equivalence tests for PM2.5 samplers are conducted with NRM biennially, and continuous measuring instruments need to be compared with the measuring instruments verified with NRM more than 14 days a year.

To check the status of instruments, all instruments need to be inspected at authorized institutions including KRISS, KECO and KTL. Operating agencies also need to check items on a weekly, monthly or yearly basis. Those maintenance items and frequencies comply with the standard methods for air quality monitoring (PM2.5 beta ray attenuation method)

* Examples include cleaning pump muffler, checking smart heater (1 time/6 month), checking pressure sensor, cleaning and replacing internal debris filter, zero filter test during 72 hr, checking membrane span foil and beta detector count rate (1 time/year).

The detailed calibration method is provided in the regulation related to “law on environmental test and inspection”.

3.2.4. The PM2.5 data validation

The data handling is conducted as shown below.

Table 3-6. Data handling method for PM2.5

Raw Data collection	Measuring data are sent to NIER, The primary measurement agencies inspect and make first confirmation, and NIER inspect and make final confirmation.
Agency of Data validation	NIER

and publishing	
Data validation process	Data trend, available measuring period, ratio of PM2.5 and PM10 * Every measuring device has to pass the type approval and equivalence test.
Data treatment	Hourly data are calculated every one hour. Daily data (daily mean) are calculated by averaging monitored data from 0 o'clock to 24 o'clock (available data process rate ≥ 75%).
Data publishing	The monthly and annual data are published by NIER.

3.3. Monitoring method for PM10

3.3.1. Monitoring target, quality standard and manual

Beta-ray attenuation method has been mainly used for continuous monitoring of PM10 in Korea. Although PM10 gravimetric method is described as a test method for monitoring air quality in the standard method, beta ray method has been used in the field.

Table3-7. Requirement of automatic sampler for PM10 monitoring

Item	Requirement
Dynamic Measure range	0-1000 μg /m^3/hour

3.3.2. Approved instruments

Approved instruments for PM10 are listed in Table 3-8.

Table 3-8 List of approved PM10 instruments

Instrument	Model	Month of Approval
PM-10 continuous monitor[2)]	DA-5300	Sep. 2002
	E-BAM	Nov. 2002
	DIGS150	Jul. 2003
	FH62-1	Sep. 2003
	DA-8300	Apr. 2004
	SPM-613D	Jan. 2005
	MP101M	Oct. 2005
	F-701-20	Dec. 2007
	SPM-613	Jun. 2008
	E-BAM-5LPM	Jul. 2008
	KN-610	Nov. 2008

	PM-711	May 2009
	PM-711D	Aug. 2011
	ANA5	Jul. 2013
	MEZUS-610	Oct. 2013
	E-BAM	Nov. 2014
	BAM1020	Nov. 2014
	FH62C14	May 2015
	BAM-1022	Jun. 2015
	MP101M	Aug. 2015

2) Method: beta ray attenuation method

3.3.3. QA/QC

3.3.3.1. Mechanical condition check

PM10 QA/QC primarily focuses on checking the mechanical condition. Flow rates and various factors such as temperature and pressure are monitored periodically. The status of the instrument also will be checked by authorized institutions regularly. The aim is to apply PM10 equivalence tests that meet the guideline for monitoring network operations. The detailed calibration method is provided in the regulation related with “law on environmental test and inspection”.

3.3.3.2. Data quality controls of PM10

PM10 was measured simultaneously every 5 minutes using FH62C14. To ensure data reliability, collected PM10 data was subject to quality control (QC). Five QC checks were performed as follows:

1) Check physical limit: Hourly upper and lower values of instrument detectable concentration limit have to be eliminated as being unrealistic. PM10 observational values fall outside of subjectively chosen lower (0μg/m^3) and upper (1,000μg/m^3) limits.
2) Check error code of instrument: Whenever special condition occurs, the instrument will save error messages. Value having an error message is eliminated.
3) Check persistence of time series: Check on a minimum required variability instantaneously during a certain period, once the measurement of the parameter has been done for at least 60 minutes. If the 5-minute values do not vary over the past 60 minutes by more than the specific limit then the current 5-minute value fails the check.
4) Check time continuity: Similar to the buddy check, time continuity is checked to eliminate gross outliers.
5) Check for spikes in time series: The spikes in the time series are checked. The outlier

detection is based on the double-difference time series, using the median that is a robust outlier estimator.

Table 3-9 Steps of quality controls for PM10

Step	Description
I	Check physical limit
II	Check error code of instrument
III	Check persistence of time series
IV	Check time continuity
V	Check for spikes in time series

4. Mongolia

4.1 Monitoring target, quality standard and manual

The definitions of the particulate matter monitored in Mongolia are summarized in Table 4-1. The air quality standards for PM are summarized in Table 4-2.

Table 4-1. Definition of PM in Mongolia

PM	Definition
TSP	TSP is defined as particulate matter with diameter smaller than or equal to 100μm.
PM_{10}	PM_{10} is defined as particulate matter with diameter smaller than or equal to 10μm, and is collected by a cutter whose 50% cut off diameter is 10μm.
$PM_{2.5}$	$PM_{2.5}$ is defined as the Particulate matter which diameter smaller than or equal to 2.5μm, and is collected by a cutter with a 50% cut off diameter for 2.5μm.

Table 4-2. Limit values of PM air quality standards in Mongolia

PM	Averaging period	Concentration (μg/m^3)	Notes
TSP	30 minute	500	30 minute mean should be less than or equal to 500μg/m^3.
	24 hours	150	24-hour mean should be less than or equal to 150μg/m^3.
	1 year	100	Annual mean should be less than or equal to 100μg/m^3.
PM_{10}	24 hours	100	24-hour mean should be less than or equal to 100μg/m^3.
	1 year	50	Annual mean should be less than or equal to 50μg/m^3.
$PM_{2.5}$	24 hours	50	24-hour mean should be less than or equal to 50μg/m^3.
	1 year	25	Annual mean should be less than or equal to 25μg/m^3.

Excerpted from Ambient air quality standard of Mongolia (MNS4585:2007)

4.2. Monitoring method for PM2.5

4.2.1. Equivalency test

An Equivalency test of an automatic sampler to the gravimetric method is conducted by the Ministry of Environment and Green Development and Tourism in Mongolia. The test method is described in a regulation (Specification and test procedure for ambient air quality continuous automated monitoring system for PM10 and PM2.5), the test lasts 23 days at least, and 23 pairs of data will be obtained. Then the regression equation between the candidate automatic value and gravimetric method value is obtained, according to the special parameter of the regression equation to assess the candidate automatic instruments.

4.2.2. Approved instruments

Model-type approval has been performed since 2014. Table 4-3 summarizes a list of approved samplers and continuous monitors.

Table 4-3. List of approved PM2.5 instrument in Mongolia

Equipment name	Model Name	Technical Specification	Manufacturer
Particle counter	Dusttrak	Count PM_1,$PM_{2.5}$,PM_{10},TSP	TSI, USA
GENT air Sampler	GENT	$PM_{10-2.5}$, $PM_{2,5}$	USA
Particle counter	AQMS-900(PM10)	Beta attenuation method	HORIBO, Beijing SDL
Focused Photonic	BPM-200	Beta attenuation method	
Metone	BAM 1020(2013)	Beta attenuation method	
Metone	BAM 1020(2015)	Beta attenuation method	

4.2.3. QA/QC

Quality assurance and quality control (QA/QC) is essential to obtain accurate and traceable monitoring data. The necessary QA/QC activities are required in some regulations (Automated methods for ambient air quality monitoring HJ/T193-2005); QA/QC activities are for the PM2.5 automatic analyzer and are summarized in Table 4-4 (same as PM10).

Table 4-4. QA/QC activities are for the PM2.5 automatic analyzer

Activities	Frequency	Action Criteria
Clean the sample inlet and cutter	1/2 month	
Check flow rate	Once tape or filter is changed	
Calibrate flow rate	1/6 month	

Calibration of standard foil	Depending on necessity	
Calibration of sensors for temperature and air pressure	1/6 month	
Equivalency test for new instrument	Once a new instrument is installed.	
Equivalency test for instrument in service	1/year	
Precision audit	1/3month	
Accuracy audit	1/year	

5. Japan

5.1. Monitoring target, quality standard and manual

The definitions of particulate matter monitored in Japan are summarised in Table 5-1. The air quality standard (Table 5-2.) applies to mass concentrations of PM2.5 and SPM. The monitoring methods for mass concentration are defined in a monitoring manual released by the Ministry of Environment (Table 5-3). The standard methods for the chemical constituents in the PM2.5 and TSP are available in Table 5-3. The sampler should be set at a height of 3m to 10m from ground surface.

Table 5-1. Definition of monitoring target

PM	Definition
PM2.5	Particulate matter collected using a cutter with 50% cut off diameter for 2.5 μm. Consequently, particulate matter with diameter of 2.5 μm or less roughly corresponds to PM2.5.
SPM	Particulate matter with diameter of 10 μm or less roughly corresponds to PM6.5 - PM7.
PM10	Particulate matter collected using a cutter with 50% cut off diameter for 10 μm. Consequently, particulate matter with diameter of 10 μm or less roughly corresponds to PM10.
TSP	Particulate matter with diameters less than 100 μm

Table 5-2 Limit values of air quality standards

PM	Concentration	Averaging period	Notes
PM2.5	15 μg m^{-3}	1 year	Less than or equal to
	35 μg m^{-3}	24 hour	The annual 98 percentile values of the 24-hour mean at a certain site should be less than or equal to 35 μg m^{-3}
SPM	0.10 mg m^{-3}	1 day	Not exceeded
	0.20 mg m^{-3}	1 hour	Not exceeded
PM10	None	-	-
TSP	None	-	Several chemical substances in TSP have target values

Table 5-3 Availability of the manual of the standard method

PM	Monitoring	Chemical analysis
PM2.5	Standard methods for monitoring of air quality (version 6), March 2010	Methods for sampling, analysis of ion components, inorganic elements, carbon,

		polycyclic aromatic hydrocarbons, water-soluble organic carbonaceous components, levoglucosan, gaseous components, released gradually since April 2012
SPM	Standard methods for monitoring of air quality (version 6), March 2010	None
PM10	None	None
TSP	None	Methods for sampling, analysis of pollutants in TSP, March 2011

5.2. Monitoring method for PM2.5

The primary method to determine PM2.5 mass concentration is a gravimetric method that samples the mass of particulate matter collected on a filter using a proper sampler, which are then measured and converted to concentration in ambient air. This method corresponds to the Federal Reference Method adapted by the United States Environmental Protection Agency (US EPA). Automatic samplers that produce values are considered to be able to obtain values equivalent to mass concentrations measured using the primary method are also approved (Beta ray attenuation method, taper element oscillating microbalance method (TEOM) and light scattering photometry method). The requirements for automatic samplers (Table 5-4) are listed in the monitoring manual.

Table 5-4. Requirements for automatic sampler for PM2.5 monitoring

Item	Requirement.
Cut off diameter	・50% cut off diameter should be 2.5±0.2 μm and ・(20% cut off diameter/ 80% cut off diameter) ≤1.5
Time resolution	One hour is preferable.
Dynamic range	24 hours average concentration of 2 – 200 μg m^{-3} should be measurable. One hour average concentration of 1000 μg m^{-3} should be measurable.
Maintenance and calibration	A logical calibration method should be established. Stability can be attained by routine maintenance work.
Variance between the instruments	Should be reasonably small
Flow rate	Should be set according to the characteristics of a cutter. Actual flow rate should be controlled and indicated on the monitor.
Dehumidifier	Should be installed.

5.2.1. Equivalency test

An equivalence of an automatic sampler to the primary method was assessed by the Ministry of the Environment, Japan. Since April 2014, it has been assessed by the manufacturer itself, and then the result of the equivalence test has been re-evaluated by the authorized institution, instead of the Ministry of the Environment. The method to demonstrate the equivalence has been presented in the manual “Standard methods for monitoring of air quality (version 6)” as a reference. Briefly, a test is conducted in summer and winter at both urban and non-urban sites. That means at least four tests are conducted for one candidate instrument. More than 20 values should be obtained in one round. The obtained values are compared to the values of the primary method, and evaluated based on the number of outliers of the control limit.

5.2.2. Approved instrument

Instruments that have demonstrated equivalencies are listed in the table below.

Table 5-5. Approved PM2.5 automatic sampler

Instrument	Manufacturer	Technique
PM-712	Kimoto Electric Co., Ltd.	Beta attenuation method
PM-717	Kimoto Electric Co., Ltd.	Beta attenuation method
FPM-377	DKK-TOA Corporation	Beta attenuation method
APDA-375A	Horiba, Ltd.	Beta attenuation method
FH62C14	Thermo Fisher Scientific	Beta attenuation method
SHARP 5030	Thermo Fisher Scientific	Hybrid method of light scattering and beta attenuation
MP101M	Environment S.A.	Hybrid method of light scattering and beta attenuation
TD5014i	Thermo Fisher Scientific	Beta attenuation method

5.2.3. QA/QC

Quality assurance and quality control (QA/QC) are essential to provide accurate and traceable monitoring data. In order to achieve them, required calibration, check and maintenance for the PM2.5 automatic samplers are summarised in Table 5-6. The detailed calibration method is provided in the manual “Standard methods for monitoring of air quality (version 6)”.

Table 5-6. Required calibration, checks and maintenance for PM2.5 monitoring

Calibration, Checks and Maintenance	Frequency	Action Criteria
~Common~		
Sensitivity check with a calibration filter, etc.	≥1 / Month	
Blank test	≥1 / Year	
Equivalency test	Depending on the necessity, this should be conducted when a new or renewed instrument is installed.	
Check of indicated value on flowmeter	every 6 months	±2%
Check of deviation of flow rate	Every sample	4% / 24 hours
Check of the actual flow rate	1-2 / Year	±5%
Checks and calibration of sensors for temperatures	1-2 / Year	
~Beta attenuation method only~		
Check and exchange of a filter	1 / 1-3 Months	
~Light scattering method only~		
Calibration of F values	≥1 / Month	
Clean up of lump	Every month	
Check and correction of the optical axis	Every 3 months	
Exchange of lump	1 / 6-12 months	
Clean of the detector	Every 3 months	

Excerpted from “Standard methods for monitoring of air quality (version 6)”

5.2.3. PM2.5 data validation

The data handling is conducted as below.

Table 5-7. Data handling method for PM2.5 and SPM

<table>
<tr><td>Raw Data collection</td><td>Monitored data are sent to central monitoring station.</td></tr>
<tr><td>Agency of Data validation and publishing</td><td>Data settlement is implemented by municipality. After data settlement, data is published by municipality and Ministry of Environment of Japan.</td></tr>
<tr><td>Data validation process</td><td>There are several data check steps.
1) Daily data check (particularly online data)
2) Monthly data validation (internal consistency tests check: mutual data comparison and data plots check)
3) Data screening to detect error or invalid data (historical consistency check with previous data)
4) Tracking the cause of error data or invalid data
5) Criteria for outlier detection:
Data correction is needed if data is between lower and upper value, and data above upper value should be treated as outlier.
Data below lower value can be used without correction.

<table>
<tr><td colspan="2" rowspan="2">Item</td><td colspan="2">Instrument Sensitiveness</td><td colspan="2">Zero value</td><td colspan="2">Flow rate</td></tr>
<tr><td>Lower value</td><td>Upper value</td><td>Lower value</td><td>Upper value</td><td>Lower value</td><td>Upper value</td></tr>
<tr><td rowspan="2">SPM</td><td>β</td><td>±4%</td><td>±10%</td><td>± 5 μg/m³</td><td>±10 μg/m³</td><td>±5%</td><td>±10%</td></tr>
<tr><td>P</td><td>±4%</td><td>±10%</td><td>±1%</td><td>±2%</td><td></td><td></td></tr>
<tr><td rowspan="3">PM2.5</td><td>β</td><td rowspan="3">±3%</td><td rowspan="3">±10%</td><td rowspan="3">± 1.5 μg/m³</td><td rowspan="3">± 3.0 μg/m³</td><td rowspan="3">－</td><td rowspan="3">±4%</td></tr>
<tr><td>T</td></tr>
<tr><td>O</td></tr>
</table>
β :Beta attenuation method
P: Piezo balance method
T : Taper element oscillating microbalance method (TEOM)
O: Light scattering photometry method</td></tr>
<tr><td>Data treatment</td><td>1) Hourly data are calculated every hour on the hour and data is set as a mean value of later time (e.g. if monitoring started from 1pm to 2pm, monitored data are treated as 2 pm's mean data)</td></tr>
</table>

	2) Daily data (daily mean) are calculated by averaging monitored data from 0 o'clock to 24 o'clock 3) As for PM2.5, minus value (hourly data) should be used to calculate daily mean instead of modifying to plus (As for SPM, there is no standard of minus value treatment)
Data publishing	1) The monthly and annual data are published by municipality and Ministry of Environment of Japan. 2) Standardized hourly data is provided by NIES (National Institute of Environmental Studies).

Excerpted from "Standard methods for monitoring of air quality (version 6)"

5.3. Monitoring method for SPM

The primary method to determine SPM mass concentration is a gravimetric method that samples mass of particulate matter collected on a filter using a proper sampler, which are then measured and converted to concentration in ambient air. Other monitoring techniques for SPM monitoring adapted in Japan are light scattering method, piezo balance method, beta attenuation method and tapered element oscillating microbalance (TEOM) method. The instruments using beta attenuation method are installed in most monitoring stations in Japan. The dynamic range required for SPM monitoring is 0–1000 – 0-10000 μg m^{-3}.

5.3.1. Equivalency test

The equivalency test using a reference material is ideal. Alternatively, an equivalency test using ambient air is proposed in the manual. For the test, more than three SPM samples are collected to determine SPM concentration using the primary method. Simultaneously an automatic sampler monitors SPM mass concentration. The equivalency is evaluated by the primary method using the difference between the measured values and the determined value. It should be ±10 μg m^{-3} or ±10% on hourly data.

5.3.2. QA/QC

Quality assurance and quality control (QA/QC) are essential to provide accurate and traceable monitoring data. In order to achieve them, required calibration, check and maintenance for a beta attenuation automatic SPM sampler, which is the most-installed SPM sampler in Japan, are summarised in Table 5-7. The detailed calibration method is provided in the manual “Standard methods for monitoring of air quality (version 6)”.

Table 5-7. Required calibration, checks and maintenance for a beta attenuation SPM sampler

Calibration, Checks and Maintenance	Frequency	Action Criteria
Sensitivity check with a calibration filter	≥1 / Month Exchange of a filter	±4%
Blank test	≥1 /Year	±10 μg m^{-3} or ± 1% of maximum measureable value
Equivalency test using ambient air sample	Preferably before a series of monitoring / sapling system is changed	
Equivalency test using reference material	If possible	
Exchange or clean up of tube	1 / 6-12 Months	
Check and exchange of filter	1 / 1-3 Months	
Clean up of flowmeter		
Check of actual flow rate	1-2 / Year	±7%
Exchange of pump	1 / 1-3 Year	
Exchange of diaphragm	1 / 6-12 Months	
Exchange of seals for pump	1 / 6-12 Months	
Check of indicated value on flowmeter	Every month	±3%
Clean up of coarse particle collector	Every 3 months	
Clean up of cutter	Every 6 months	
Clean up of flowmeter	1 / 6-12 months	

Excerpted from “Standard methods for monitoring of air quality (version 6)”

5.3.3 The SPM data validation

The data handling is conducted as shown in Table 5-7.

Appendix

I. Comparison of monitoring method among countries

II. Original Monitoring Manual and Regulations in each country

I. Comparison of monitoring method among countries

< PM2.5 >

Monitoring Condition and Air Quality Standards

		China	Korea	Japan
Definition		PM2.5 is defined as particulate matter with diameter smaller than or equal to 2.5 μm, and is collected by a cutter with a 50% cut off diameter for 2.5μm.	Suspended Solid or liquid particulate matter in the air, with an aerodynamic equivalent diameter of 2.5 μm or less (Same as those by US EPA).	Particulate matter collected using a cutter with 50% cut off diameter for 2.5μm. Consequently, particulate matter with diameter is 2.5 μm or less roughly corresponds to PM2.5.
Air quality standards	Primary	≤15 μg m^{-3}/year (Annual 95 percentile values from 24-hour mean ≤ 35 μg m^{-3}) ≤35μg m^{-3}/day(24-hour)	25 ㎍/㎥/year 50 ㎍/㎥/24hr	≤15 μg m^{-3}/year and ≤35 μg m^{-3}/day(24-hour)
	Secondary	≤35 μg m^{-3}/year (Annual 95 percentile values of the 24-hour mean ≤ 75 μg m^{-3}) ≤75 μg m^{-3}/day(24-hour)		
Setting conditions			1.5m ≤ Height from ground surface < 30m	3m ≤ height from ground surface ≤ 10m

Data handling

			China	Korea	✓ Japan
Data treatment process	Definition of its process (Yes/ No)		Yes. Data treatment process is defined by manual.	Yes. Data treatment process is defined by manual.	Yes. Data treatment process is defined by manual.
Data analysis and treatment	Time resolution and its treatment	Hourly	Hourly data is calculated with every hour and the data is set as a mean value of the later time	✓ Available data treatment process is defined by manual. ✓ Hourly data is calculated every one hour.	✓ Hourly data is treated as reference data. ✓ Hourly data is calculated with every hour on the hour and the data is set as a mean value of the later time (e.g. if the monitoring started from 1pm to 2pm, the monitored data is treated as 2 pm's mean data.)
		Daily	Daily data (daily mean) is calculated by averaging monitored data from 0 o'clock to 24 o'clock(at least includes 20 hourly datas).	✓ Daily data (daily mean) is calculated by averaging monitored data from 0 o'clock to 24 o'clock(available data process rate ≥ 75%).	Daily data (daily mean) are calculated by averaging monitored data from 0 o'clock to 24 o'clock..
	Minus value treatment		Minus value is deleted as error data or modified to the detection limit value(depends on the situation)	Minus value is deleted as error data by primary operating agencies.	Minus value (hourly data) should be used to calculate the daily mean data not modifying to plus
Data discloser	Data format (Yes/ No)		The hourly data is published on the website of CNEMC(China National Environmental Monitoring Center)	Yes. The monthly and annual data is published by NIER(National Institute of Environmental Research).	Yes. The monthly and annual data is published by municipality and Ministry of Environment of Japan. The Standardized hourly data is provided by NIES (National Institute of Environmental Studies).

Method and Requirement of Automatic analyzer etc.

		China	Korea	Japan
Method for PM2.5	Standard method of PM2.5	✓ Gravimetric method	✓ Gravimetric method	✓ Gravimetric method
	Automatic method of PM2.5	✓ Beta ray attenuation method ✓ Taper element oscillating microbalance method (TEOM)	✓ Beta ray attenuation method	✓ Beta ray attenuation method ✓ Taper element oscillating microbalance method (TEOM) ✓ Light scattering photometry method
Automatic	Requirement (Yes/No)	Yes	Yes	Yes
	The number of approved instrument	✓ 19 model-types of Beta attenuation method ✓ 1 model-types of TEOM	✓ 6 model-types of Beta attenuation method	✓ 6 model-types of Beta attenuation method ✓ 2 model-types of Hybrid method of light scattering and beta attenuation
	Dynamic Measure range	0-1000 μg m^{-3} or 0-10000 μg m^{-3}	0-1000 μg/m^3/hour	✓ 2 – 200 μg/m^3/24hours ✓ 1000 μg /m^3 /hour

Maintenance and Calibration method etc.

			China	Korea	Japan
Maintenance (QAQC)	Equivalency test	Process	・Equivalency tests on automatic samplers to the gravimetric method are conducted by the China national environmental monitoring center (CNEMC).	・Equivalency test of on automatic sampler to the gravimetric method has been performed by NIER(National Institute of Environmental Research).	・ Equivalency test is assessed by a manufacturer itself, and then the result of the equivalence test has been re-evaluated by the authorized institution, instead of the Ministry of the Environment.
		Method	・The test lasts 23 days at least, and 23 pairs of data will be obtained. ・Then the regression equation between the candidate automatic value and gravimetric method value is obtained, according to the special parameter of the regression equation to assess candidate automatic instrument.	・15 day(23h/day) Collected sampling with gravimetric method at least 3 day/month.	・Test is conducted in summer and winter at both urban and non-urban sites, that means at least four tests are conducted for one candidate instrument. More than 20 values should be obtained in one round. ・The obtained values are compared to the values of the primary method, and evaluated based on the number of outliers of the control limit.
	Calibration manual (Yes/ No)		Yes. The necessary QA/QC activities are required in some regulations (Automated methods for Ambient air quality monitoring HJ/T193-2005	Yes. Each calibration method based on method is defined by manual.	Yes. Each calibration method based on method is defined by manual
	QAQC check		Frequency is summarized in table 2-6. Clean sample inlet and cutter, Flow rate, Calibrate flow rate, Calibration of standard foil, Calibration of sensors for temperature and air pressure, Equivalency test for new instrument, Equivalency test for instrument in service, Precision audit, Accuracy audit	・Cleaning pump muffler, Checking smart heater(1 time/6 month). ・Checking pressure sensor, cleaning and replacing internal debris filter, zero filter test during 72 hr, checking membrane span foil and, beta detector count rate(1 time/year).	Frequency is summarized in table 5-6. Sensitivity check with a calibration filter, Blank test, Equivalency test, Indicated value on flowmeter, Deviation of flow rate, Actual flow rate, Check and calibration of sensors for temperatures **~ for Beta attenuation method only~** Check and exchange of a filter **~Light scattering method only~** Calibration of F values, Clean up of lump, Check and correction of the optical axis, Exchange of lump, Clean of the detector

< PM10 / SPM >

Monitoring Condition and Air Quality Standards

		China (PM10)	Korea (PM10)	Japan (SPM)
Definition		≤ 10μm (50% cut off)	Particulate matter less than 10 microns. It is tiny solid and/or liquid particles of soot, dust, smoke, fumes, and aerosols (Same as those by US EPA).	≤ 10μm (100% cut off) Roughly corresponding to PM6.5 - PM7.
Air quality standards	Primary	≤40 μg m^{-3}/year (Annual 95 percentile values of the 24 -hour mean ≤ 50 μg m^{-3}) ≤50μg m-3/day(24-hour)	50 μg/㎥/year 100 μg/㎥/24hr	≤0.10 mg m^{-3}/day And ≤0.2 mg m^{-3}/hour
	Secondary	≤70μg m^{-3}/year (Annual 95 percentile values from 24-hour mean ≤ 150 μg m^{-3}) ≤150μg m^{-3}/day(24-hour)		
Setting conditions			1.5m ≤ Height from ground surface < 30m	3m ≤ height from ground surface ≤ 10m

Data handling

			China (PM10)	Korea (PM10)	Japan (SPM)
Data treatment process	Definition of its process (Yes/ No)		Yes. Data treatment process is defined by manual.	Yes. Data treatment process is defined by manual.	Yes. Data treatment process is defined by manual.
Data analysis and treatment	Time resolution and its treatment	Hourly	Hourly data is calculated with every hour and the data is set as a mean value of the later time.	✓ Available data treatment process is defined by manual. ✓ Hourly data is calculated every one hour.	Hourly data is calculated with every hour on the hour and the data is set as a mean value of the later time (e.g. if the monitoring started from 1pm to 2pm, the monitored data is treated as 2 pm's mean data.)
		Daily	Daily data (daily mean) is calculated by averaging monitored data from 0 o'clock to 24 o'clock(at least includes 20 hourly datas).	Daily data is calculated by averaging monitored data from 0 o'clock to 24 o'clock(available data process rate ≥ 75%).	Daily data (daily mean) is calculated by averaging monitored data from 0 o'clock to 24 o'clock.
	Minus value treatment		Minus value is deleted as error data or modified to the detection limit value(depends on the situation)	Minus value is deleted as error data by primary operating agencies.	There is no standard of minus value treatment.
Data discloser	Data format (Yes/ No)		The hourly data is published on the website of CNEMC(China National Environmental Monitoring Center)	Yes. The monthly and annual data is published by NIER (National Institute of Environmental Research).	Yes. The monthly and annual data is published by municipality and Ministry of Environment of Japan. The Standardized hourly data is provided by NIES (National Institute of Environmental Studies).

Method and Requirement of Automatic analyzer etc.

		China (PM10)	Korea (PM10)	Japan (SPM)
Monitoring method for PM10(SPM)	Standard method of PM10(SPM)	✓ Gravimetric method	Gravimetric method	✓ Gravimetric method
	Automatic method of PM10(SPM)	✓ Beta ray attenuation method ✓ Taper element oscillating microbalance method (TEOM)	✓ Beta ray attenuation method	✓ Light scattering photometry method ✓ Piezo balance method ✓ Beta ray attenuation method ✓ Taper element oscillating microbalance method (TEOM)
Automatic	Requirement (Yes/ No)	Yes	Yes	Yes.
	The number of approved instrument	✓ 10 model-types of Beta attenuation method	20 model-types of Beta attenuation method	All the instrument which satisfy the requirement shown in the manual should be approved. The number of the approved instrument correspond to that of the instrument used for SORAMAME monitoring system. The number is not aggregated.
	Dynamic Measure range	0-1000 μg m^{-3} or 0-10000 μg m^{-3}	0-1000 μg/m^3/hour	0–1000μg/m^3 – 0-10000 μg/m^3

Maintenance and Calibration method etc.

			China (PM10)	Korea (PM10)	Japan (SPM)
Maintenance (QAQC)	Equivalency test	Process (Yes/ No)	✓ Equivalency tests for automatic samplers to the gravimetric method are conducted by the China national environmental monitoring center (CNEMC)	✓ The status of the instrument also will be checked by authorized institutions regularly.	✓ The evaluation is conducted by municipality on the basis of manual defined by the Ministry of Environment, Japan. ✓ The equivalency is evaluated using the difference between the measured values and the determined value by the primary method. It should be ±10 μg m^{-3} or ±10% on hourly data.
		Method	✓ The test lasts 10 days at least, and 10 pairs of data are obtained. ✓ Then the regression equation between the candidate automatic value and gravimetric method value is obtained, and the candidate automatic instruments are assessed according to the special parameter of the regression equation.	✓ PM10 equivalence tests are applied to the guideline for monitoring network operations.	✓ An equivalency test using ambient air is proposed in the manual. ✓ More than three SPM samples are collected to determine the SPM concentration using the primary method.
	Calibration manual (Yes/ No)		✓ Yes. The necessary QA/QC activities are required in some regulations (Automated methods for ambient air quality monitoring HJ/T193-2005)	Yes. The necessary QA/QC activities are required.	Yes. As for beta attenuation method and Piezo balance method, the calibration method is defined by manual, and the should be monitored by standard method simultaneously in open air in case of necessary.

	QAQC check	Clean sample inlet and cutter, Fow rate, Calibrate flow rate, Calibration of standard foil, Calibration of sensors for temperature and air pressure, Equivalency test for new instrument, Equivalency test for instrument in service, Precision audit, Accuracy audit	<Mechanical Condition Check) ✓ Flow rates and various factors such as temperature and pressure are monitored periodically. <Data Quality Control> Five QC checks were performed as follows: 1) The physical limit: Upper and lower values of instrument detectable concentration limit. 2) Error code of instrument: Saved error code during unusual condition 3) The persistence of time series: Minimum required variability of instantaneous during certain period 4) The time continuity: Gross outlier elimination using difference of PM10 5) Spikes in the time series: Outlier elimination using the median that is a robust outlier estimator	Frequency is summarized in table 5-7. Sensitivity check with a calibration filter, Blank test, Equivalency test using ambient air sample, Equivalency test using reference material, Exchange or clean up of tube, Check and exchange of filter, Cleaning up of flowmeter, Check of actual flow rate, Exchange of pump, Exchange of diaphragm, Exchange of seals for pump, Check of indicated value on flowmeter, Clean up of coarse particle collector, Clean up of cutter, Clean up of flowmeter

II. Original Monitoring Manual and Regulations in each country