Annex 2-3:
Lecture Materials for Training

2.3.5 Air Quality

Lecture Material -01

Form for Air Quality Monitoring Data and its Key Points

Air Quality Analysis

Form for Air Quality Monitoring Data and its Key Points

In an environmental monitoring, it is important how to use the data especially for investigation and identification of pollutants. Thus, the obtained data should be input in a unified table, and a report should be prepared periodically (monthly, seasonally, and annually) using input data in accordance with its objectives such as a) description of current environmental situation, b) materials for environmental awareness to the citizens, and c) detailed information for taking an action by decision makers and administrative authorities.

1. Example table for summarization of the results

In an ambient air quality monitoring, the following conditions should be clarified in the monitoring plan:

(1) Type of pollution source:
  a) Fixed sources such as factories,
  b) Mobile sources such as automobiles and airplanes, and
  c) Area (non-point) sources such as smoke by field burning, blowing up of dust and soil.

2. The differences in land uses:
    a) Region of residences.
    b) Business Region.
    c) Industrial region.
    d) Region mixed of residences and industry.
    e) Region with main roads and bordering.
    f) Suburban region.

3. The differences in the investigation targets:
    a) The observation of the conformity conditions for environmental standards.
    b) The prevention of damages before they occur.
    c) The accumulation of data and the correspondence to the conditions of emergency by the data that allow making decisions.
    d) Obtaining the basic data for establishing the countermeasures for preventing air pollution in the region.
    e) Evaluating the effectiveness of the countermeasures from the data that are obtained before after these countermeasures are taken.
    f) Investigation for the purpose of proper arrangement to fix monitoring station.
    g) Taking the countermeasures of the complaints.

The subjects of measurements carried out for detecting pollutants are selected based on the types of the sources of generation.

Source	Kind	Atmospheric pollutant
Combustion	Gases, Dusts	SO2, NO_x, CO, HC, C, Acids
Car	Gases, Dusts	NO_x, CO, HC, C
Oil refinery	Gases, Dusts, Mists	SO2, H2S, HC, NH3, CO, R-SH, Acids
Chemical plant	Gases, Dusts, Mists	SO2, H2S, HC, F, NH3, CO, R-SH,
Furnace, electric furnace and metal refining	Gases, Dusts, Fumes	Acids, F, Cl, SO2, NOx, CO, HC, C, Fumes
Food and fodder processing	Gases, Dusts	Malodorous substance

For monitoring the ambient air quality with respect to investigation targets, the following procedure is implemented:

1) The differences in the measuring procedure:

a) Continuous measurements for one hour:
Automatic continuous monitoring equipment for SO_2, etc.

b) Intermittent measurements for one hour
Handy sampler with impinger.

c) Several hours measurement:
Handy sampler, High Volume (Hi-Vol) sampler, Passive sampler.

d) Measurements range from one day to several days:
High Volume (Hi-Vol) sampler, Passive sampler.

e) One week measurements of the average concentration
Low Volume (Low-Vol) sampler, Passive sampler.

f) Measurements for one month:
Dust jar, deposit gauge, PbO_2 method, and Alkali filter paper method.

2) The differences in measurements with interval:

a) Automatic continuous measurements throughout the year.
b) Season measurements.
c) Measurements at fixed periods for every month.
d) Daily four measurements at morning, noon, evening, and midnight.
e) Measurements correspond to necessity.

The following table represents a form of the summary of the results that are collected throughout a month of monitoring as an example.

Summary table of monitoring Results (Example)

(Month: ______________)

【__________DFEA】

Sampling Points	Date (day)	Air Quality															Meteorological condition				
		Nitrogen Oxide (NO, NO_2, NO_x) (μg/m^3)						Sulfur dioxide (SO_2) (μg/m^3)		Hi-Vol Sampler SPM (μg/m^3)		Hydrocarbon (HC) (μg/m^3)		Dust jar (kg/km^2/month)			W/D (16 Direc.)	W/S (m/s)	Temp. (℃)	Humi. (%)	Weather
		NO		NO_2		NO_x		Ave.	Max.	Ave.	Max.	Ave.	Max.	Falling dust	Pb	Zn etc.	Most freq.	Ave.	Ave.	Ave.	
		Ave.	Max.	Ave.	Max.	Ave.	Max.														
A	1 2 3 4																				
	Average																				
B	1 2 3 4																				
	Average																				
C	1 2 3 4																				
	Average																				
D	1 2 3 4																				
	Average																				
E	1 2 3 4																				
	Average																				

Notes: ＊Ave. : Average value, Max. : Maximum value, Min. : Minimum value

＊ In this table, monthly four measurements are assumed.

＊For the average values of NO_2, SO_2, etc, multiple daily measurements are assumed.

(2) Monthly report of the monitoring results

The following condition is assumed for which monitoring is carried out and a form of the monthly report is prepared.

After the sampling point of the region has been decided, measurement results of the monitoring are assumed. However, the case of 24 hours of continuous measurements can be considered, also the case of fixed periods of measurements at four selected times; morning, noon, evening, and midnight, can be considered.

The case of fixed periods of sampling is mentioned below. The subjects of measurements are selected in accordance with the objective.

After we obtained the data of the suspended particulate matters (SPM), heavy metal or ion analysis will be implemented, then a different form would be considered.

Monthly Report of Air Quality Monitoring Result (Example)

Monitoring Point：
Monitoring Month：
【__________DFEA】

Measured day	hour	NO (ppm)	NO2 (ppm)	NOx (ppm)	SO2 (ppm)	CO (ppm)	Ox (ppm)	SPM (μg/m3)	HC (μg/m3)	W/D (16 Drec.)	W/S (m/s)	Temp (℃)	Humi (%)
	8〜9 12〜13 16〜17 20〜21												
	Ave.												
	8〜9 12〜13 16〜17 20〜21												
	Ave.												
	8〜9 12〜13 16〜17 20〜21												
	Ave.												
	8〜9 12〜13 16〜17 20〜21												
	Ave.												
	8〜9 12〜13 16〜17 20〜21												
	Ave.												
Hourly	Max.												
	Min.												
	Ave.												
Standard exceed times													

In the monthly report of the automatic continuous measurements, the following data are recorded within a month: hourly maximum value, hourly minimum value, hourly average value, maximum of the daily average values, minimum of the daily average values, average of the daily average values, 98 % of the hourly values, the environmental standard exceed times and days are indispensable.

Also, it is considered, the measurement subjects are selected after the condition of the sources of generation in the region and the situation of the pollution.

The following table represents a form of the case of preparing a monthly report about the monitoring results.

Monthly Report of Air Quality Monitoring Results (Example)

Monitoring Point:
Monitoring date (month, year):
【__________DFEA】

Measurement day		NO (ppm)	NO$_2$ (ppm)	NO$_x$ (ppm)	SO$_2$ (ppm)	CO (ppm)	O$_x$ (ppm)	SPM (μg/m^3)	HC (μg/m^3)	W/D (16 Direc.)	W/S (m/s)	Temp. (℃)	Humi. (%)
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
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22													
23													
24													
25													
26													
27													
28													
29													
30													
31													
Hourly	Max.												
	Min.												
	Ave.												
	50% Value												
	98% Value												
Daily	Max.												
	Min.												
	Ave.												
No. of data collecting times													
No. of defective data													
Measurement rate (%)													
Standard exceed times										—	—	—	—
Standard exceed days										—	—	—	—

Note: For the values that exceed the environmental quality standard, a sign is made at those values so that they can be distinguished easily.

(3) Daily report of the monitoring results

Daily Report of Air Quality Monitoring Results (Example)

Monitoring Point:
Monitoring Date:

【________DFEA】

Measurement time	NO ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NO_x ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	CO ($\mu g/^{m3}$)	O_x ($\mu g/m^3$)	HC ($\mu g/m^3$)	SPM ($\mu g/m^3$)	W/D (16 Direc.)	W/S (m/s)	Temp. (℃)	Humi. (%)	Solar R. (w/m^2)
0～1													
1～2													
2～3													
3～4													
4～5													
5～6													
6～7													
7～8													
8～9													
9～10													
10～11													
11～12													
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15～16													
16～17													
17～18													
18～19													
19～20													
20～21													
21～22													
22～23													
23～24													
Max. value													
Min. value													
Ave. value													
No. of data													
No. of defective data													
Measurement rate (%)													
Standard exceed times										—	—	—	—

Note:

- For the values that exceed the environmental quality standard, a sign is made at those values so that they can be distinguished easily.
- Regarding the SPM, it is assumed that the sampling is made by Hi-Volume Air Sampler and for 24 hours.

(4) When arranging individual monitoring results

Nitrogen Oxide (NO, NO_2, NO_x) Monitoring Results (Example)

Sampling Date：

	Sampling time	Item	A point		B point		C point		D point		Notes
			ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	
1		NO NO_2 NO_x									
2		NO NO_2 NO_x									
3		NO NO_2 NO_x									
4		NO NO_2 NO_x									

Sulfur dioxide (SO_2) Monitoring Results (Example)

Sampling Date:

	Sampling time	A point		B point		C point		D point		Notes
		ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	
1										
2										
3										
4										

Carbon Oxide (CO) Monitoring Results (Example)

Sampling Date：

	Sampling time	A point		B point		C point		D point		Notes
		ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	
1										
2										
3										
4										

Oxidant (Ox) Monitoring Result (Example)

Sampling Date：

	Sampling time	A point		B point		C point		D point		Notes
		ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	
1										
2										
3										
4										

High Volume Air Sampler Monitoring Results (Example)

(Unit: μg/m^3)

Sampling point	A	B	C	D	Notes
Sampling time Item					
SPM (PM10, TSP)					
pH					
Cl^-					
NO_3^-					
SO_4^{2-}					
NH_4^+					
Pb					
Zn					
Cd					
Cu					
Ni					
Fe					
Mn					
Cr					
V					
Al					
Ca					
Mg					
Organic Carbon (O-C)					
Elemental Carbon (E-C)					
Total Carbon (T-C)					

Monitoring Results of the falling dust (Example)

Monitoring Month： (Unit：ton/km^3/Month)

Item	Sampling point								Notes
	A	B	C	D	E	F	G	H	
pH									
Water-soluble substance									
Cl^-									
NO_3^-									
SO_4^{2-}									
NH_4^+									
Ca^{2+}									
Na^+									
Water insoluble substances									
Extracted Materials (Tar)									
Combustibility materials									
Ash									
Pb									
Zn									
Cd									
Cu									
Ni									
Fe									
Mn									
Cr									
V									
Al									
Ca									
Mg									

Lecture Material -02

Making of collection element (filter) for Air Quality Analysis

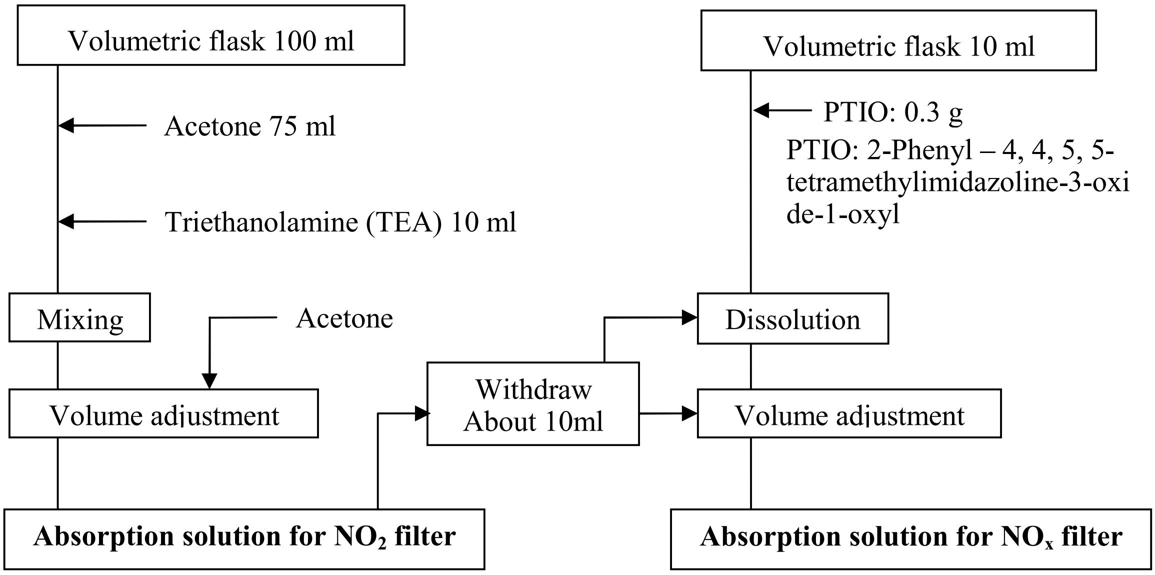
Air Quality Analysis

Making of collection element (filter)

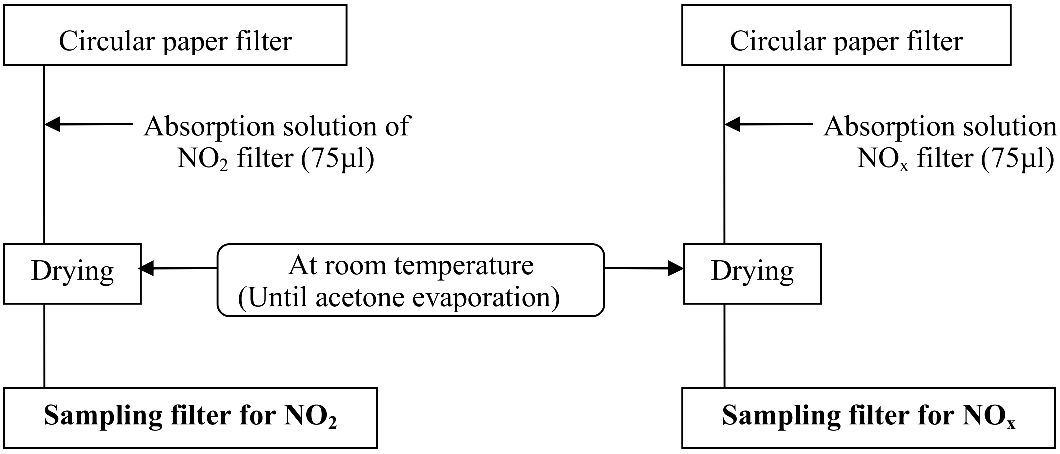
1. NO2 and NOx collection element

1. Cut a cellulose fiberglass filter into circular pieces by using a holing tool.
2. Put the circular filters on a piece of nylon.
3. Prepare absorption solution by following the chart below.
4. Distribute a certain quantity of the absorption solution on each circular filter, and then let it dry by following the chart below.
5. After drying, put the circular filters into glass (or plastic) containers and close tightly.

(1) Preparing absorption solution for NO_2 and NO_x filter



(2) Preparing sampling filter for NO_2 and NO_x

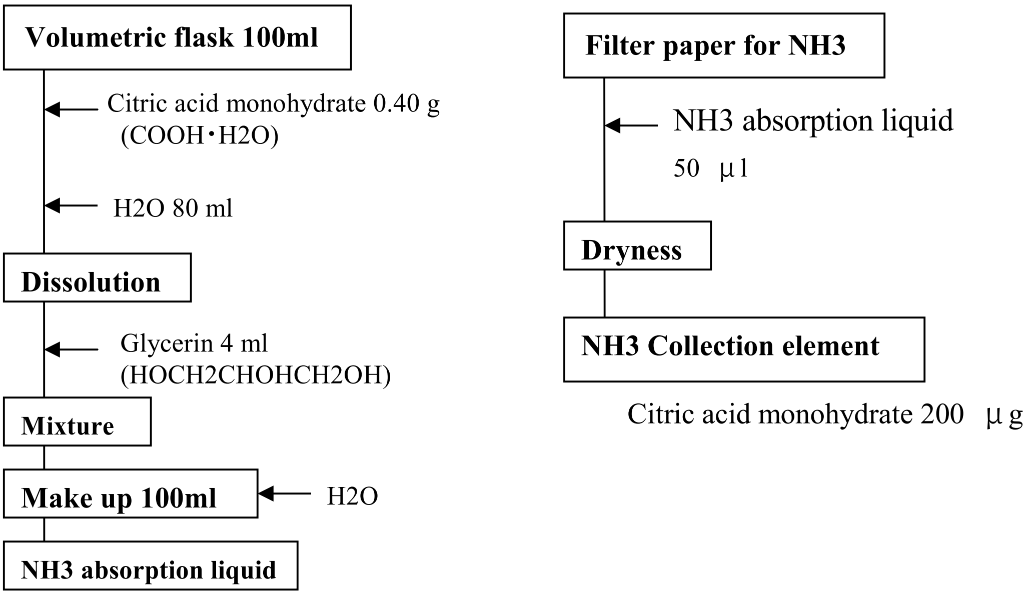


<u>Note:</u> NO_2 sampling filter can also be used for sampling SO_2

2. SO2 collection element

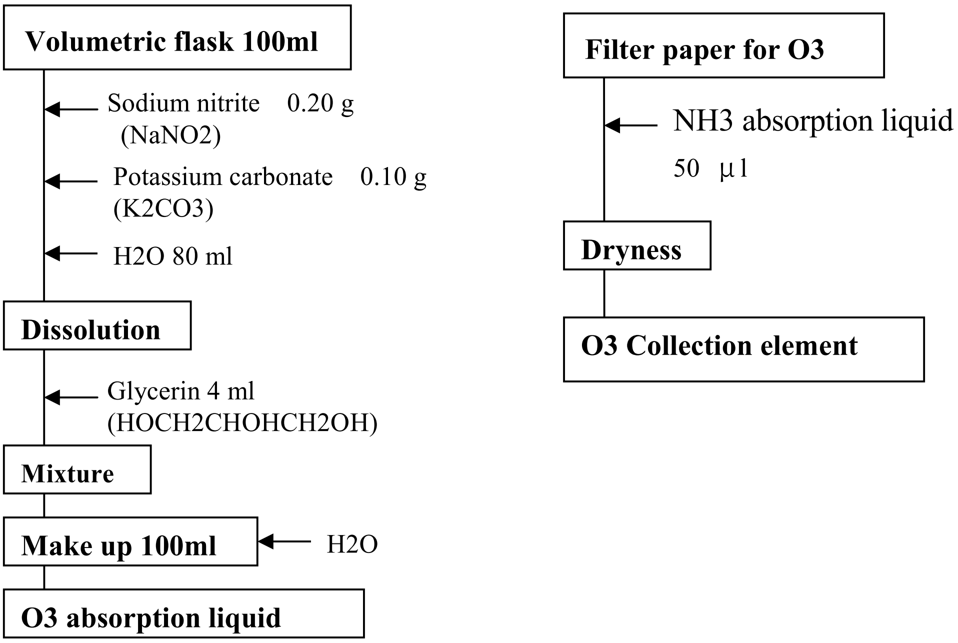
The method of making the SO2 collection filter paper is the same as the method of making NO2.

3. NH3 collection element



Flow of making of NH3 absorption liquid and Collection element

4. O3 collection element (Draft)



Flow of making of O3 absorption liquid and Collection element

Proposal of the Determination Method for the Environmental Impact Assessment and the Scope of the Regional Investigation

Comparatively, Homs has various big factories. Regarding the investigation plan, we studied the behavior of the air pollutants and the environmental impact depending on the targeted factory.

By considering the weather conditions of Homs region, we predict mathematically the ambient air dispersion and propose a method for determining the necessary scope of the investigation target of the considered stationary source of pollution (factory). Furthermore, by studying the stack effective height we explain the evaluation of the pollutants impact of a stationary source of pollution on the surroundings and the effect of its stack height. This proposed method for determining the necessary scope of the investigation target can also be applied to regions other than Homs.

1. Conclusions

As for the examination results and by considering a factory with a stack of 100 m height, the scope of air quality investigation targets is the area of the radius 10 km. Within this scope, the area of the radius 5 km is established as the important investigation area.

The reasons are explained as follows:

a) By analyzing the meteorological observation for a whole year, it can be noticed that Homs is dominated by west wind, but various wind directions emerge (but east wind does not). However, in the around-year investigation it is inappropriate to establish an investigation region regarding only west wind direction.

b) In the seasonally short term investigation, the target area subjected to investigation can be narrowed as can be understood form the Wind Rose.

c) Tentatively, by assuming a factory with a stack of 80 ~ 90 m height, the estimated effective stack height is 120 m depending on the discharge gases temperature and flux. In this case, the maximum concentration above the ground, Cmax, occurs within the scope of 10 km from the source of pollution for all air stability classes A ~ D, and Cmax value falls generally in the range 0.020 ~ 0.200 ppm depending on the atmospheric stability classes.

d) The maximum concentration at 10 km from the source of pollution has the general value of 0.020 ppm for all classes of atmospheric stability (concentration at the background, BG, should be added to this value).

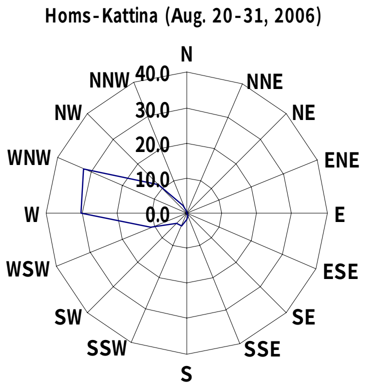
e) Depending on the weather conditions, a serious impact is possible on the area which extends within 5 km from the smoke source.

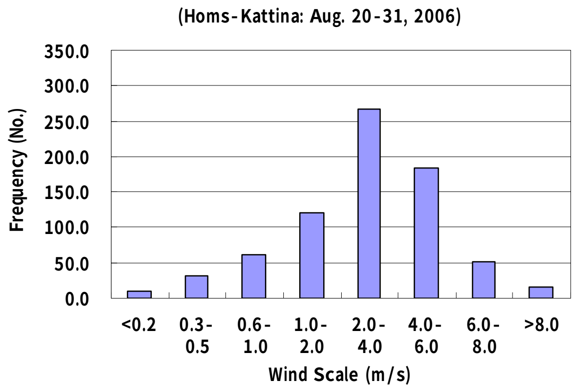
f) The height of a factory stack is one of the countermeasure methods for greatly eliminating the environmental impact of that factory on its vicinity.

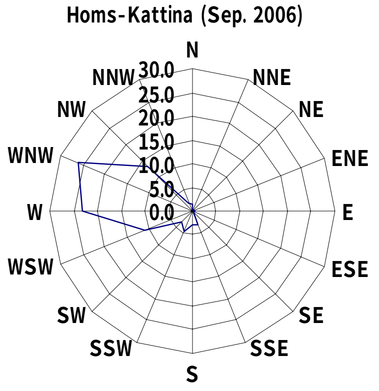
2. Ambient air dispersion prediction and environmental impact assessment

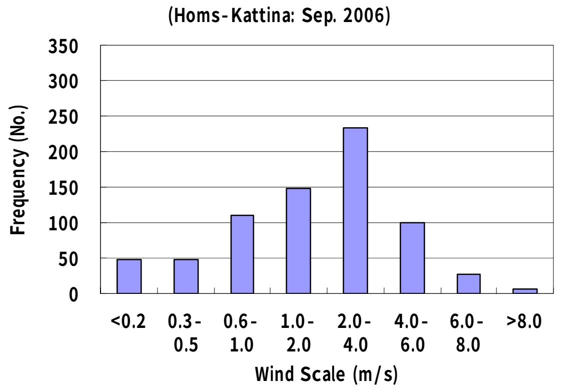
(1) Meteorological analysis and evaluation

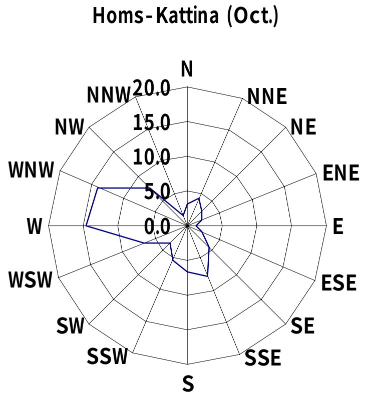
The weather conditions of the targeted region are of great importance for the sake of predicting air quality concentration originated from the pollution sources and determining the scope of investigation. Thus, we analyzed the meteorological data of Kattina village in Homs for the period from Aug. 2006 to Jun. 2007, and evaluated the weather characteristics of Homs region. Figure 2.1 shows the wind rose and the frequency of the wind velocity.

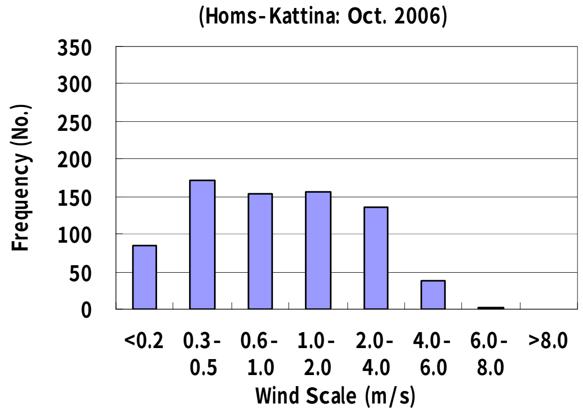


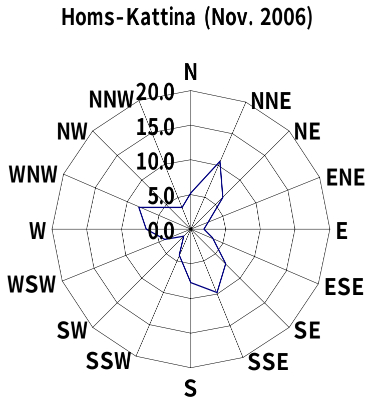












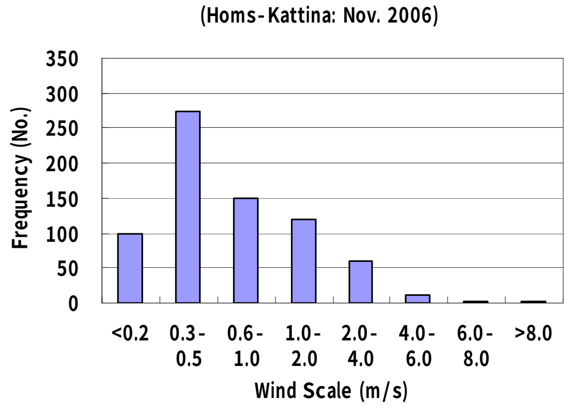
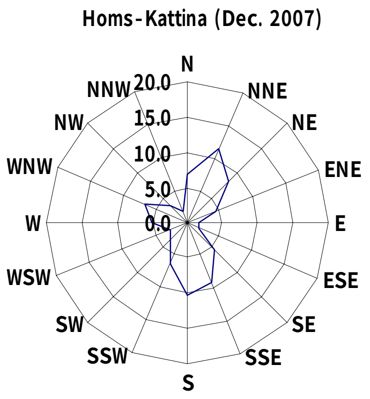
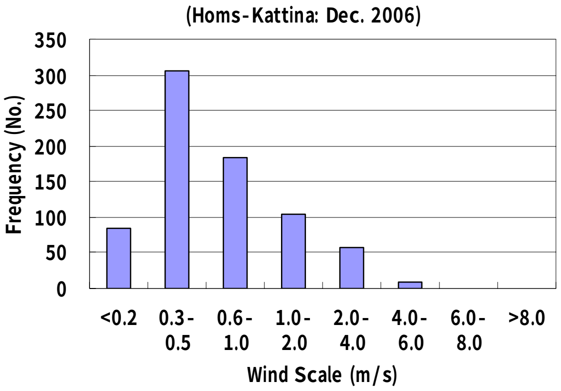
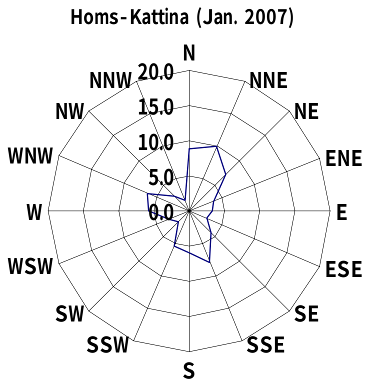
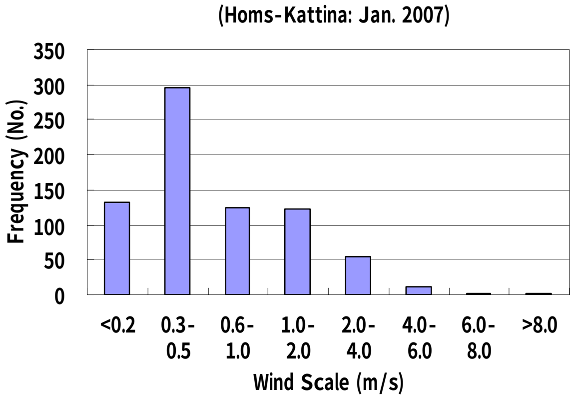


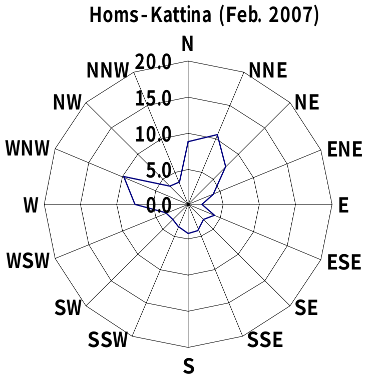
Figure 2.1 (1) Wind Rose **Frequency of the wind velocity**

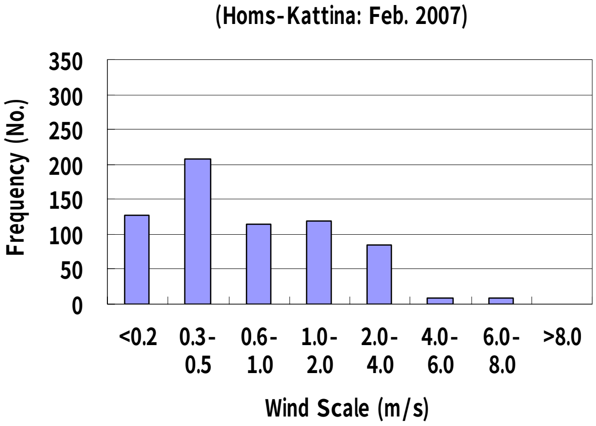


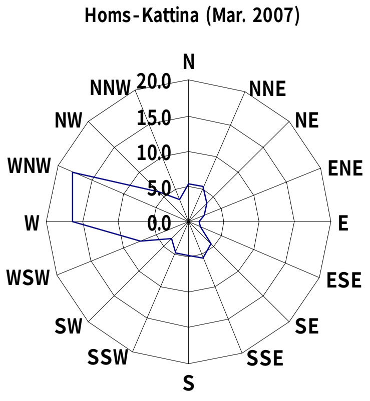












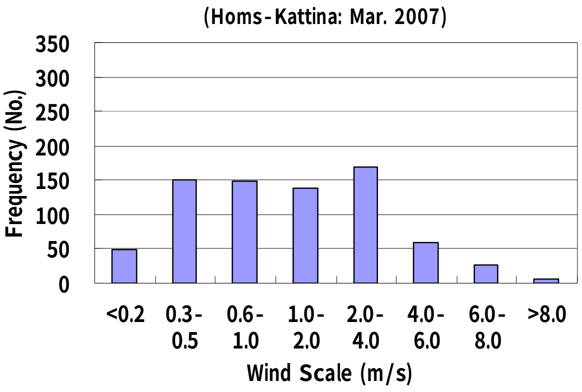
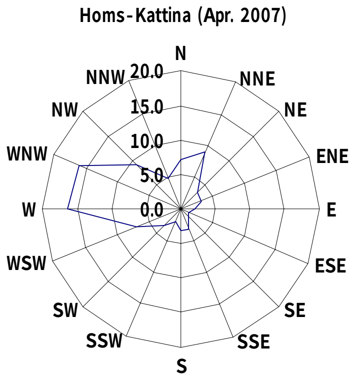
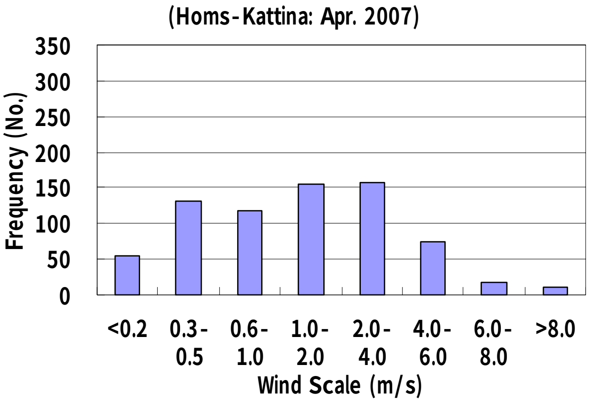
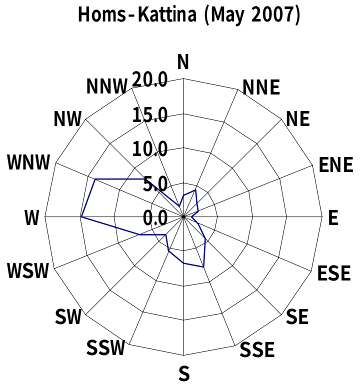


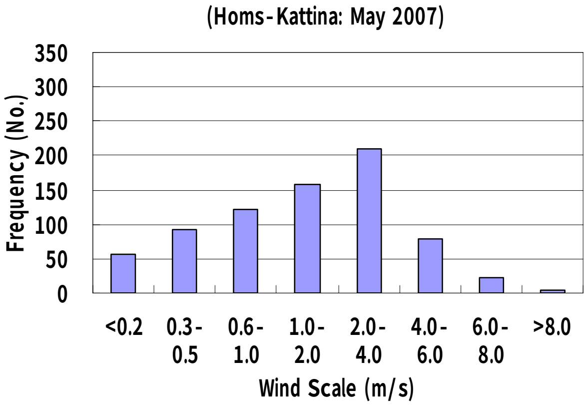
Figure 2.1 (2) Wind Rose

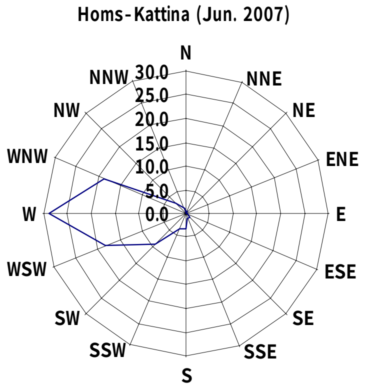
Frequency of the wind velocity











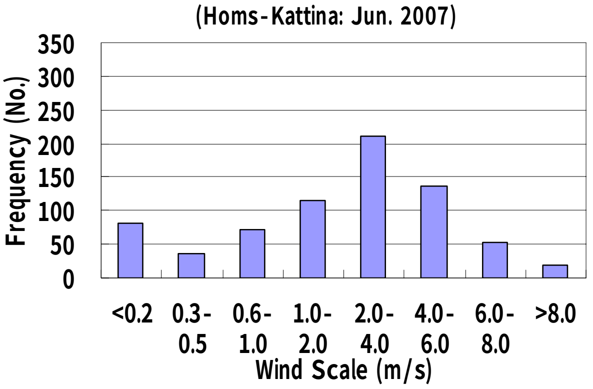


Figure 2.1 (3) Wind Rose **Frequency of the wind velocity**

Figure 2.2 shows the daily change of the maximum, minimum and average temperature of the meteorological data obtained for the period 21 Aug. 2006 ~ 27 Jun. 2007.

Especially, in the clear nights in winter and in accordance with the radiative cooling, the temperature of the ground surface drops and air temperature becomes higher than ground surface temperature, and this might lead to the formation of an inversion layer. Under such conditions, atmospheric air becomes extremely stable and the pollutants discharged into the vicinity of the ground surface can hardly diffuse, therefore, concentration becomes extremely high.

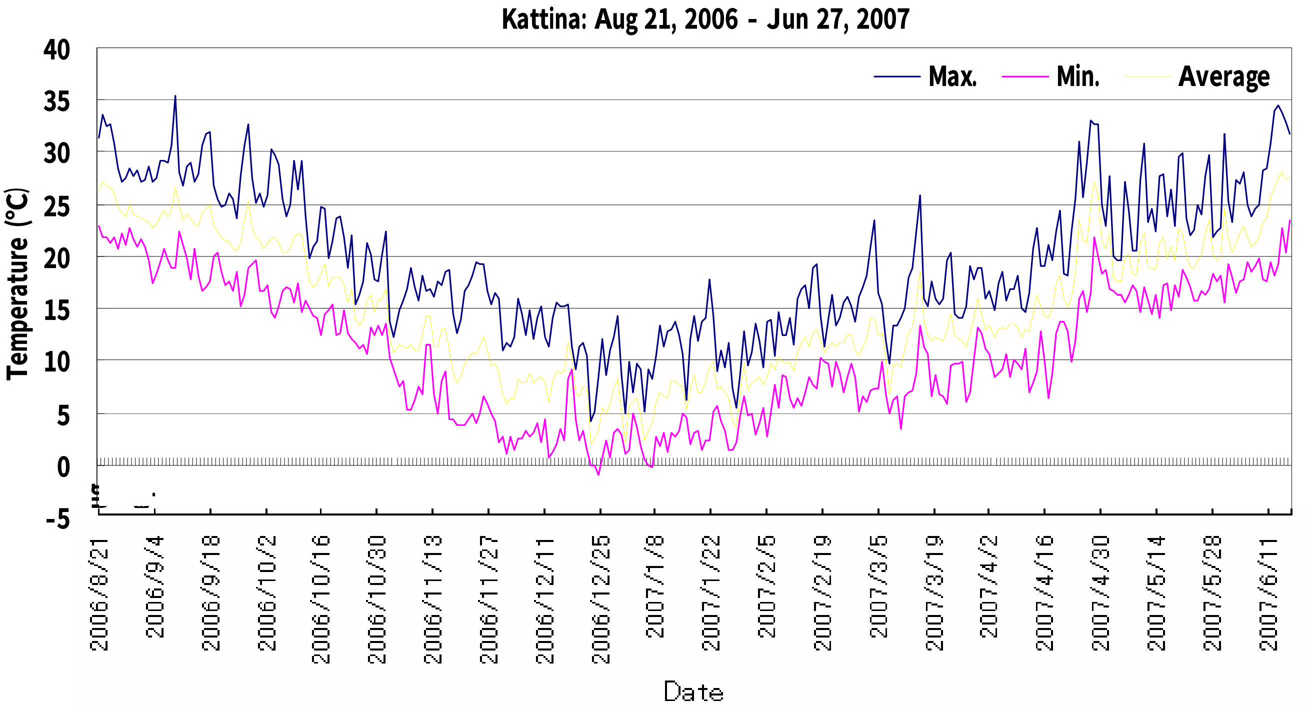


Figure 2.2 Daily change of the maximum, minimum and average temperature

(2) Atmospheric dispersion model (plume type)

a) The setup condition of the atmosphere dispersion calculation (example)

Table 1 Setup Condition of the Atmosphere Dispersion Calculation

NO_x Concentration in the exhaust gases		ppm	2000
Exhaust gas flux (total)		m^3/s	12.56
Considered pollutant flux (Q_{NOx})		m^3/s	0.02512
Atmospheric stability class (A - G) and the setup of the wind velocity (U)	A	m/s	2.0
	B	m/s	2.0
	C	m/s	3.0
	D	m/s	4.0
	E (Night)	m/s	3.0
	F (Night)	m/s	2.0
	G (Night)	m/s	1.0

b) Equation of the atmosphere dispersion model

In the prediction of the concentration of the air pollutants that are discharged from the pollution sources, plume equation of air dispersion is used generally.

- Point source dispersion formula (when wind is blowing)

$$C = \frac{Q}{2\pi \cdot \sigma_y \cdot \sigma_z \cdot U} \exp\left\{ - \frac{y^2}{2\sigma_y^{\ 2}} \right\} \cdot \left[\exp\left\{ - \frac{(He\ - z)^2}{2\sigma_Z^{\ 2}} \right\} + \exp\left\{ - \frac{(He^{\ 2} + z)}{2\sigma_Z^{\ 2}} \right\} \right]$$

Where,

C: Concentration at the forecast point (m^3/m^3)

y and z: Distances of the horizontal direction (y) and the vertical direction (z) from the point stationary source (stack) to the forecast point (m). (z is the distance from the ground surface to the pollutant sampling point, and usually is set at 1.5 m; the level of human breathing of air).

Q: Considered pollutant flux in the point stationary source (m^3_{NOx}/s).

U: Velocity of the wind (m/s)

(The direction of leeward is assumed to be the direction x).

(By definition: Leeward is the direction in which the wind is blowing).

(By definition: Windward is the direction from which the wind is coming).

He: Effective stack height (m)

σ_y: Dispersion width along the right-angle (horizontal) direction (y), (m).

σ_z: Dispersion width along the vertical direction (z), (m).

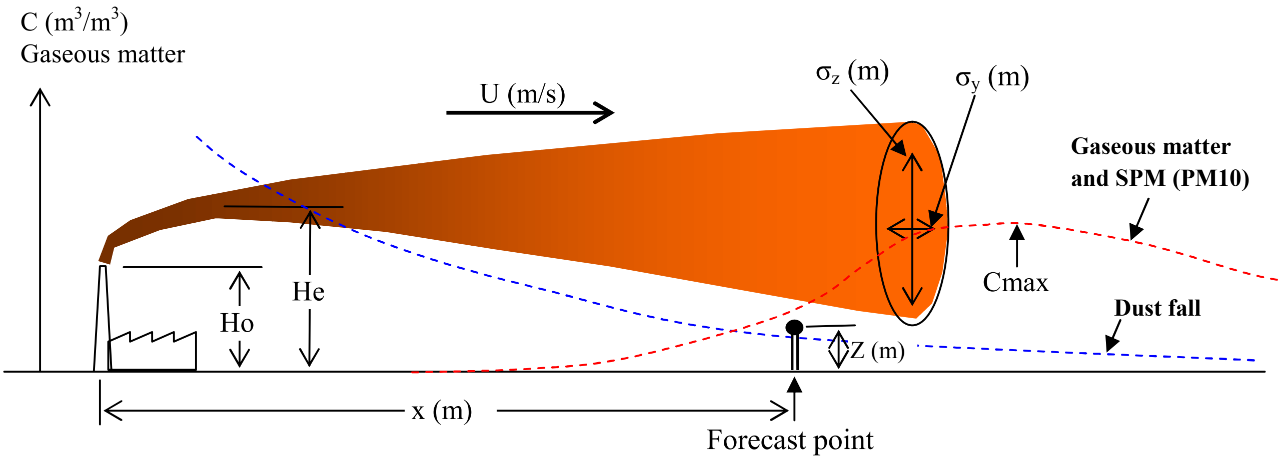


Figure 2.3 Image of the atmospheric dispersion model

Table 2 illustrates the classification of Pasquill atmospheric stability classes. Class "A" indicates extremely unstable ambient air, and thus its dispersion is fast. On the other hand, class "G" indicates extremely stable ambient air, and thus its dispersion is very slow.

Table 2 Pasquill atmospheric stability classes classification

Wind velocity (m/s)	Solar radiation (kW/m^2)				Net radiation (radiation reflected from the earth into the sky during night time. (kW/m^2)		
	0.60 ~	0.30 ~ 0.60	0.15 ~ 0.30	~ 0.15	-0.020 ~	-0.040 ~ -0.020	~ -0.040
~ 2	A	A - B	B	D	D	G	G
2 ~ 3	A - B	B	C	D	D	E	F
3 ~ 4	B	B - C	C	D	D	D	E
4 ~ 6	C	C - D	D	D	D	D	D
6 ~	C	D	D	D	D	D	D

Note: In addition to the above mentioned classification, there is a classification method that takes into account the cloudiness degree.

Regarding the classification of the atmospheric stability classes, the relation between the horizontal dispersion width (σ_y) and the vertical dispersion width (σ_z) with the distance of the pollution source is shown in figure 2.4.

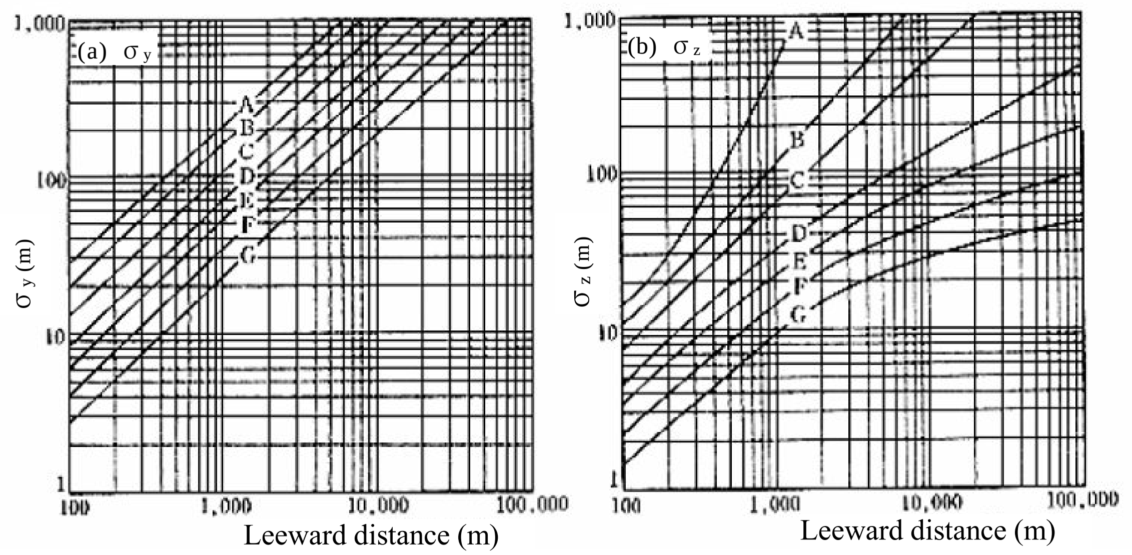


Figure 2.4 Dependency of σ_y and σ_z on the distance of the pollution source and the atmospheric stability classes

(2) Pollutant concentration distribution in the leeward direction

The relation between the pollutants concentration in the main stream of the gaseous pollutants and the distance from the stationary source of pollution is shown in figure 3 (each figure is obtained for a certain effective stack height (He) and all atmospheric stability classes). From these figures we can notice the followings:

- Cmax concentration differs greatly in accordance with the weather conditions, i.e., atmospheric stability classes.

- High concentration values are generated when air is unstable.
- When the location of Cmax is at short distance form the pollution source, the concentration Cmax becomes high.
- The higher the effective stack height (He), the longer the distance of Cmax from the pollution source and the smaller the value of Cmax.

(Case 1)

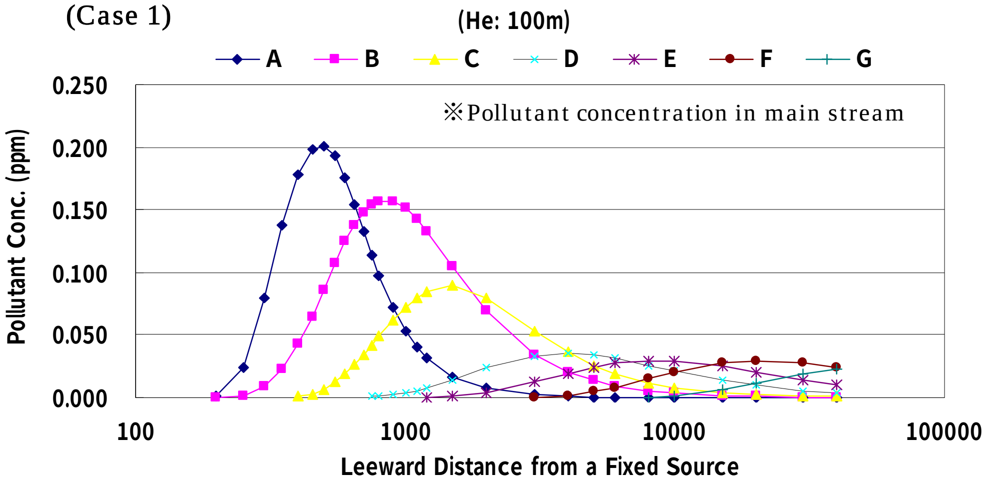


Figure 3-(1) Relation between the pollutant concentration and the distance from the stationary source along with the atmospheric stability classes (He: 100m)

(Case 2)

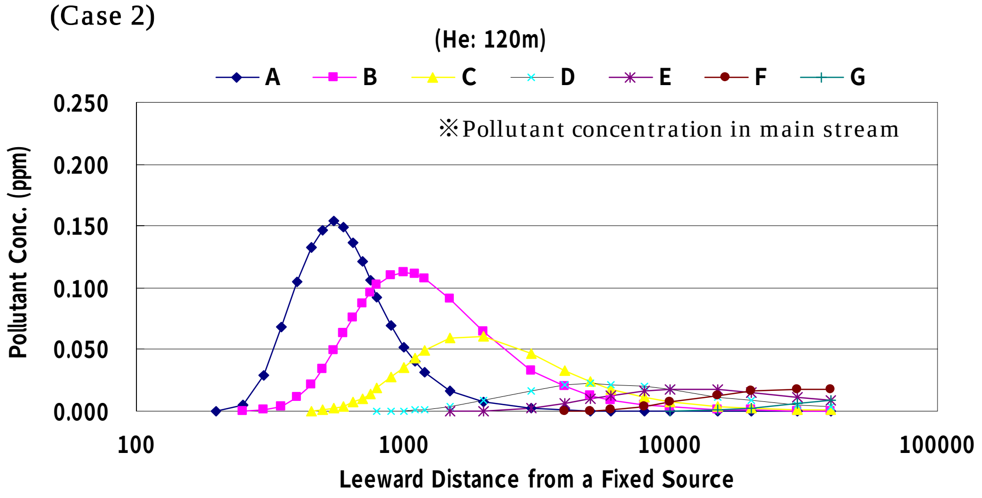


Figure 3-(2) Relation between the pollutant concentration and the distance from the stationary source along with the atmospheric stability classes (He: 120m)

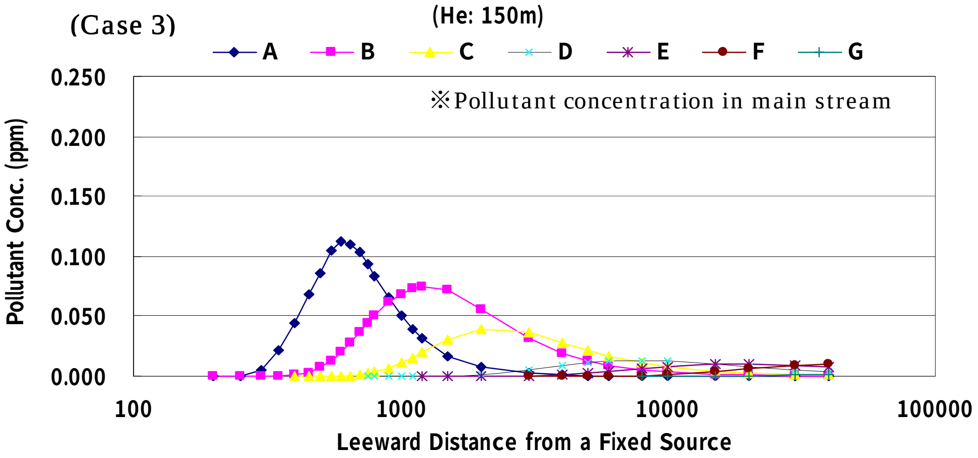


Figure 3-(3) Relation between the pollutant concentration and the distance from the stationary source along with the atmospheric stability classes (He: 150m)

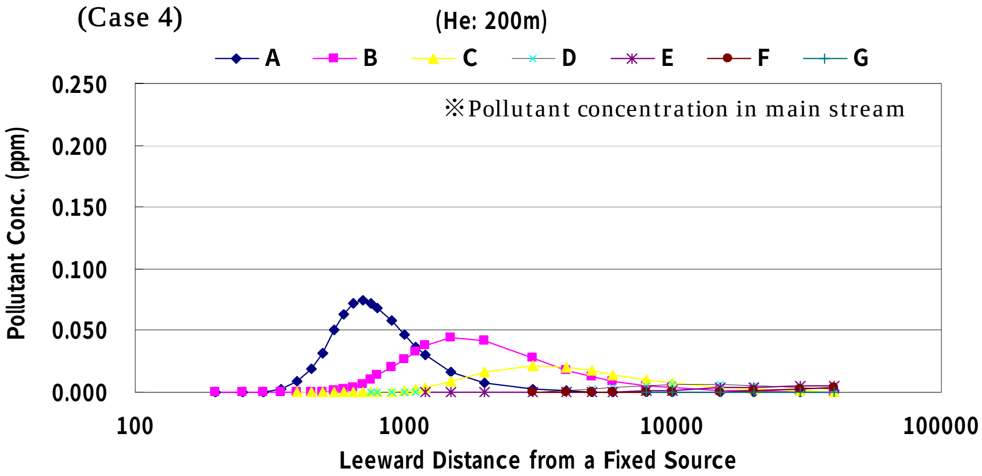


Figure 3-(4) Relation between the pollutant concentration and the distance from the stationary source along with the atmospheric stability classes (He: 200m)

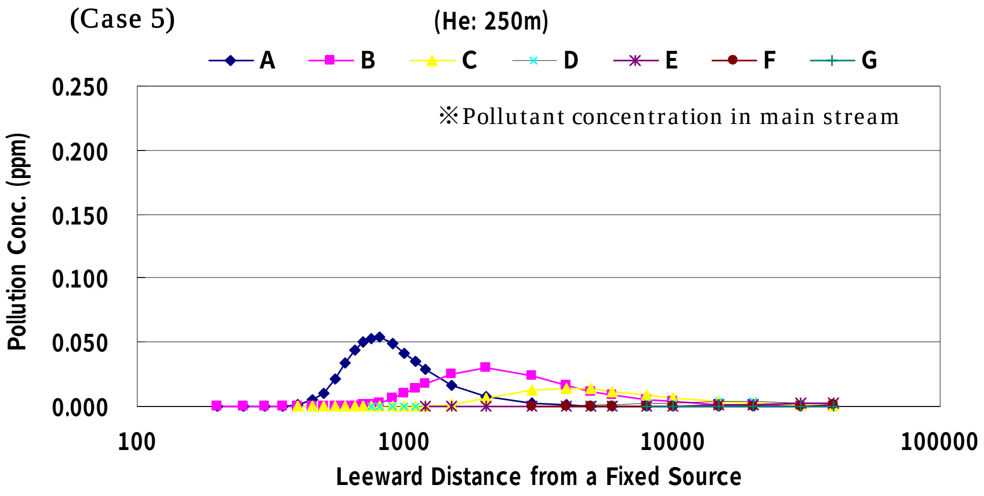


Figure 3-(5) Relation between the pollutant concentration and the distance from the stationary source along with the atmospheric stability classes (He: 250m)

Figure 3 Relation between the pollutant concentration and the distance from the stationary source of pollution (each figure is obtained for a certain effective stack height (He) and all atmospheric stability classes)

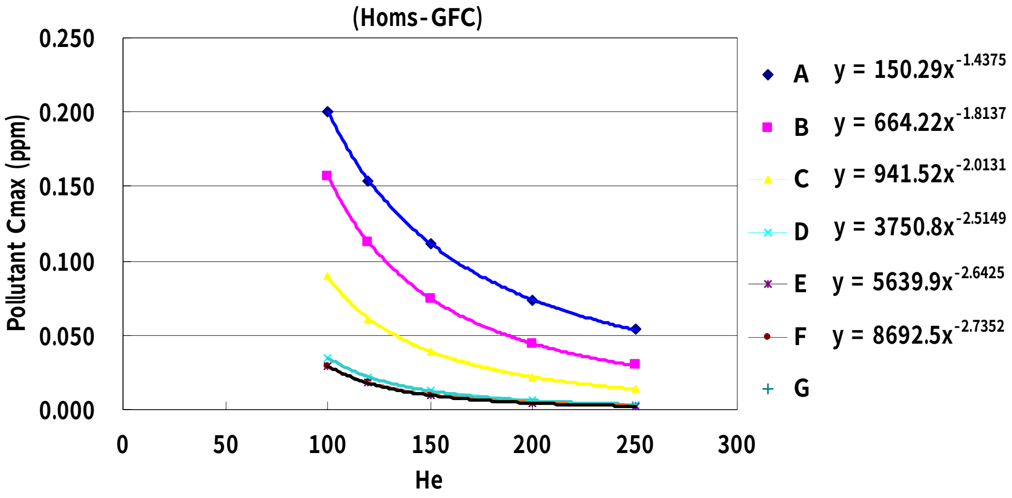
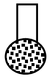
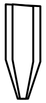
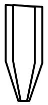
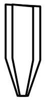
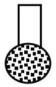
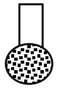
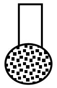
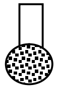


Figure 4 Relation between Cmax and the effective stack height (He) for the various atmospheric stability classes.

(Point of consideration)

In case of pollution source with a high stack, the more unstable the ambient air is, the bigger the impact of the concentration above the ground, as was mentioned above. But, in case of pollution source with a short stack, conversely, the more stable the ambient air is, the bigger the impact of the concentration above the ground. Therefore, it is necessary to consider this point.

About the Measurement Item and the Absorbance Measurement

Measuring Item	Measuring Method	Impinger	Flowmeter (L/min)	Leaving time after coloring (min)	Wave Length	Colored liquid	Contrast solution of cell	Note
Nitrogen Oxides（NO_x）	Saltzman Reaction Method	Bubbler 	0.2 – 0.4 (0.4)	15	550 nm	Purplish red	Distilled water	Subtract absorbance of the absorption liquid from the sample.
Sulfur dioxide（SO_2）	Pararosaniline Method	Nozzle 	0.5 – 2.0 (1.0)	20	560 nm	Purplish blue	Colored operation to absorption liquid	
Ozone (O3)	Neutral potassium iodide method		1.0 – 2.0 (1.0)	No necessity of leaving	362 nm	Light yellow	Distilled water	Subtract absorbance of the absorption liquid from the sample.
Fluorine (F)	Alizarin complexone absorption photometry (ALC)		0.5 – 2.0 (1.0)	30 or more	620 nm	Blue	Blank test solution	
Ammonia (NH_3)	Nessler Method		0.5 – 1.0 (1.0)	10	400 nm	Yellow	Distilled water	Absorbance of Blank test solution is subtracted from the sample.
Hydrogen sulphide (H_2S)	Methylene blue Method		0.5 – 2.0 (1.0)	30	670 nm	Blue	Blank test solution	Colored operation avoids direct sunlight.
Hydrogen chloride (HCl)	Mercury (Ⅱ) thiocyanate Method		1.0 – 2.0 (1.0)	5	460 nm	Dark-red	Blank test solution	
Hydrogen cyanide (HCN)	Pyridine – pyrazolone Method		1.0 – 2.0 (1.0)	50	620 nm	Blue	Blank test solution	

Lecture Material -07

Additional training lecture for air quality SOPs

Air Quality Analysis

Additional training lecture for air quality SOPs

May 28-2007

1. Basic knowledge of chemistry

In this file an explanation of the common items in the air pollutants Standard Operation Procedure (SOPs) is presented.

Matter can be classified into three types; elements, compounds, and mixtures. An element is the simplest type of matter and consists of only one kind of atom (Ex: hydrogen, oxygen, carbon,…). Atom is the smallest form of an element. A compound is a type of matter composed of two or more different elements that are chemically bound together. Molecule is the smallest form of a compound. For example ammonia: it is a compound consists of the element nitrogen (N) and the element hydrogen (H).

An atom is electrically neutral and composed of a positively charged central nucleus surrounded by one or more negatively charged electrons. The atomic nucleus consists of protons, which have positive charges, and neutrons, which have no charges (the only exception is the simplest hydrogen nucleus which does not have neutrons).

The atomic number of an element equals the number of protons in the nucleus of each of its atom. The mass number of an atom is the sum of the total number of protons and neutrons in the nucleus of that atom.

Atomic symbol is a representative of an element name. For example: ${}^{35}_{17}Cl$, where Cl is for the element chlorine, and 35 is its mass number, and 17 is its atomic number.

(1) Atomic symbol and weight

Carbon atom has been given the number 12 as its atomic weight (mass number), which has been considered as the standard. The other atoms have atomic weights that are relative to the carbon atomic weight.

The element symbol is a term that represents an element's name: H for Hydrogen, O for Oxygen, C for Carbon, N for Nitrogen, S for Sulfur, Cl for Chlorine, Na for Sodium and Ca for Calcium.

Followings are the atomic weights of the elements that are frequently used:

(H: 1), (O: 16), (C: 12), (N: 14), (S: 32), (Cl: 35), (Na: 23), (Ca: 40.1)

(2) Molecular formula and molecular weight

The sum total of the atomic weight of an element is its molecular weight. Both atomic and molecular numbers are absolutes.

(3) Amount of a substance (= mol)

The number of substance entities (atoms or molecules or ions or electrons) in 1 mole of a substance is the Avogadro's number which equals 6.022×10^{23} entity. The

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amount of a substance that expresses the molecular weight with the gram unit is called mol: 1000 mol = 1 kmol.

1 mol of carbon-12 contains 6.022 × 10^{23} carbon-12 atoms and weighs 12 g

1 mol of H_2O contains 6.022 × 10^{23} H_2O molecules and weighs 18 g

Q1: How many grams are there in 1 mol of CO_2?

Q2: How many kg are there in 0.5 kmol of O_2?

(4) Valence

The outer electrons of an atom, which are the ones involved in chemical bonding, are often called valence electrons.

Valence is the measurement of the power of an atom to combine with others, by the number of Hydrogen atoms it can combine with or displace.

Valence	Element
1	H, F, Cl, Br, Na, K, Ag, Cu, (Hg)
2	O, S, Ca, Ba, Mg, Zn, Cd, (Cu), (Fe), (Pb), Hg, (V)
3	N, P, B, Al, Fe, Ti, (V)
4	C, Si, (Ti), Pb, (V)
5	V

(5) Boyle Charles's law

The physical behavior of a sample of gas can be described completely by four variables: pressure (P), volume (V), temperature (T), and amount (number of moles).

a) Boyle’s law: at constant temperature, the volume occupied by a fixed amount of gas is inversely proportional to the applied (external) pressure: ***PV* = constant**.

b) Charles’s law: at constant pressure, the volume occupied by a fixed amount of gas is directly proportional to its absolute temperature: ***V/T* = constant**.

Therefore, a change of a gas from a state represented by pressure P_1, volume V_1, and absolute temperature T_1 to a state represented by pressure P_2, volume V_2, and absolute temperature T_2 can be described mathematically as:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Q3: A gas at the following condition: P = 2.5 atm, T = 150 ºC, V = 200 m^3. Calculate its volume at the standard conditions (P = 1 atm, T = 0 ºC)

Note: in the above equation, temperature must be in the Kelvin scale (K) (where: K = ºC + 273.15).

(6) Chemical change and reaction equation

$$2H_2 + O_2 \rightarrow 2H_2O$$

Points:

- In a chemical reaction, the kind of atoms and their numbers in the right-hand and left-hand of the reaction equation do not change.
- The mass in the right-hand and the mass in the left-hand of the reaction equation are the same:

$2H_2$	+	O_2	→	$2H_2O$
4 g		32 g		2(18) g
36 g				36 g

- The volume ratios of the right-hand and left-hand of the reaction equation are related to each other in an integer number of comparison coefficient:

  Note: at the standard conditions (T = 0 ºC, P = 1 atm) the standard molar volume equals 22.4 L.

$2H_2$	+	O_2	→	$2H_2O$	(water vapor)
2 mol		1 mol		2 mol	(amount of substances)
2×22.4 L		22.4 L		2×22.4 L	(volume)
2		1		2	(mass)

Q4: What are the mass and the volume of CO_2 and H_2O that are resulted from the combustion of 100 g of Methane (CH_4)

Point 1: writing the chemical reaction equation

Point 2: by observing the reaction equation, examining the relation between the volume and the mass.

CH_4	+	$2O_2$	→	CO_2	+	$2H_2O$	(water vapor)
1 mol		2 mol		1 mol		2 mol	(amount of substances)
22.4 L		2×22.4 L		22.4 L		2×22.4 L	(volume)
16 g		64 g		44 g		36 g	(mass)

Mass calculation:

By burning 16 g of CH_4, 44 g of CO_2 and 36 g of H_2O are released. Therefore, by burning 100 g of CH_4, the following equations are used to calculate the masses:

$$CO_2 = \frac{100 \times 44}{16} = 275\ (g)$$

$$H_2O = \frac{100 \times 36}{16} = 225\ (g)$$

Volume calculation:

By burning 100 g of CH_4, the following equations are used to calculate the volumes:

$$CO_2 = \frac{100 \times 22.4}{16} = 140\ (L)$$

$$H_2O = \frac{100 \times 44.8}{16} = 280\ (L)$$

(7) Molar concentration (Molarity)

Molarity is defined as the numbers of moles of solute per liter of solution (the unit is mol/L).

Q5: If we dissolve 10 g of sodium hydroxide (NaOH) in 500 ml of water, what is the molar concentration?

(8) Acid, base, and neutralization

An acid is a substance that produces H^+ ions when dissolved in water, and a base is a substance that produces OH^- ions when dissolved in water.

The number of H^+ contained in an acid molecule is called the valence of the acid.

The number of OH^- contained in a base molecule is called the valence of the base.

Acid of valence =1: Hydrochloric acid (HCl), Nitric acid (HNO_3), Acetic acid (CH_3COOH)

Acid of valence =2: Sulfuric acid (H_2SO_4), sulfurous acid (H_2SO_3)

Base of valence =1: Sodium hydroxide (NaOH), ammonia (NH_3)

Base of valence =2: Calcium hydroxide ($Ca(OH)_2$), magnesium hydroxide ($Mg(OH)_2$)

The reaction between an acid and a base is a transfer of hydrogen ion H^+ (proton).

The quantitative relation of the neutralization titration is shown as follows:

(Amount of the acid substance) × (valence number) = (Amount of the base substance) × (valence number)

Therefore, if the following equation expresses the acid-base neutralization:

$$n_{acid} \times v_{acid} \times a_{acid} = n_{base} \times v_{base} \times a_{base}$$

Where, n: concentration (mol/L), v: volume (L), a: valence number

(9) Oxidation and reduction

In oxidation-reduction reaction, the key chemical event is the net movement of electrons from one reactant to the other. This movement of electrons occurs from the reactant (or atom in the reactant) with less attraction for electrons to the reactant (or atom) with more attraction for electrons. (Oxidation is the loss of electrons, and reduction is the gain of electrons).

a) Points

- Oxidation and reduction are synchronous (take place simultaneously).
- If substances A and B undergo a chemical reaction and A is oxidized, then B is reduced.

b) Definitions

[Definition 1] Transfer of oxygen:

- Oxidation is a reaction in which a substance is combined to oxygen atom.
- Reduction is a reaction in which a substance losses oxygen atom.

[Definition 2] Transfer of hydrogen:

- Oxidation is a reaction in which a substance losses hydrogen atom.
- Reduction is a reaction in which a substance is combined to hydrogen atom.

[Definition 3] Transfer of electron (basic):

- Oxidation is a reaction in which a substance losses electron.
- Reduction is a reaction in which a substance gains electron.

Form example, during the formation of magnesium oxide, Mg undergoes oxidation and O_2 undergoes reduction. The loss and gain are simultaneous, but we can imagine them occurring in separate steps:

Oxidation (electron loss by Mg): $Mg \rightarrow Mg^{2+} + 2e^-$

Reduction (electron gain by O_2): $\frac{1}{2}O_2 + 2e^- \rightarrow O^{2-}$

(Note: atomic number of Mg is 12, and that of O is 8)

Therefore, we say that O_2 oxidizes Mg, and thus O_2 is the oxidizing agent. Similarly, Mg reduces O_2, and thus Mg is the reducing agent.

c) Oxidation number

Oxidation number is a number assigned to an element in chemical combination which represents the number of electrons lost (or gained, if the number is negative), by an atom of that element in the compound.

<u>Rules:</u>

Oxidation number of a simple substance (an atom in its elemental form) = 0

Oxidation number of H = +1

Oxidation number of O = -2

Oxidation number of alkali metals = +1

Sum of the oxidation numbers of the atoms in a compound = 0

Oxidation number of a polyatomic ion such as SO_4^{-2} equals the valence number of the ion (the ion charge).

Example: Metallic ion (Fe) is a simple atomic substance, therefore, its oxidation number is 0. Oxidation number of Fe in the compound Fe_2O_3 is 3.

Q6: What is the oxidation number of Mn in the compound $KMnO_4$?

$KMnO_4$ = (1)+MN+(-2×4) = 0

Thus, Mn = +7

d) Value of oxidizing agent and reducing agent

The value of oxidizing agent and reducing agent is determined depending on the number of electron transfer in 1 mol of both agents.

- Potassium permanganate ($KMnO_4$) acidic solution

$$2KMnO_4 + 3H_2SO_4 \rightarrow 2MnSO_4 + K_2SO_4 + 3H_2O + 5(O)$$

Oxidation number of Mn atom: +7 +2

Electron transfer: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

Thus, $KMnO_4$ is an oxidizing agent with the value 5 because 5 mol of electron transfer is deprived.

- Sodium hydrochloride (NaClO)

$$NaClO \rightarrow NaCl + O$$

Oxidation number of Cl atom: +1 -1

Electron transfer: $ClO + 2e^- \rightarrow Cl^{-1} + O$

Thus, NaClO is an oxidizing agent with the value 2.

- The metal sodium (Na)

$$Na \rightarrow Na^+ + e^-$$

Oxidation number of Na atom: 0 +1

Thus, Na is a reducing agent with value 1 by considering the electron transfer of 1 mol.

- Hydrogen (H)

$$H_2 + (O) \rightarrow H_2O$$

Oxidation number of H: 0 +1

Electron transfer: $H_2 \rightarrow 2H^+ + 2e^-$

Thus, H2 is reduction agent with the value 2.

Q7: Is Cl_2 an oxidation agent or a reduction agent, and what is the value?

Q8: Is sodium thiosulfate ($Na_2S_2O_3$) an oxidation agent or a reduction agent, and what is the value?

[Reference]: $2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6$

Q9: Is potassium iodate (KIO_3) an oxidation agent or a reduction agent, and what is the value?

[Reference]: $KIO_3 + 5KI + 3H_2SO_4 \rightarrow 3K_2SO_4 + 3H_2O + 3I_2$

(10) Hydrogen ion exponent (pH)

The number of moles of H^+ ions in a liquid solution falls in the range $10^0 \sim 10^{-14}$. This expressed, for simplicity, as the term pH:

$$pH = -\log [H^+]$$

The concentration of H^+ ion in neutral water is 10^{-7} mol/L therefore its pH equals 7:

$$pH = -\log (10^{-7}) = -7(-1) = 7$$

Q10: What are the H^+ ion concentration, pH, and hydroxide ion concentration of

0.004 mol/L hydrochloric acid (HCl)?

- In diluted solution, strong acid and strong alkali ionizes (dissociate into ions) completely.
- The relation ship between hydroxide ion (OH^-) and hydrogen ion (H^+) is given as follows:

$$[OH^-] \times [H^+] = 10^{-14}$$

0.004 mol/L (HCl) = 0.004 mol/L (H^+)

$pH = -\log [H^+] = -\log(4\times10^{-3}) = -(\log 4 + \log 10^{-3})$

by substituting the value: log 4 = 0.602, we get:

pH = -(0.602 -3) ˜ 2.4

the concentration of the hydroxide ion (mol/L) is given as:

$$\left[OH^-\right] = \frac{10^{-14}}{\left[H^+\right]} = \frac{10^{-14}}{4\times10^{-3}} = 2.5\times10^{-12}$$

2. Method of unit conversion (ppm ↔ mg/m^3)

At the condition of 20 ºC and 760 mmHg (1.013 Pa), the following equations are used for unit conversion:

$$ppm = mg/m^3 \times \frac{24.04}{M}$$

$$mg/m^3 = ppm \times \frac{M}{24.04}$$

The following table shows the concentration unit conversion of some gases:

C (ppm) = A × C (mg/m^3)

C (mg/m^3) = B × C (ppm)

Gas name	Chemical formula	Factor	
		A	B
Nitrogen dioxides	NO_2	0.52	1.91
Nitrogen monoxide	NO	0.80	1.25
Sulfur dioxide	SO_2	0.38	2,66
Ozone	O_3	0.50	2.00
Hydrogen fluoride	HF	1.20	0.83
Ammonia	NH_3	1.41	0.71

Hydrogen sulphide	H_2S	0.71	1.42
Hydrogen chloride	HCl	0.66	1.52
Hydrogen cyanide	HCN	0.89	1.12
Carbon monoxide	CO	0.86	1.16
Carbon dioxide	CO_2	0.55	1.83
Methane	CH4	1.50	0.67
Ethane	C2H6	0.80	1.25
Benzene	C_6H_6	0.31	3.25
Formaldehyde	HCHO	0.80	1.25

3. Other topics

(1) The duration of leaving a solution as it is before coloring and absorbance measurement (change of coloring intensity).

(2) The procedure of calculating air pollutants concentration.

Lecture Material -08

Analysis of Air Quality Monitoring Data and Guidance of Assessment Procedure

Air Quality Analysis

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1. Analysis of air quality monitoring data and guidance of assessment procedure, etc.

(1) Correlation analysis

1) Correlation between items

Table 1-1 Relation between air quality concentration and weather conditions

	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	W.V.	Temp.	Humi.
NO	—										
NO_2	NO	—									
NO_x	NO	NO_2	—								
SO_2	NO	NO_2	NO_x	—							
CO	NO	NO_2	NO_x	SO_2	—						
O_3	NO	NO_2	NO_x	SO_2	CO	—					
PM10	NO	NO_2	NO_x	SO_2	CO	O_3	—				
NM-HC	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	—			
W.V.	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	—		
Temp.	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	W.V.	—	
Humi.	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	W.V.	Temp.	—
Solar R.	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	W.V.	Temp.	Humi.

NM-HC: Non Methane Hydrocarbon W.V.: Wind Velocity Solar R.: Solar Radiation

Table 1-2 Relation between air quality concentration and traffic

	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	Large Veh.	Small Veh.	Passenger car
NO	—										
NO_2	NO	—									
NO_x	NO	NO_2	—								
SO_2	NO	NO_2	NO_x	—							
CO	NO	NO_2	NO_x	SO_2	—						
O_3	NO	NO_2	NO_x	SO_2	CO	—					
PM10	NO	NO_2	NO_x	SO_2	CO	O_3	—				
NM-HC	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	—			
Large Veh.	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	—		
Small Veh.	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	Large Veh.	—	
Passenger car	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	Large Veh.	Small Veh.	—
Large Veh. mixing rate	NO	NO_2	NO_x	SO_2	CO	O_3	PM10	NM-HC	Large Veh.	Small Veh.	Passenger car

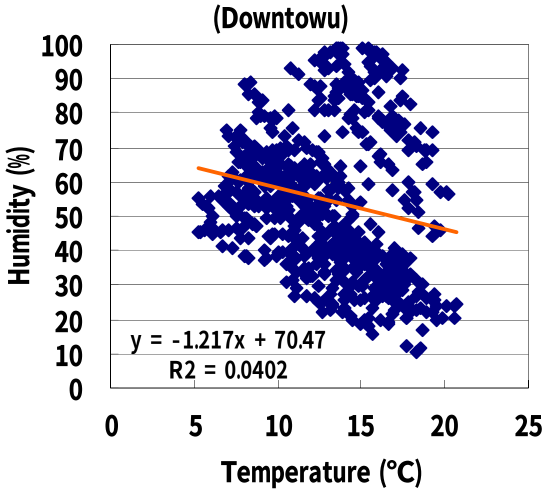
Veh.: vehicle Large Veh.: Large-scale freight car Small Veh.: Small-scale freight car

a) Aleppo

i) Temperature - Humidity (data of November 2006)

The relation between temperature and humidity is illustrated in figures 1-1 which shows all data (all data indicates measurement of a complete month (24 readings a day for 30 days).

- Data discrepancy is big, i.e., data is greatly scattered. This data represents the monthly weather conditions.
- There is a tendency that when atmospheric temperature rises humidity decreases.
- The relation between temperature and humidity can be divided into two groups.
- Compared to other locations, humidity in the water treatment station is high.



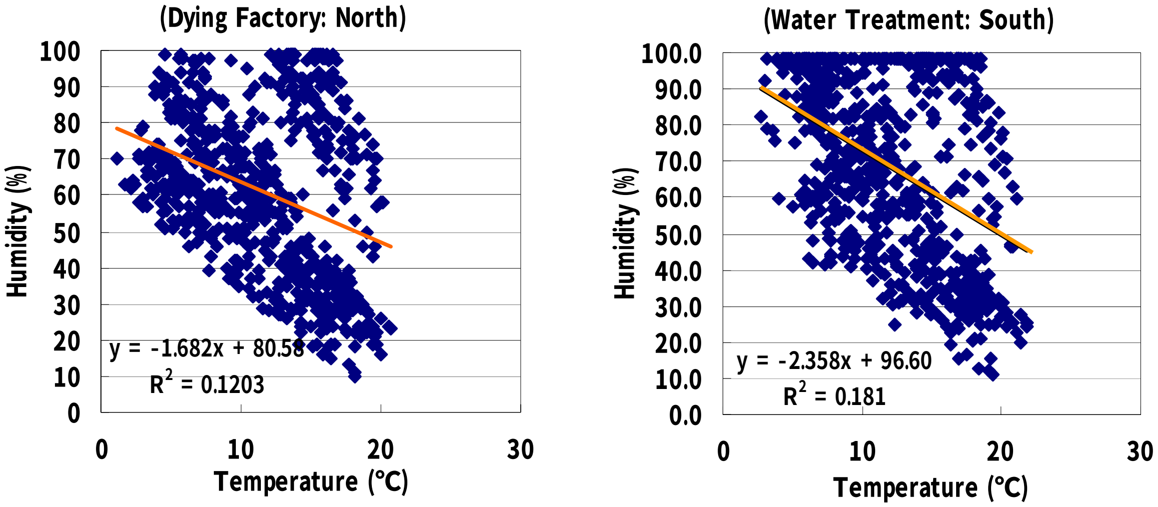
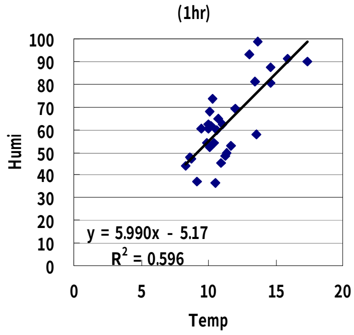
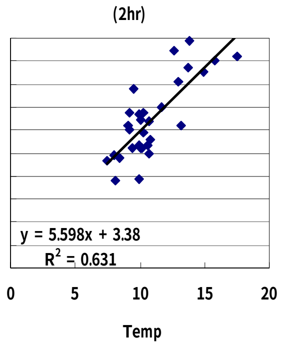
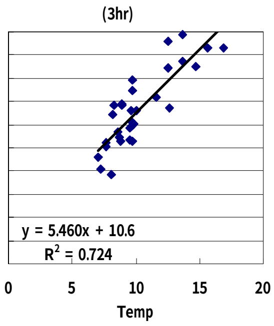


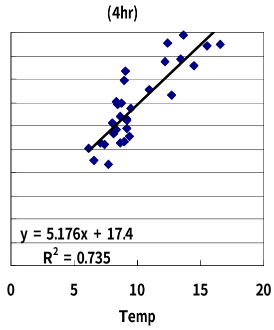
Figure 1-1 Relation between temperature and humidity (hourly data for one month)

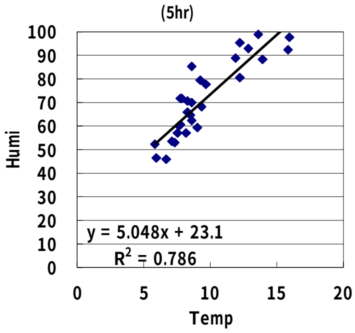
For the sake of analyzing the cause of data discrepancy, we investigated temperature and humidity data in the downtown because there is almost no interrelation (discrepancy is the biggest) as can be seen in the figure 1-1. After collecting the recorded data from the weather stations, the relation between temperature and humidity for each hour reading can be represented as shown in table 1-3 and figures 1-2. (**Note:** the hour above each figure means that the data is for the complete considered month at that hour).

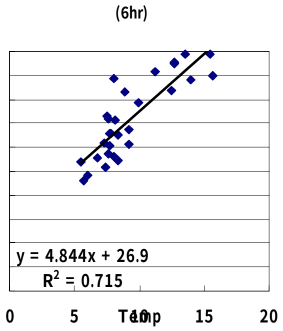

(1hr)
Humi
Temp
y = 5.990x - 5.17
R2 = 0.596
0
5
10
15
20
0
10
20
30
40
50
60
70
80
90
100

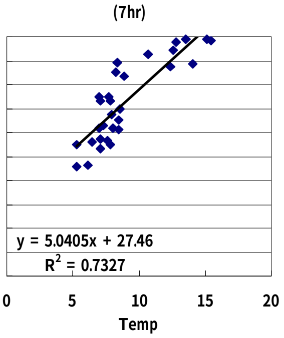

(2hr)
Temp
y = 5.598x + 3.38
R2 = 0.631
0
5
10
15
20

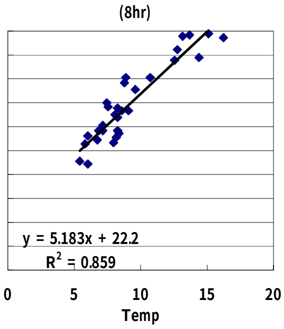

(3hr)
Temp
y = 5.460x + 10.6
R2 = 0.724
0
5
10
15
20

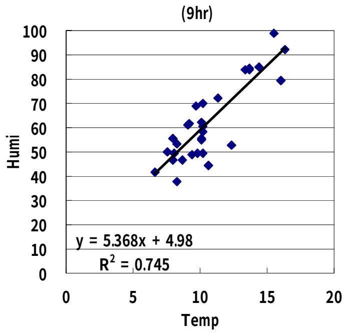

(4hr)
Temp
y = 5.176x + 17.4
R2 = 0.735
0
5
10
15
20

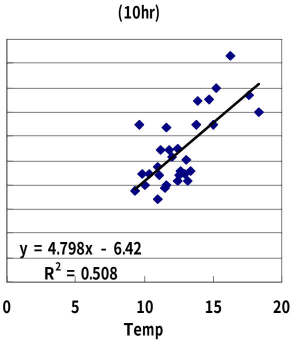

(5hr)
Humi
Temp
y = 5.048x + 23.1
R2 = 0.786
0
5
10
15
20
0
10
20
30
40
50
60
70
80
90
100

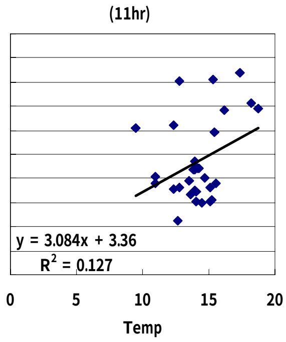

(6hr)
Temp
y = 4.844x + 26.9
R2 = 0.715
0
5
10
15
20

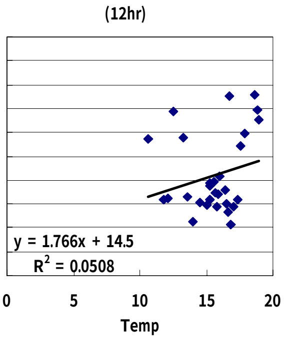

(7hr)
Temp
y = 5.0405x + 27.46
R2 = 0.7327
0
5
10
15
20

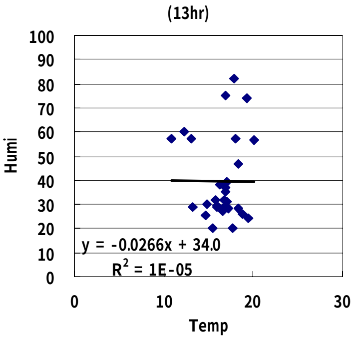

(8hr)
Temp
y = 5.183x + 22.2
R2 = 0.859
0
5
10
15
20

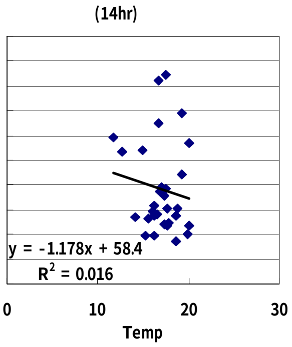

(9hr)
Humi
Temp
y = 5.368x + 4.98
R2 = 0.745
0
5
10
15
20
0
10
20
30
40
50
60
70
80
90
100

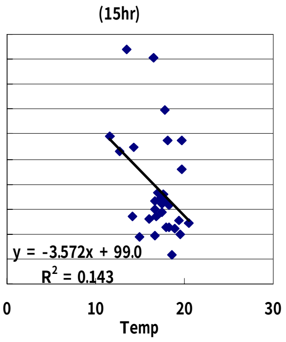

(10hr)
Temp
y = 4.798x - 6.42
R2 = 0.508
0
5
10
15
20

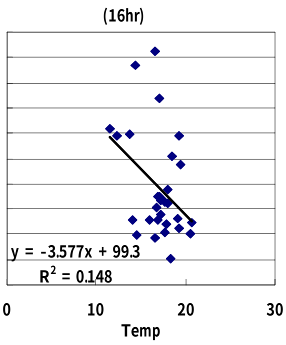

(11hr)
Temp
y = 3.084x + 3.36
R2 = 0.127
0
5
10
15
20


(12hr)
Temp
y = 1.766x + 14.5
R2 = 0.0508
0
5
10
15
20


(13hr)
Humi
Temp
y = -0.0266x + 34.0
R2 = 1E-05
0
10
20
30
0
10
20
30
40
50
60
70
80
90
100


(14hr)
Temp
y = -1.178x + 58.4
R2 = 0.016
0
10
20
30


(15hr)
Temp
y = -3.572x + 99.0
R2 = 0.143
0
10
20
30


(16hr)
Temp
y = -3.577x + 99.3
R2 = 0.148
0
10
20
30

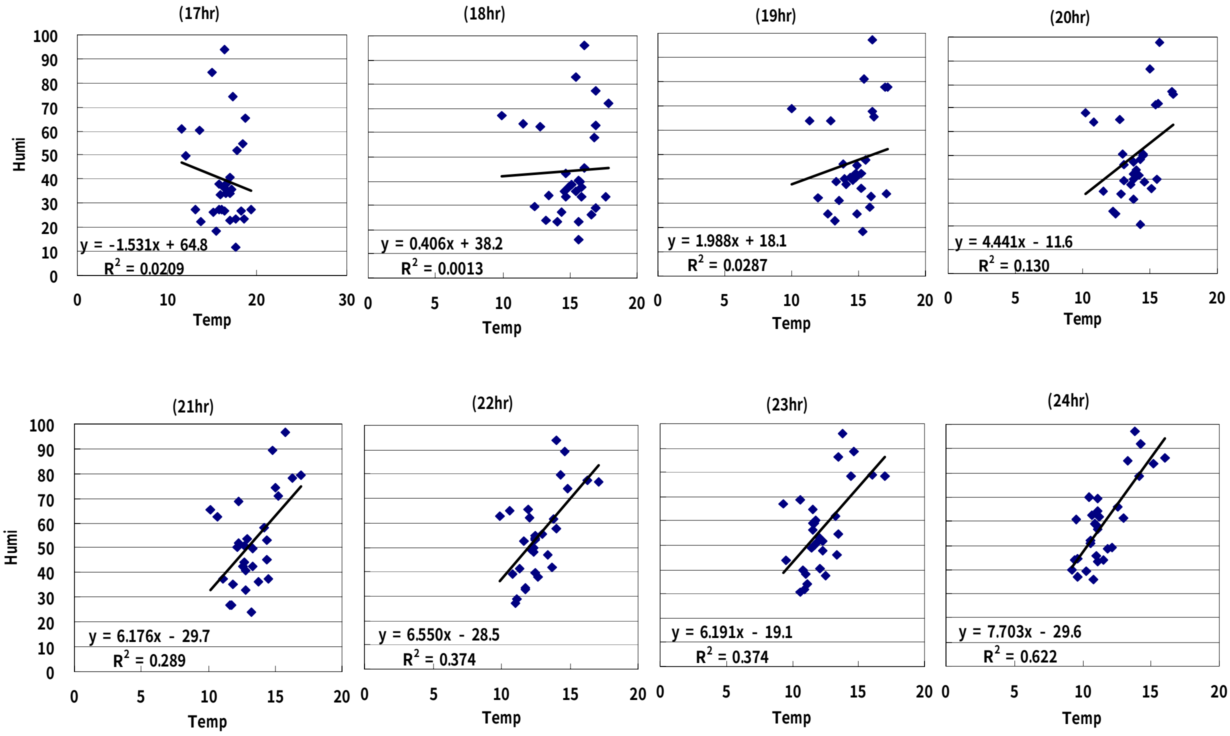


Figure 1-2 Relation between temperature and humidity (same hour for 30 days data)

Table 1-3 The hourly relations between temperature and humidity in Downtown, Aleppo

(Data: November 2006) X: Temperature y: Humidity

Time	Mathematical relation	R^2	R	Time	Mathematical relation	R^2	R
1	y = 5.990x - 5.17	0.596	0.772	13	y = -0.0266x + 34.0	0.0000	0.000
2	y = 5.598x + 3.38	0.631	0.794	14	y = -1.178x + 58.4	0.016	0.126
3	y = 5.460x + 10.6	0.724	0.851	15	y = -3.572x + 99.0	0.143	0.378
4	y = 5.176x + 17.4	0.735	0.857	16	y = -3.577x + 99.3	0.148	0.385
5	y = 5.048x + 23.1	0.786	0.887	17	y = -1.531x + 64.8	0.021	0.145
6	y = 4.844x + 26.9	0.715	0.846	18	y = 0.406x + 38.2	0.0013	0.036
7	y = 5.040x + 27.5	0.733	0.856	19	y = 1.988x + 18.1	0.029	0.170
8	y = 5.183x + 22.2	0.859	**0.927**	20	y = 4.441x - 11.6	0.130	0.361
9	y = 5.368x + 4.98	0.745	0.863	21	y = 6.176x - 29.7	0.289	0.538
10	y = 4.798x - 6.42	0.508	0.713	22	y = 6.550x - 28.5	0.374	0.612
11	y = 3.084x + 3.36	0.127	0.356	23	y = 6.191x - 19.1	0.374	0.612
12	y = 1.766x + 14.5	0.051	0.226	24	y = 7.703x - 29.6	0.622	0.789
All data: y = -1.217x + 70.47 (R= 0.200)							

R^2: Determination coefficient R: Correlation coefficient

🟪 : R > 0.8 🟧 : R > 0.7 🟨 : Positive 🟩 : Negative

- In the afternoon, there is no interrelation between temperature and humidity.
- As for the relation between temperature and humidity, all data shows negative relation (figures 1-1). However, by eliminating the data of afternoon period, a positive

relation is shown by the remaining time zone.

- From the middle of the night until morning the interrelation data scattering is very small (R value is big).
- The data of the dawn time zone shows a strong interrelation (interrelation coefficient is more than 0.8).

Generally, when atmospheric temperature rises humidity decreases (negative relation), and if we observe their hourly changes we can understand this trend. Figure 1-3 shows the hourly change of temperature and humidity in the Downtown of Aleppo within the period 11 ~ 20 Nov 2006 (total 10 days). However, by studying the hourly data of temperature-humidity relation as shown in figures 1-2, a new learning is gained; it is not necessarily that the relation is negative.

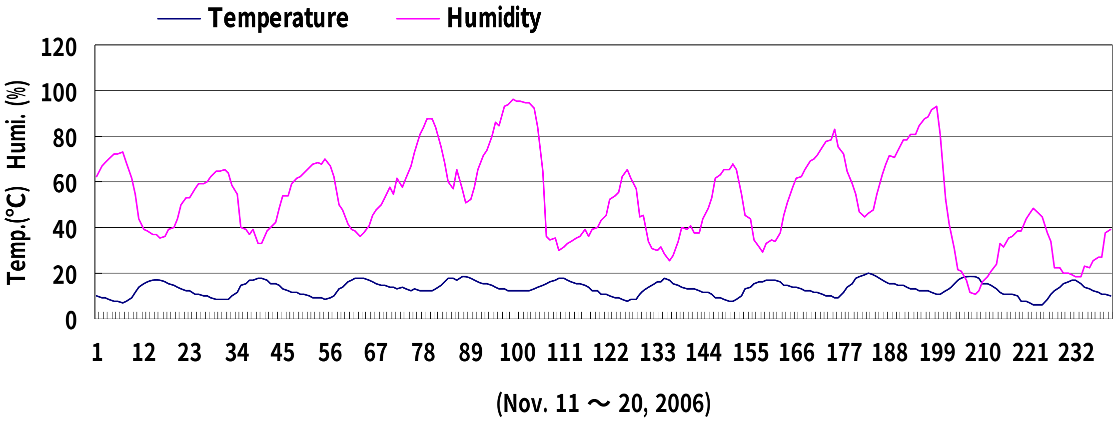


Figure 1-3 Hourly change of temperature and humidity in the Downtown of Aleppo

Figure 1-4 shows the relation between temperature and humidity (data of two days; 48 hours). By excluding unique weather conditions, the data of a short period of time shows high negative interrelation.

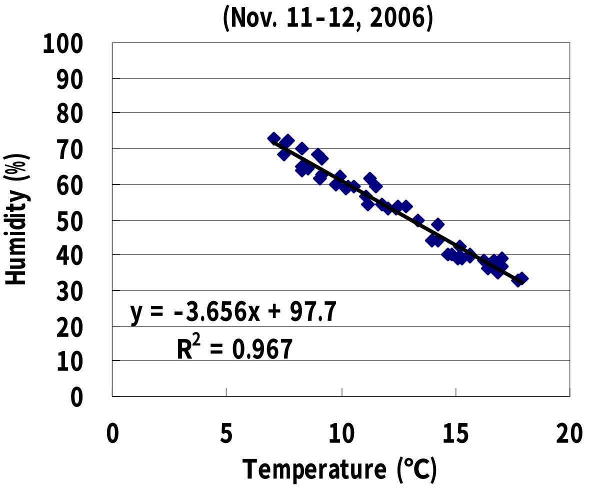


Figure 1-4 Relation between temperature and the humidity (tow days data)

By summarizing the above explained subject, the following points can be adopted:

- The generalization of "humidity decrease with atmospheric temperature increase" is realized.
- When the relation between temperature and humidity of a specified hour is positive, it does not mean that when atmospheric temperature increases humidity increases, but it means that "when atmospheric temperature is high, humidity is also high". For the case of high atmospheric temperature, further increase in its temperature results in humidity decrease.

ii) Temperature – Solar Radiation (data of September 2006)

The relation between temperature difference and solar radiation is shown in the figures below.

Note: temperature difference indicates the difference between the temperature readings of two successive hours as shown in the following equation:

Temp. Diff = Temp (at hour 2) - Temp (at hour 1)

- The relation between temperature difference and solar radiation is positive.
- The range of data fluctuation differs for the different measuring points (meteorological stations).
- Regarding water treatment station point (the location of the meteorological station), it is possible that surface water has an effect based on wind direction.

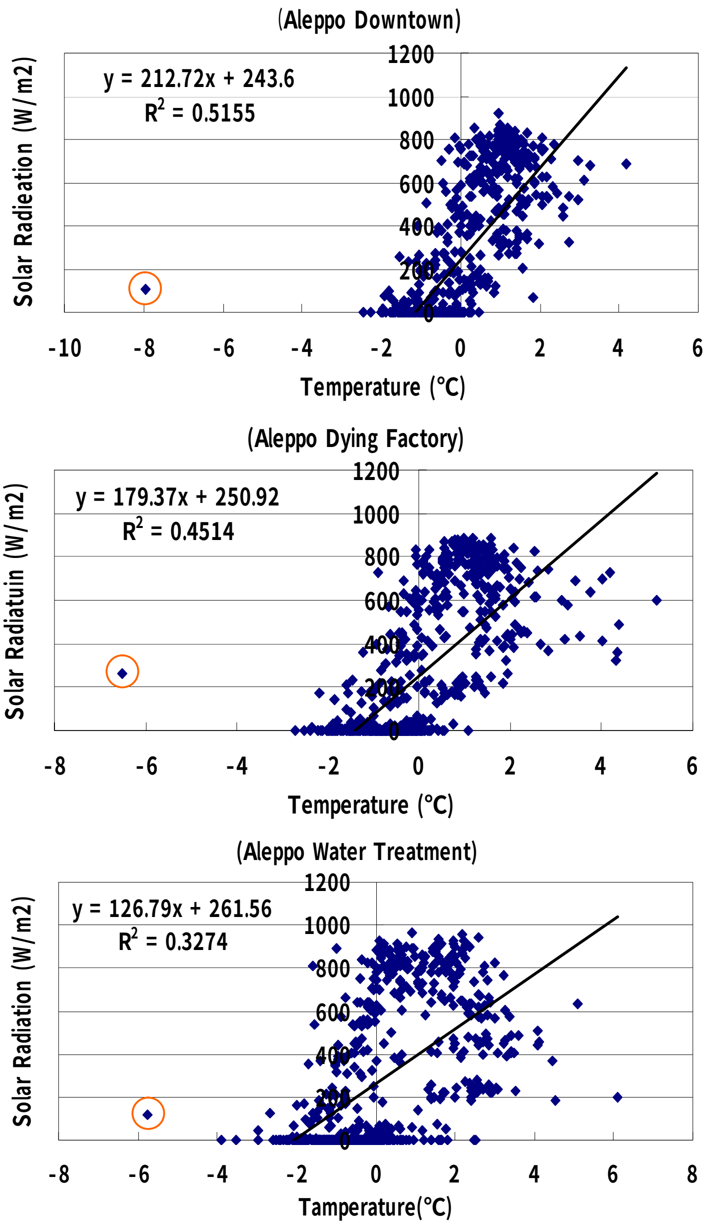


Figure 1-5 Relation between temperature and the solar radiation (one month data)

The red circles in figure 1-5 show drastic atmospheric temperature drop, which is believed to be caused by the passage of cold front. The drastic atmospheric temperature drop occurred in 25 September 2006 at 13:00. Therefore, people in charge of air quality monitoring checked the weather conditions of the days 24, 25 and 26 Sep.

Figure 1-6 shows the weather conditions in Downtown, Aleppo for the three considered days. Form this figure we can realize the following points:

- In 25 Sep. and around 13:00, wind direction was from west to south, then the it changed to the north.
- The atmospheric temperature drop was accompanied by simultaneous humidity increase.
- Solar radiation suffered a big change, which was cause by the change of the weather from clear sky into cloudy.

Comparatively, after 13:00 the wind velocity became so slow that clouds were at a stagnant condition. Under such weather conditions, there is a tendency that air quality concentration became high in the ground vicinity. However, if we continuously collect air quality data we can clearly understand the relation between the front passage and the concentration.

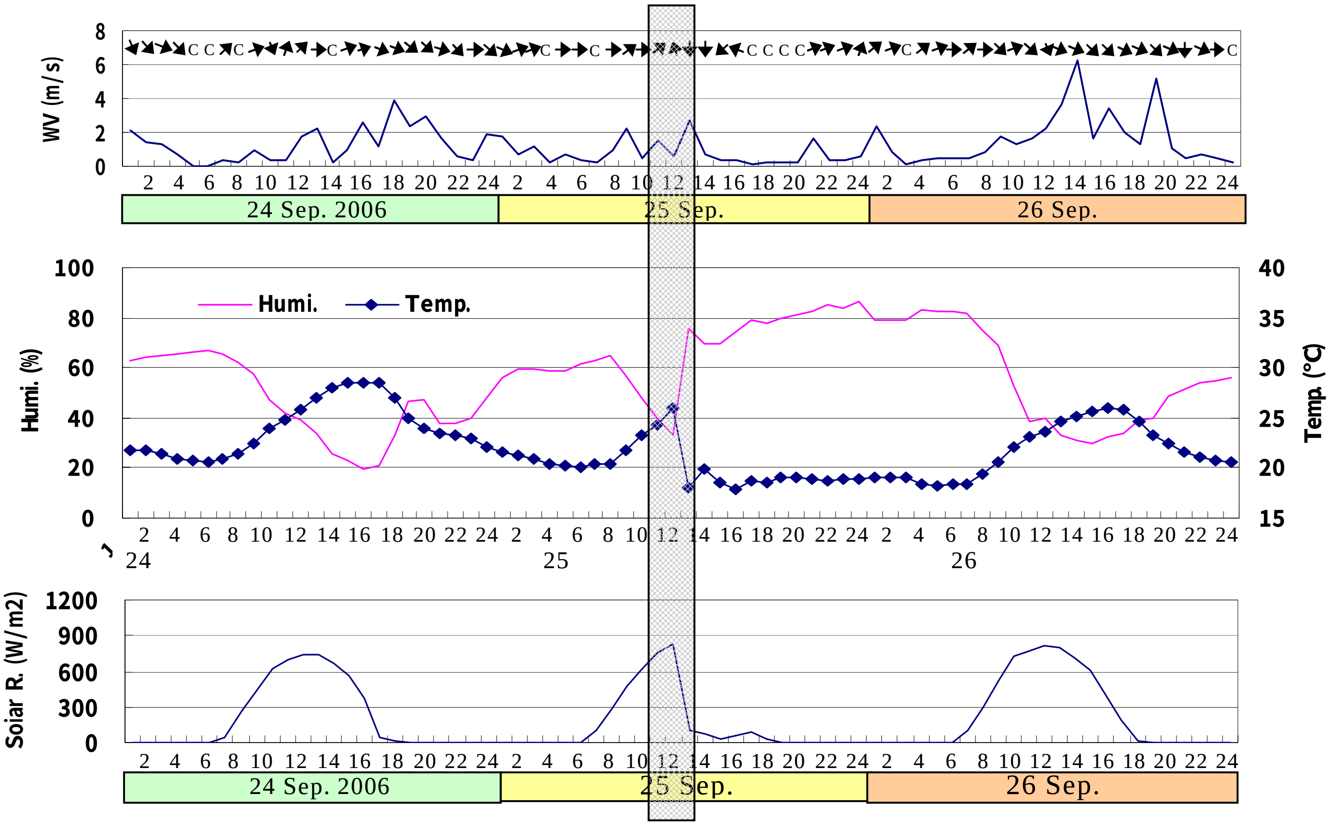
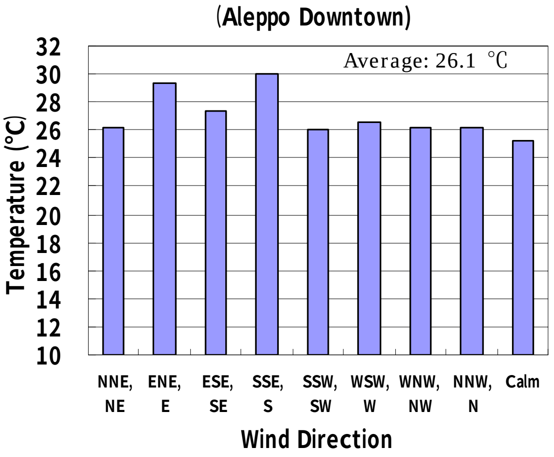
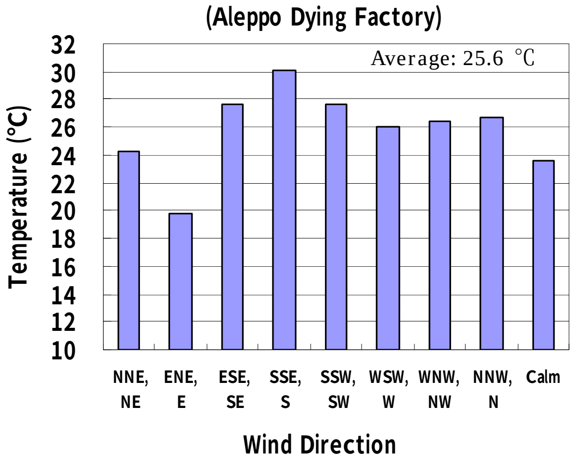


Figure 1-6 Weather condition of Aleppo downtown station with the passage of the cold front.

iii) Wind Direction – Temperature (data of September 2006)

Generally, it can be said that the temperature of a south wind is greater than that of a north wind (south wind is warmer). Figure 1-7 shows the relation between the temperature and wind direction in September. In Aleppo downtown and dying factory areas there is a tendency that the south wind (symbol S) is warmer than the north wind ((symbol N). Contrarily, in water treatment area the tendency is that the north wind (symbol N) is warmer than the south wind (symbol S). Around this station location, a large area extending from east to south is devoted for city wastewater treatment facility that includes an aeration process. Because of the latent heat being expended for evaporating the water, air temperature decreases.





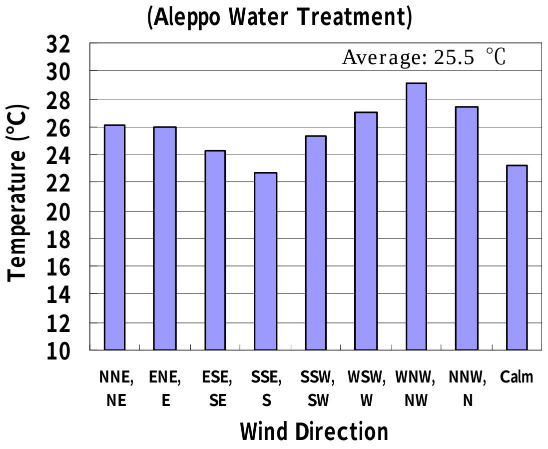


Figure 1-7 Relation between temperature and wind direction

2) Correlation between points (meteorological stations)

a) Temperature

i) Aleppo (data of November 2006)

Average temperature

Downtown: 12.9 (℃) Dying Factory:11.6 (℃) Water Treatment: 12.3 (℃)

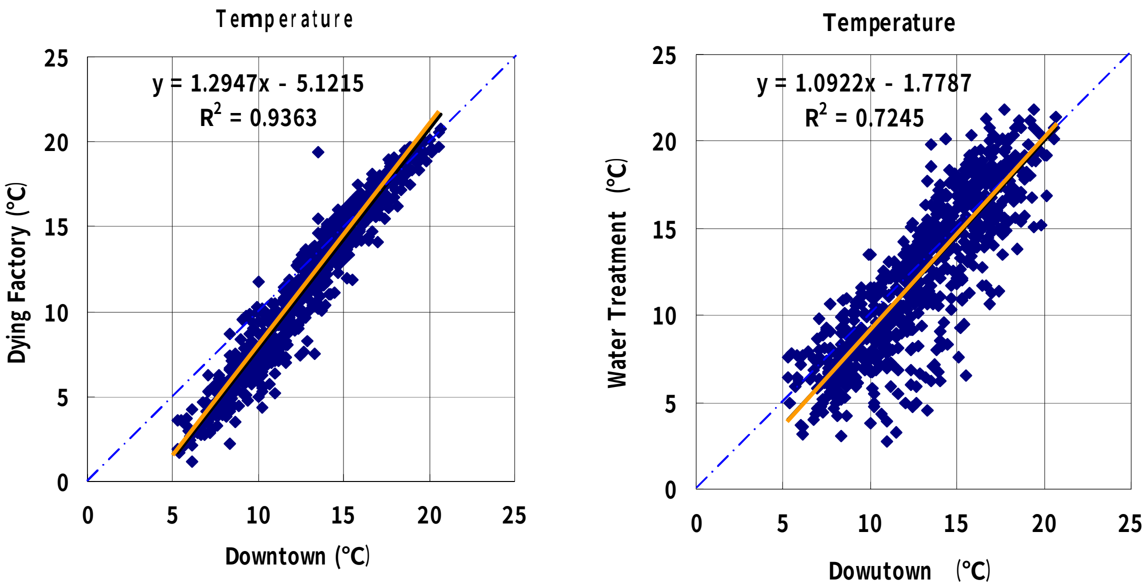


Figure 1-8 Temperature in different stations in Aleppo

ii) Homs (data of November 2006)

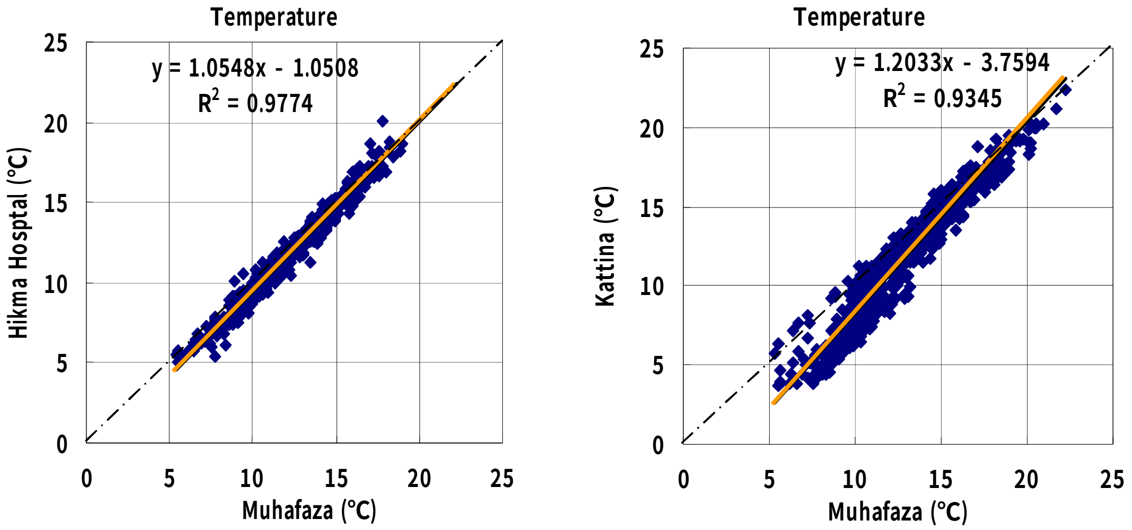


Figure 1-9 Temperature in different stations in Homs

iii) Temperature comparison between Damascene, Homs and Aleppo

(Data of November 2006)

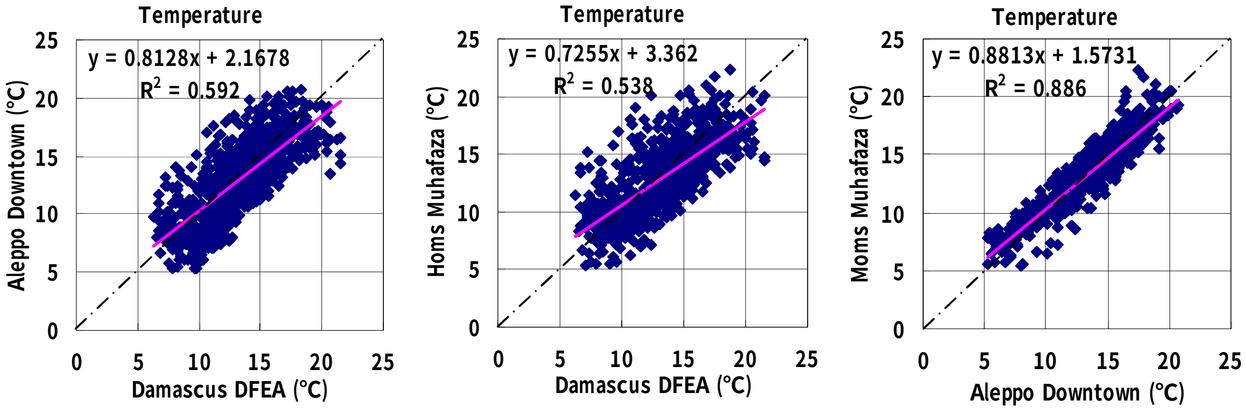


Figure 1-10 Temperature comparison between Damascus, Aleppo and Homs

The Capacity Development of Environmental Monitoring at Directorates for Environmental Affairs in Governorates

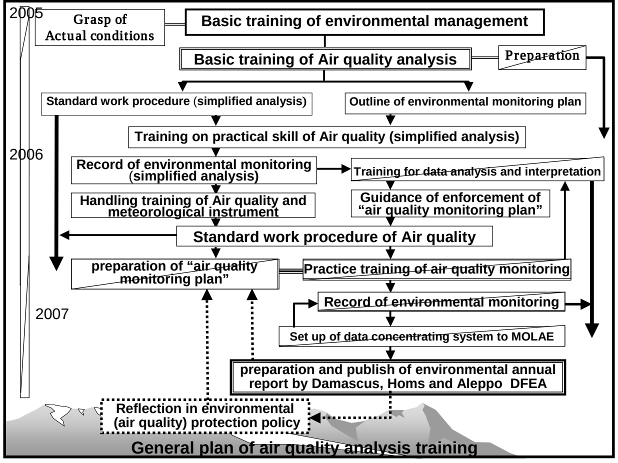
Basic Air Quality Monitoring Course
(No. 1)

January 2006

The JICA Expert Team (Air Quality Analysis)

Basic Air Quality Monitoring Course

(General plan of air quality analysis training)



General plan of air quality analysis training

Basic Air Quality Monitoring Course

(Lecture for Basic Air Quality Monitoring)

Lecture-1: **Basic knowledge of**

- **measurements method of air pollution**

Lecture-1: **Basic knowledge of measurements method of air pollution**

1. Content of Lecture

Plan of lecture (1)

Lecture	Training Items	Contents
1	Basic knowledge of method for measuring air pollution	a) Content of lecture b) Introduction c) Sampling method of gaseous matter d) Method for measuring suspended particulate matter (SPM) e) Method for measuring descent dust
	Discussion	
2	Gaseous matter measuring method	a) Method for measuring sulfur dioxide and sulfuric acid mist b) Method for measuring nitrogen oxide c) Method for measuring carbon monoxide d) Method for measuring hydrogen sulphide e) Method for measuring Ozone
	Discussion	

Lecture-1: **Basic knowledge of measurements method of air pollution**

Plan of lecture (2)

Lecture	Training Items	Contents
3	Sampling of SPM and Consideration in sampling	a) Content of explanation b) Basic knowledge c) Method for measuring SPM weight d) Outline of method of heavy metal analysis of SPM
4	Passive Sampler Method for Air Pollution Monitoring (Simple sampler method)	a) Outline of Passive sampler for short-term (NO, NO2,SO2,O3) b) Principle of air quality Passive sampler c) Investigation method that uses passive sampler d) Sampling plan e) Analytical Method for NO, NO2 and NOx e) Calculation of Concentration for NOx, NO2 and NO f) Comparison of Integrated Sampling and Real-Time
	Discussion	

2. Introduction

◆Points to keep in mind for measuring air pollution

① There are many kinds of a pollutant.

② There is a situation showing a special air pollution form by <u>terrain</u>, the <u>kind of local industry</u> and <u>weather condition</u>.

③ Clarification of an research purpose (grasp of degree and trend of pollution by general pollutant, or grasp of pollution influence from particular source ⇒Examination of an investigation method)

◆Three pollution forms from the point of view of an air pollution episode

Type	Pollution form	Feature
No.1	London	It consists mainly of smoke and soot, SPM, SO2 by coal.
No.2	Los Angeles	Issuing from petroleum fuel. Hydrocarbon and NO2 become smog form generating O3, peroxide, aldehyde by photochemical reaction. It's mainly caused by vehicle emission, and in addition, terrain and ocean weather condition.
No.3	Muse	Pollution by chemicals drained from industrial zone.

◆Correspondence to new environmental problem

① Global warming
(Framework Convention on Climate Change / Kyoto Protocol)

② Depletion of ozone layer
(Vienna Convention for the Protection of the Ozone /Montreal Protocol on Substances that Deplete the Ozone Layer)

③ Acid rain

④ Forest and desertification
('Agenda 21' adopted with UNCED (United Nations Conference on Environment and Development : "Earth Convention. "))

⑤ Biological diversity and wild flora and fauna
(Convention on Biological Diversity (CBD))

⑥ Transboundary movement of chemical and toxic waste
(Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal Rotterdam agreement, Stockholm agreement concerning Persistent Organic Pollutants, Rotterdam agreement)

⑦ Marine pollution
(North-west Pacific Action Plan:NOWPAP)

⑧ Recycling problem (waste problem)

---

(1) Regular element and contaminant in atmosphere

1) Regular element of atmosphere

Materials that are included more than the stationary components are considered as contaminats.

The main regular element of atmosphere

Kind of gases	Concentration	
	Volume (%)	Weight (%)
Nitrogen (N2)	78.1	77.5
Oxygen (O2)	21.0	23.2
Argon (Ar)	0.93	1.28
Carbonic acid gas (CO2)	0.037	0.057
Neon (Ne)	0.0018	0.0012
Helium (He)	0.0005	0.000072
Methane (CH4)	0.00022	0.00012
Krypton (Kr)	0.00010	0.00029
Nitrous oxide (N2O)	0.00005	0.00015
Hydrogen (H2)	0.00005	0.000003
Xenon (Xe)	0.000008	0.000036

---

2) Air pollutant and classification

◆Classification of air pollutant

Gaseous matter

Particulate matter
- Dusts: Collapse of material
- Fumes: Sublimation, Distillation
- Mists: Coagulation of steam and chemical reaction

※ These materials tend to generate complex components by photochemical reaction in the atmosphere.

Classification of air pollutant

Classification	Air pollutant
Sulphur compound	SO2, SO3, H2SO4, H2S, R-SH
Nitrogen compound	NO, NO2, HNO2, HNO3, NH3
Oxygen compound	O3, PAN, CO, CO2
Halogen compound	F, Cl, HF, HCl
Organic compound	HC, R-CHO, Halogen compound
Particulate matter	Fry Ash, CaCO3, C, ZnO, PbCl2, NaF, Secondary generation particle

Source of air pollutant

Source	Kind	Atmospheric pollutant
Combustion	Gases, Dusts	SO2, NOx, CO, HC, C, Acids
Car	Gases, Dusts	NOx, CO, HC, C
Oil refinery	Gases, Dusts, Mists	SO2, H2S, HC, NH3, CO, R-SH, Acids
Chemical plant	Gases, Dusts, Mists	SO2, H2S, HC, F, NH3, CO, R-SH,
Furnace, electric furnace and metal refining	Gases, Dusts, Fumes	Acids, F, Cl, SO2, NOx, CO, HC, C, Fumes
Food and fodder processing	Gases, Dusts	Malodorous substance

<Damascus Countryside> Cement factory

There is a residential estate around 5km to the right direction in this photo, it is concerned influence by a weather condition (wind direction, atmospheric stability etc.).

Lecture-1: **Basic knowledge of measurements method of air pollution**

<Damascus⇔Homs>　Asphalt factory

Regularly, asphalt factory is low smoke source. There is a problem on work environment.

Lecture-1: **Basic knowledge of measurements method of air pollution**

<Homs>

Nitrogenous Fertilizers Company、Triple Sulfur Phosphate Company

Discharge of SO2, NOx、F compound、SO3, and mine dust is the problem.
The yellow effluent gas is by high concentration NO2 gas.
There is a distinct odor around the factory.

Lecture-1: **Basic knowledge of measurements method of air pollution**

<Homs> Woods in the vicinity of Quattina village

By mine dust from the chemical factory, the forest seems to become like fog deposit.

Lecture-1: **Basic knowledge of measurements method of air pollution**

<Homs>　Homs refinery

Hazardous gas and bad odor such as VOC、H2S
Soil contamination by oil leakage
Drift of heavy metal-containing oil coke (field heaping on the right side)

Lecture-1: **Basic knowledge of measurements method of air pollution**

<Aleppo>　Cement factory

Mine dust is exhausted from factory stack 3〜5 ton per day.
Japanese emission standards：0.1g/Nm3 (general standard)
If it's100,000m3 per hour of emission gas, it is 0.24 ton per day at a maximum.
It will be 0.12 ton per day at a maximum by special standards.

Lecture-1: **Basic knowledge of measurements method of air pollution**

(2) Research purpose and research item

1) Clarification of research purpose

- a) Time variation of air pollution phenomenon（daily, weekly, seasonal and annual variations）…continuous research
- b) Clarification of object of investigation：
  Is it a large area or a specific source (surrounding area)?
- c) Degree of pollution comparisons of various places
- d) Grasp of distance attenuation of pollutant from source
- e) Comparison before and after measures (control) execution
- f) Chemical reaction investigation of Secondary generation matter etc.

2) Selection of investigation item

- a) Combustion of petroleum fuel such as automobile exhausts
  （NOx、SO2、HC, O3, Ox, CO, SPM)
- b) Industrial emission (Exhaust gas)
  Estimate materials of source of pollution by the kind of factory, and pick up measurement item (NOx, SO2, SO3, HC, H2S, F compound, Cl2, HCl, SPM, Falling dust , Heavy metal)
- c) Secondary generation matter
  （O3, Ox, PAN, SPM, R-CHO, SO_4^{-2}, $NO3^-$）

Lecture-1: Basic knowledge of measurements method of air pollution

(3) Selection of investigation place

◆Points to keep in mind for selection of research point

a) <u>Consideration for land–use</u>：House, commerce, industry, and the rural districts, etc.
   ＊Grasp the characteristics according to each industrial area.
b) Give consideration to relation between main source of pollution and main direction of the wind
   ＊Set up point on the leeward of main direction of the wind too（B.G. point）.
c) Relation between height of source and the highest concentration (C_{max}) point
   ＊As the standard, the C_{max} point is a distance 10-20 times the height of the source.
ｄ） Decision of number of points
   ＊When grasping wide area concentration distribution, set one point in each 5km2 as a rough guide.
   ＊when grasping the influence from a road, it is 20m, 50m, 100m or 200m from windward, the road edge of windward or the road edge of leeward.

◆Points to keep in mind to decide measuring point.

a) Points that can represent the surrounding area
b) Points that are not covered by buildings or trees
c) Attention on sampling height
   ＊1.5m above the ground is enough for gaseous matter, but 3～10m above the ground is needed for SPM and dust fall.

Lecture-1: Basic knowledge of measurements method of air pollution

(4) Selection of method for measuring

1) 2 classifications of method for measuring of air environment
   a) Grasp the situation of air pollution in the whole area
      ＊It can be figure out the contamination status to some extent by the method for NO2 simple sampler and dust fall.
   b) Scientific judgment for the petition of the pollution issue
      ＊Grasp of the absolute density of the specific pollutant is indispensable

2) Classification from the measurement time perspective
   a) Multiplication metrology
      ＊Deposit gauge、PbO2 method of SO2 measurement、passive sampler
   b) Time metrology
      ＊SO2 with impinger：Pararozarinin method、NOｘ：Saltsman method
   c) Automatic continuous metrology
      ＊Chemiluminescence method、Conductometric method、FID method、Fluorescent brightness method
   d) Density metrology at moment
      ＊Detection tube method

（remarks）The watch is always an ideal in an important point by an automatic continuous metrology, but before that, it is necessary to understand the basis of the measuring method.
There are collection efficiency of the sample, analysis accuracy, operativeness, a labor, and cost etc. as a consideration matter.

Lecture-1: Basic knowledge of measurements method of air pollution

Outline of measuring method of air pollution

pollutant	Accumulation measuring method	Time and instantaneous measuring method	Automatic continuous measurement method
Particulate matter			
Dust fall	Deposit gauge Dust jar	Petore plate method	
SPM	Low-vol. sampler	H-vol. sampler Digital SPM meter	β rays absorption method Digital SPM meter Piezoelectric balance method
Gaseous matter			
SO2, SO3	PbO2 method Alkali filter method Passive sampler	Pararosaniline method Detection tube method Passive sampler	UV fluorescence method Flame photometry Solution conductivity method
NO, NO2	Passive sampler	Saltzman method Passive sampler	Chemiluminescence method Absorptiometry
H2S	Zinc acetate cylinder method	Methylene Blue method Detection tube method	SO2 conversion IR absorption Test paper photoelectric method
CO		Detection tube method	NDIR法
O3, Ox	Rubber crack method	KI Absorptiometry（Ox) Passive sampler	Chemiluminescence method（O3) UV absorption method（O3) KI Absorptiometric（Ox)
HC		FID method	FID method
Other gases		Impinger method Detection tube method	

Lecture-1: Basic knowledge of measurements method of air pollution

(5) Capacity correction method of the collection atmosphere and conversion method of measurements

1) Capacity correction method of the collection atmosphere

The following three ideas exist as a capacity correction method.

① 0 ℃, 760 mm-Hg（1013mb)… （Japan: Chimney exhaust gas）
② 20 ℃, 760 mm-Hg（1013mb) … （Japan: Ambient air）
③ 25 ℃, 760 mm-Hg（1013mb)

The general type of the capacity correction method is shown below about ① and ② listed above.

（0 ℃, 760 mm-Hg）

$$V_0 = v \times \frac{273}{273+t} \times \frac{p}{760}$$

（20 ℃, 760 mm-Hg）

v : Collection capacity
p : The atmospheric pressure
t : Temperature

$$V_0 = v \times \frac{273+20}{273+t} \times \frac{p}{760}$$

Gas 1 mole＝22.41 ℓ at 0 ℃, 760 mm-Hg、24.05 ℓ at 20 ℃, 760 mm-Hg

---

Lecture-1: Basic knowledge of measurements method of air pollution

2) Conversion of concentration of gas

About unit conversion（ppm ⇔ mg/m3)

（0 ℃, 760 mm-Hg）

$$\text{ppm} = \text{mg/m}^3 \times \frac{22.41}{M} \quad \Longleftrightarrow \quad \text{mg/m}^3 = \text{ppm} \times \frac{M}{22.41}$$

（20 ℃, 760 mm-Hg）

$$\text{ppm} = \text{mg/m}^3 \times \frac{24.05}{M} \quad \Longleftrightarrow \quad \text{mg/m}^3 = \text{ppm} \times \frac{M}{24.05}$$

About the unit

(M : Molecular weight)

1 ppm = 1 / 10^{-6} (= μℓ / ℓ = mℓ / m^3)
1 % = 10,000 ppm
1 ppm = 1,000 ppb = 1,000,000 ppt
1 g = 1,000mg = 1,000,000 μg
1 μg = 1,000ng = 1,000,000 pg
1 atm = 760 mm-Hg = 1013mb

Lecture-1 Basic knowledge of measurements method of air pollution

3. Sampling method of gaseous matter in atmosphere

3. Sampling method of gaseous matter in atmosphere

Here, it explains at the measurement of the manual of the gaseous substance.

(1) State of gas

Steam: The one that is liquid at normal temperature
（H_2O, C_6H_6, R-OH, $(CH_3)_2CO$, Hg）
Gas：The one that doesn't liquefy at even 0℃
（O_2, N_2, CH_4, NH_3, CO, CO_2)

(2) Note when sampling it

- a) When an explosiveness and ignited material is handled, the one that the switch etc. spark should not be used.
- b) Consideration of the person who operates it for working environment.
- c) Particular attention should be given to the oxygen deprivation and the gas inhalation when sampling in a special place.
- d) The gas introduction tube should be shortened as much as possible.
- e) Teflon is good for the gas introduction tube, but if it's not possible to prepare it, consider it according to the measurement element.
- f) Leakage of the sampler should be checked before using it.
- g) When using a long gas introduction tube, clean up by the sampling air before sampling.
- h) Take care for the bend of the gas introduction tube.
- i) Sample it according to the provided flowing quantity.

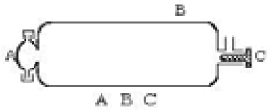
---

(3) Method of sampling gas

1) Vacuum method
Vacuate the vacuum bottle with the vacuum pump（< 0.2mb）.

<point>

- ◇ Vacuum level
- ◇ Pay attention for leak.



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2) Deflatable flexible bag technique (Pressure decrease method)

◇Benefit

- a) Because the vacuum level is low, it is possible to decompress it easily（> 13 mb）.
- b) The worry of the leakage is a little.
- c) It is advantageous on the safety side.

◇Defect

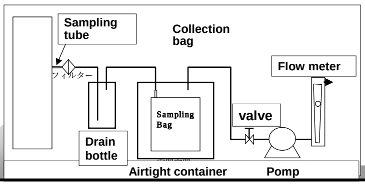
- a) The temperature and the pressure when decompressing it are necessary.
- b) The temperature and the atmospheric pressure when sampling it are necessary.
- c) The capacity calculation is necessary.

---

3) Bag sampling method

Sample it by pumping the sample air into various bags.

- Write the type and application of the bag.
- Sampling bag for gas analysis made of poly vinyl fluoride (Tedlar)（Most gases OK, such as acid gas, alkaline gases, and VOC)
- Nylon bag（with inside PP）
- Saran bag（material with low reactiveness such as gases of freon system and CO)
- polyethylene bag（material with low reactiveness such as gases of freon system and CO)
- low-pressure polyethylene bag（SO_2）



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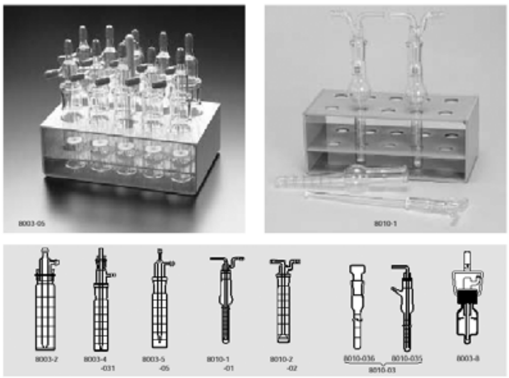
4) Gas absorption method

- Method with the gas absorption bottle (Impinger)
- It is a method of absorbing the target gas element to the absorption liquid.
- With the absorption liquid, for an alkaline gas, the acidic solution is general, and for acid gas, alkaline solution is general. Prepare suitable absorption liquid for the target gas element.

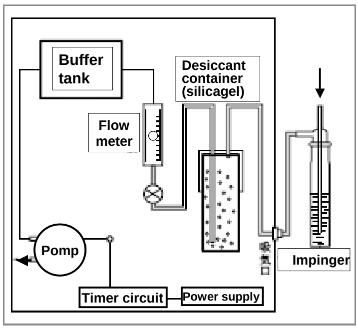
- ① NO_2： Saltzman absorption liquid
- ② SO_2： Mercuric chloride ($HgCl_2$)absorption liquid
- ③ Cl ： o-Tolidine dihydrochloride absorption liquid
- ④ HCl ： Distilled water
- ⑤ F compound ： Distilled water（Sampling for a long time）
- ⑥ H_2S ：（$ZnSO_4$＋NaOH＋（$NH_4)_2SO_4$）solution
- ⑦ Ox ： Neutral potassium iodide (KI) absorption liquid
- ⑧ NH_3 : Boric acid solution

- There are some types of impingers, and we use it properly according to the purpose.



Type of impinger

Lecture-1: **Basic knowledge of measurements method of air pollution**



Lecture-1: **Basic knowledge of measurements method of air pollution**

Stand Sampler

Stand Sampler

スタンドサンプラーは、環境中の特定化学物質など、有害粒子状物質、あるいはガス・蒸気状物質の液体捕集法に適したサンプリングセットです。

Air Auto Sampler

Air Auto Sampler

エアオートサンプラーは、化学物質等による汚染大気を各種溶液中に一定時間毎に定量ずつ自動的に連続採取します。その吸収液を化学分析することにより、汚染成分を検出し、汚染度を知るのに用います。

Lecture-1: **Basic knowledge of measurements method of air pollution**

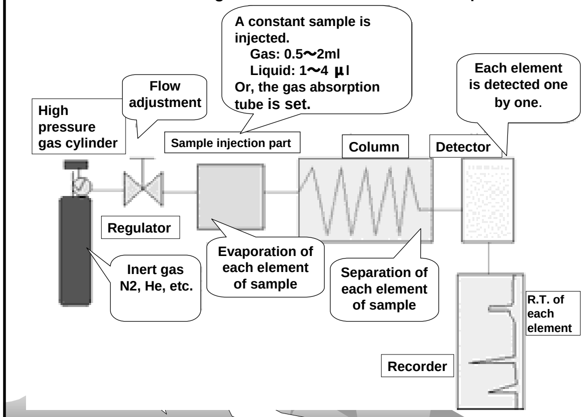
5) Gas adsorption method

It is a method of making the solid adsorbent adsorb a target gas element.

General adsorbent

	Absorbent	Feature
a)	Silicagel	strongly adsorbs the compound with the polarity radical. (ex : H2O)
b)	The activated carbon	advantageous though adsorbs the one of the organic solvent system.
c)	Molecular sieve	The function of the molecular sieve can be used.
d)	Alumina	
e)	Alkali filter paper	Adsorption of acid gas
f)	PbO2 cylinder	Long-term sampling of SO2 gas in the atmosphere
g)	The cold cohesion	cold cohesion to solid. (SF6, fluorocarbon halon gas) The refrigerative is a dry ice - acetone and liquid oxygen.
h)	The use of the separation tube of Gas chromatography	examine it according to a target gas.

Lecture-1: **Basic knowledge of measurements method of air pollution**



Gas chromatography (GC) device schematic diagram

Lecture-1: **Basic knowledge of measurements method of air pollution**

6) Condensation method

absorption method that condense the target gas in the trap tube.

Principle：It lowers the temperature enough and decreases the vapor pressure.

Refrigerants are

- **a) Ice (-0 ℃)**
- **b) Ice — Salt (−21.3 ℃)**
- **c) Dry ice — Acetone (-78 ℃)**
- **d) Dry ice — Methanol (-78 ℃)**
- **e) Liquid oxygen (-183 ℃)**
- **f) Liquid Nitrogen (-195 ℃)**

Dewar bottle

Lecture-1: **Basic knowledge of measurements method of air pollution**

7) Pyrolysis Collection method

◇Purpose

- **a) When it is not possible to do sensitive analysis as it is.**
- **b) When it is not possible to do Collection easily by usual Collection method.**

◇Practical example

- **a) Pyrolysis of decompose halogenated hydrocarbon and collect Cl2 and HCl with absorption solution.**
- **b) Pyrolysis of decompose gassy tetramethyl lead and collect lead oxide.**

Lecture-1: **Basic knowledge of measurements method of air pollution**

(4) Gas collection efficiency

We examine the situation when using the impinger here.

(1) Factor which defines gas collection efficiency
- a) Amount of absorption liquid
- b) Absorbed material (solubility)
- c) The Shape of impinger, the shape of nozzle, and the depth of nozzle
- d) Suction flow velocity

(2) Examination of easy collection efficiency

◇Assume solubility doesn't change with time.

Collection efficiency (E) is shown by the following expression.

$$E = \frac{Ci - Ce}{Ci\,V} \quad , V = \frac{Ci - Ce}{Ci}$$

Ci : Target element density
Ce : Concentration that passes by without being collected in the absorption liquid
V : Ventilated total air

Lecture-1 **Basic knowledge of measurements method of air pollution**

4. Method for measuring suspended particulate matter

(1) SPM measuring method

Type	Application	Feature
Low volume air sampler (LV-Sampler)	Collection of SPM Gravimetric analysis	Filter paper collection Grasp of long term mean concentration
Each particle size LV-Sampler	Ditto	For air pollution study
High volume air sampler(HV-Sampler)	Mass collection of SPM、and TSP Gravimetric analysis Compositional analysis	Filter paper collection Grasp of short term mean concentration
Each particle size HV-Sampler	Ditto	For air pollution study
Piezo balance method	SPM automatic continuous measurement	Measurement of mass concentration Measurement of decrease in frequency of quarts resonator
β ray absorption method	SPM automatic continuous measurement	Measurement of mass concentration Measurement of increase of amount of β ray absorption
Light –scattering method	SPM automatic continuous measurement Grasp of instantaneous value	Measurement of relative concentration (Conversion into the mass concentration is required.) Measurement of amount of light scattering with particle
Tape air sampler	SPM automatic continuous measurement	Measurement of relative concentration Using tape of filter paper Measurement of amount of absorption of furnace paper

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Lecture-1: **Basic knowledge of measurements method of air pollution**

(2) Comparison of permissible levels of SPM

Comparison of permissible level according to particle size

Classification	Syria	Japan	USA
TSP	240 mg/m3 (24hr) 150mg/m³ (1year)	・・・・・・	・・・・・・
PM10 (SPM)	100 µg/m3 (24hr) 50 µg/m3 (1year)	200µg/m3 (1hr) 100µg/m3 (24hr)	150µg/m3(24hr)
PM2.5	・・・・・・	・・・・・・	65µg/m3(24hr)

(3) Weight density measuring method

1) LV-Sampler

It is a standard metrology of the mass concentration evaluation in Japan.
It is used to correct the mass concentration of the relative concentration.

Measurement method : Multistep sizing type
Suction flowing quantity：20〜30 ℓ / min
Diameter of filter paper：55 mmϕ
∗Note : When the sampling duration is short, the measurement error grows.

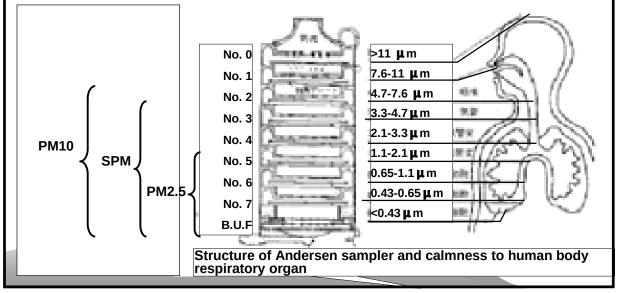
100 µg/m3 × 30 ℓ / min × 24 hr = 4.32 mg
100 µg/m3 × 20 ℓ / min × 24 hr = 2.88 mg

図3 ローボリウム・エアーサンプラ

Lecture-1: **Basic knowledge of measurements method of air pollution**

2) Each particle size LV-Sampler (Andersen LV-Sampler)

Measurement method : Classify with multistep and porous impactor method
Measuring range：0.4µm 〜 >10µm, 8 steps + Backup filter
Suction flowing quantity ：28.3 ℓ / min
Diameter of filter paper ：80 mmϕ



Structure of Andersen sampler and calmness to human body respiratory organ

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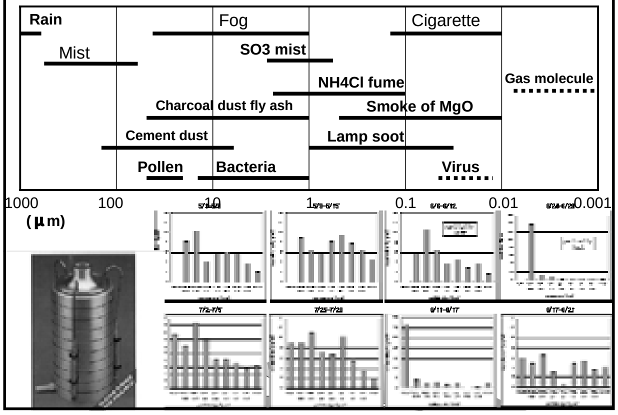
Lecture-1: **Basic knowledge of measurements method of air pollution**



Lecture-1: **Basic knowledge of measurements method of air pollution**

3) HV Sampler

① PM10 (SPM)

Measurement method：Porous impactor method
Monotreme impactor method
Cyclone method
Measuring range：<10µm
PM10 > 10µm 50% cut
SPM > 10µm 100% cut (Japan)
Suction flowing quantity ：800〜1500 ℓ / min
Filter paper size：8 × 10 inch (203 ×254 mm) or 120 mmϕ

② TSP

Measurement of the mass concentration of total suspended particulate matter. (No classification)

4) Each particle size HV-Sampler

Measurement method ：Classify with multistep and porous impactor method
Measuring range ：0.4µm 〜 >10µm, 4 steps + Backup filter
Suction flowing quantity ：About 1000ℓ / min

(Sampler's composition)

- ◇ Inlet
- ◇ Filter holder
- ◇ Air pomp
- ◇ Flow controller
- ◇ Timer

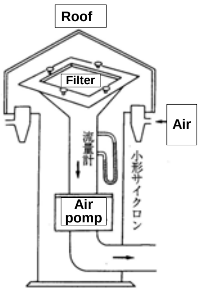


図7.32 HV Sampler (PM10)

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(4) β ray absorption method

SPM collection: Glass fiber filter

> 10 μm cut: Cyclone method or multistep method

Composition of sampling part

- Filter sending system
- Collection part
- Steady flow device
- Pomp
- Detector (Geiger – Muller counter or Ionization chamber)
- β ray source

β ray source	Half - life	Coverage (mg / cm2)
^{14}C	5730Y	0.01〜10
^{35}S	87d	0.02 〜15
$^{14}7Pm$	2.6Y	0.02 〜20
^{204}Tl	3.8Y	0.1〜100
^{90}Sr	28Y	0.4 〜400

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5. Measuring method of dust fall

(1) Outline

1) The main dust fall measuring method

Name	Main use country	Sampler	Method of collection	Collection period	Main analysis item
(A) Deposit gauge	Britain	30cmφ rote	Ground: < 5m 0.02N-$CuSO_4$ 10ml	One month	Infusible element
(B) Dust jar	USA	Cylinder type Inside : φ11.2 cm Depth: 20.3 cm	The fourth floor rooftop 500〜1500 ml H_2O	One month	Dissolubility element
(C) APCD method	USA	Jar Inside : φ10.8cm Capacity: 3.5 ℓ	Suitable height 3000 ml H_2O	One month	
(D) APCA standard method	USA	Cylinder type Inside: φ15〜20 cm Depth: 27 cm Polyethylene	Ground: 2.5 〜15m Rooftop: 1.2 m	30 ±2 day	
(E) Standard methods of analysis for hygienic chemists	Japan	<u>Standard type</u> (British standard) <u>Simple type</u> Jar Inside: φ15-16 cm Depth: 26 cm Capacity : 6 ℓ	Ground: >5m Applies to (A). 0.02N-$CuSO_4$ 10ml	One month One month	

Deposit gauge Dust jar

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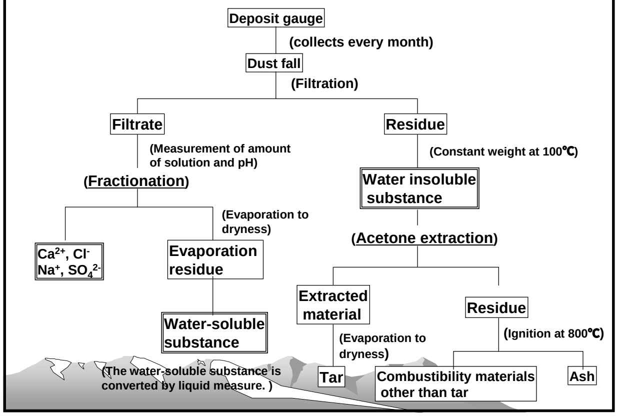
(2) Dust fall general analysis system



Deposit gauge

(collects every month)

Dust fall

(Filtration)

Filtrate

(Measurement of amount of solution and pH)

(<u>Fractionation</u>)

Ca^{2+}, Cl^-, Na^+, SO_4^{2-}

(Evaporation to dryness)

Evaporation residue

Water-soluble substance

(The water-soluble substance is converted by liquid measure.)

Residue

(Constant weight at 100℃)

Water insoluble substance

(<u>Acetone extraction</u>)

Extracted material

(Evaporation to dryness)

Tar

Residue

(Ignition at 800℃)

Combustibility materials other than tar

Ash

---

(3) Calculation

Dust fall etc. are calculated by the unit of <u>t/km²/30 day</u>.

$$\text{Dust fall etc.} = 1.273 \frac{w}{D^2} \times \frac{30}{n} \times 10^4 \ (t/km^2/30\ day)$$

w : Analysis value of Dust fall etc.
D : Diameter of dust meter (inside diameter)
n : Days of collection (n = 28〜32 days)

※ Subtract the weight of the added copper sulfate.

0.02N-$CuSO_4$ 10ml = 0.0178 g ($CuSO_4 \cdot H_2O$)

Lecture-1: **Basic knowledge of measurements method of air pollution**

(4) Recognition in dust fall measurement

1) Accumulating data

The meaning of the measurement appears by accumulating data.

2) Industrial area

It is especially effective to the industrial area where dust is exhausted and the region where coal is used.

3) Comparisons

It is convenient for mutual comparisons of the urban atmospheric pollutions.

4) Administrative action

It can be a judging material for battle against air pollution and administrative action of the city as a whole.

5) Measurement result

The measurement result is not the one to use as an absolute value but is an index that judges pollution.

B. Lecture for Basic Air Quality Monitoring

Lecture-2． Gaseous matter measuring method

1．Method for measuring sulfur dioxide and sulfuric acid mist

Lecture-2． **Gaseous matter measuring method**

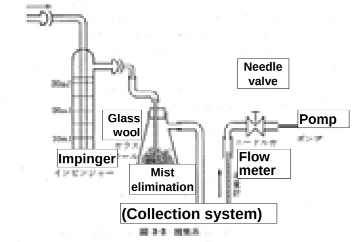
1． Method for measuring sulfur dioxide and sulfuric acid mist

(1) Sulfur Dioxide（SO2）

a) Measurement method ：Pararosaniline Method

b) Method of scavenging: Absorption liquid scavenging (impinger)

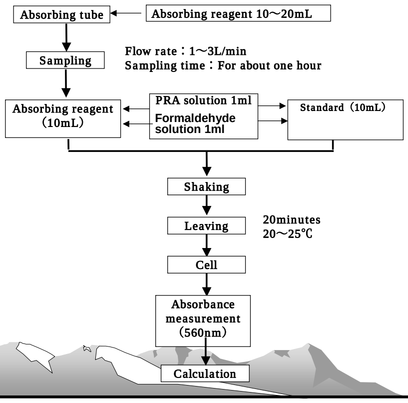
c) Composition of measuring instrument material



(Collection system)

Lecture-2． **Gaseous matter measuring method**

d) Analysis flow chart


Absorbing tube ← Absorbing reagent 10～20mL

Sampling

Flow rate：1～3L/min
Sampling time：For about one hour

Absorbing reagent（10mL）

PRA solution 1ml
Formaldehyde solution 1ml

Standard（10mL）

Shaking

Leaving

20minutes
20～25℃

Cell

Absorbance measurement（560nm）

Calculation

Lecture-2． **Gaseous matter measuring method**

e) Calculation

Get sulfur dioxide concentration in the sample atmosphere from the following expression.

$$C = \frac{A \times v}{A_S \times V} \times \frac{273 + t}{273}$$

C：Sulfur dioxide concentration（ppm）
A：Absorbance of test (sample) solution
A_S：Absorbance of standard solution
V：Amount of sample air suck（L）
v：Absorption liquid measure（mL）
t：Temperature in gas meter（℃）

Lecture-2． **Gaseous matter measuring method**

(2) Sulfuric acid mist (for reference)

※ The sampling of the sulfuric acid mist usually uses LV-sampler.

（Sampling）

a) Filter paper : For instance, Whatman No.1
b) Flow velocity : 20 ℓ/min ～ 30 ℓ/min
c) Collection time : 1 hr ～ 6 hr
   (The collection time is decided according to the pollution density.)

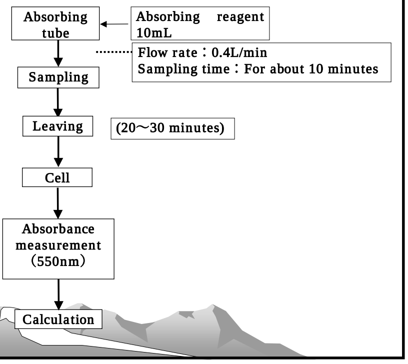
（Operation）

a) Filter paper division into 1/2
b) The furnace paper is added in T.B. T solution (2 ml).
c) Titration : 0.01N- Borax ($Na_2B_4O_7 \cdot 10H_2O$)

＊When the alkaline component is in the sample：Sulfuric acid and back titration in addition to excessive of the borax solution.

2. Method for measuring nitrogen oxide (NOx)

(1) Operation flow chart



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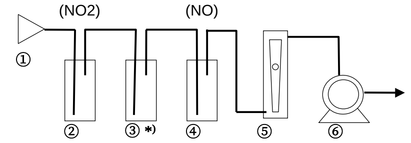
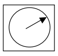
(2) Composition of measuring instrument material



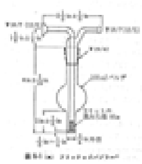
①Filter ②**Sorbent tube** ③**Bubbler for oxidation**
④ **Sorbent tube** ⑤**Rotameter** ⑥**Pomp**

Figure Measurement device



Wet gas meter for
rotameter authorization

＊) Potassium permanganate solution
(KMnO4 + H2SO4)



Sorbent tube

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(3) Calculation and Consideration

① Calculation of capacity: 1013 mb (760mmHg)、25℃
 ◇ 1 Mole = 24.47 ℓ, NaNO$_2$ = 69.00
② Saltzman coefficient = 0.72
(0.72 moles are coloration equal with the NO$_2$ 1 mole.)
 ∴ NaNO$_2$ 2.03 μg NO$_2$ 1 μℓ
 ∵ NO$_2$ 1 μℓ = $\frac{10-6}{24.47}$ × 0.72 × 69.00 = 2.03×10-6 g NaNO$_2$

③ Making of calibration curve
④ Calculation

$$\boxed{\textbf{Obtained NO}_2\textbf{ concentration (ppm)} = \textbf{Absorbance}\ \frac{\textbf{M}}{\textbf{V}}}$$

M (ppm) : Calibration coefficient
(Number of NO2 μℓ in absorption liquid 10ml
at absorbance 1(-log T = 1))
V (ℓ) : Air volume of sample

---

⑤ About the Saltzman coefficient

a) Various Saltzman coefficient

Saltzman coefficient = NO2- (solution) / NO2 (in air) ratio

Coefficient made public in the past
(experimental data)

	Saltzman coefficient (Efficiency Factor)
B. E. Saltzman	0.72
J. T. Shaw	0.72
Pappy	0.52 ～0.65
M. B. Jacobs	0.60 ～0.70
Stratman	0.62 ～1.00
F. P. Scaringelli	0.764

Saltzman coefficient 0.84 is adopted in the NOx automatic continuous measurement system of Japan industry standard (JIS).

---

b) Saltzman coefficient and error margin factor

Factor on Saltzman metrology

《Collection efficiency》
- ◇ **Composition of absorption liquid**
- ◇ **Structure of sorbent tube**
- ◇ **Absorption liquid measure (liquid level and bubbler's positions)**
- ◇ **Suck speed**
- ◇ **Microbore of glass filter of sorbent tube**

《 NO$_2^-$ (solution) / NO$_2$ (in air) ratio 》
- ◇ **Reagent composition**

《Error margin given to concentration》
- ◇ **Collection efficiency and NO$_2^-$ / NO$_2$ ratio**
- ◇ **Accuracy of measuring instrument**
- ◇ **Evaporation of absorption liquid**
- ◇ **Analysis time**
- ◇ **Oxidation efficiency (Nitrogen monoxide (NO))**

---

3. Method for measuring carbon monoxide (CO)

(1) Measuring Method

There are a lot of kinds of measuring methods of the carbon monoxide.
Three easy operation methods are outlined today.

Outline of measuring method

Measuring method	Measuring range	Feature
Detector tube method	1～30 ppm 25 ～2000 ppm	Simplicity Promptness
Infrared absorption method	0 ～20, 50, 100, 1000 ppm 0 ～10, 20, 50, 100 %	Analysis of bag collection Automatic continuous measurement
Gas chromatography method	FID: >1.0 ppm TCD: >0.1 %	Analysis of bag collection

FID: Flame Ionization detector
TCD: Thermal conductivity detector

Lecture-2. **Gaseous matter measuring method**

(2) Detector tube method

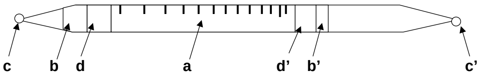
① Gas detector set

There is a detector tube method also for the long-term measurement.

Lecture-2. **Gaseous matter measuring method**

② Measuring principle

The measurement compares the length of coloring the detecting tube with the standard concentration table.



a : Detection reagent layer

c, c' : Sealed part

b, b' : Plug of cotton

d, d' : Silicagel

$K_2Pd(SO_3)_2 + CO \rightarrow K_2(SO_3)_2PdCO$

$K_2(SO_3)_2PdCO \rightarrow CO_2 + SO_2 + Pd + K_2SO_4$

(White → Dark brown)

Lecture-2. **Gaseous matter measuring method**

③ The main detecting tube (part)

Element name	Scale range (ppm)	Measuring range (ppm)	Discoloration
Carbon monoxide (CO)	1 〜30	1 〜 30	**White → Dark brown**
	50 〜 1000	25 〜 2000	
Hydrogen cyanide (HCN)	0.2 〜 7	0.2 〜 7	**Yellow → Pink**
Hydrogen fluoride (HF)	0.2 〜 10	0.09 〜 72	**Yellow → Brown**
Sulfur dioxide (SO2)	0.2 〜 5	0.05 〜 10	
Ammonia (NH3)	1 〜 30	0.5 〜 78	
Hydro chloride (HCl)	1 〜 20	0.2 〜 76	
Chlorine (Cl2)	0.05 〜1.0	0.025 〜 2.0	
Nitrogen dioxide (NO2)	0.5 〜 30	0.5 〜125	
Ozone (O3)	0.05 〜 0.6	0.025 〜 3	
Benzene (C6H6)	0.1 〜 10	0.1 〜 65	**White → Deep green**
Hydrogen sulphide (H2S)	2.5 〜 60	0.25 〜 120	**White → Brown**
	1 〜 6	0.5 〜 12	**Light yellow → Pink**
Acetone (CH3COCH3)	50 〜 4000	50 〜 12000	**Yellow → Red**
Xylene (C6H4(CH3)2)	2 〜 80	2 〜 80	**White → Brown**
Ethyl acetate (CH3CO2C2H5)	20 〜 800	20 〜 800	**Yellow → Dark brown**
Styrene (C6H5CH:CH2)	2 〜 25	2 〜 100	**White → Yellow**
Trichloroethylene (Cl2C:CHCl)	5 〜 100	2 〜 250	**Yellow → Purplish red**
	0.25 〜 4.0	0.125 〜 8.8	**Yellow → Purple**

Lecture-2. **Gaseous matter measuring method**

(3) Infrared absorption method

① Outline

The accuracy of this method is very high.

Analysis object (Continuous measurement and bag analysis)

- **a) Ambient air**
- **b) Vehicle exhaust**
- **c) Chimney measurement of factory**

Measurement elements other than CO : NOx, SO_2, CO_2, CH_4

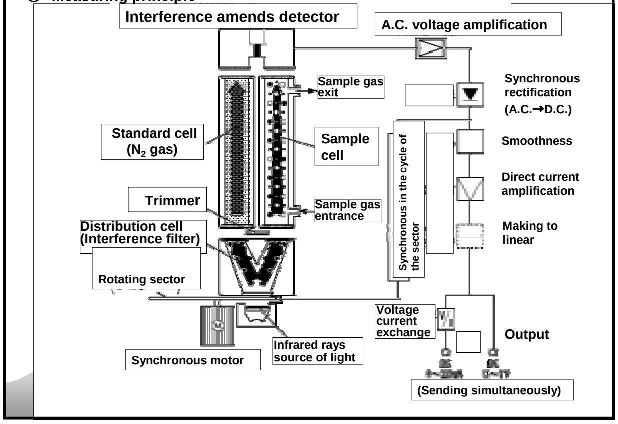
In the measuring instrument for the source : The multicomponent simultaneous measurement is also possible.

Measuring range

NOx	: 0〜50ppm･･･5000ppm
SO_2	: 0〜50ppm･･･10%
CO	: 0〜20ppm･･･100%
CO_2	: 0〜20ppm･･･100%
CH_4	: 0〜200ppm･･･100%

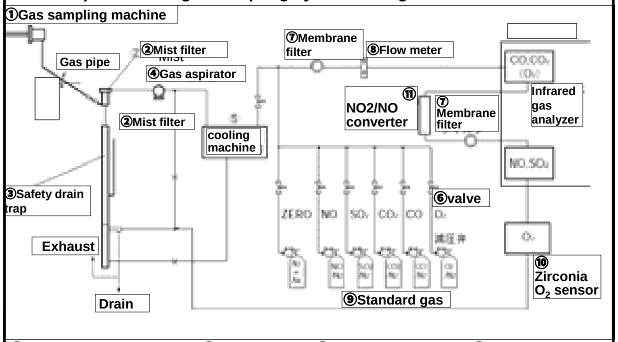
Lecture-2. **Gaseous matter measuring method**

② Measuring principle



Lecture-2. **Gaseous matter measuring method**

③ Example of stack gas sampling system configuration



①Gas sampling machine ②Mist filter ③Safety drain trap ④Gas aspirator
⑤Electronic gas cooling machine ⑥Electromagnetic valve ⑦Membrane filter
⑧Flow meter ⑨Standard gas ⑩Zirconia oxygen sensor ⑪Gas converter

4. Method for measuring hydrogen sulphide (H2S)

(1) Measuring Method

There are the main three kinds of measurement of the hydrogen sulfide.

Other methods have the iodimetry method, the controlled potential electrolysis method, Ion electrode method, and the gas chromatography, etc.

Outline of measuring method

Measuring method	Measuring range	Feature
Detector tube method	0.25 〜 120 ppm 1 〜 40 %	Simplicity Promptness
Silver nitrate volumetric determination method	10 〜500 ppm	The sensitivity is bad.
Methylene Blue method	5 〜1000 ppm	If a lot of sample gases are sucked, the sensitivity is raised.

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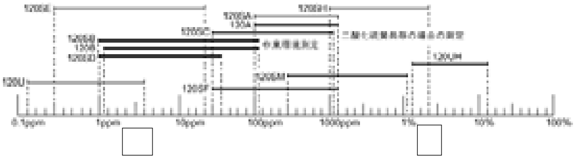
(2) Detector tube method

H_2S concentration and kind of detecting tube



(3) Methylene Blue method

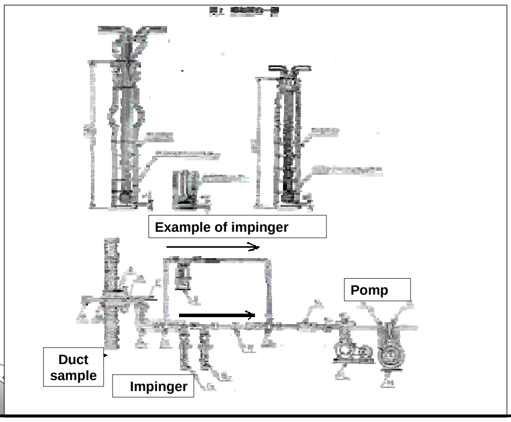
① Sampling

a) Absorption liquid

$[ZnSO_4 + NaOH + (NH_4)_2SO_4]$ solution

b) Absorption reaction

$$[Zn(NH_3)_6](OH)_2 \xrightarrow{H_2S} [Zn(NH_3)_6]S + 2H_2O$$



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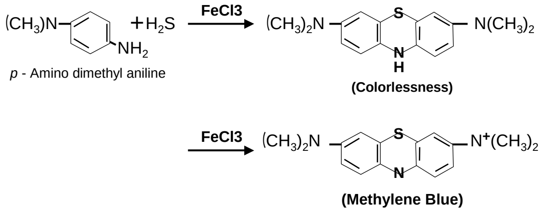
② Colored operation



p - Amino dimethyl aniline

(Colorlessness)

(Methylene Blue)

---

5. Method for measuring Ozone (O3)

(1) Measuring Method

- **Chemical method**
  - Potassium iodide (KI) method
    - Coulometric analysis (Ox)
    - Absorptiometry (Ox)
  - Phenolphthalein method (Ox)
  - Rubber crack method (Ox)
  - Olefin reaction method (O_3)
- **Physical method**
  - Chemiluminescence method (O_3)
  - UV absorption method (O_3)
  - Infrared absorption method (O_3)
- **Passive sampler**

Ox : O3, PAN, etc.

※There are a hand analysis method and a automated analysis.

---

(2) Neutral potassium iodide method

① Reaction

$$2KI + H_2O + O_3 \rightarrow 2KOH + I_2 + O_2$$

② Interfering substance

a) Negative obstruction

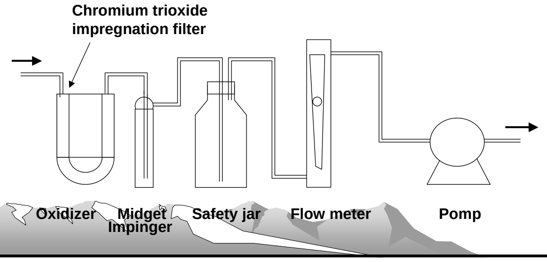
∗SO2 (Influence rate : 30 %)
∗Unsaturated hydrocarbon
∗H2S
∗DUST

b) Positive obstruction

∗NO2 (Influence rate : 10 %)
∗PAN (Influence rate : 10 %)
∗Cl
∗Peroxidation compound

(3) Collection of sample air

- ◆ **It is basically similar to the method of the collection with the impinger of SO2 and NO2.**
- ◆ **The sample removes the obstruction of SO2 first through the oxidizer.**



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① Absorption liquid

KH_2PO_4 : 13.61 g

Na_2HPO_4 : 14.20 g (or $Na_2HPO_4 \cdot 12H_2O$: 35.82 g)

KI : 10.0 g

+

H_2O

||

Volumetric flask 1000ml

② Iodine standard solution

KI 16.0 g + Iodine 3.173 g + H_2O → Volumetric flask 500ml

Thank you

The Capacity Development of Environmental Monitoring at Directorates for Environmental Affairs in Governorates

Basic Air Quality Monitoring Course (No. 2)

January 2006

The JICA Expert Team (Air Quality Analysis)

Lecture for Basic Air Quality Monitoring

Lecture-3． Sampling of SPM and Consideration in sampling

Lecture-3． Sampling of SPM and Consideration in sampling

1. Content of explanation

(1) Basic knowledge

1) Definition and classification of Aerosol and SPM
2) Existence situation of SPM in the atmosphere

(2) Method for measuring SPM weight

(3) Outline of method of heavy metal analysis of SPM

Lecture-3． Sampling of SPM and Consideration in sampling

2. Basic knowledge
(1) Definition and classification of Aerosol and SPM

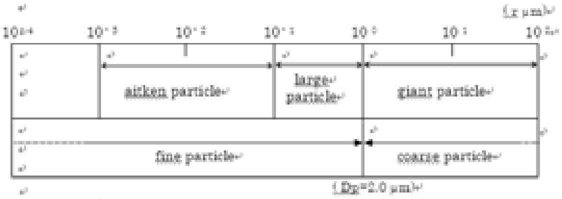
Name	State	Formation mechanism
Dust	Solid	Crushing of solid, Lifting by car and wind
Fume	Solid	Re-condensation of solid made steam
Mist	Liquid	Crushing of liquid, Condensation of steam
Fog	Liquid	Condensation of steam
Smoke	Solid + Liquid	Combustion of organic compound
Ash	Solid	Nonflammable particle generated from combustion process

---

Lecture-3． Sampling of SPM and Consideration in sampling

(2) Existence situation of SPM in the atmosphere
1) Size and classification of atmospheric aerosol

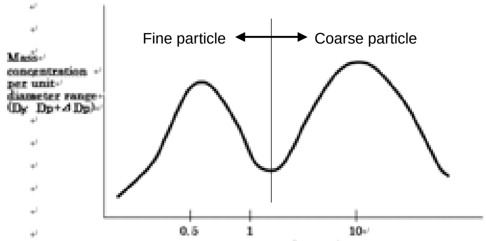
The range of the aerosol particle size is called about 10^{-3}〜100μm .



Classification according to size of atmospheric aerosol

Lecture-3． Sampling of SPM and Consideration in sampling

Usually, the particle size distribution of an atmospheric aerosol has the regularity.



Bimodal distributed model of atmospheric aerosol

Lecture-3 **． Sampling of SPM and Consideration in sampling**

2) Concentration of SPM in the atmosphere

The SPM concentration has the expressions of the particle count concentration, the mass concentration, and the relative concentration, etc.

Object	Concentration expression method	Interchangeability of concentration expression
Solute conc. in solution Volume ratio（V/V ppm）	Weight ratio（W/W ppm）	There is a single meaning relation, and conversion is easy.
Gas conc. in Air	Mole conc.（m mol/L）	
Concentration of aerosol	Particle count conc.（SPM No./cm^3） Mass conc.（mg/m^3） Relative conc.（mg/m^3）	The aerosol has differences among the size, the specific gravity, and the shape etc. of the particle. The conversion of the density indication among is not simple except a special case.

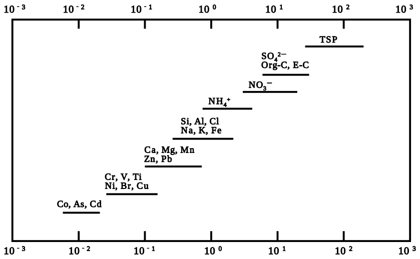
Lecture-3 **． Sampling of SPM and Consideration in sampling**

Relation between particle count conc. and mass conc. according to particle size

Particle size (D) (μm)	Weight conc. of one particle (mg/m^3)	Particle count in particle 1mg
0.1	0.52×10^{-6}	1.9×10^{12}
0.5	0.65×10^{-4}	1.5×10^{10}
1	0.52×10^{-3}	1.9×10^{9}
5	0.65×10^{-1}	1.5×10^{7}
10	0.52	1.9×10^{6}

Lecture-3 **． Sampling of SPM and Consideration in sampling**

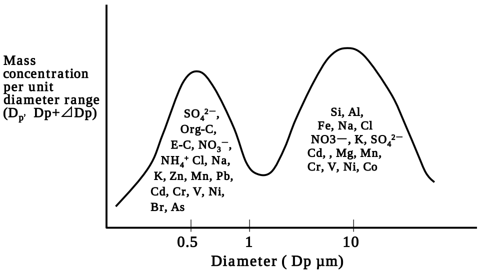
3) Chemical composition of particle



Concentration in ambient air

Concentration level of chemical composition of urban atmosphere aerosol

Lecture-3 **． Sampling of SPM and Consideration in sampling**



Relation between particle size distribution and chemical composition of atmospheric aerosol

Lecture-3 **． Sampling of SPM and Consideration in sampling**

Generation mechanism of particle and feature of chemical composition

Generation mechanism	Natural source	Artificial source
Temporary particle（Typical element）	Ocean (Na, Cl, Mg, SO$_4^{-2}$, K） Soil （Si, Al, Fe, Ca, Ti） Forest fire（Org-C, E-C, NOx, etc.） Volcanic activity （H_2S, SO_2) Plant pollen Others	Fixed source（Heavy metal, Org-C, E-C）〔Factory and incineration plant〕 Mobile sources（V, Org-C, E-C)〔Car, ship, and airplane〕 Others
Secondary particle（Cause element）	Sulphur compound（H_2S, $CH_3S_2CH_3$, etc.）〔It originates in the ocean and the biological activity.〕 Nitrogen compound（NOx, NH_3, N_2O, etc.）〔It originates in the biological activity. 〕 Hydrocarbon compound（terpene, etc.）〔Plant origin〕	Sulphur compound（SO_2）〔It originates in the fossil fuel.〕 Nitrogen compound（NOx, etc.）〔It originates in combustion.〕 Hydrocarbon compound（Hydrocarbon）〔It originates in the industrial activity and combustion. 〕

Lecture-3 **． Sampling of SPM and Consideration in sampling**

Feature of Primary particle and secondary particle

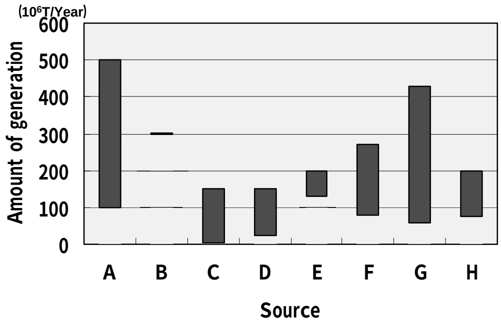
	Primary particle	Secondary particle
Generation mechanism	The particle is discharged directly from the source as a particle.	This particle is changing of the material discharged as a gas into the particle by the photochemical reaction and the neutralizing reaction.
Particle diameter	Coarse particle（Crushing is a subject, and there is a limit in making minutely. ）	Fine particle（The aitken particle when generating it coagulates and grows up to $0.1 < r < 1.0\,\mu m$ with other particles.）
Typical particle	Soil particle and sea salt particle	Sulfate and nitrate aerosol

Lecture-3, Sampling of SPM and Consideration in sampling

対流圏粒子（粒径Dp＜40μm）の発生源と発生量

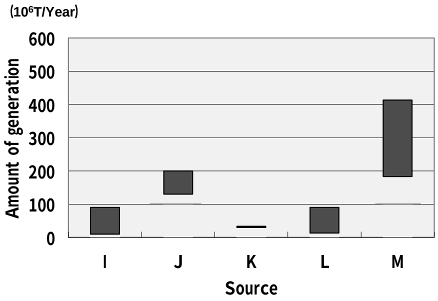
発 生 源		発生量（10^6T/Year）
自然発生	Primary particles	
	(A) Soil and rock	100 〜 500
	(B) Sea salt	300
	(C) Forest fire	3 〜 150
	(D) Volcanic activity	25 〜 150
	Secondary particles	
	(E) Sulfate from H2S	130 〜 200
	(F) Ammonium salt from NH3	80 〜 270
	(G) Nitrate from NOx	60 〜 430
	(H) Hydrocarbon from plant	75 〜 200
	小 計	773 〜 2200
人為発生	(I) Primary particles	10 〜 90
	Secondary particles	
	(J) Sulfate from SO2	130 〜 200
	(K) Nitrate from NOx	30 〜 35
	(L) Hydrocarbon Compound	15 〜 90
	小 計	185 〜 415
合 計		958 〜 2615

Lecture-3, Sampling of SPM and Consideration in sampling



Source and incidence volume of troposphere particle (1)

Lecture-3, Sampling of SPM and Consideration in sampling

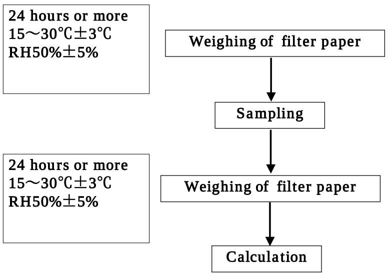


Source and incidence volume of troposphere particle (2)

Lecture-3, Sampling of SPM and Consideration in sampling

3. Method for measuring SPM weight

(1) Measurement of weight



24 hours or more
15〜30℃±3℃
RH50%±5%

Weighing of filter paper

Sampling

24 hours or more
15〜30℃±3℃
RH50%±5%

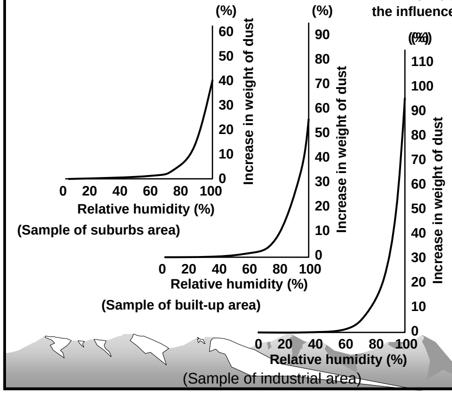
Weighing of filter paper

Calculation

Lecture-3, Sampling of SPM and Consideration in sampling

(2) Humidity influence of weight of dust)

※ When it becomes 55% or more, the influence of humidity grows.



(Sample of suburbs area)

(Sample of built-up area)

(Sample of industrial area)

Lecture-3, Sampling of SPM and Consideration in sampling

4. Outline of method of heavy metal analysis of SPM

(1) Purpose of sampling

◇ Particle concentration measurement
◇ Heavy metal analysis
◇ Ion analysis (SO_4^{2-}, NO_3^-, Cl^-, F^- ,NH_4^+, pH)
◇ Organic compound analysis (P(a)H, R-CHO, Aromatic hydrocarbon, etc.)
◇ Analysis of organic carbon and element carbon

(2) Choice of filter

◇ Mechanical stability
◇ Chemical stability (Gas adsorption, Hygroscopicity)
◇ Particle sampling efficiency
◇ Flow resistance
◇ Contain substance
◇ Cost and availability

Lecture-3 **.** **Sampling of SPM and Consideration in sampling**

(3) Type of filter

- ◇ **Cellulose fiber filter**
- ◇ **Glass fiber filter**
- ◇ **Quartz fiber filter**
- ◇ **Teflon fiber filter**

(4) Analytical approach of Heavy metal

Analytical method	Metal
Atomic absorption spectrophotometer	Fe, Mn, Zn, Pb, Ni, V, Cr, As, Ag, Al, Ti, Si, Ge, Be, Co, W, Mo,
Emission spectrophotometer	Fe, Mn, Zn, Cd, Pb, Cu, Ni, V, Cr, Hg, Se, Bi, Sn, As, Ag, Na, K, Al
Flame spectrophotometer	Na, K, Ca, Mg, Sr, Zn
spectrophotometer	Fe, Mn, Zn, Cd, Pb, Cu, Ni, V, Cr, Hg, Se, Sn, As, Ag, Al, Si, Ti, Sb, Tl, Ge, Zr, Co, W, Mo, Be
Polarograph	Fe, Mn, Zn, Cd, Pb, Cu, Ni, V, Cr, Hg, Se, Sn, Sb, As, Ag, Al, Tl, Zr, Co, W, Mo, Be

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Lecture-3 **.** **Sampling of SPM and Consideration in sampling**

⟪Metal content in Glass fiber filter paper⟫

(μg / 14 in^2 = μg / 35.56cm^2)

Maker	Toyo Rosi	Mine Safety Appllances	Gelman Instrument	Whatman	Whatman	Kimoto Elektric
Brand name	GB-100 R	M.S.A. 1106BH	Gelman A	Whatman GF/A ('69. Dec.)	Whatman GF/A ('70. Dec.)	PF-2
Material	Glass fiber	Glass fiber	Glass fiber	Glass fiber	Glass fiber	Polystyrene
Fe	55.2	85	64	220	120	66
Ni	4	7	1	7.5	5.2	<0.5
Mn	2.1	2.5	1.5	15	10	1.5
Cr	2.2	3.2	1.8	5	3.3	1.5
Sb	-	20	15	30	17	15
Pb	4.5	50	10	40	15	6
Zn	9	15	4625	25000	3175	18
Cd	<0.1	<0.1	<0.1	1.0	<0.1	<0.1
Cu	1.5	900	1.1	2.6	1.8	5.3
Ca	280	650	550	3250	1250	420
Mg	252	3000	320	800	300	
Na	5600	275	3150	20500	10000	195
K	395	7	325	415	840	150

Lecture-3 **.** **Sampling of SPM and Consideration in sampling**

⟪Metal content in membrane filter paper⟫

(μg / ϕ47 mm)

Maker	Toyo Rosi			Satrius			Millipore		
Brand name	TM-5	TM-3	TM-2	MF-14	MF-40	MF-50	MF-NC	MF-PH	MF-HA
Pore size (μm)	0.1	0.3	0.45	0.1	0.3	0.45	0.1	0.3	0.45
Si	0.9	0.8	1.5	0.6	0.3	0.4	1.3	2.0	1.7
Al	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Fe	0.8	0.8	0.9	0.6	0.6	0.6	0.6	0.6	0.6
Mn	0.2	0.2	0.1	<0.1	<0.1	<0.1	0.2	0.1	<0.1
Pb	0.5	0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zn	0.70	1.23	0.30	0.75	0.50	0.95	0.57	0.55	0.23
Cu	1.8	1.7	1.7	0.1	0.2	0.2	0.4	<0.1	0.04
Ca	8.70	5.25	6.60	9.25	13.0	8.60	3.75	6.25	6.50
Mg	1.50	1.15	1.45	0.60	1.35	1.10	0.85	1.15	1.30
Na	83.5	52.0	44.0	8.8	16.5	15.5	6.7	9.4	10.0
K	1.32	1.08	1.10	3.88	2.30	1.75	2.55	2.92	3.62

B. Lecture for Basic Air Quality Monitoring

Lecture 4. Passive Sampler Method for Air Pollution Monitoring

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Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

Content of explanation

1. Outline of Passive sampler for short-term (NO, NO2,SO2,O3)
2. Principle of air quality passive sampler
3. Investigation method that uses Passive sampler
4. Sampling Plan
5. Analytical Method for NO, NO2 and NOx
6. Calculation of Concentration for NOx, NO2 and NO
7. Comparison of Integrated Sampling and Real-Time Monitors

Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

1. Outline of Passive sampler for short-term (NO, NO2,SO2,O3)

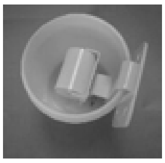
Scavenging NO, NO2, SO2, O3, and NH3 in the atmosphere

① Leave it during fixed time and Scavenge element in the atmosphere.
② When the exposure time ends, collect the sampler.
③ Extract the scavenging element in the filter paper by water, and analyze it.

★ Feature ★

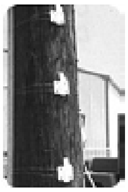
- ◆ **Measure NO and NO2 at the same time**
- ◆ **It is reusable as many times as needed**
- ◆ **It is the best for the air pollution concentration profile measurement.** **(The personal exposure measurement is also possible)**
- ◆ **Measuring range : 0 ～ 3,000 ppb/ day**
- ◆ **Sensitivity : 2ppb/ day**
- ◆ **Measuring time : For 8-24 hours usually (One week or less at the most)**
- ◆ **Analysis method : Spectrophotometer, Ion chromatograph**
- ◆ **Sampler is ideal for low-cost air monitoring programs.**

Shelter for rain protection



Diameter: 60mm

Height: 70mm



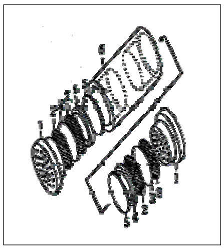
Collection filter paper

※ There is Passive sampler also for a long term.

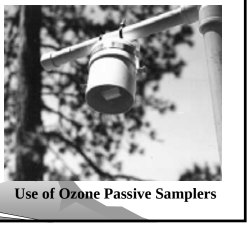
Collection filter paper of NO2, NOx, SO2, NH3, and O3 in atmosphere.

- Size 14.5mmφ
- Refrigeration preservation
- Various scavenging liquids are impregnated
- 20 pieces contained

Ambient Air Passive Sampler forNO-NO2, NOx, SO2, O3, NH3



1. Diffuser End Cap
2. Stainless Steel Screen
3. Pre-Coated Collection Pad
4. Retainer Ring
5. Inner Base Pad
6. Sampler Body



Use of Ozone Passive Samplers

Lowest detectable range

NO2	24 hr 2.3 ppb	168 hr 0.32 ppb
NOx	24 hr 2.3 ppb	168 hr 0.32 ppb
SO2	24 hr 3.8 ppb	168 hr 0.54 ppb
O3	24 hr 2.7 ppb	168 hr 0.39 ppb

Upper detectable range

NO2	24 hr <25 ppm	168 hr <3.6 ppm
NOx	24 hr <25 ppm	168 hr <3.6 ppm
SO2	24 hr <25 ppm	168 hr <3.6 ppm
O3	24 hr <0.8 ppm	168 hr <0.11 ppm

Table 1 Shelf life associated with Passive Sampler Components

	Refrigerated Storage Method	Frozen Storage Method
Sealed in glass vial pouch	90 days	1 year
Resealed in vial, after opening	90 days	
Loaded sampler in bag placed in orange vial with lid	90 days	
Exposed loaded sampler, in bag placed in orange vial with lid	14 days	
Extracted solution in water, in sealed vial	90 days	

※ Recommended sampling height : 2.5 Meters

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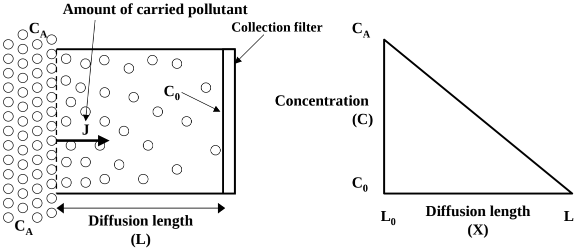
2. Principle of air quality passive sampler

(1) Molecular diffusion law (Fick's first diffusion law)



《Fick's first diffusion law》

$$J = -D\,(\Delta C / \Delta X)$$

D : Molecular diffusion coefficient (cm^2 / sec)

$$\Delta C = C_A - C_0$$

$$\Delta X = L - L_0$$

$$J = D\,(C / L)$$

J : Amount of carried pollutant (ng / cm2 / sec)
D : Molecular diffusion coefficient (cm2 / sec)
C : Concentration (ng / cm3)
L : Length (cm)

$$J \times A = D \times A\,(C / L) = W / t$$

A : Area (cm2)
W / t : Collection velocity (ng / min)

※ The concentration is proportional at the speed of the collection.

$$C = \alpha \times (W / t)$$

α : Ratio constant

3. Investigation method that uses Passive sampler

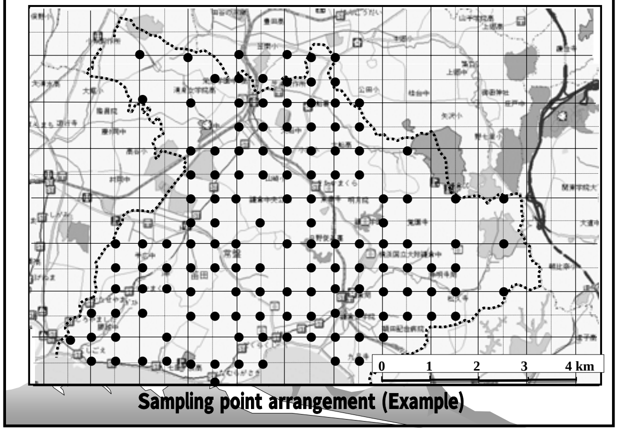
- ◆ Grasp of large area air pollution concentration distribution
- ◆ Diffusion investigation of contaminant from road (Density attenuation, NO→NO2 conversion)
- ◆ Concentration distribution investigation according to height of the ground
- ◆ Investigation of the impact from fixed source
- ◆ Measurement of individual exposure-dose

It is possible to use it from the viewpoint of the environmental education.

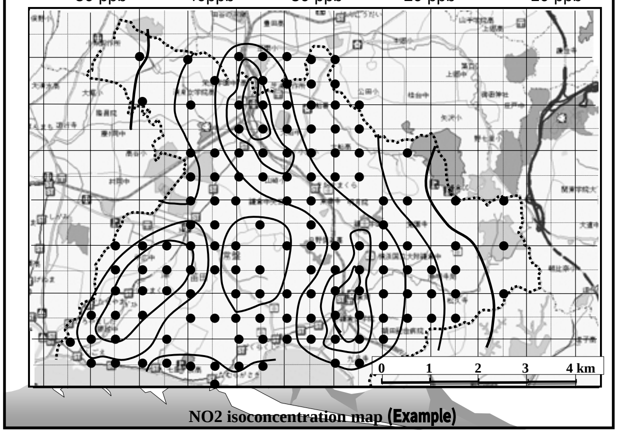
4. Sampling Plan

It is important to plan the sampling program according to the investigation purpose.

(1) Arrangement of sampling point
  ① Grasp of regional pollution
  ② Grasp of influence from source (factory and road)
  ③ Research purpose
(2) Sampling time
  ① season, month
  ② day of the week
(3) Sampling period
  ① 8 hours, 24 hours and one week
(4) Sampling frequency
(5) Other considerations
  ① Talent of investigation
  ② Budget of investigation
  ③ Machine parts of investigation



Sampling point arrangement (Example)

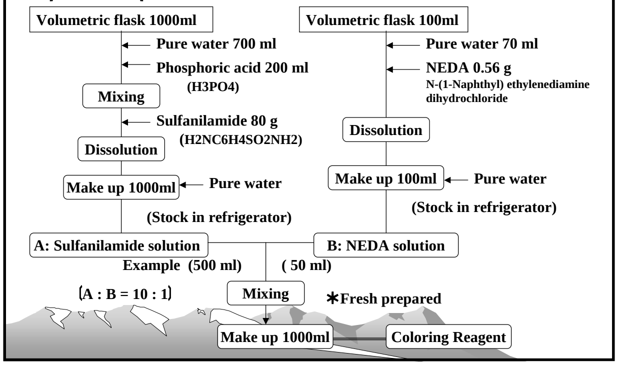


NO2 isoconcentration map (Example)

5. Analytical Method for NO, NO_2 and NO_x

(1) Preparation Procedure of Coloring Reagent

(Method - A)

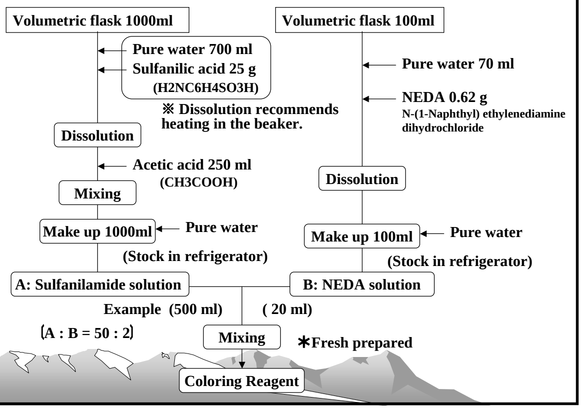


Volumetric flask 1000ml
← Pure water 700 ml
← Phosphoric acid 200 ml (H_3PO_4)
Mixing
← Sulfanilamide 80 g ($H_2NC_6H_4SO_2NH_2$)
Dissolution
Make up 1000ml ← Pure water
(Stock in refrigerator)
A: Sulfanilamide solution

Volumetric flask 100ml
← Pure water 70 ml
← NEDA 0.56 g
N-(1-Naphthyl) ethylenediamine dihydrochloride
Dissolution
Make up 100ml ← Pure water
(Stock in refrigerator)
B: NEDA solution

Example (500 ml) (50 ml)
(A : B = 10 : 1)
Mixing
∗Fresh prepared
Make up 1000ml — Coloring Reagent

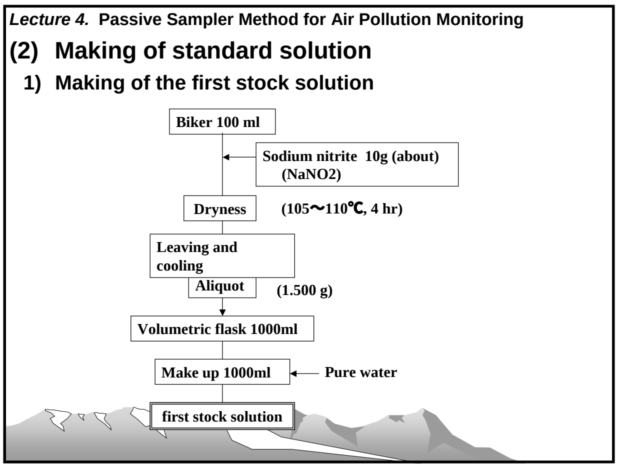
(Method - B)



Volumetric flask 1000ml
← Pure water 700 ml
← Sulfanilic acid 25 g ($H_2NC_6H_4SO_3H$)
※ Dissolution recommends heating in the beaker.
Dissolution
← Acetic acid 250 ml (CH_3COOH)
Mixing
Make up 1000ml ← Pure water
(Stock in refrigerator)
A: Sulfanilamide solution

Volumetric flask 100ml
← Pure water 70 ml
← NEDA 0.62 g
N-(1-Naphthyl) ethylenediamine dihydrochloride
Dissolution
Make up 100ml ← Pure water
(Stock in refrigerator)
B: NEDA solution

Example (500 ml) (20 ml)
(A : B = 50 : 2)
Mixing
∗Fresh prepared
Coloring Reagent



Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

(2) Making of standard solution

1) Making of the first stock solution

Biker 100 ml

Sodium nitrite 10g (about) (NaNO2)

Dryness (105〜110℃, 4 hr)

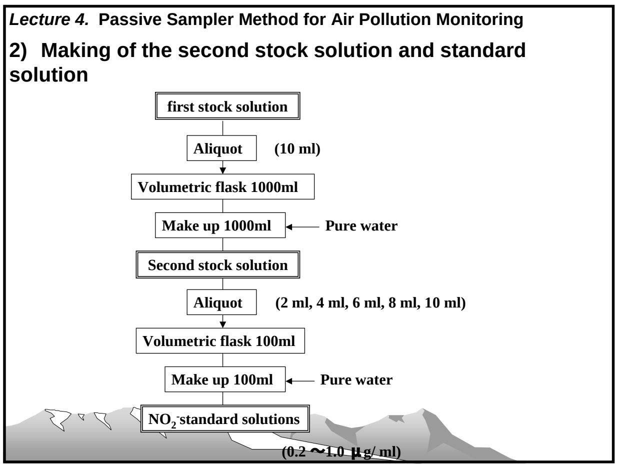
Leaving and cooling

Aliquot (1.500 g)

Volumetric flask 1000ml

Make up 1000ml ← Pure water

first stock solution



Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

2) Making of the second stock solution and standard solution

first stock solution

Aliquot (10 ml)

Volumetric flask 1000ml

Make up 1000ml ← Pure water

Second stock solution

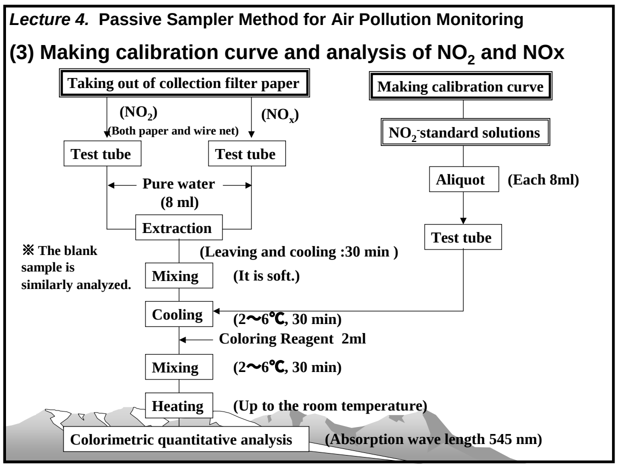
Aliquot (2 ml, 4 ml, 6 ml, 8 ml, 10 ml)

Volumetric flask 100ml

Make up 100ml ← Pure water

NO_2^-standard solutions

(0.2 〜1.0 μg/ ml)



Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

(3) Making calibration curve and analysis of NO_2 and NOx

Taking out of collection filter paper

(NO_2) (Both paper and wire net) → Test tube

(NO_x) → Test tube

← Pure water (8 ml) →

Extraction (Leaving and cooling :30 min)

※ The blank sample is similarly analyzed.

Mixing (It is soft.)

Cooling (2〜6℃, 30 min)

← Coloring Reagent 2ml

Mixing (2〜6℃, 30 min)

Heating (Up to the room temperature)

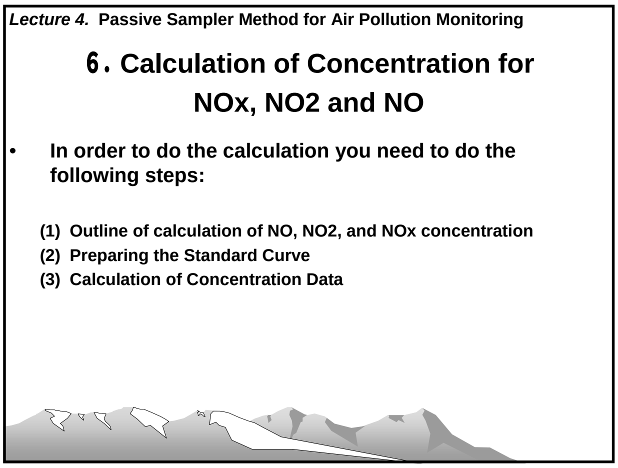
Colorimetric quantitative analysis (Absorption wave length 545 nm)

Making calibration curve

NO_2^-standard solutions

Aliquot (Each 8ml)

Test tube

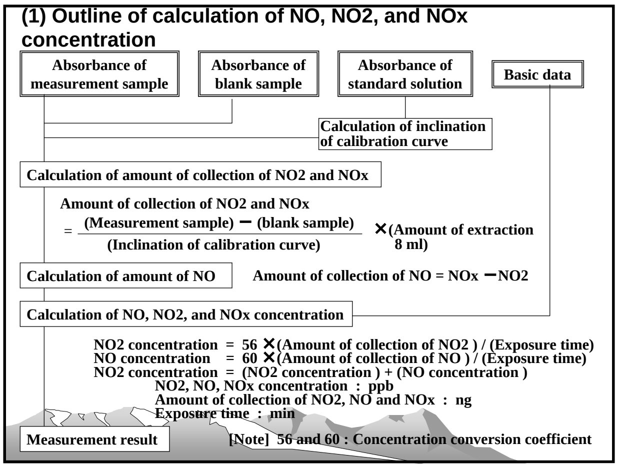


Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

6. Calculation of Concentration for NOx, NO2 and NO

- In order to do the calculation you need to do the following steps:

(1) Outline of calculation of NO, NO2, and NOx concentration
(2) Preparing the Standard Curve
(3) Calculation of Concentration Data



(1) Outline of calculation of NO, NO2, and NOx concentration

Absorbance of measurement sample

Absorbance of blank sample

Absorbance of standard solution

Basic data

Calculation of inclination of calibration curve

Calculation of amount of collection of NO2 and NOx

$$\text{Amount of collection of NO2 and NOx} = \frac{\text{(Measurement sample)} - \text{(blank sample)}}{\text{(Inclination of calibration curve)}} \times \text{(Amount of extraction 8 ml)}$$

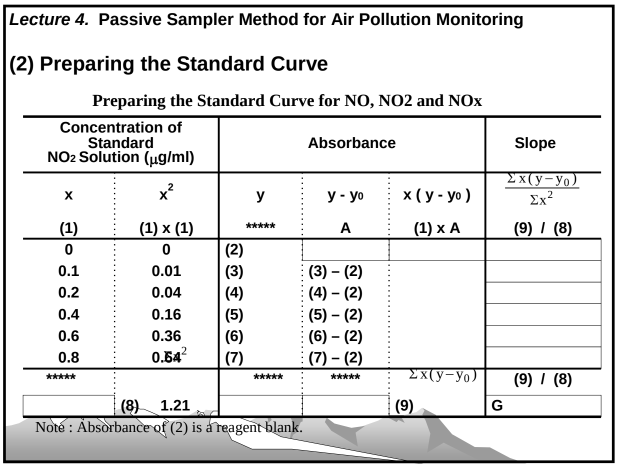
Calculation of amount of NO   Amount of collection of NO = NOx − NO2

Calculation of NO, NO2, and NOx concentration

NO2 concentration = 56 ×(Amount of collection of NO2) / (Exposure time)
NO concentration = 60 ×(Amount of collection of NO) / (Exposure time)
NO2 concentration = (NO2 concentration) + (NO concentration)
NO2, NO, NOx concentration : ppb
Amount of collection of NO2, NO and NOx : ng
Exposure time : min

Measurement result

[Note] 56 and 60 : Concentration conversion coefficient



Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

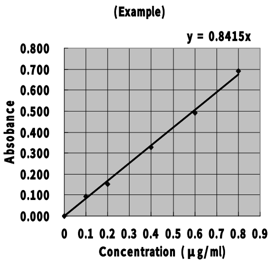
(2) Preparing the Standard Curve

Preparing the Standard Curve for NO, NO2 and NOx

Concentration of Standard NO_2 Solution (μg/ml)		Absorbance			Slope
x (1)	x^2 (1) x (1)	y *****	y - y_0 A	x (y - y_0) (1) x A	$\frac{\Sigma x(y-y_0)}{\Sigma x^2}$ (9) / (8)
0	0	(2)			
0.1	0.01	(3)	(3) – (2)		
0.2	0.04	(4)	(4) – (2)		
0.4	0.16	(5)	(5) – (2)		
0.6	0.36	(6)	(6) – (2)		
0.8	0.64	(7)	(7) – (2)		
*****	Σx^2	*****	*****	$\Sigma x(y-y_0)$	(9) / (8)
	(8) 1.21			(9)	G

Note : Absorbance of (2) is a reagent blank.

Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**



Standard Curve for NO, NO2 and NOx

Slope of the Standard Curve (G) = 0.8415

Slope can be obtained by using the spreadsheet program of Excel etc.

x	y	y - y0
0.0	0.012	0.000
0.1	0.104	0.092
0.2	0.165	0.153
0.4	0.339	0.327
0.6	0.502	0.490
0.8	0.704	0.692

Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

(3) Calculation of Concentration Data

Table (1) Calculation of Concentration Data For NOx , NO2 and NO

Compound	Blank Absorbance				Slope	Temp. (ºC)	R. H. (%)	Conc. Conversion Coefficient	
	Bℓ 1	Bℓ 2	Bℓ 3	Average				αNO_2	αNO
NOx				(1)=	G =	(20ºC)	-70%	α_{NO2} = (56)	α_{NO} = (60)
NO_2				(2)=				α_{NO2} =	α_{NO} =

Slope : Slope of the Standard Curve R. H. : Relative Humidity Conc. : Concentration
αNO2 = 56 and αNO = 60 when Temperature = 20ºC and Relative Humidity = 70%.
Please follow the table of the manual about other combinations of the temperature and the relative humidity.

Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

Table (2) Calculation of Concentration Data For NOx , NO2 and NO

	Specification			Samples			
	Sample Number			1	2	3	4
	Sample Location						
	Sampling Time (min)	(3)	= (3)				
NOx	Sample Absorbance	(4)	= (4)				
	Absorbance	(5)	= (4) – (1)				
	Solution Concentration (μg/ml)	(6)	= (5) / G				
	Collected Weight (ng)	(7)	= (6) × 8 × 1000				
	Concentration (ppb)	(8)	= (13) + (15)				
NO_2	Sample Absorbance	(9)	= (9)				
	Absorbance	(10)	= (9) – (2)				
	Solution Concentration (μg/ml)	(11)	= (10) / G				
	Collected Weight (ng)	(12)	= (11) × 8 × 1000				
	Concentration (ppb)	(13)	= α_{NO2} × (12) / (3)				
NO	Collected Weight (ng)	(14)	= (7) – (12)				
	Concentration (ppb)	(15)	= α_{NO} × (14) / (3)				

Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

【Calculation example】

《Setting of calculation condition》

- ◆Sampling time：Feb. 26 10:18 〜 Feb. 27 10:10 = 1450 min
- ◆ Absorbance :

	Sample	Paper blank
NOx	0.343	0.149 (Average)
NO2	0.094	0.009 (Average)

- ◆ Slope of the Standard Curve (G) = 0.8415
- ◆ Conc. Conversion Coefficient : α_{NO2} = (56), α_{NO} = (60)

《Amount of collection 》

a) Amount of collection NOx (In the NO2 conversion)
= ((0.343 – 0.149) / 0.8415) ×8 ml = 1.844 μg NO2 (= 1844 ngNO2)
b) Amount of collection NO2
= ((0.094 – 0.009) / 0.8415) ×8 ml = 0.808 μg NO2 (= 808 ngNO2)
c) Amount of collection NO (In the NO2 conversion)
= 1844 – 808 = 1036 ngNO2

《How to obtain parts-per-billion (ppb) concentration》

a) NO (ppb) = (α_{NO} ×W_{NO}) / t
= 60 × 1036 / 1432 = 43 (ppb)
b) NO2 (ppb) = (α_{NO2} ×W_{NO2}) / t
= 56 × 808 / 1432 = 32 (ppb)
c) NOx (ppb) = NO (ppb) + NO2 (ppb)
= 43 (ppb) + 32 (ppb) = 75 (ppb)

Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

αNO and αNO2 as a function of temperature and relative humidity

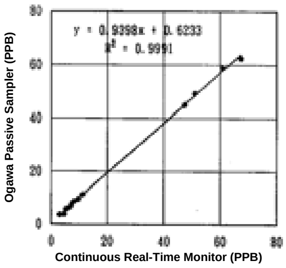
Temp (ºC)	R.H. (%)	α_{NO2}	α_{NO}	Temp (ºC)	R.H. (%)	α_{NO2}	α_{NO}	Temp (ºC)	R.H. (%)	α_{NO2}	α_{NO}
-10	50	84	61	7	60	65	62	24	70	55	59
-9	50	83	61	8	60	64	62	25	80	53	61
-8	50	81	61	9	60	64	61	26	80	52	61
-7	50	80	61	10	60	63	61	27	80	52	60
-6	50	79	61	11	60	63	61	28	80	52	60
-5	50	78	61	12	60	62	60	29	80	52	59
-4	50	77	61	13	60	62	60	30	80	52	59
-3	50	76	60	14	60	61	60	31	80	52	58
-2	50	75	60	15	70	58	63	32	80	51	58
-1	50	74	60	16	70	58	62	33	80	51	57
0	50	74	60	17	70	57	62	34	80	51	57
1	60	68	64	18	70	57	61	35	80	50	57
2	60	68	63	19	70	57	61	36	80	50	56
3	60	67	63	20	70	56	60	37	80	50	56
4	60	66	63	21	70	56	60	38	80	50	56
5	60	66	63	22	70	56	60	39	80	49	55
6	60	65	62	23	70	55	59	40	80	49	55

Temp : Temperature (ºC) R.H. : Relative Humidity(%)

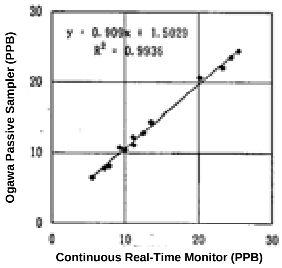
Lecture 4. **Passive Sampler Method for Air Pollution Monitoring**

7. Comparison of Integrated Sampling and Real-Time Monitors

(NO)



(NO2)



Reference:
Yokohama City Research Institute of Environmental Science, Yokohama, Japan, Report No. 128, March 1997

Thank you

(Lec. AQA-11)

Air Pollution Monitoring Results

August 2007

The JICA Expert Team (Air Quality Analysis)

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1. Damascus

(1) Total Suspended Particulate Matter (TSP)

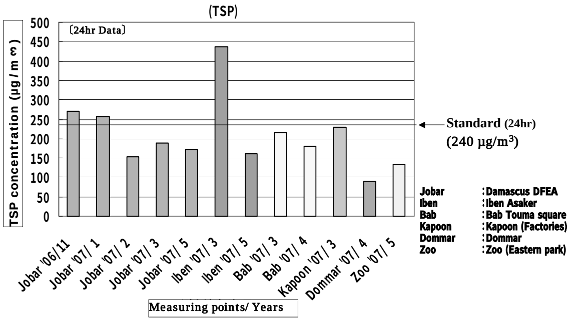

Figure 1-1 Comparison of TSP concentration in different locations and the environmental quality standard

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(2) Suspended Particulate Matter (PM10)

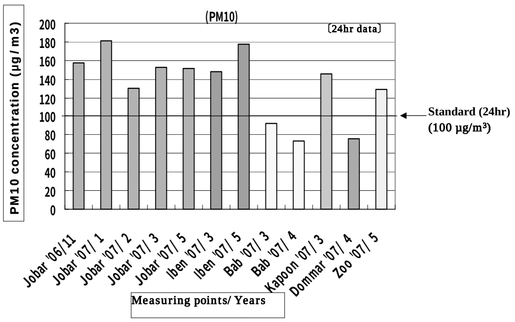

Figure 1-2 Comparison of PM10 concentration in different locations and the environmental quality standard

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(3) Sulfur dioxide (SO2)

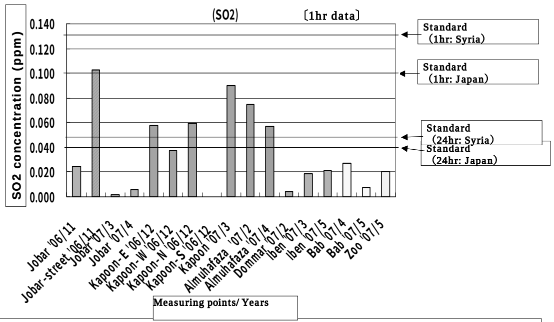

Figure 1-3 Comparison of SO_2 concentration in different locations and the environmental quality standard

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(4) Nitrogen dioxide (NO2)

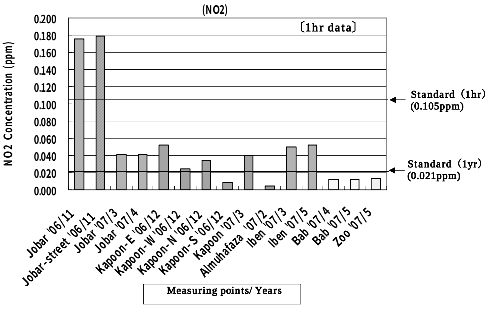

Figure 1-4 Comparison of NO_2 concentration in different locations and the environmental quality standard

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2. Homs

(1) Suspended Particulate Matter (PM10)

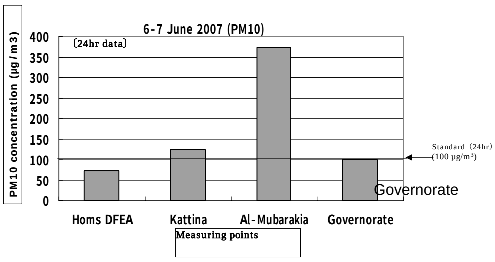


Figure 2-1 Comparison of PM10 concentration in different locations and the environmental quality standard

(2) Sulfur dioxide (SO2)

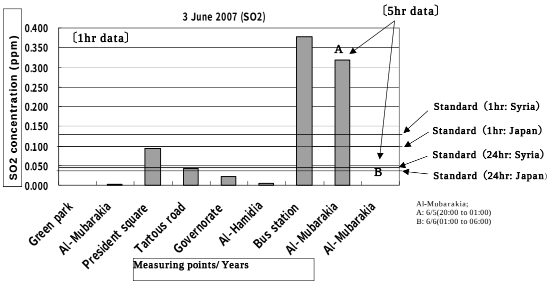
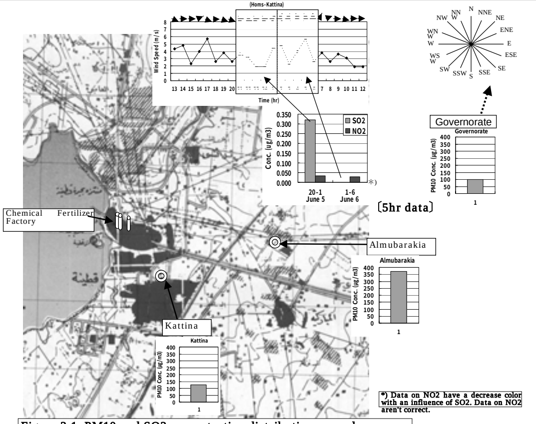


Figure 2-2 Comparison of SO_2 concentration in different locations and the environmental quality standard



*) Data on NO2 have a decrease color with an influence of SO2. Data on NO2 aren't correct.

Figure 3-1 PM10 and SO2 concentration distribution around the chemical fertilizer factory and weather condition

(3) Nitrogen dioxide (NO2)

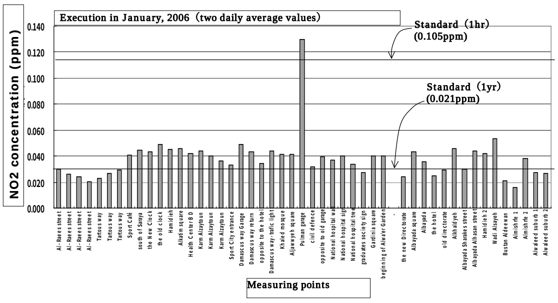


Figure2-4 Comparison of NO2 concentrations In different locations by passive samplers

3. Aleppo

(1) TSP and PM10

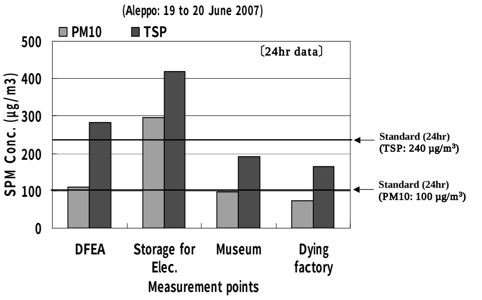


Figure 3-5 Comparison of SPM concentration in different locations and the environmental quality standard

The PM10 concentration in the circumference area of the cement factory is shown in figure 3-6. Data are for 24 hours (Hi-Vol samplers) and for a mean for 7 days (Low-Vol samplers).

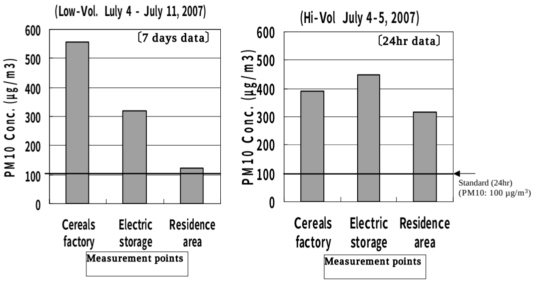


Figure 3-6 PM10 concentration in the area around the cement factory

(2) Wide area NO2 concentration distribution

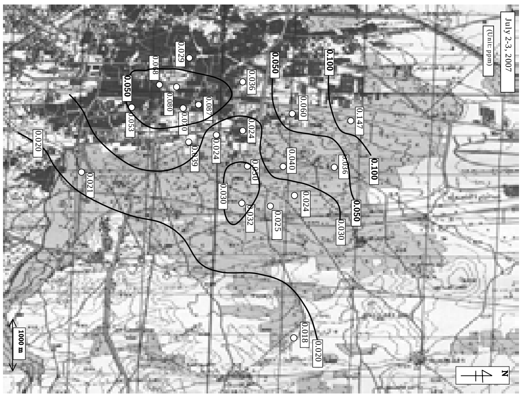
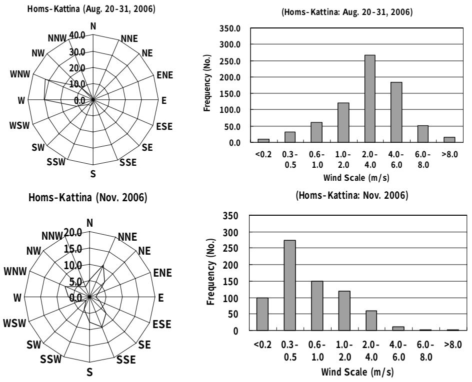
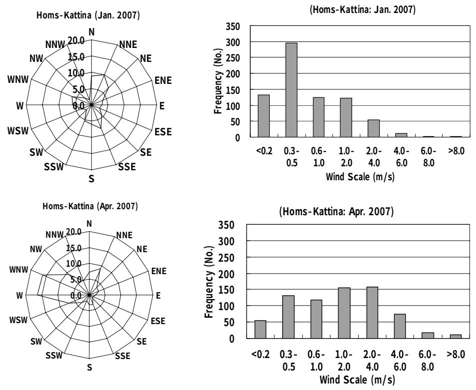


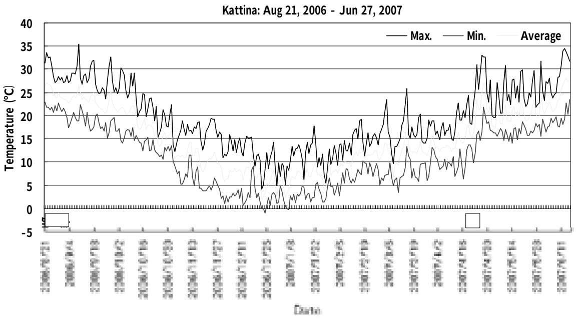
Figure3-8 NO_2 concentration lines in Aleppo suburb area

Weather data (reference)

Homs (Kattina station)







One-hour value change in temperature