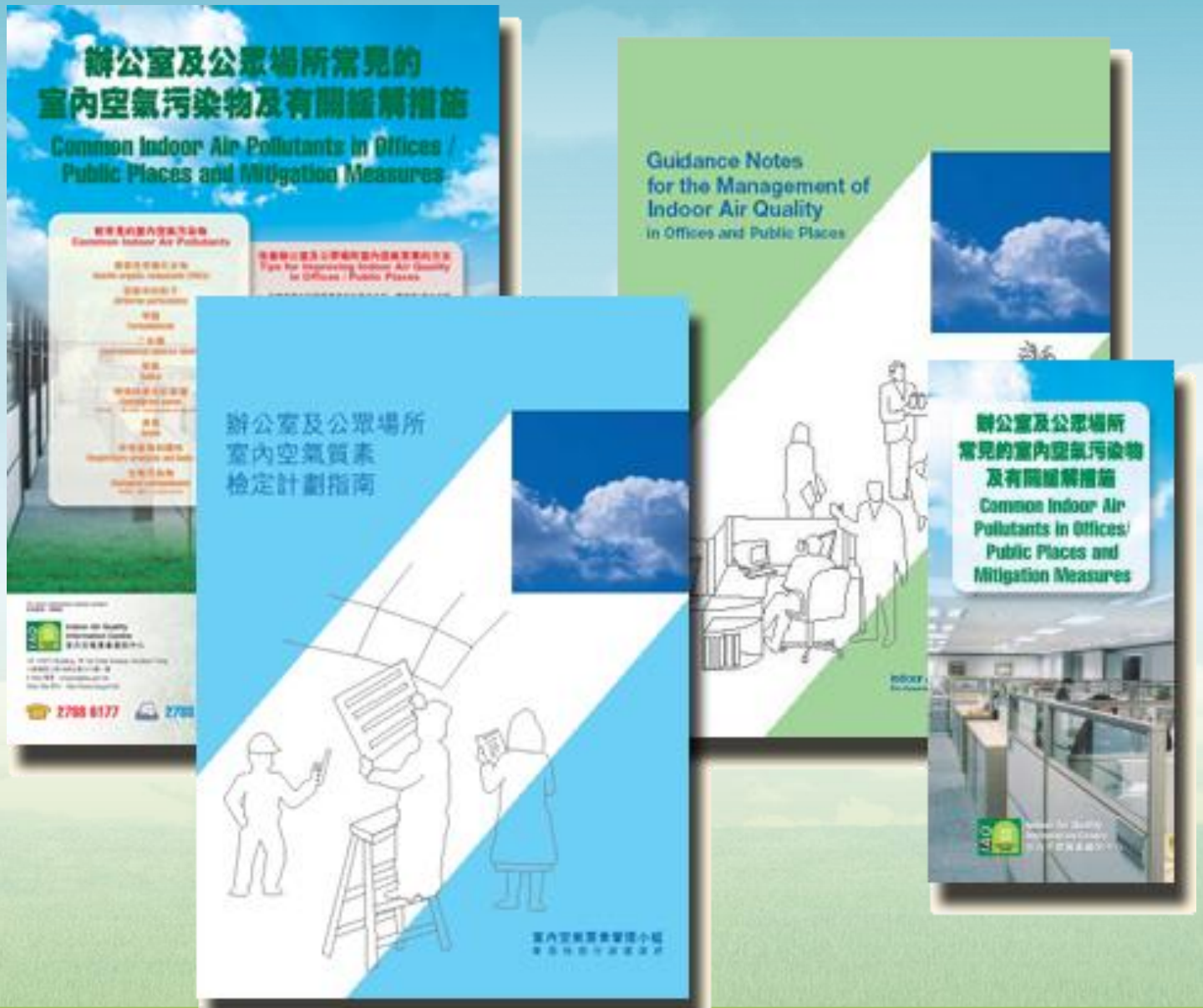
Indoor Air Quality measurement in Hong Kong

YEUNG Lam Lung

Department of Chemistry

HK University of Science and Technology

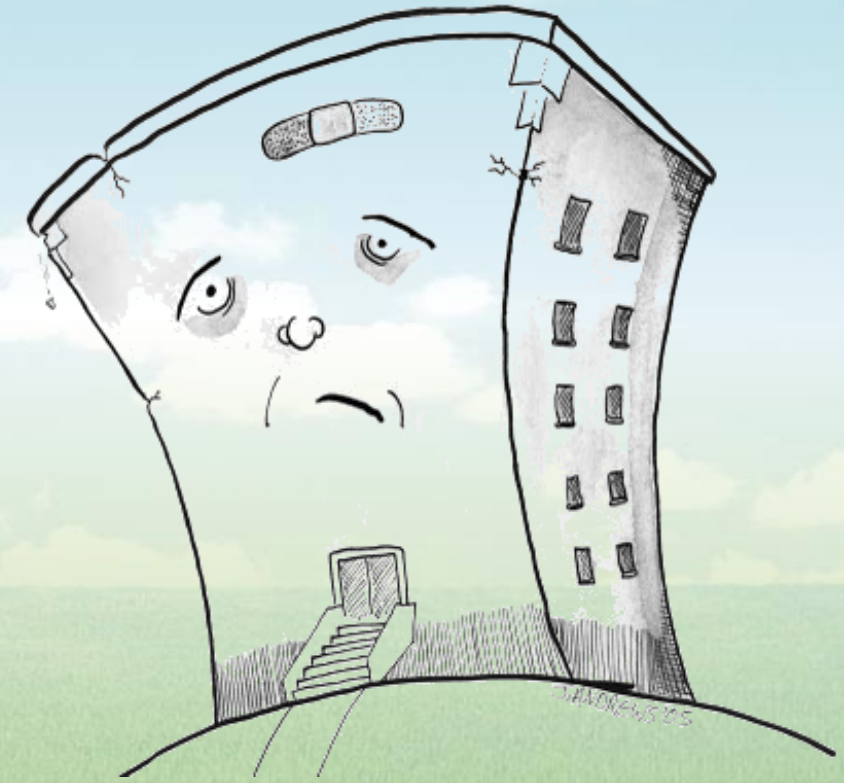
IAQ Certification Scheme



Sick Building Syndrome (SBS)

or

Building Related Illness (BRI)



Sick Building Syndrome (SBS)

- Irritation and itching eyes
- Nose and throat irritation
- Runny or congested nose
- Other flu-like symptoms
- Chest tightness
- Itchy skin occasionally with the development of rash
- Headaches
- Poor concentration
- Irritability

Guide on IAQ Certification Scheme

The GN applies to all buildings or totally enclosed areas served with mechanical ventilation system for human comfort except:

1. Domestic building
2. Medical building
3. Industrial building

Key Features of the IAQ Certification Scheme

- 2 Level Excellent or Good Class
- Voluntary for annual certification
- Certificate valid for 5 years for renewal full certification
- In between the 4 years recertification for CO_2 and RSP
- Building owner maintain post certification IAQ

Parameter	Unit	8-hour average [a]	
		Excellent Class	Good Class
Room Temperature	°C	20 to < 25.5 [b]	< 25.5 [b]
Relative Humidity	%	40 to < 70 [c]	< 70
Air movement	m/s	< 0.2	< 0.3
Carbon Dioxide (CO_2)	ppmv	< 800 [d]	< 1,000 [e]
Carbon Monoxide (CO)	$\mu g/m^3$	< 2,000 [f]	< 10,000 [g]
	ppmv	< 1.7	< 8.7
Respirable Suspended Particulates (PM_{10})	$\mu g/m^3$	< 20 [f]	< 180 [h]
Nitrogen Dioxide (NO_2)	$\mu g/m^3$	< 40 [g]	< 150 [h]
	ppbv	< 21	< 80
Ozone (O_3)	$\mu g/m^3$	< 50 [f]	< 120 [g]
	ppbv	< 25	< 61
Formaldehyde (HCHO)	$\mu g/m^3$	< 30 [f]	< 100 [f, g]
	ppbv	< 24	< 81
Total Volatile Organic Compounds (TVOC)	$\mu g/m^3$	< 200 [f]	< 600 [f]
	ppbv	< 87	< 261
Radon (Rn)	Bq/m^3	< 150 [i]	< 200 [f]
Airborne Bacteria	cfu/m^3	< 500 [j, k]	< 1,000 [j, k]

12 IAQ Parameters

Physical Parameters - *Thermal Comfort*

Temperature
Humidity
Air Movement

Chemical Parameters

Organic Pollutants - Volatile Organic Compounds (VOCs)
Formaldehyde (HCHO)

Combustible Gases - Carbon Dioxide (CO_2)
Carbon Monoxide (CO)
Nitrogen Dioxide (NO_2)

Others - Ozone (O_3)
Radon (Rn)
Respirable Suspended Particulate(PM_{10})

Biological Contaminants - Total Airborne Bacteria and Fungi counts

Temperature

Excellent Class: 20-25.5°C

Good Class: less than 25.5°C

Relative Humidity

Excellent Class: 40-70%

Good Class: less than 70%

Q-Trak

Temperature & Relative Humidity Measurement

Air Movement

Excellent Class: less than 0.2 m/s

Good Class: less than 0.3 m/s

Air Flow and Ventilation Measurement

Hot Wire Anemometer

Air Movement

- A certain amount of air movement round the human body is essential for thermal comfort.
- It is also important in dispersing air pollutants. The required level of airflow depends on the air temperature and humidity.
- In the hot and humid summer months, for example, greater air movement can help produce a more comfortable environment.

Air Movement

- Airflow is determined by
  - Ventilation
  - Convection currents (created by hot air rising and cool air falling) in a room.

- Blocked or unbalanced ventilation systems, or too low pressure levels in ventilation ducts may restrict air movement, producing a "stuffy" atmosphere which makes occupants feel uncomfortable.

Air Movement

- Airflow is also sensitive to:
  - Changes in room occupancy
  - Installation or removal of partition walls
  - Size, quantity and arrangement of office equipment and furniture
- Too much air movement results in draughts and excessive cold.

Formaldehyde (HCHO)

Excellent Class: less than 30 $\mu g/m^3$

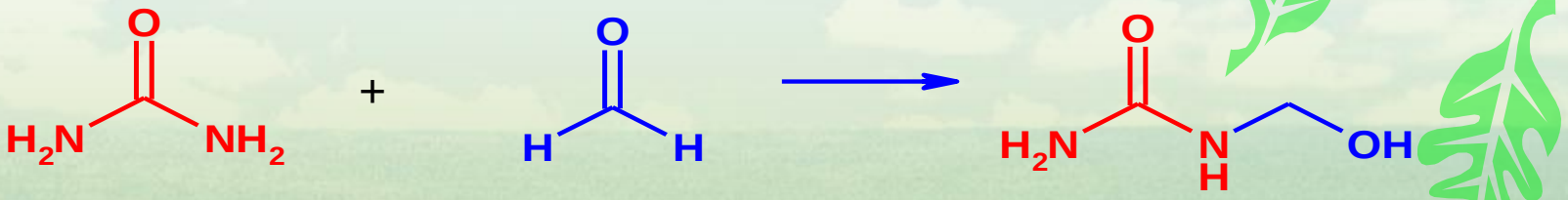
(24 ppbv)

Good Class: less than 100 $\mu g/m^3$

(81 ppbv)

Formaldehyde (HCHO)

- A kind of Volatile Organic Compounds (VOCs)
- Comes from pressed wood products, carpet adhesives, smoking or other incomplete combustion process
- Can be a problem in areas where there are a large amount of carpets and pressed wood furniture



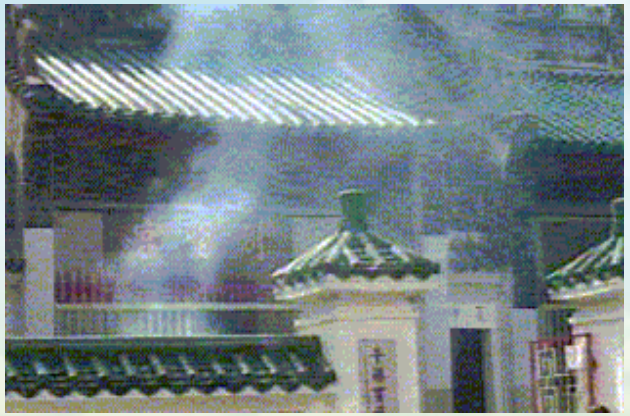
Urea + Formaldehyde → Urea-formaldehyde foam

Formaldehyde (HCHO)

Can also be formed by burning wood, kerosene, incense or natural gas, by automobiles, and by cigarettes.

Health impacts

- irritating effect to eyes, nose and respiratory system
- sensitization
- a suspected human carcinogen

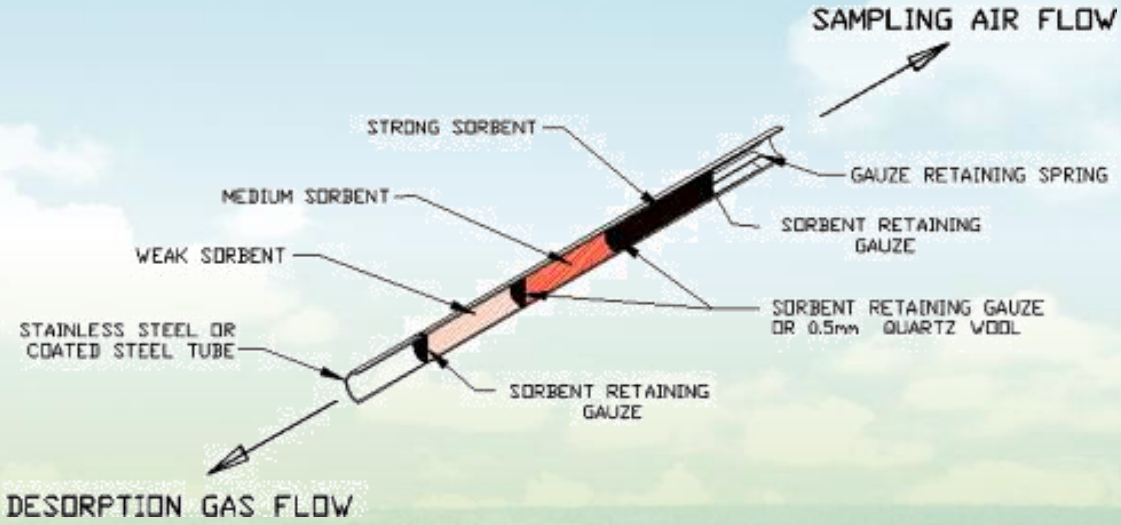


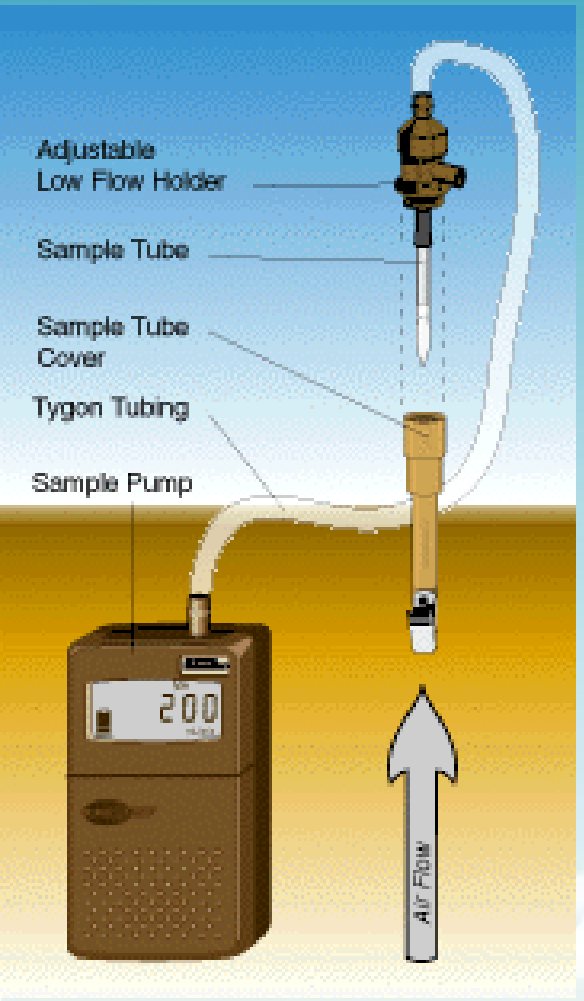
Air Sampling Strategies

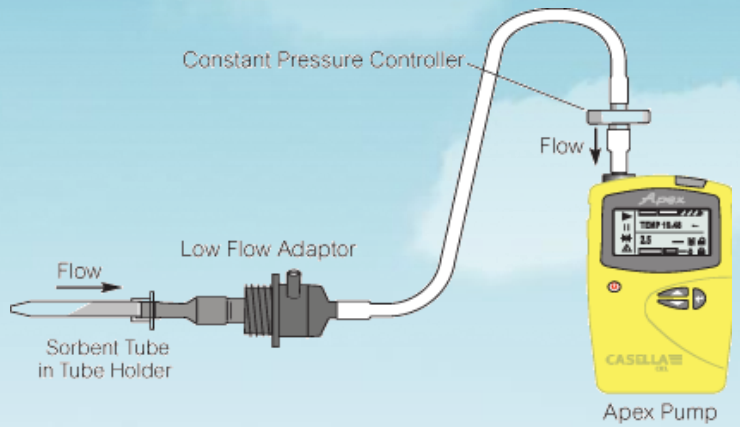
- Active Sampling
- Passive Sampling

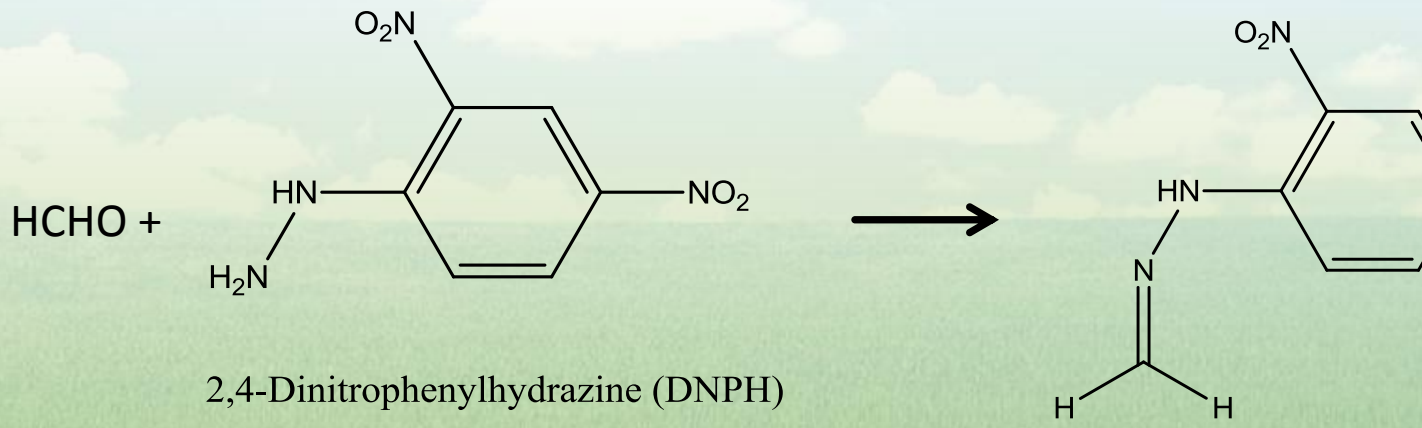
Active Sampling

- Actively drawing air through a sorbent filled cartridge or tubes by a personal sampling pumps



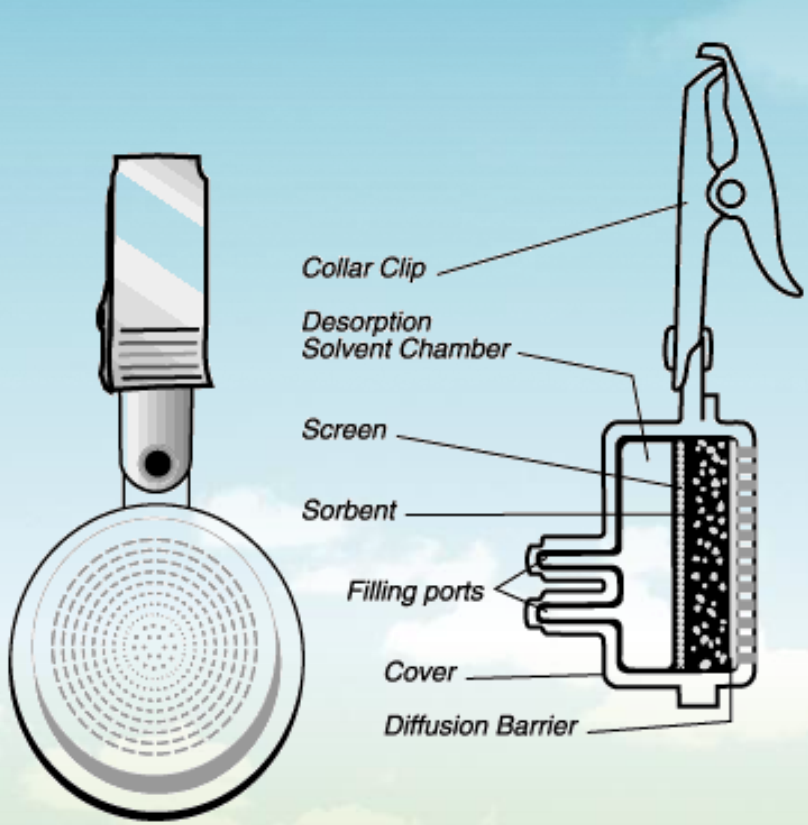


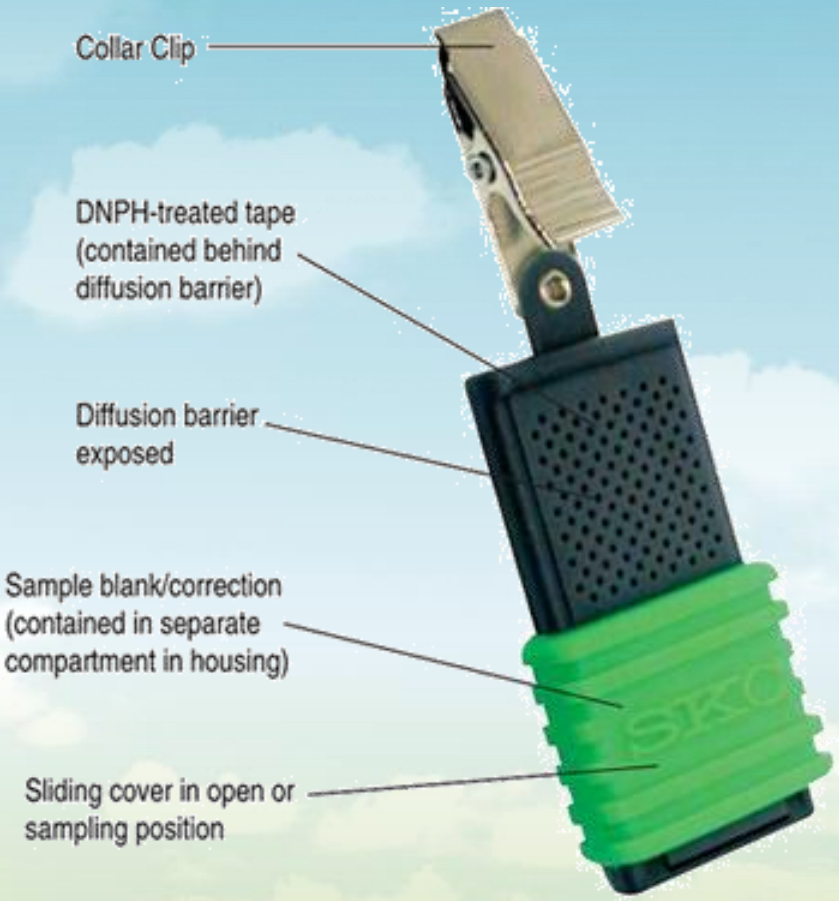




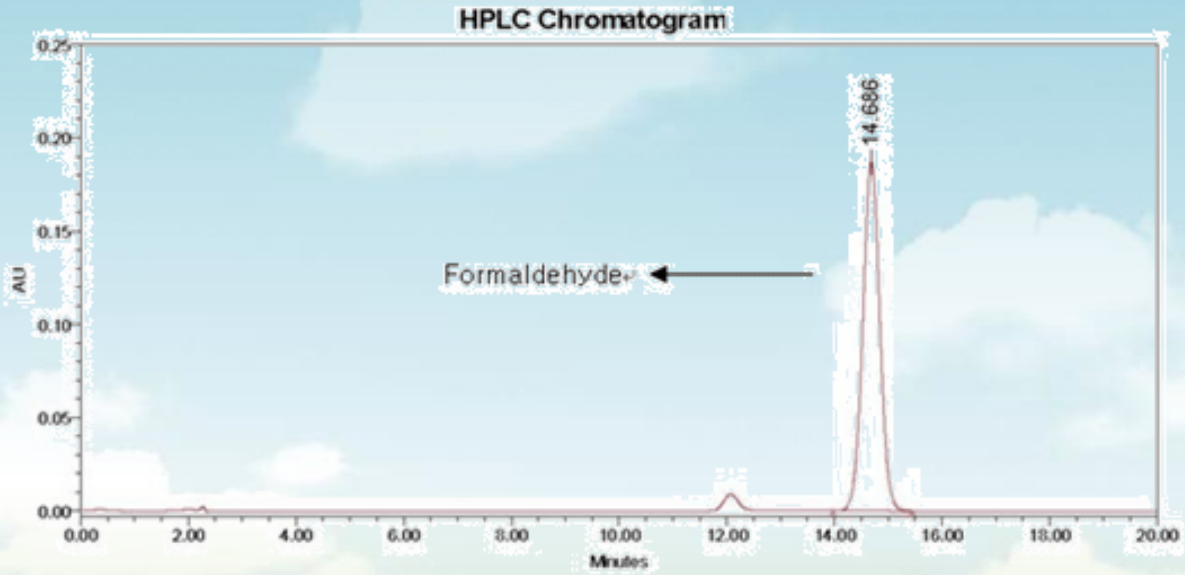
2,4-Dinitrophenylhydrazine (DNPH)

Passive Sampling





High Performance Liquid Chromatography (HPLC)



Conditions

- SampleName : STD 100
- Column : (4.6 X 250mm) TSK ODS 100V
- Eluent : DI:ACN=60:40
- Flow rate : 1.0 mL
- Sample Conc. : 0.50mg/L
- Injection : 10 uL
- Temperature : 40
- Detector : (360nm) UV-Detector
- Software : EMPOWER

Volatile Organic Compounds (VOCs)

Excellent Class: less than 200 $\mu g/m^3$
(87 ppbv)

Good Class: less than 600 $\mu g/m^3$
(261 ppbv)

Volatile Organic Compounds (VOCs)

Classification of Organic Compounds

According to their boiling points,

Organic compounds can be classified as 3 categories:

- Very volatile,
- Volatile
- Semi-volatile

50-260^{o}C (WHO 1986)

Volatile Organic Compounds (VOCs)

Classification of Organic Compounds

According to their chemical structure/functional group:

- Aliphatic (straight chain)
- Aromatic (compounds with benzene ring)
- Halogenated hydrocarbons (Chlorine atom)
- Oxygenated compounds

Source of VOCs: Petroleum products, perfumes, pesticides, plastics, pigments, paints, adhesives and smoking

Volatile Organic Compounds (VOCs)

Fundamental VOC Emission Processes

- Evaporation
- Desorption
- Diffusion within a material

Materials	Decade Time
Wet (Paints, Adhesives)	First few hours
Dry (Building materials)	Months

Volatile Organic Compounds (VOCs)

Pollutants	Indoor Sources
Benzene, Ethylbenzene, Toluene, Xylenes	ETS, solvents, paints, fax machine, computer terminals, adhesives, floor tile adhesives, styrenefoam
Carbon Tetrachloride (CCl_4)	Solvents, refrigerant, fire extinguishers, grease solvents
Tetrachloroethylene ($Cl_2C=CCl_2$)	Dry cleaned fabrics, upholstered furniture covering, spot/textile cleaner, fax machines and printers
Chloroform ($CHCl_3$)	Solvents, dyes, pesticides, fax machines, computer terminals, printers and chlorinated water
Dichlorobenzene	Insecticide, dry cleaning agent, deordorant, mod and mildew control and air freshener

Volatile Organic Compounds (VOCs)

Symptoms

- Eye irritation: burning, dry, watery eyes
- Throat irritation: dry throat
- Respiratory problems: shortness of breath; asthma
- Headaches; poor concentration; dizziness, tiredness, irritability.

Volatile Organic Compounds (VOCs)

Environmental Tobacco Smoke (ETS)

More than 4,500 compounds have been identified in both vapour and particulate phases

Tobacco smoke is composed of:

Main Stream (MS) : Smoke exhaled by smokers

Side Stream (SS) : Smoke released directly from burning cigarette

acetaldehyde	dibenzo(a,i)pyrene	N-nitrosdi-n-propylamine
acrylonitrile	dibenzo(a,e)pyrene	N-nitrosopyrrolidine
arsenic	dibenzo(a,l)pyrene	N-nitrosodi-n-butylamine
benz(a)anthracene	dibenzo(a,h)pyrene	*ortho*-toluidine
benzene	formaldehyde	styrene
benzo(a)pyrene	hydrazine	urethane
benzo(b)fluoranthene	indeno(1,2,3,-cd)pyrene	vinyl chloride
benzo(k)fluoranthene	lead	1,1-dimethylhydrazine
cadmium	nickel	2-nitropropane
chromium VI	N-nitrosodiethanolamine	2-napthylamine
DDT	N-nitrosodiethylamine	4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone [NNK]
dibenz(a,h)acridine	N'-nitrosodimethylamine	4-aminobiphenyl
dibenz(a,j)acridine	N'nitrosonornicotine	5-methychrysene
dibenz(a,h)anthracene	N-nitrosopiperidine	7H-dibenzo(c,g)carbazole

Volatile Organic Compounds (VOCs)

Photo-ionization detectors (PID) device

ppbRAE

Certificate of Calibration

Model
PGM7240

Serial Number
181377

This instrument has been calibrated using calibration gases and procedures which are traceable to N.I.S.T. Test and calibration data is on file with the manufacturer.

Calibration Date
October 17, 2008

Approved by

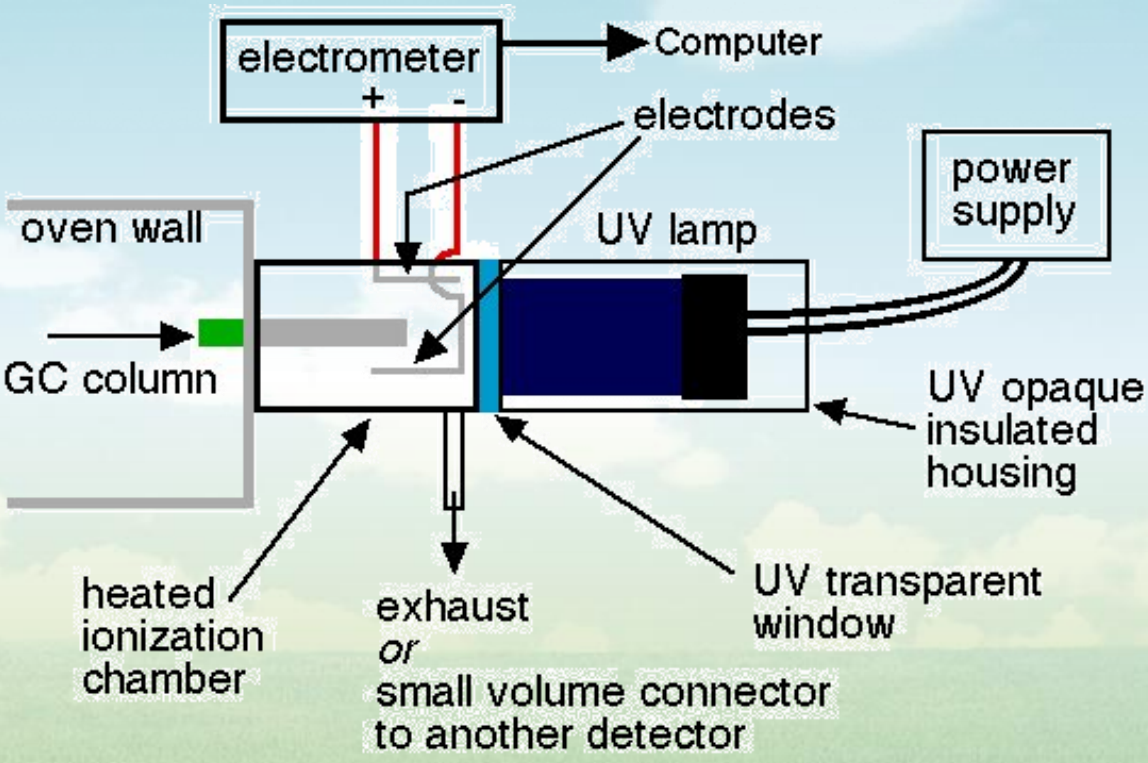
RAE Systems Inc.

RAE

Certified Reference isobutylene (TVOC) at 10 ppm

Photo-ionization Detector

$$R + h\nu \longrightarrow R^{+} + e^{-}$$



Carbon Monoxide (CO)

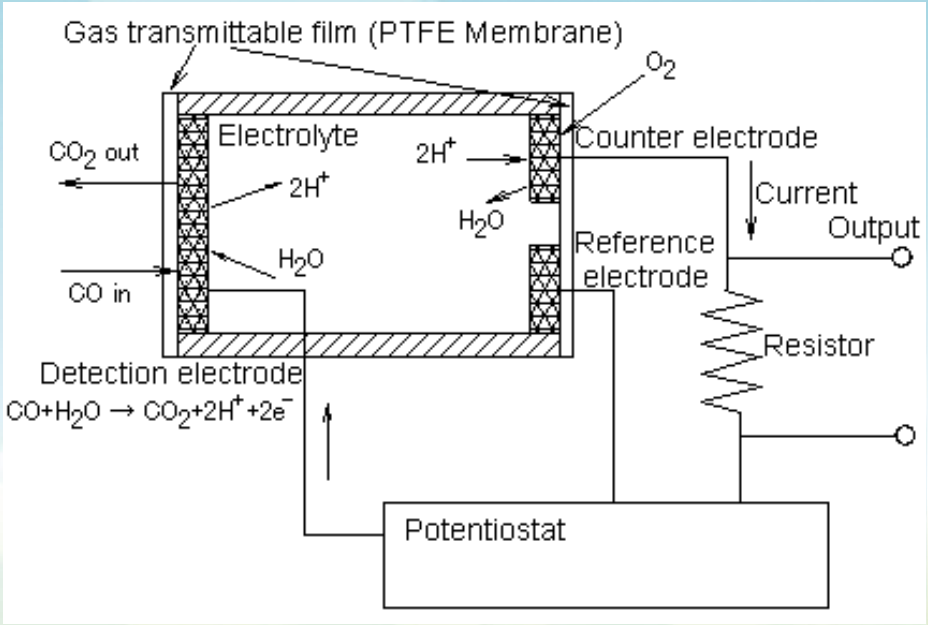
Excellent Class: less than 2000 $\mu g/m^3$ (1.7ppmv)

Good Class: less than 10000 $\mu g/m^3$ (8.7ppmv)

Carbon Monoxide (CO)

- By-product of incomplete combustion process
- From heavy traffic
- Can bring more CO to the indoor environment if the ambient air is dirty
- Fresh air supply point must be located away from car parks or other traffic sources
- Extremely toxic and can kill if the level is too high as it takes away the oxygen transportation sites in blood

CO Electrochemical Cell



Carbon Dioxide (CO_2)

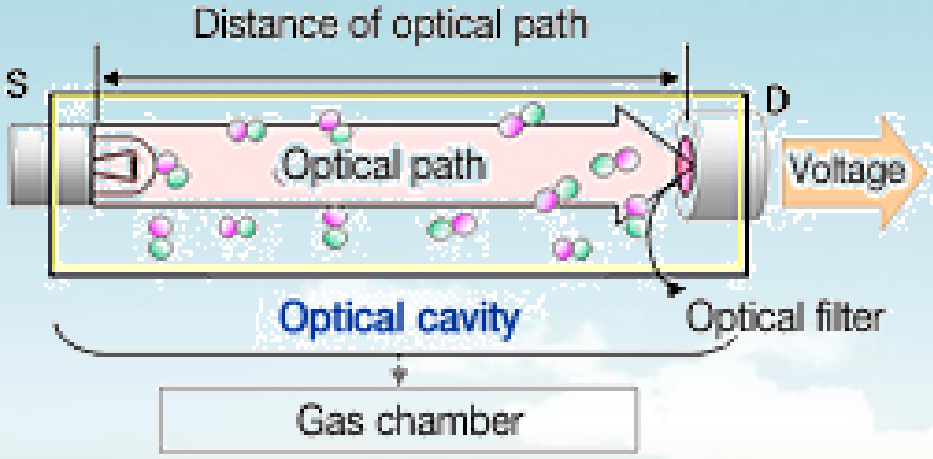
Excellent Class: less than 800 ppmv

Good Class: less than 1000 ppmv

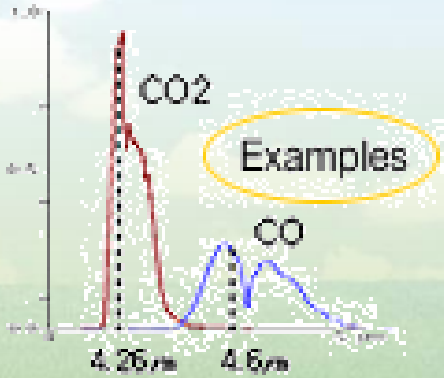
Carbon Dioxide (CO_2)

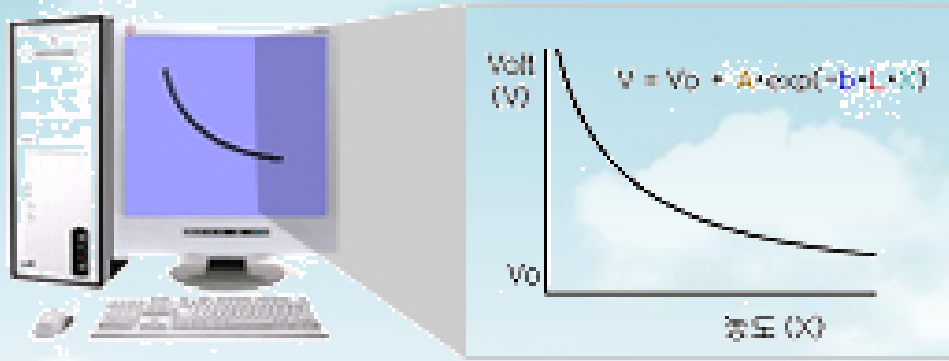
- A surrogate gas for bio-effluent from the building occupants
- In ambient air, the level is around 400 ppm
- In indoor environment, a level of 1000 ppm has been used as an indicator for ventilation adequacy
- Health impacts:
  - not a toxic gas and no known health impact if the level is not too high. Industrial standards are from 5000 to 30000 ppm

CO2 NDIR Detector



GAS MOLECULE
S LIGHT SOURCE
D OPTICAL DETECTOR





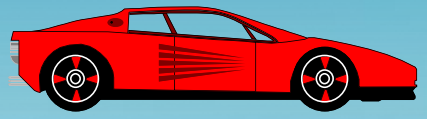
Beer-Lambert Theory

b Absorption rate
L Distance of optical path

I/O ratio of CO2

Apart from the health issue,

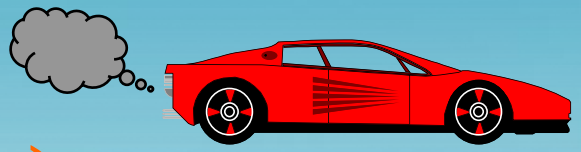
- An indicator of the ventilation condition
- Each person: CO2 exhalation rate: 0.3L/min
- I/O ratio close to 1, implies good ventilation



Nitrogen Dioxide (NO_2)

Excellent Class: less than 40 $\mu g/m^3$
(21 ppbv)

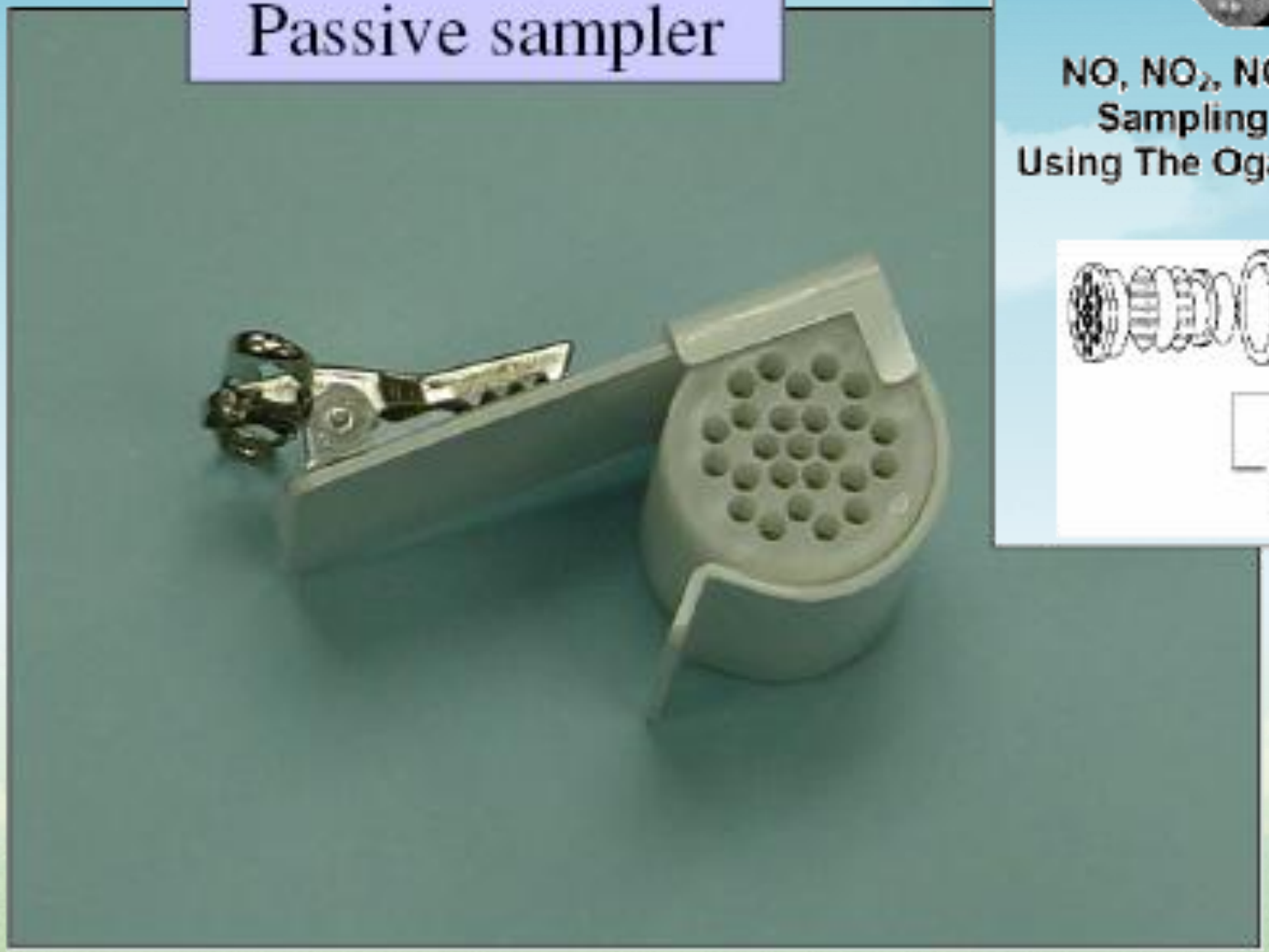
Good Class: less than 150 $\mu g/m^3$
(80 ppbv)



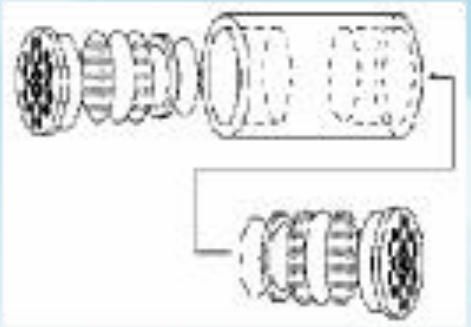
Nitrogen Dioxide (NO_2)

- Comes from incomplete combustion process, either indoors or outdoors
- Can be high in kitchen environment or in area close to heavy traffic
- Cannot be removed by traditional filtration systems
- Health impacts:
  - causes irritation to eyes & respiratory system

NO2 Ogawa Passive sampler



NO, NO_2, NOx and SO_2 Sampling Protocol Using The Ogawa Sampler*



Ozone (O_3)

Excellent Class: less than 50 $\mu g/m^3$

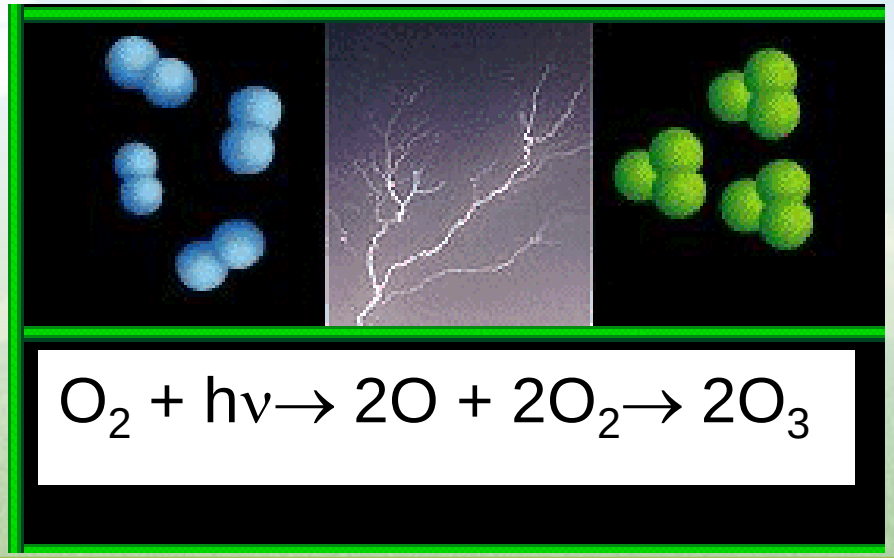
(25 ppbv)

Good Class: less than 120 $\mu g/m^3$

(61 ppbv)

Ozone (O_3)

- Can be produced by equipment that utilizes ultra-violet light or high voltage and causes ionization of air
- Office equipments such as photocopiers, laser printers and ionizers can produce ozone



Ozone (O_3)

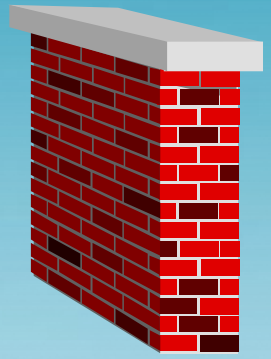
- Very reactive and not tend to accumulate in the indoor environment
- Can only be found in substantial concentration near the source.
- Influence on Health:
  - Cause serious damage to lung if inhaled in high concentration
  - Irritates the eyes and respiratory tract

Ozone (O_3)

- It can be a very powerful cleaning tool for indoor air pollutants such as smoking
- Air purifiers or Personal air purifiers (PAP) for de-odorizing


UV light emitter for checking Ozone meter
ECO SENSORS

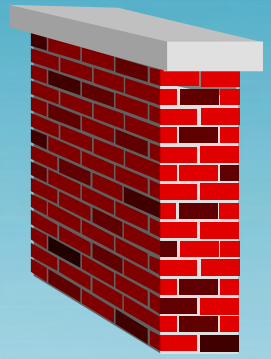
Radon (Rn)



Excellent Class: less than 150 Bq/m^3

Good Class: less than 200 Bq/m^3

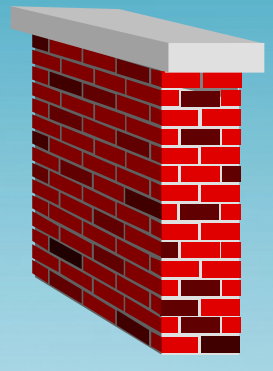
Radon (Rn)



- A radioactive gas that has no taste, smell nor color
- It is formed when radium (Ra-226) found in soils and rocks, particularly granite. (Ra-226) is the source of gaseous Rn-222 emission.

$$^{226}Ra \rightarrow ^{222}Rn \rightarrow ^{218}Po \rightarrow ^{214}Bi \rightarrow \rightarrow \rightarrow ^{210}Pb$$

Radon (Rn)



- Comes from soil gas entry and building materials emission
- High radon level when HVAC system is off and when a large amount of granite decoration materials exist
- Health effects:
  - When radon or its decay products are inhaled, some will be deposited in lung and will continue to emit radiation
  - Cause lung cancer in underground miners and it is the second main cause of lung cancer

Radon (Rn)

“Control of Radon Concentration in New Buildings” to set out:

- The radon concentration limit for protection of the public health
- Factors to be considered for he design of new ventilation systems and building and mitigation measures
- The measurement protocols.

Radon Durridge RAD7 711

Respirable Suspended Particulate (RSP)

Excellent Class: less than 20 $\mu g/m^3$

Good Class: less than 180 $\mu g/m^3$

Respirable Suspended Particulate (RSP)

- In the form of PM_{10}
- Can be treated by a good air filtration system but part of it will still get into the indoor environment
- Both organic and inorganic matters can be attached on it. Health effect is complicated.
- High RSP level in smoking zone where Environmental Tobacco Smoke (ETS) exists
- Use of standalone air cleaning devices

Respirable Suspended Particulate (RSP)

- Combustion particulates (tobacco smoke, emissions from cooking, heating appliances, and incense burning
- Animal particulates (pollen and insect parts)
- Microbial particulates (bacteria, virus, mould and spores)
- Mineral particulates (asbestos)
- Radioactive particulates

Respirable Suspended Particulate (RSP)

- Health impacts:
  - smoke particles from combustion cause respiratory irritation and infection
  - itching and irritation to the skin, eyes, nasal & upper respiratory system
  - aggravation of existing respiratory or cardiovascular disease
  - lung cancer

Airborne Bacteria and Fungi

Excellent Class: less than 500 cfu/m^3

Good Class: less than 1000 cfu/m^3

Airborne Bacteria and Fungi

Definition of Bioaerosol

Bioaerosols are airborne particles, large molecules or volatile compounds that are living, containing living organism or are released from a living organism.

Definition quoted from the ACGIH guidebook for the assessment of bioaerosol in the indoor environment

Airborne Bacteria and Fungi

- The size of bioaerosol particles may vary from 0.01 micron to 100 micron

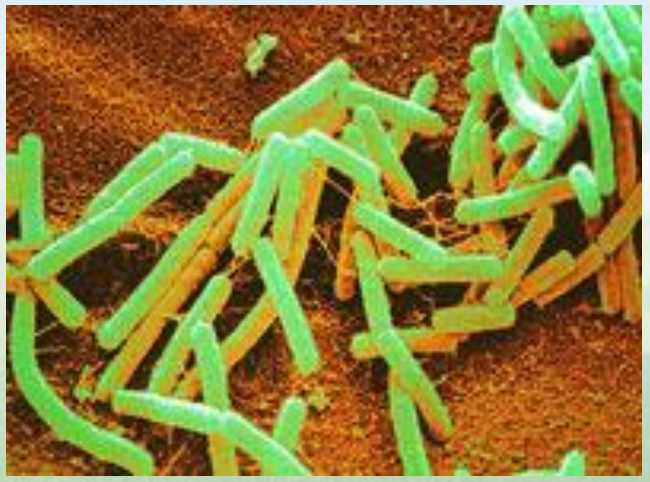
- Similar to ordinary non-viable particle, the behavior of bioaerosols are governed by the principles of gravitation, electromagnestism, turbulence and diffusion

Airborne Bacteria and Fungi

Microbes

They are minute particles of living matter which occur in three main forms generally known as

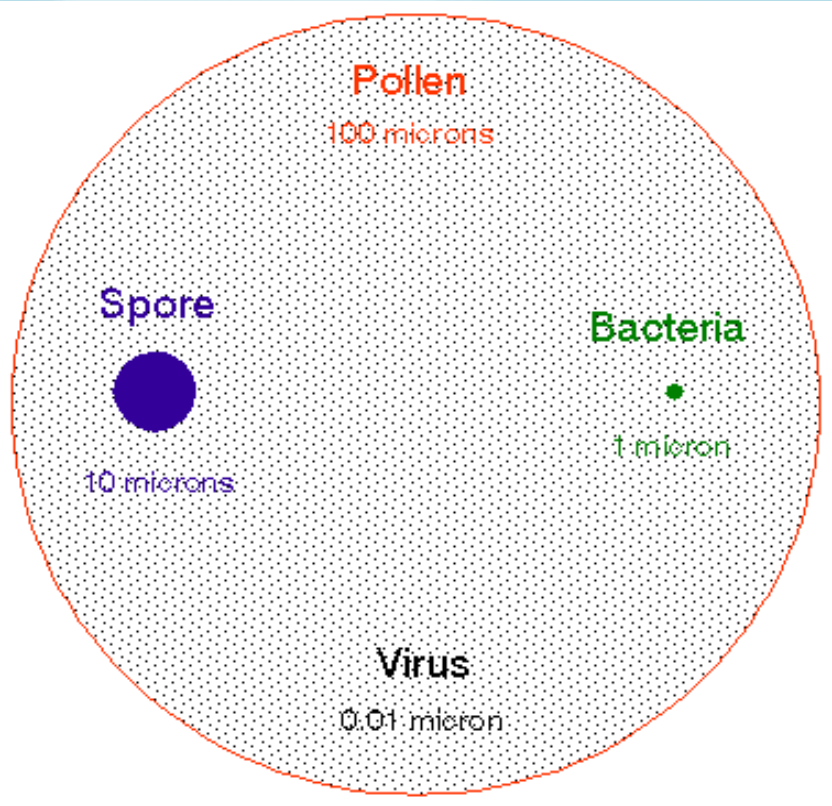
- Viruses
- Bacteria
- Fungi



Airborne Bacteria and Fungi

Size Comparison

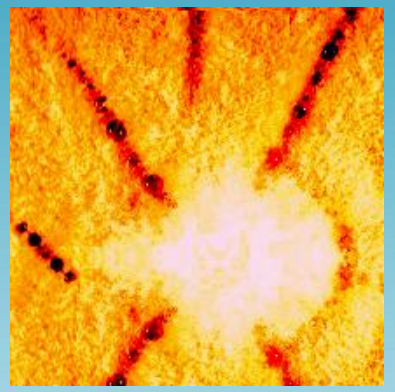
In this diagram, approximately 100,000 of these virions fit within the 100 micron circle representing the pollen.



Bacteria

- High counts of environmental bacterial such as Staphylococcus epidermis, Micrococcus, and Flavobacterium shed from skin flakes indicate inadequate poor ventilation.
- The presence of bacteria in indoor environment does not necessarily imply that human infections.
- Legionella pneumophilia, Mycobacterium tuberculosis, and Corynebacterium diphtheria are of IAQ concern.
- Outbreaks of Legionnaires' disease in the past occurred in buildings that had air-conditioning systems with cooling towers or evaporative condensers
- Endotoxin present in outer cell wall of gram-negative bacteria is associated with sick building syndrome

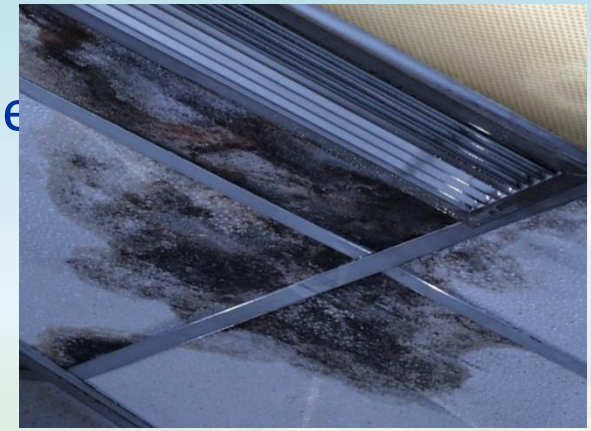
Fungi

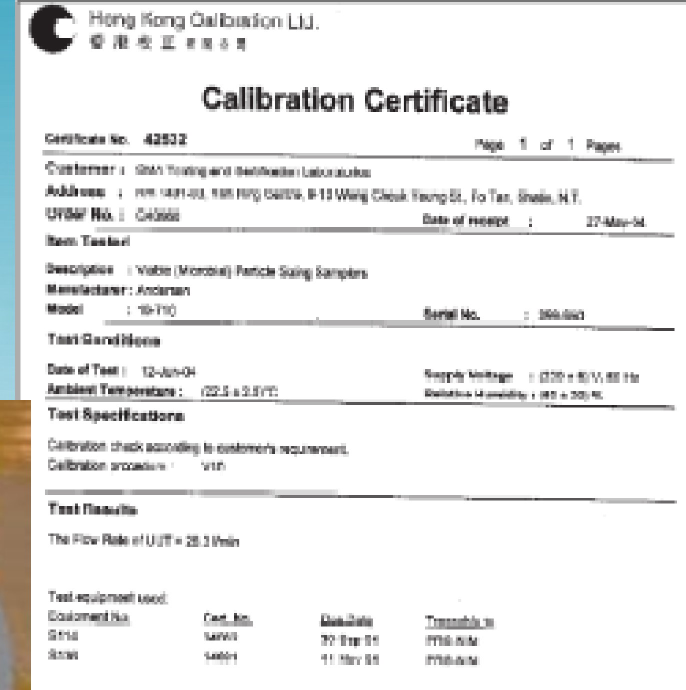


- Fungal growth favored by high temperature and high humidity
- Most fungi can induce allergic and asthmatic reactions in human
- Proliferation of fungi can produce VOCs that contributes to mouldy smell
- The VOCs are thought to contribute to SBS
- Examples of toxigenic fungi: Stachybotrys atra, toxigenic Aspergillus, Penicillum aurantiogrisem, Cryptococcus and Histoplasma.

Airborne Bacteria and Fungi

- Problem with poor HVAC system and carpet environment
- Damp environment and still air favor the growth of micro-organisms
- Health impact:
  - health effect is complicated
  - some bacteria can be fatal and some cause allergic effect





Hong Kong Calibration Ltd.

Calibration Certificate

Certificate No. 42532 Page 1 of 1 Pages

Date of receipt : 27-May-04

Item Tested

Description : Viable (Microbial) Particle Sizing Samplers
Manufacturer : Andersen
Model : 10-710

Test Conditions

Date of Test : 12-Jun-04

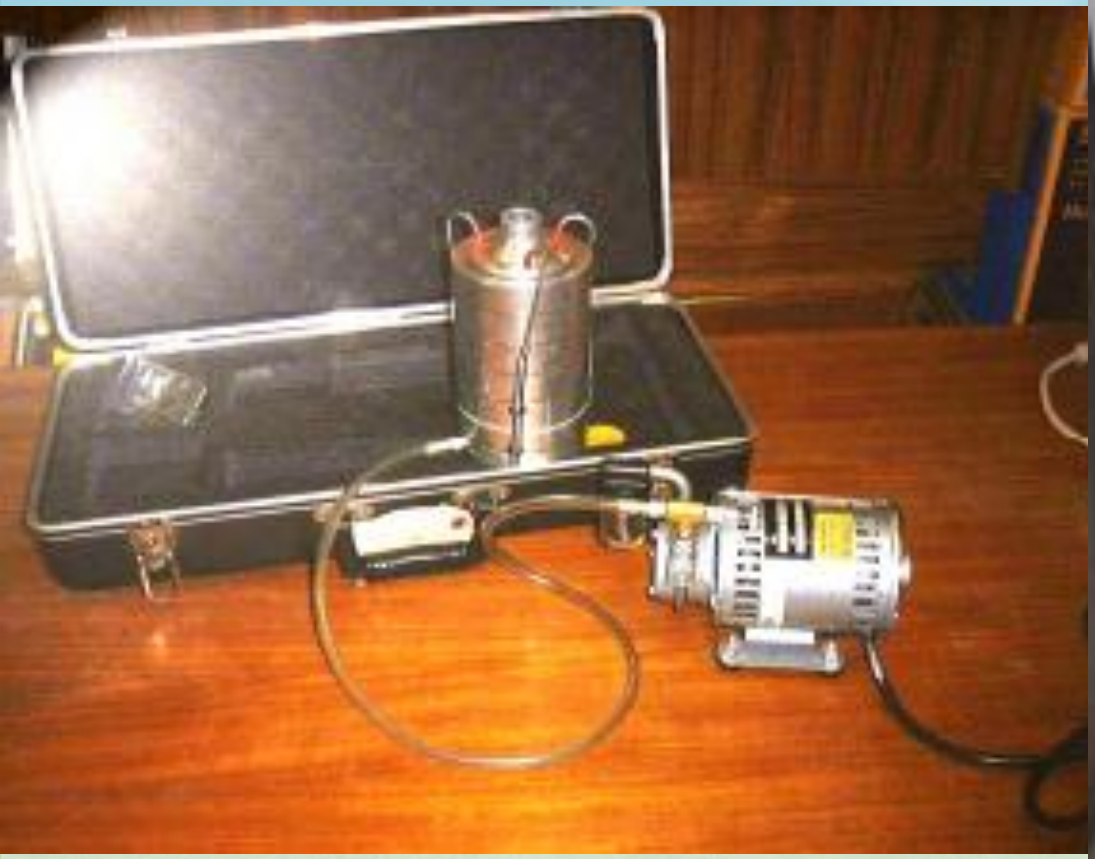
Test Specifications

Calibration check according to customer's requirement.

Test Results

The Flow Rate of U.U.T = 28.3 l/min

Test equipment used:




COLONY
COUNTER
11