Department of Technologies and Installations for Waste Management

Emission and Transport of Air Pollutants

Lecture 3

Methods of emission measurement

1

Measurement

- ***Emission measurement***
- ***Air pollution measurement***
- ***Meteorological condition measurement***

2

Emission

- ***Emission –*** *direct or indirect introduction* ***to air****, water or soil of* ***substance*** *or energy in form of heat, noise (of frequency 16 Hz to 16 kHz), vibration or electromagnetic field* ***in the result of human activity****.*
- ***Emission,*** *which may be harmful for human being or environment, is called* ***pollution.***

3

Emission

- ***Emission of pollution*** *is expressed in mass unit of the substance related to time unit, e.g.* ***g/s****,*
- ***Emission index*** *is indirect way of emission expression, like* ***g/Mg, g/GJ,***
- ***Concentration of substance*** *is expressed as mass unit related to total volume, e.g.* ***g/m³****,*
- ***Concentration*** *is also expressed as a number of substance particles (or volume) to total amount of paricles (or total volume):*
  - ***ppm*** *– parts per million,*
  - ***ppb*** *– parts per billion, etc.*

4

Emission

Units conversion

$$S_i\ (\%) = (V_i / V)100$$

$$S_i\ (ppm_v) = (V_i / V)10^6$$

$$S_i\ (mg/m^3_{st}) = S_i\ (ppm_v) M_i / 22{,}42$$

5

Emission measurement

Quantities, which are measured in combustion process:

- temperature,
- gas composition:
  - **CO, CO_2, O_2,**
  - **NO_x, SO_2, hydrocarbones,**
  - **fly ash,**
- streams of air, fuel and exhaust gas.

6

Emission measurement – gas analyzers

- NDIR analyzer – measurement of CO, CO_2, NO, SO_2,
- FTIR analyzer - measurement of any substance,
- FID analyzer – measurement of sum of hydrocarbons,
- CLD analyzer – measurement of NO_x,
- electrochemical analyzer – measurement of O_2, CO, CO_2
- chromatography – measurement of any substance,
- dust analyzer: gravimetric analyzer, optical analyzer

7

Emission measurement – gas conditioning

- gas sampling – probe,
- prefiltration – dust removal (above 0,2 μm),
- gas transport – heated line,

- drying – moisture removal (a separate device, or mounted in analyser).

8

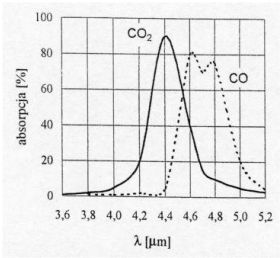
Emission measurement – NDIR analyzer

NDIR analyzer - *Non-Dispersive InfraRed* – applied to measurement of CO_2, CO, NO i SO_2.

Principle of operartion:
- comparision of infra-red radiation absorption by two gases:
  - tested gas,
  - standard gas.

9

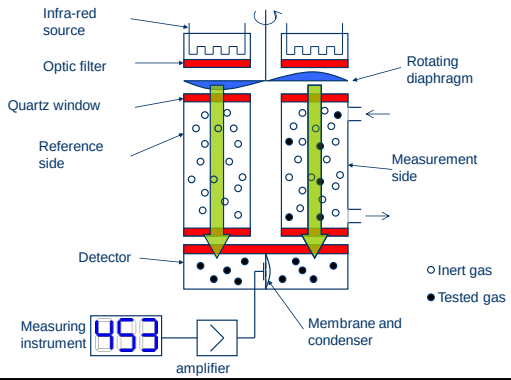
Emission measurement – NDIR analyzer



Absorption of infra-red radiation by CO i CO_2

10

Measuring principle for NDIR



Emission measurement – NDIR analyzer – example device

- measurements of gases which absorb IR (infrared) in wavelength of 2-9 μm: CO, CO_2, NO, SO_2, NH_3, H_2O, CH_4,
- minimum range: CO 0-10 ppm, CO_2 0-5 ppm,
- maximum range: on require

NDIR BA 6000-IR analyzer

12

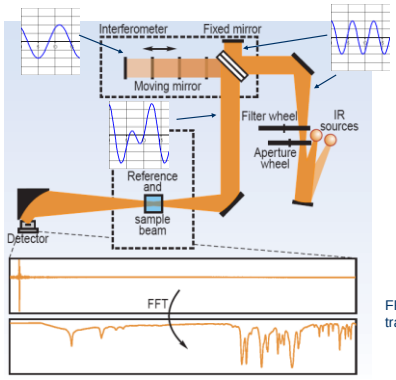
Emission measurement – FTIR analyzer

FTIR analyzer - *Fourier Transform Infrared Spectroscopy*

Principle of operation:
• similar to NDIR,
• FTIR uses very wide scope of wavelenght, which makes possible to measure many gases simultanouesly.

13

Emission measurement – FTIR analyzer



interferogram

FFT – fast Fourier transformation

IR spectrum

Emission measurement – FTIR analyzer – example device

FTIR CX-4000 i DX-4000 analyzers

CX-4000 (stationary)

DX-4000 (portable)

15 • simoltanoeus measurement up to 50 gases, like HF, HCl, NO, NO_2, N_2O, CO, CO_2, SO_2, H_2O, NH_3

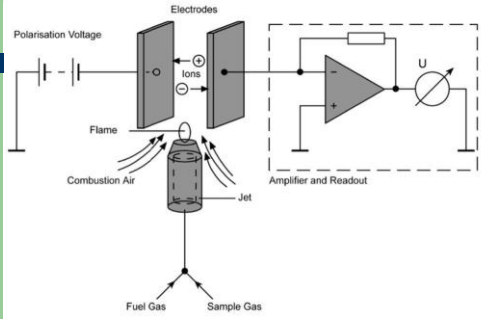
Emission measurement – FID analyzer

FID - *Flame Ionization Detector*
• measurement of total organic hydrocarbons *(THC)*

Principle of operation:
• based on phenomenon of hydrogen flame ionization.

16

Emission measurement – FID analyzer



17

Emission measurement – FID analyzer – example devices

EuroFID (stationary)

FID3006 (portable)

18 • minimum range: 1 ppm
• maximum range: 100%, related to C_3H_8

• minimum range: 10 ppm
• maksimum range: 10%, related to C_3H_8

Emission measurement – CLD analyzer

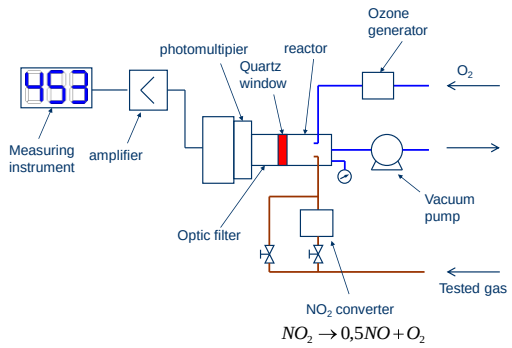
CLD - ChemiLuminescence Detector
• measurement of NO_x

Principle of operation:
• method based on phenomenon of electromagnetic radiation emission of wavelength 0,6-3 nm in reaction:

$$NO + O_3 \rightarrow NO_2 + O_2 + h\nu$$

19

CLD detector - principle of operation



$$NO_2 \rightarrow 0{,}5NO + O_2$$

Emission measurement – CLD analyzer – example device

600-HCLD analyzer

• four range measurement of NO or NO_x from 0-1 ppm to 0-3000 ppm

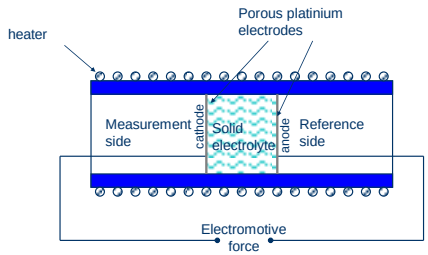
21

Emission measurement – electrochemical analyzer

Principle of operation:
• electrochemical reaction of tested gas,
• measurement of electrochemical signal,
• measurement of O_2, SO_2, CO

22

Principle of operation of O_2 analyzer



cathode: $O_2 + 4e^- \rightarrow 2O^{2-}$ anode: $2O^{2-} \rightarrow O_2 + 4e^-$

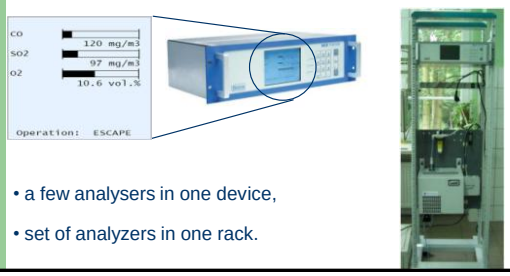
Emission measurement – electrochemical analyzer – example device

Electrochemical analyzer C-101

• measurement range O_2: 0,1-25%

24

Emission measurement - complex solution



- a few analysers in one device,
- set of analyzers in one rack.

25

Chromatography

- is a technique of mixture separation useing different speed of adsorption and desorption of individual components,
- In gas chromatography (GC), separation of analyts takes place between two phases:
  - a solid stationary phase (solid material or often a liquid silicone-based material)
  - and a mobile phase - gas (most often Helium, Argon, N_2) used for transport of analysed mixture.

26

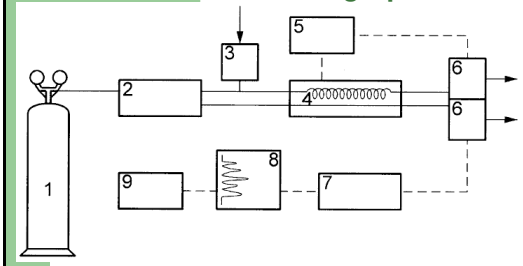
Chromatography

Adsorption - process of bounding of gaseous or liquid substances on surface of solid phase.

Desorption – process of releasing adsorbed gas or liquid components from solid phase.

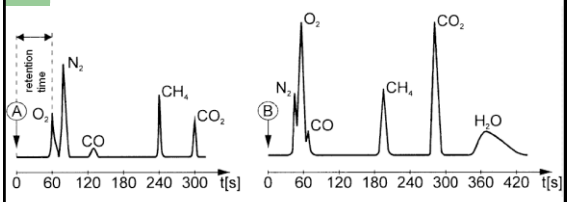
27

Chromatograph



1 – gas bottle (He) ; 2 – gas stream regulator; 3 – sampler; 4 – packed or capillar column; 5 – temperature regulation of column and detector; 6 – detector; 7 – amplifier; 8 – register; 9 – integrating unit.

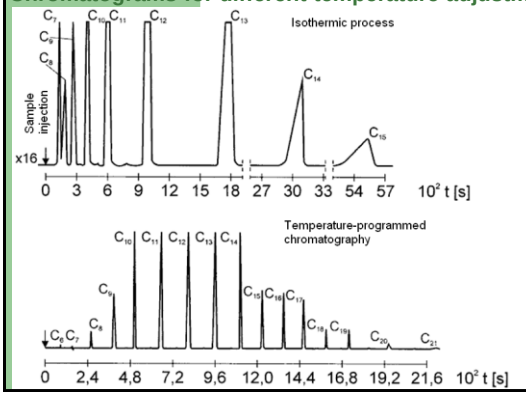
Result - chromatogram



Well matched separation

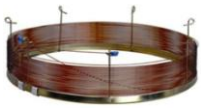
Badly matched separation

Chromatograms for different temperature adjustment



Chromatography

Gas chromatography is always carried out in a column, which is typically "packed" or "capillary". The stationary phase is adhered to the inside of a small-diameter glass or metal tube.

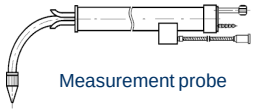


Gas Chromatograph GC-17A

31

Emission measurement – fly ash Gravimetric method

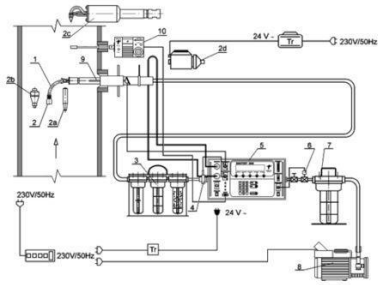
Gravimetric method – isokinetic measurement of fly ash contained in exhaust gas.
Sample gas is sucked with the same velocity as there is in duct. Dust is separated on filter.



Measurement probe

32

Scheme of ash gravimetric device



1 – probe; 2 – ash separator; 3 – moisture separator;
4 – higrometer module; 5 – control unit; 6 – valves;
7 – equlizing tank; 8 – suction agregate; 9 – thermocouple;
10 – measurement of reference parameters

Emission measurement – fly ash example device

Control unit EMIOTEST^{R} 2598

34

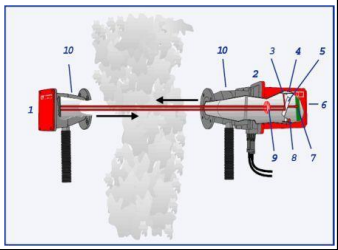
Set to measurement fly ash, gas stream and PCDD/Fs, PAH and metals

35

Emission measurement – fly ash Optic method

Measurement of abatement of light beam passing through exhaust gas.

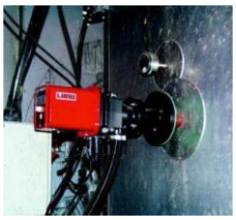
1 – reflector
2 – transmitter and receiver
3 – reference detector
4 – measurement detector
5 – beam splitter
6 – control pannel
7 – measurement diode
8 – reference diode
9 – lens
10 – air blow



36

Emission measurement – fly ash Optic method – example device

range: 0-999 mg/m^3 or opacity 10-100%



37

Emission

- www.stat.gov.pl/gus/publikacje (Ochrona Środowiska 2009)

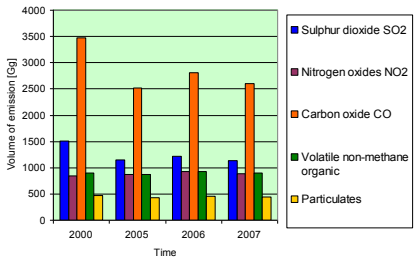
38

Total emission of main air pollutants in Poland, in gigagrams, [GUS]

Specification	2000	2005	2006	2007
Sulphur dioxide SO_2	1511	1145	1222	1131
Nitrogen oxides NO_2	844	875	921	885
Carbon dioxide CO_2	320588	318216	329599	328172
Carbon oxide CO	3472	2521	2804	2603
Volatile non-methane organic	904	867	929	898
Ammonia NH_3	322	271	287	292
Particulates	464	430	458	436

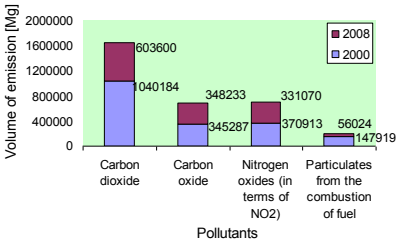
39

Total emission of main air pollutants in Poland



40

Air pollutants emission from plants especially noxious to air purity in 2000 and 2008 in Poland



41

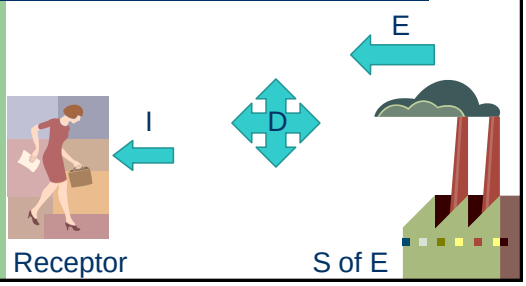
Air Pollution – Imisja – Pollution concentration in air

- **Air pollution** means an amount of a given particulate or gas pollutant per volume unit of air (also known as pollution concentration) – **IMISJA (μg/m^3)**

  Pollution concentrations are used to estimate the level of air pollution by comparing them with permissible levels of substances in the air.

42

Source of Emission, Emission, Dispersion, Air pollution (I), Receptor



43

Pollution dispersion in the air

- **Dispersion** – transport and diffusion prosesses of pollution
- **Wet deposition –** is the mass of substances or a chemical element introduced to the surface together with atmospheric precipitation. A monthly wet deposition is calculated as a product of an average concentration of a substance and a monthly sum of precipitation. An annual wet deposition is calculated on the basis of monthly sums.
- **Dry deposition –** pollution movement to the surface
- **Deposition by mist and cloud droplets –** direct introduction of pollution from mist and droplets of clauds to receptor

44

Air pollution

- **Admissible air pollution standards** were established by the virtue of the Ordinance of the Minister of Environment.
- Comparison of measured air pollution concentrations to admissible air pollution standards is used to control of air pollution degree.

45

Pollution standarts

(Dz.U. nr 16, poz. 87, 2010 rok)

Pollution standards cover 167 substances. The substances are determined in w ***μg/m³ of air*** *by areas:*
- ***spa areas,***
- ***other areas***

and by
- ***1 hour concentrations,***
- ***and annual average (calendar year) concentrations.***

46

Air pollution monitoring

In ***air pollution monitoring*** *are used methods:*
- *passive method,*
- *aspiration method,*
- *isolation method.*

47

Air pollution monitoring

- ***Passive method*** *of monitoring consist of* ***1-month exposition*** *of special samplers hang on 3 m above ground. Samplers contain* ***absorptive disk*** *made from blotting paper saturated 0,1 ml, 20% triethanolamine water solution.*
- *Monitored gases:* ***NO_2, SO_2*** *penetrate (by diffusion) into sampler where are absorbed on disk. After the exposition period samplers are analysed on ion chromatograph.*

48

Air pollution monitoring

- *In **aspiration method** well known air quantity is intaken and passed through liquid or solid sorbent. It is used in case of **low concentration of pollution.***

49

Air pollution monitoring

- *In **isolation method** defined air quantity is taken into container and next analysed. It is used in case of **high concentration of pollution.***

50

Air pollution measurement

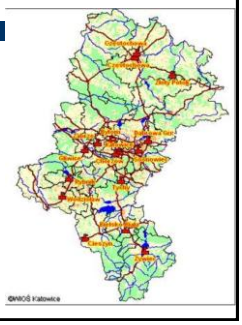
- National and regional (local) air monitoring system
- Analysed substances: fly ash, SO_2, NO_2, CO, O_3, CH_4, aliphatic hydrocarbons (calculated as CH_4), aromatic hydrocarbons (total).

51

Air monitoring station system in Silesia district

12 automatic container stations

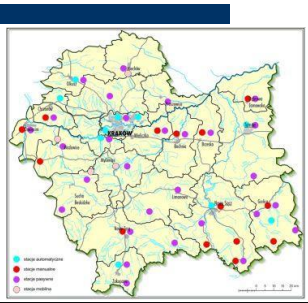
http://www.katowice.pios.gov.pl
http://stacje.katowice.pios.gov.pl



52

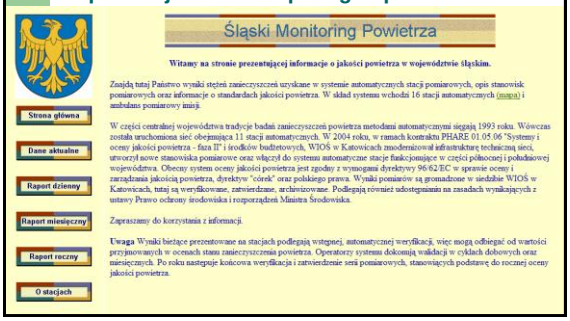
Air monitoring station system in Małopolska district

- Automatic station
- Manual station
- Passive station
- Mobile station



53

Silesian air monitoring system
http://stacje.katowice.pios.gov.pl/iseo/



Silesian air monitoring system
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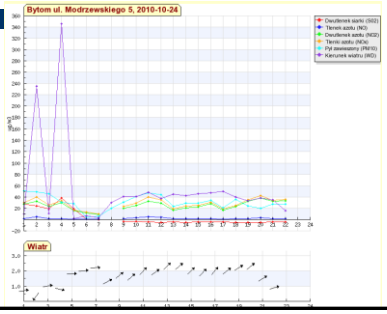
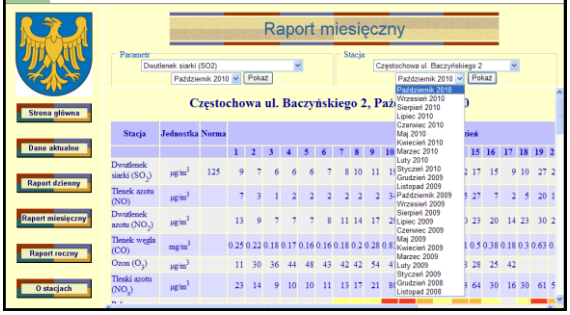


56

Silesian air monitoring system
http://stacje.katowice.pios.gov.pl/iseo/



Silesian air monitoring system
http://stacje.katowice.pios.gov.pl/iseo/

Measurements in Silesia voivodeship

- Total suspended ash – weight method PN–84/Z–04030/02.
- SO_2 measurement – by means of pararosaniline hydrochloride and formaldehyde
- NO_2 measurement by means of spectrophotometry method, according to PN-89/Z–04092/08.

59

Measurements in Silesia voivodeship

- Measuring analyzers for SO_2:

- Advanced Pollution Instrumentation
- Environnement AF 21 M
- Dasibi Environmental 4108 W/PERM
- Horiba ASPA – 350 E
- Monitor Labs

- Measuring analyzers for NO_2:

- Advanced Pollution Instrumemntation
- Environnement AC 30 M
- Horiba ANPA-350E
- Monitor Labs

60

Measurements in Silesia voivodeship

- Measuring analyzers for suspended ash of particles below10 μm:
- Horiba FH 62 I-N-ADPA 351 E
- Rupprecht and Patashnick TEOM PM10
- AMIZ
- Measuring analyzers for CO:
- Horiba APMA –350 E
- Monitor Labs
- Measuring analyzers for O_3:
- Advanced Pollution Instrumentation API 400
- Horiba APOA – 350 E
- Monitor Labs

61

Air Monitoring System in the US

- **There are 3 types of ambient monitoring networks in Nevada:**
- SLAMS: State or Local Air Monitoring Stations
- SPMS: Special Purpose Monitor Stations
- NAMS: National Air Monitoring Stations

62

Air monitoring station system in Gliwice (Sikornik, Mewy 34)

Measured Parameters:
- SO_2
- NO_2
- NO
- NO_x
- PM10
- Meteorological Parameters:
  - Wind direction
  - Wind velocity
  - Air Temperature
  - Air relative humidity
  - Total radiation
  - Air-pressure
  - Precipitation

63

Air monitoring station system in Bielsko - Biała

64

Dust particle monitoring system

$C_t = (m_2 - m_1)1000/V$ mg/m$^3_{st}$

$m_{1,2}$ – mass of filter (without and with dust)
V – volume of air (air stream*time)

65

Ash concentration

Fly ash concentration in air mg/m^3

$$C_c = \frac{m_2 - m_1}{V} * 1000$$

where:

m_2 – mass of filter with ash, mg,
m_1 – mass of filter without ash, mg,
V - volume of air calculated as multiplication of air flow and time , dm^3.

66

Mobile trailer for ambient gas monitoring

67

Meteorological condition measurement

- **Measurements:**

- Wind direction
- Wind velocity
- Air Temperature
- Air relative humidity
- Air-pressure
- Total radiation
- Precipitation

68

Heliograph - the Campbell–Stokes sunshine recorder

A quartz glass sphere, ~ 10 cm in diameter, mounted on top ~2,2 m stand.

69

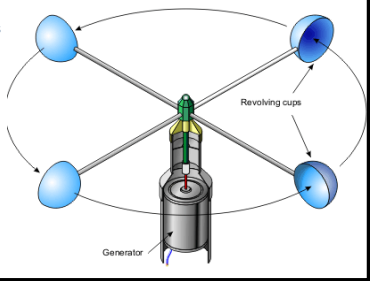
Heliograph - the Campbell–Stokes sunshine recorder

As sunlight passes through the sphere, it becomes focused and burns a "line" through a piece of treated paper which is positioned beneath the quartz glass sphere.
Any break in the "burn line" is indicative of cloud cover. The treated paper is marked in such a way that the time of cloud cover occurrence can be determined.

70

Cup (Robinson) Anemometer

Each time the anemometer completes a full rotation, the magnet on the cup is detected by a reed switch, triggering an output pulse proportionate to the wind speed. The number of pulses is counted over a period of time, and converted into an average **wind speed** that is recorded on a display or weather station.



71

The rotating cup anemometer

Wind speed and direction are normally measured at a height of 10 m above the surface.

72

Precipitation measurement

- **Atmospheric precipitation samples** collected in accordance with a Polish Standard on atmospheric precipitation examination PN-91/C-04642.02. These are 24 h samples, so-called precipitation samples, the sampling of which starts at 6.00 GMT and lasts for 24 h. The samples are collected into sterile PE container, with an inlet are at the height of 1.5 m above the ground. Collected samples are analysed in the laboratories with various analytical methods. The value of concentration for a particular period is calculated as a weighted average, where the weight is a 24 h sum of precipitation.

73

Hellmann rain-gauge, pluviometer

The top funnel of the instrument catches rain and delivers it to the measuring cylinder.

74

Pluviometer

In Poland is used Hellmann pluviometer of inlet area of 200 cm^2 or 500 cm^2 in the mountain.

75

Questions for exam

1. What is the difference between emission and air pollution?
2. Convert 450 ppm NO_2 to mg/m^3_{st}
3. Why emission and air pollution are measured?
4. What composition of air pollution is meassured in monitoring stations?
5. What is the principle of NDIR and FTIR analyzer?
6. What is the principle of FID analyzer?
7. What is measure in meteorological stations?
8. What Helilograf and Anemometer is used for?
9. Methods of fly ash measurements.
10. Kind of pollution deposition.

76