Department of Technologies and Installations for Waste Management

Emission and Transport of Air Pollutants

Lecture 6

Gas pollutants dispersion

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Regulation act of Environment Ministry concerning reference values of some substance in ambient air (Dz. U. nr 16, poz. 87 z 2010 roku)

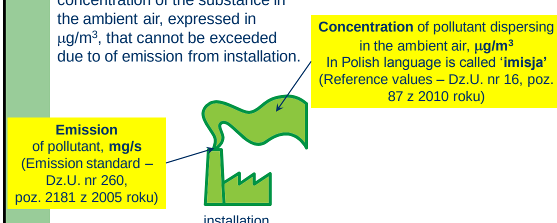
• on the ground of 222 article of **Environment Protection Law** (Dz. U. nr 62, poz. 627 from 2001 with later changes).

Art. 222.

1. W razie braku standardów emisyjnych i dopuszczalnych poziomów substancji w powietrzu ilości gazów lub pyłów dopuszczonych do wprowadzania do powietrza ustala się na poziomie niepowodującym przekroczeń:
   a) wartości odniesienia substancji w powietrzu,
   b) wartości odniesienia substancji zapachowych w powietrzu.
2. Minister właściwy do spraw środowiska, w porozumieniu z ministrem właściwym do spraw zdrowia, określi, w drodze rozporządzenia, wartości odniesienia dla niektórych substancji w powietrzu.

Reference values of substances

Reference value is the highest concentration of the substance in the ambient air, expressed in μg/m^3, that cannot be exceeded due to of emission from installation.



Reference values of substances (Dz. U. nr 16, poz. 87 z 2010 roku)

• Emitted substance is dispersed in the atmosphere by means of spreading, transport and diffusion phenomenon.

• Concentration of dispersed substance cannot exceed the reference value.

Dispersion of substance depends on:

- emission,
- emission source parameters: height, outlet diameter, as well as velocity of exhaust gas and its temperature,
- climate conditions – wind, temperature, precipitation (rain, snow, hail),
- terrain roughness.

Regulation act (Dz. U. nr 16, poz. 87 z 2010 roku) contains:

- reference values for some substances in ambient air (incl. numerical designation and average period) – appendix 1 and 2,
- conditions in which reference values are expressed, i.e.: 293 K; 101,3 kPa,
- reference methods of modeling the value of substance in the ambient air – appendix 3.

Regulation act contains reference values, average in period of: one hour – D_1, one year– D_a,

Substance number in act

Number according to CAS – Chemical Abstract Service Registry Number

Average reference value for one hour and one year

Tabela 1

Lp.	Nazwa substancji[1)]	Oznaczenie numeryczne substancji (numer CAS)[2)]	Wartości odniesienia w mikrogramach na metr sześcienny (µg/m³) uśrednione dla okresu	
			jednej godziny	roku kalendarzowego
1	Acetaldehyd (aldehyd octowy)	75-07-0	20	2,5
2	Aceton	67-64-1	350	30
3	Acetonitryl	75-05-8	20	2,5
4	Akrylaldehyd (akroleina)	107-02-8	10	0,9
5	Akrylonitryl	107-13-1	5	0,5
6	Alkohol furfurylowy	98-00-0	100	13
7	2-Aminoetanol (etanoloamina)	141-43-5	30	1,6

Basic terms

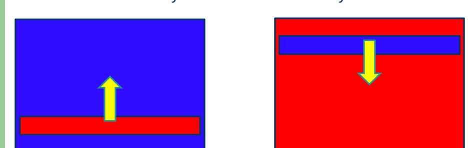
- **Substance background** is present **content of substance in the air**, which is given by **Environment Protection Inspectorate**, and expressed as **average concentration in the year**.
- **For other substances** (not given by Inspectorate), the background is **10% of reference value** average in the year.
- **Ash background** is **10% of reference value** of ash deposition.

Basic terms

Atmosphere equilibrium state - change of air temperature with altitude (thermal vertical gradient).

Atmosphere equilibrium state

Differences of air density causes moves of air layers :



Warmer air soars

Colder air falls

- warmer air (lower density)
- colder air (higher density)

Atmosphere equilibrium state

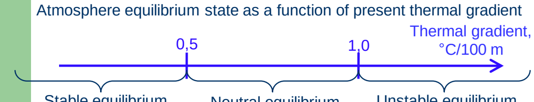
- Temperature of the air falls down as altitude grows.
- Rate of this process depends on moisture content.

Atmosphere equilibrium state

Air cooling rate along height

Air	Cooling rate, °C/100m	Thermal gradient
Dry (not saturated)	1	Dry-adiabatic
Wet (saturated)	0,5	Wet-adiabatic

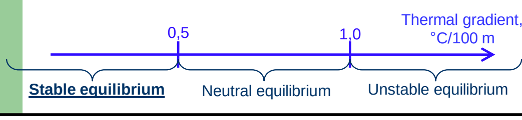
Atmosphere equilibrium state as a function of present thermal gradient



Atmosphere equilibrium state

■ stable equilibrium state occurs when present thermal gradient is lower than wet-adiabatic (0,5°C/100 m), i.e. temperature drop is e.g. 0,3°C per 100 m;

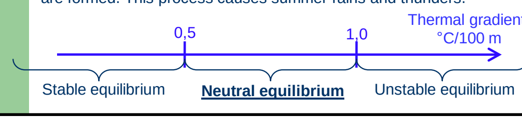
In such conditions, each portion of air (dry or wet) becomes finally cooler than the ambient one, and falls down (lack of convection).



Atmosphere equilibrium state

■ neutral equilibrium state occurs when present thermal gradient is between wet-adiabatic (0,5°C/100 m) and dry-adiabatic (1°C/100m), i.e. temperature drop is e.g. 0,6°C per 100 m;

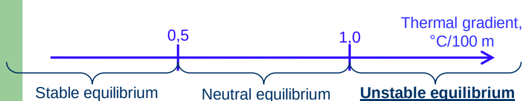
This state is most common one. Soaring of non-saturated air in this state is frequently caused by atmospheric front, or terrain topography (mountains). When air is wet enough, on certain level it becomes saturated, and then condensation process takes place, and clouds are formed. This process causes summer rains and thunders.



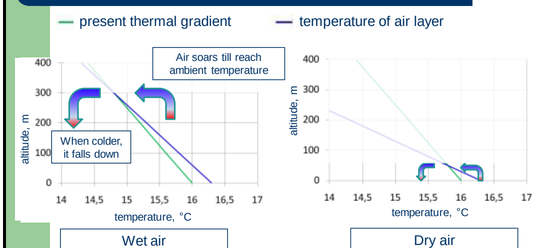
Atmosphere equilibrium state

■ unstable equilibrium state occurs when present thermal gradient is higher than dry-adiabatic (1°C/100m), i.e. temperature drop is e.g. 1,2°C per 100 m;

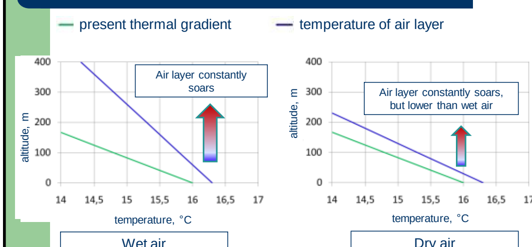
In this state each portion of air constantly soars, because it is warmer than the ambient one. This state is typical near to the surface, during hot and sunny days.



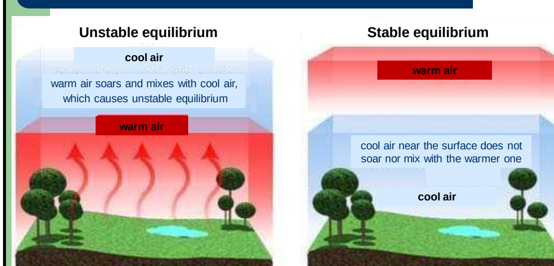
Example conditions for **stable equilibrium**:
- present thermal gradient: 0,4 °C/100 m
- ambient temperature: 16 °C
- air temperature near the surface: 16,3 °C



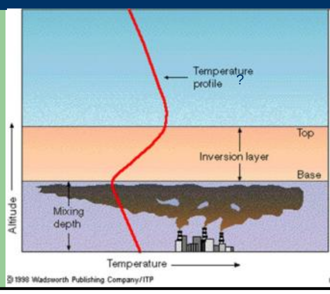
Example conditions for **unstable equilibrium** :
- present thermal gradient : 1,2 °C/100 m
- ambient temperature: 16 °C
- air temperature near the surface: 16,3 °C



Atmosphere equilibrium state



Inversion layer



Inversion is state of the atmosphere, where temperature grows along altitude.

$$\frac{\mathrm{d}T}{\mathrm{d}z} > 0$$

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Influence of atmosphere stability on pollutant dispersion

Real gradient – change of ambient temperature with altitude

Adiabatic gradient – change of moving portion of air with altitude

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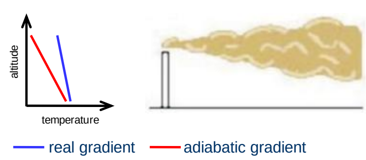
Influence of atmosphere stability on pollutant dispersion

Stable state – lack of vertical moves of pollutants



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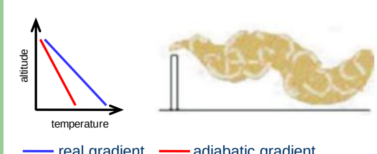
Influence of atmosphere stability on pollutant dispersion

Unstable state – vertical moves of pollutants



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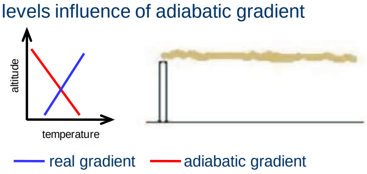
Influence of atmosphere stability on pollutant dispersion

Inversion phenomenon – inversion in atmosphere levels influence of adiabatic gradient



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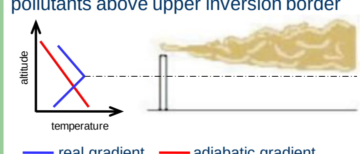
Influence of atmosphere stability on pollutant dispersion

Lower inversion phenomenon – dispersion of pollutants above upper inversion border



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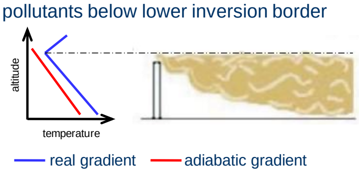
Influence of atmosphere stability on pollutant dispersion

Upper inversion phenomenon – dispersion of pollutants below lower inversion border



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Atmosphere equilibrium states

Regulation act contains six equilibtium states:

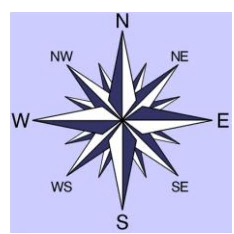
- extremly unstable,
- unstable,
- lightly unstable,
- neutral,
- moderately stable,
- stable.

Meteorological situation is described by atmosphere equilibrium state and wind velocity. Regulation act defines 36 meteorological situations.

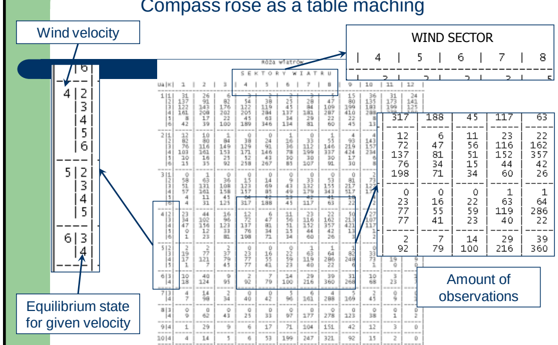
Atmosphere equilibrium state	Wind velocity, m/s (at altitude 14 m)
1 – extremly unstable	1 – 3
2 – unstable	1 – 5
3 – lightly unstable	1 – 8
4 – neutral	1 – 11
5 – moderately stable	1 – 5
6 – stable	1 – 4

Wind velocity is defined with precision to 1 m/s

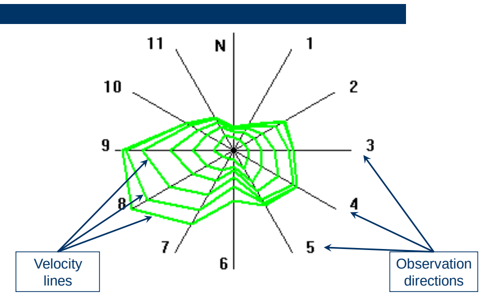
Compass rose – statistical matching of observations amounts of meteorological situations (atmosphere sate and wind velocity) in 12 or 16 directions.



Compass rose as a table maching



Graphical form of compass rose



Terrain roughness factor – describes aerodynamic roughness of terrain by means of number coefficient z_0.

No.	Type of terrain	Factor z_0
1	water (lakes, etc.)	0,00008
2	meadows, grass-lands	0,02
3	fields	0,035
4	orchards, thickets, copses	0,4
5	forests	2,0
6	Dense rural buildings	0,5
7	Towns up to 10000 inhabitants	1,0
8	City between 10 000 to 100 000 inhabitants	
8.1	- low buildings	0,5
8.2	- high buildings	2,0

No.	Type of terrain	Factor z_0
9	City between 100 000 to 500 000 inhabitants	
9.1	- low buildings	0,5
9.2	- medium buildings	2,0
9.3	- high buildings	3,0
10	City above 500 000 inhabitants	
10.1	- low buildings	0,5
10.2	- medium buildings	2,0
10.3	- high buildings	5,0

$$z_0 = \frac{1}{A}\sum_i A_i \cdot z_{0i}$$

Basic terms

Maximal concentration S_m – maximal concentration of gas substance, averaged for one hour, **in particular meteorological situation** (for ash is denoted by S_{mp}). For each substance S_m is calculated for each meteorological situation (total 36 values for each substance).

Distance x_m – distance between emission point and point of the maximal concentration S_m (or S_{mp} for ash).

Basic terms

The highest maximal concentration S_{mm} – the highest value among all 36 values of maximal concentration S_m for particular substance.

Distance x_m – distance between emission point and point of the highest maximal concentration S_{mm}.

Ash deposition criteria – for single emission source (or for set of considered sources), below conditions should be fulfilled:

1) $$\sum_f \sum_e \bar{E}_{fe} \leq \frac{0{,}0667}{n} \sum_e h_e^{3{,}15}$$

where: f – number of ash fraction,

e – emission source number (from 1 to n),

n – amount of emission sources,

$\bar{E}_{fe}$ – average emission of particular ash fraction f for emission source e for calculation period, mg/s

h_e – height of emission source, measured from ground level , m

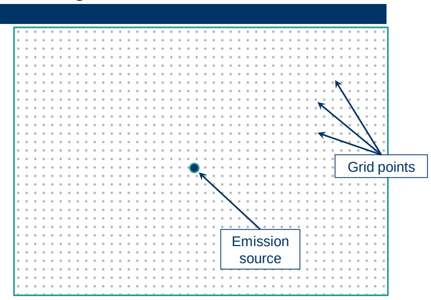
Ash deposition criteria – for single emission source (or for set of considered sources), below conditions should be fulfilled:

2) total ash emission does not exceed 10 000 Mg,

3) cadmium emission does not exceed 0,005% of calculated ash emission,

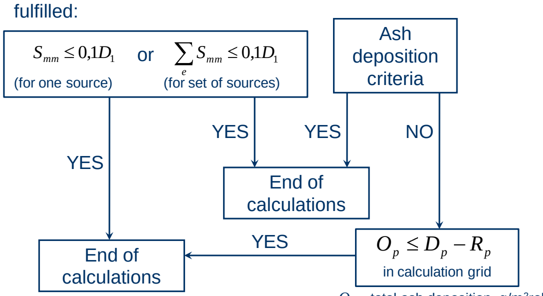
4) lead emission does not exceed 0,05% of calculated ash emission.

Calculation of concentration of substances in the atmosphere – calculation are made in points of **calculation grid** of considered area.



Short range of calculation

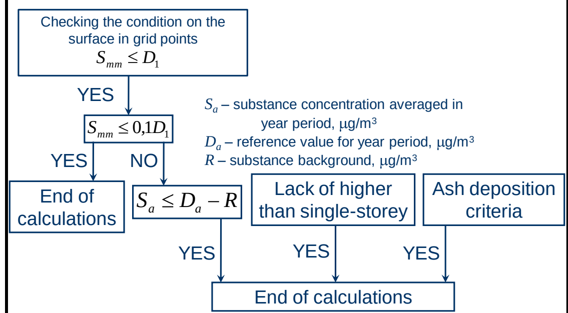
Short range of calculation are made, when some criteria are fulfilled:



O_p – total ash deposition, g/m²rok
D_p – ash reference value, g/m²rok
R_p – ash deposition background, g/m²rok

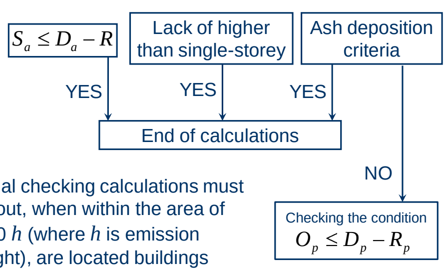
Full range of calculation

When criteria of short range of calculation are not fulfilled, a full range calculations in calculation grid are made:



Full range of calculation

When criteria of short range of calculation are not fulfilled, a full range calculations in calculation grid are made:



An additional checking calculations must be carried out, when within the area of diameter 10 h (where h is emission source height), are located buildings higher than single-storey, crèche, nursery school, school, hospital or sanitarium.

Full range of calculation

When calculations made due to buildings near emission source showed that calculated concentrations exceed reference value D_1, or when condition $S_{mm} \le D_1$ is not fulfilled, then must be calculated **frequency of exceeding of reference value** or **permissible substance concentration**.

Full range of calculation

Reference value, or permissible concentration of substance in the air is considered as fulfilled, when frequency of exceeding of D_1 value, averaged to one hour, is not higher than **0,247% time in year for SO_2** and not higher than **0,2% time in year for other substances**.

Exam questions

1. Define reference value.
2. Define substance background.
3. What is denoted by D_1 and D_a?
4. What is the relationship between thermal vertical gradient and atmosphere equilibrium state?
5. Describe inversion phenomenon.
6. Draw thermal vertical gradient for A-izothermic equilibrium atmosphere state , B- stable equilibrium atmosphere state C- unstable equilibrium atmosphere state D- equilibrium atmosphere state with inversion layer E- neutral equilibrium atmosphere state?
7. What does mean S_m, S_{mm} ?
8. Calculation showed that $S_{mm} > 0{,}1D_1$ what conditions should be fulfilled in order to obtain possitive result of reference value calculation?