Tananyag fejlesztés idegen nyelven

Prevention of the atmosphere

KÖRNYEZETGAZDÁLKODÁSI AGRÁRMÉRNÖKI MSC

(MSc IN AGRO-ENVIRONMENTAL STUDIES)

Új Magyarország Fejlesztési Terv

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London smog
Acid rain: the chemical process

Lecture 14

Lessons 40-42

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Lesson 40

History of great London smog (1952) – some facts. The weather during the great London smog I.

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The London smog

- A period of cold weather combined with an anticyclone and windless conditions caused the disreputable great London smog in 1952. Due to the cold weather, households were burning more coal than usual to keep warm. Although the event was going on 5 days from 5th to the 9th December, medical reports estimated that 4,000 people had died prematurely and 100,000 more were made ill due to the smog's effects on the human respiratory tract.
- The airborne pollutants in London smog mostly came from coal burning forming a thick polluted air layer above the city.

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Fig. 99 The London smog

http://www.museumoflondon.org.uk/museumoflondon/images/microsites/derivatives//exploring/133/mid/HG1695_20.jpg

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History of London smog

- As the weather has changed (1952), the smog-plume quickly dispersed in the air. The London citizens did not think any trouble regarding the environmental circumstances, as there was not surprise such an event in Great Britain. The polluted air broke into the flats as well. The city was full of dark clouds reaching the ground level. The citizens call the event as „ pea soupers" that used to be, but not very often.
- The 1952s phenomenon is assumed the worst air pollution event in the history of the United Kingdom.

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- The news about London smog reached the audience of the whole world. The London smog is considered as the most significant in terms of its impact on environmental research, government regulation, and public awareness of the relationship between air quality and health. As a result of the frightful facts, new policy was introduced to Great Britain, what resulted a really clean air in London in our days.
- Recent research work estimated the number of fatalities again, and found the number of death higher than earlier, at around 12,000.

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- The basis of the Great Smog of London was the emitted smoke from approximately one million coal-fired stoves, in addition to the emissions of local industry. From the Industrial revolution the Londoners were familiar to increased smoke and sulfur release coming from combustion of coal.
- Thousands of tons of black soot, tar particles, and sulfur dioxide had accumulated in the air. The concentration of PM_{10} ranged between 3,000 and 14,000 μg/m³ during December, 1952. This amount of particulate was approximately 50 times higher than the average aerosol level in London, at the time.

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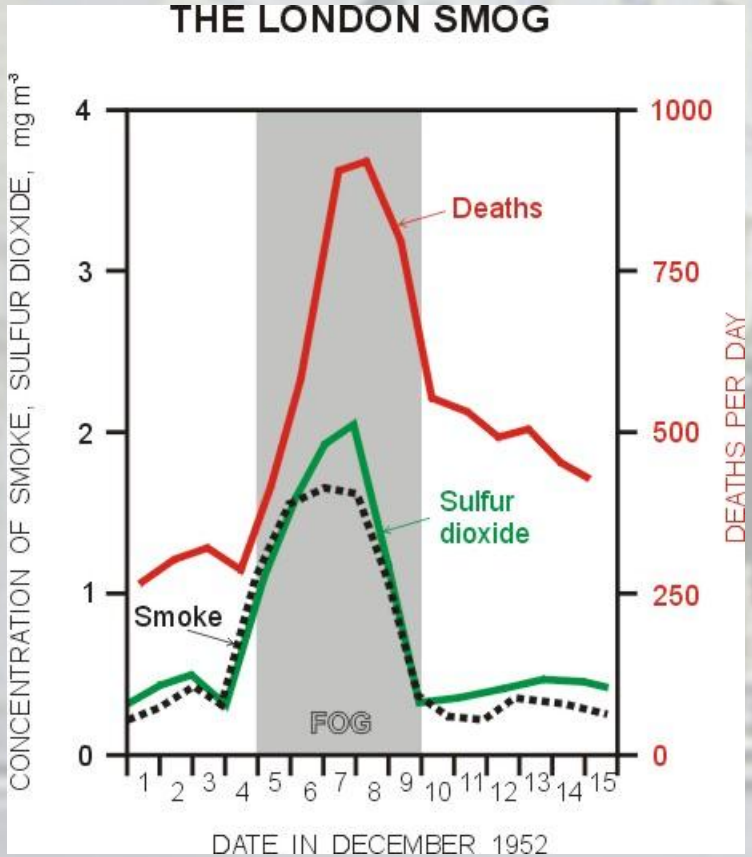
Fig. 100 Components of London smog with deaths during the Greatest one in 1952



www.ems.psu.edu/~lno/Meteo437/Figures437.html

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- The today's aerosol concentration of PM_{10} is around 30 μg/m³ showing the favorable air conditions in London.
- Not only the particulates, but the other main pollutant of the London smog, the sulfur dioxide was also strongly dangerous; the sulfur dioxide levels during December of 1952 were 7 times greater than normal level. It means at 700 parts per billion (ppb) at the time.

  <u>Antecedents in weather of forming smog</u>
- At the very beginning of smog formation, the first night (4 December) has light winds, cool air together with high air humidity at ground-level;

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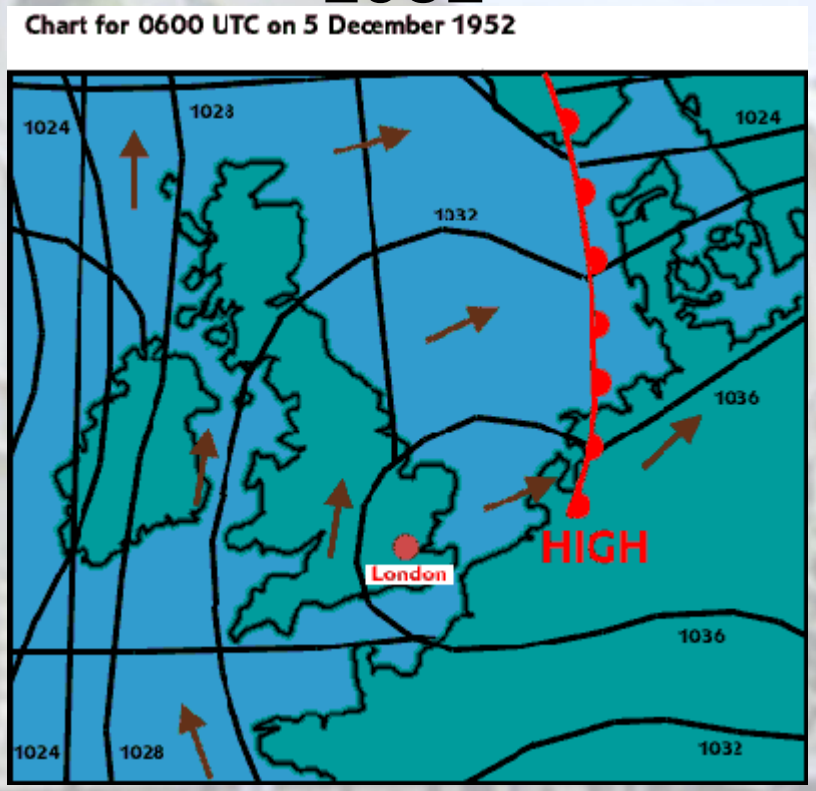
Fig. 101 The weather map of London on 5th Dec. 1952



www.martinfrost.ws/htmlfiles/great_smog.html

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The beginning of December 1952 offered ideal conditions for the formation of a thick contaminated air layer.

- The next day (5 December) was followed by a settled temperature *inversion*, that closed the way of pollutant air to the higher levels of the atmosphere. The anticyclone pushed back the contaminant; the lack of vertical air motion accumulated the sulfur dioxide and particulates.
- One of the awkward and dangerous consequences of the London smog events is the deterioration of atmospheric visibility.

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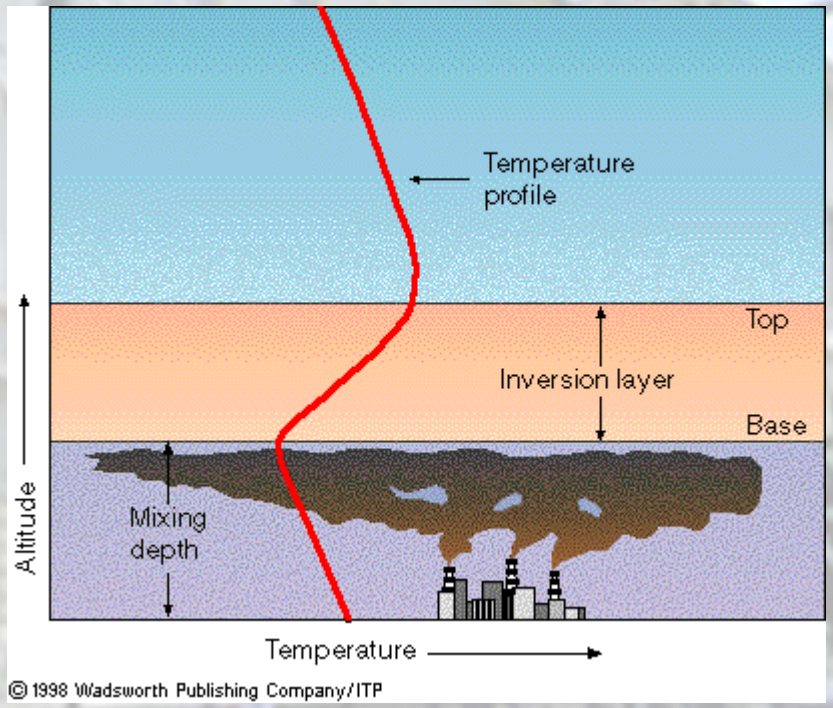
Fig. 102 Impact of inversion on pollution dispersion



http://apollo.lsc.vsc.edu/classes/met130/notes/chapter18/graphics/inversion_trap.gif

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Lesson 41

The weather during the great London smog II. The impact of smog compounds (SO_2). Last step of London smog – the acidification

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- During the smog event, in the following 4 to 5 days experienced visibility less than 500 meters with 48 hours below 50 meters visibility was observed in London. Heathrow Airport had visibility levels below 10 meters for nearly 48 hours following the morning of December 6. During the smog event life in London was completely blocked by hindering all kinds of transportation:

  - road,

  - rail, and

  - air transport was unable to operate due the impaired visibility.

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- Five days were necessary to transport the dense air mass full of with sulfur dioxide and particulates through the Thames Estuary and into the North Sea.
- The existence of soot and sulfur dioxide alone is enough to harm the human health and the building surroundings (objects of „virtu”). The London air also contained a lot of atmospheric water and this with sulfur dioxide formed a solute sulfuric acid. The end of smog used to be the acid rain.
- The attendance of pollutant of different states, both gas SO_2 and particulates, was not restricted to the open air, they entered to the houses of Londoners.

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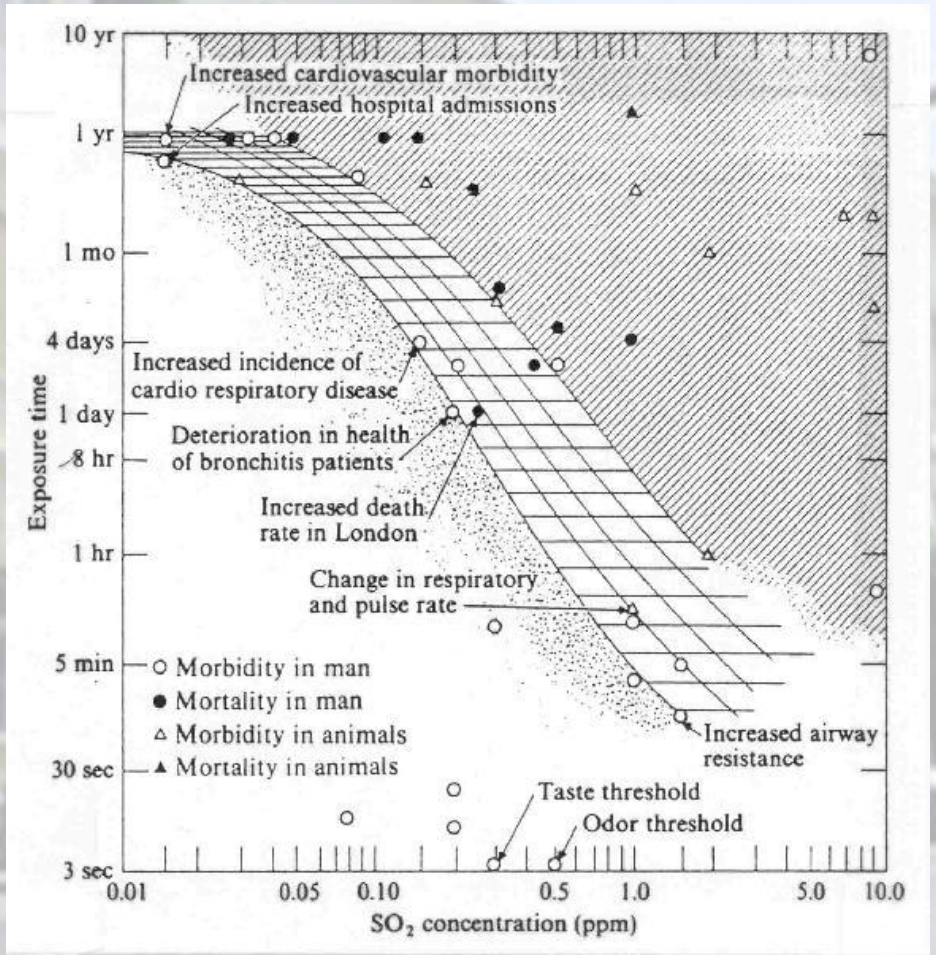
Fig. 103 The health impact of SO_2



www.ems.psu.edu/~lno/Meteo437/Figures437.ht

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- The London smog caused the following injuries in humans. The most serious injury was the increased number of deaths due to:

- pneumonia,
- bronchitis,
- tuberculosis, and
- heart failure.

Less serious short-term harms appeared as,chest pains, lung inflammation, diminished breathing ability, damaged respiratory cells, permanent lung damage, and increased incidence of asthma attacks.

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- The deaths peaked on the 8th and 9th of December at 900 per day. The people knew something was wrong…The comparison of air quality to increased number of deaths gave the answer for the question.
- Observations presented, that only two-thirds of the original 4,000 dead were over 65 years of age. The number of deaths in the middle-age category (age between 45 and 64 years) was three times greater than in general. Estimation shows that the increment in death following the main stream of smog was about 4,000.
- There is no data about the increased risk of cancer later on.

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- There is little information about the „tied” illnesses. The health conditions in London during the winter of 1952 were catastrophic. Real disaster was formed due combining the coal burning and special weather conditions.

Afterword

The Londoners registered the heavy blow and the Clean Air Act 1956 was borne to cope the smog harms. In this regulation the government gave the possibility to the local authorities in forms of fund. The aim was to cover the expenses of change from coal to other environment-friend fuels such as gas or oil.

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- Later on, in 1968, in the frame of the Clean Air Act , its streamline was extended to the industry by increasing the chimney's height. The taller chimneys allowed the pollution to be released higher into the atmosphere. This latter projection was not as successful as the first one, because researchers are aware that the sulfur dioxide transmission resulted the acidification of far distance places. Discovery of transboundary pollution helped in recognizing the relationship between local and regional pollution events. The local smog turned into regional acid rain.
- This measure helped the Londoners, but not the other citizens of Great Britain.

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- The real solution is not the rise of chimney level, but the change in used coal, declining the pollutant emission.
- Nowadays in London other measures are applied. Among others

  - the introduction of smokeless zones; extra „penalty” fee when entering the city,

  - the controls imposed on industries to the reduction of their pollutant release and

  - relocation of heavy sources.

The air quality in London improved from step to step! This town’s attitude may serve a positive example for other countries.

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Acid rains (acid deposition)- regional environmental problem

- The fossil fuel combustion emits large amount of harmful compounds. After chemical reactions these take part in modifying the pH of the atmosphere. Among the others the sulfur dioxide (SO_2) and nitrogen oxides (NO_x) have of primary importance in air pH determination. The term acid rain is a sum of wet and dry deposition from the atmosphere containing higher than normal amounts of nitric and sulfuric acids.
- It is important to mention, that not only the above two chemical compounds are responsible for the pH of the air or rainwater.

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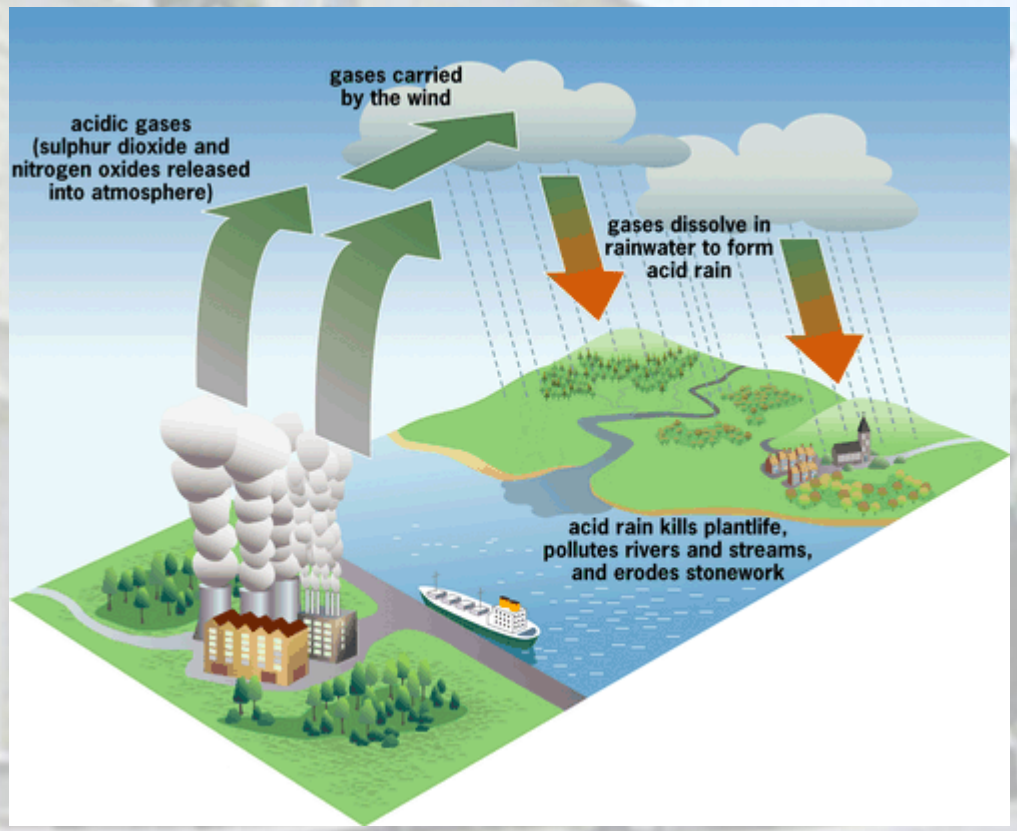
Fig. 104 The scheme of acid rain formation



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Lesson 42

Chemical reactions leading to increased acidity of the air (rainfall)

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Mass transfer between gases and cloud droplets

- The mass transfer impacts the chemical composition of the atmosphere and also precipitation quality.
- The effect of the sulfate is the highest in forming acid rain. We focus on this compound.
- For sulfate production the following solutions are,
  - molecular diffusion of gases into liquid cloud particles
  - transfer takes place at the surface of the drop
  - diffusion of gases happens inside the drop
  - aqueous-phase chemical reactions.

At first the dissolution of gases is discussed.

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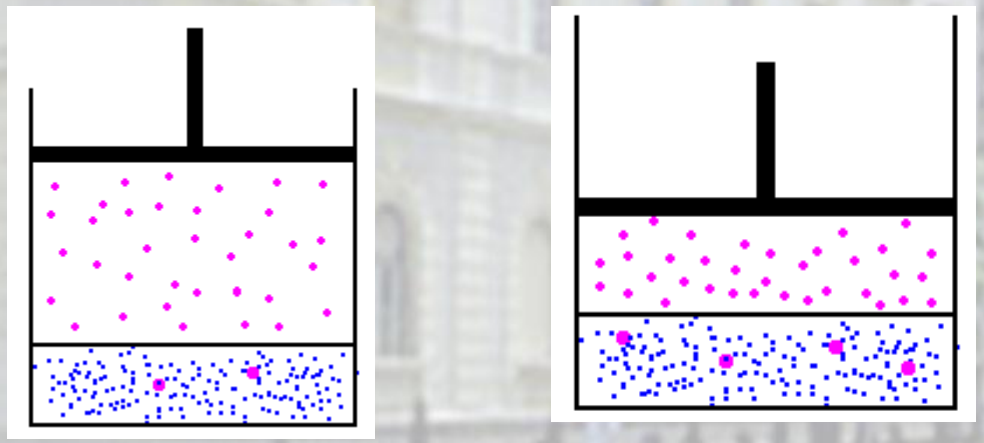
- The solution of gas in liquid may be expressed by Henry's law, where the intensity of solution depends on gas concentration; the partial pressure of the given gas. The partial pressure controls the number of gas molecule collisions with the surface of the solution.



Low pressure equilibrium
Low concentration

Double the pressure equilibrium
Double the concentration

Fig. 105 The Henry's law

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- Not only the partial pressure of the gas determines the solution; the pH also impacts the process.
- Solution of different acidic particles in clouds decreases the actual pH of the rain (cloud) water. The continuous presence of carbon dioxide in the atmosphere declines the so called neutral pH of 7. The neutral pH of the atmosphere and also rainwater is less than 7, it is only 5.6. This value will be the starting point in calculating the atmospheric acidity with denotation of „natural" rainwater. In far from dense habitats this value is a few tenth less; it is at about 5.1 - 5.2.

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The formation of „natural” rainwater pH dissolving the carbon dioxide of the air in rainwater,

$$H_2O + CO_2 \rightarrow H_2CO_3$$

In the following step the carbonic acid ionizes in water forming low concentrations of hydronium and carbonate ions:

$$2\ H_2O + H_2CO_3 \longleftrightarrow CO_3^{2-} + 2\ H_3O^+$$

The acid rains have a more precise denomination; this is the *acid deposition*. The phenomena includes more dissolved additional acids to H_2CO_3.

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- The rain or cloud particle's pH below 5 is considered as acid rain. There are two basic compounds which dominate in acid rain formation; the sulfate and the *nitrate*.
- The important chemical processes regarding the pH determination in the atmosphere, cloud and rainwater included, can be found in the Table 15. There are three groups of chemical reactions producing NO_3^- and SO_4^{--},

  - gas-phase reactions
  - heterogeneous reactions and
  - aqueous-phase reactions.

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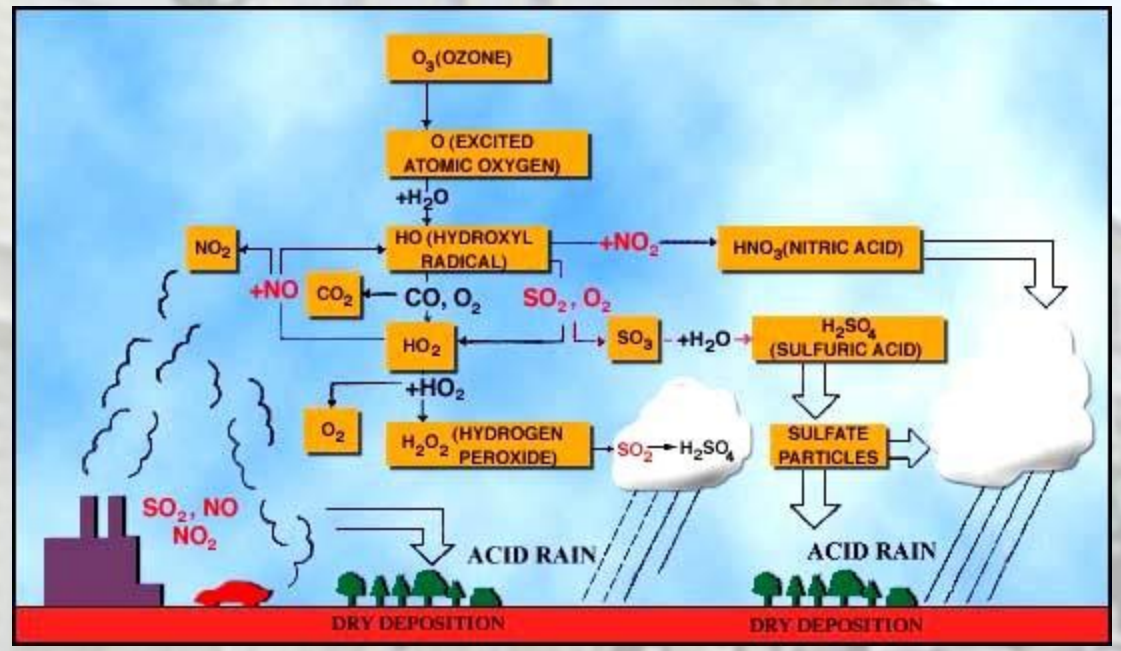
Fig. 106 The „general” formation of acid rain



www.globalchange.umich.edu/.../water_nitro.html

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Gas-phase reactions

Sulfur dioxide and nitrogen dioxide

- Sulfur dioxide is oxidized in the reaction with the hydroxyl radical through an intermolecular reaction,

$$SO_2 + OH\cdot \rightarrow HOSO_2\cdot$$

that will be continued as,

$$HOSO_2\cdot + O_2 \rightarrow HO_2\cdot + SO_3.$$

The water dissolves the sulfur trioxide (SO_3) soon, and finally sulfuric acid is formed,

$$SO_3 + H_2O \rightarrow H_2SO_4.$$

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- To nitrogen dioxide reaction free radical is necessary. This radical is the hydroxyl radical, that is almost always present in the atmosphere. The equation is,

$$NO_2 + OH\cdot \rightarrow HNO_3$$

Finally nitric acid is formed.

Reactions inside the droplets

At first the sulfur dioxide dissolves in water, and in the second step it dissociates:

$$SO_2 + H_2O \longleftrightarrow H^+ + HSO_3^-$$

$$HSO_3^- \longleftrightarrow H^+ + SO_3^{2-}$$

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Oxidation

There are also some oxidation reactions in the atmosphere, when the sulfur (IV) oxides to sulfur (VI).

These oxidation reactions need other chemical compounds. There are two types of oxidation;

- without catalyst - the partners may be the ozone and the hydrogen peroxide.

- In the next case the reaction partner is the oxygen. Here, the presence of a catalyst is necessary (iron and manganese). These catalyst can also be found in the cloud droplets.

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Table 15 Sum of reactions forming the components of acid deposition

Gas-phase reactions	
	$SO_2 + OH \rightarrow H_2SO_4 + HO_2$
	$NO_2 + OH \rightarrow HNO_3$
	$NO_2 + O_3 \rightarrow NO_3$
	$NO_2 + NO_3 \rightarrow N_2O_5$
	$N_2O_5 + H_2O \rightleftarrows 2HNO_3$
	$COV + NO_3 \rightarrow HNO_3 + \ldots$
Heterogeneous reactions	
	$NO_3 \rightarrow HNO_3$
	$N_2O_5 + H_2O \rightleftarrows 2HNO_3$
Aqueous-phase reactions	
	$S(IV) + H_2O_2 \rightarrow S(VI)$
	$S(IV) + O_3 \rightarrow S(VI)$
	$S(IV) + O_2 \xrightarrow{Fe,\ Mn} S(VI)$
	$NO_3 \rightarrow NO_3^- + H^+$
	$N_2O_5 + H_2O \rightleftarrows 2(NO_3^- + H^+)$

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Neutralization by bases

- There is a pollutant in the air, the ammonia that can neutralize the pH of the atmosphere. The ammonia gas dissociates in the air producing ammonium ions (NH_4^+):

$$NH_3 \longrightarrow NH_4^+ + OH^-.$$

The importance of other basis is not as excellent as the ammonium ions. They are the alkaline ions,

- Calcium (Ca^+)
- Natrium (Na^+)
- Potassium (K^+)

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Thank you for attention!

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