Al-Mustaqbal University
Department of Fuel and Energy Engineering Techniques
Second stage
Subject: Pollution
Lecturer: Dr. Malik Mustafa
Second semester

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3) Acid rain

Acid rain is mainly caused by the release of sulfur dioxide (SO_2) and oxide of nitrogen (NO_x) during fossil fuel combustion and the use sulfur coal and oil. When these gases are discharged into atmosphere they react with water, oxygen, and other gases in the atmosphere to form sulfuric acid, ammonium, and nitric acid. These acids then disperse over large areas because of wind patterns and fall back to the ground with rainwater as acid rain.

Unpolluted rain is naturally acidic with a pH of about 5.6 due to CO2 in the atmosphere, which reacts with rainwater forming carbonic acid (H2CO3):

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

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$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

Carbonic acid is a weak acid and the acidity in rainwater can quickly be neutralized on contact with materials. But the present of sulfuric acid or nitric acid in the atmosphere could lower the pH of rain droplets to value below 5.6 and such rain is considered acidic and it called "acid rain".

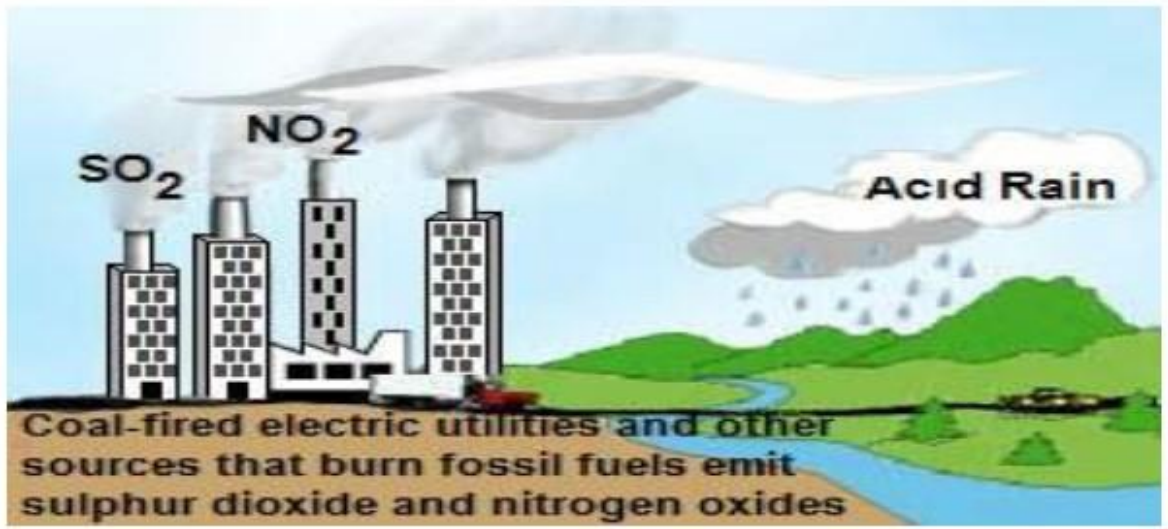

Fig.11 Acid Rain

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Effects of acid rain

The harmful effects caused by acid deposition can be categories under many effects:

1- Effects on water bodies: acid rain causes acidulation of lake and streams and contributes to damage of tree at high elevation and much sensitive forest.

2- Effect on material: acid rain accelerates the decay of building, bridge, and other structures may by corrosion.

3- Effect of human health: acid rain caused acidification of air, water and food that damage the human health. It can also release heavy metals from the pipes of the distribution systems into the potable water supply.

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Chemical processes of acid formation in atmosphere

A large part of SO_2 in the atmosphere is oxidized to sulfur trioxide SO_3:

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

Also SO_2 reacted with atmospheric ozone to give sulfur trioxide SO_3:

$$SO_2 + O_3 \longrightarrow SO_3 + O_2$$

Sulfur trioxide SO_3 is then quickly combined with moisture (water) in the atmosphere to form sulfuric acid mist:

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

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$$SO_3 + H_2O \longrightarrow H_2SO_4$$

The overall reaction is:

$$2SO_2 + O_2 + 2H_2O \longrightarrow 2H_2SO_4$$

Nitrogen dioxide reacts with atomic oxygen to give nitrogen trioxide:

$$NO_2 + O \longrightarrow NO_3$$

Also NO_2 reacted with atmospheric ozone to give nitrogen trioxide NO_3:

$$NO_2 + O_3 \longrightarrow NO_3 + O_2$$

NO_3 reacted with NO_2 forming N_2O_5, which react with moisture (water) forms nitric acid:

$$NO_3 + NO_2 \longrightarrow N_2O_5$$

$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

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Control strategies for acid rain

1- The use of low sulfur coal or substitution of coal by other fuels.

2- Alternative methods for power generation instead of thermal power plants, such as hydropower facilities or nuclear power.

3- Installation of flue gas desulfurization systems in large power plants can reduce emission of SO_2.