

Lecture 10: Acid Rain

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What is Acid Rain?

Acid rain is rain or any other form of precipitation that is usually acidic i.e. has low pH.

Caused by emissions of sulfur dioxide and nitrogen oxide which react with water molecules in the atmosphere to produce acid rain

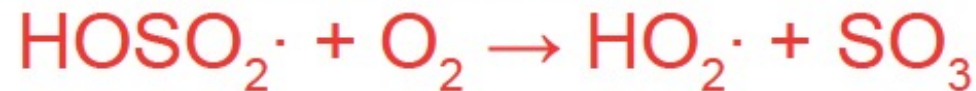
SO_2 and NO_2 → carried long distances by strong winds → deposited in acidic rain, snow, fog or dust

Gas phase chemistry

In the gas phase sulfur dioxide is oxidized by reaction with the hydroxyl radical via an intermolecular reaction:



which is followed by:



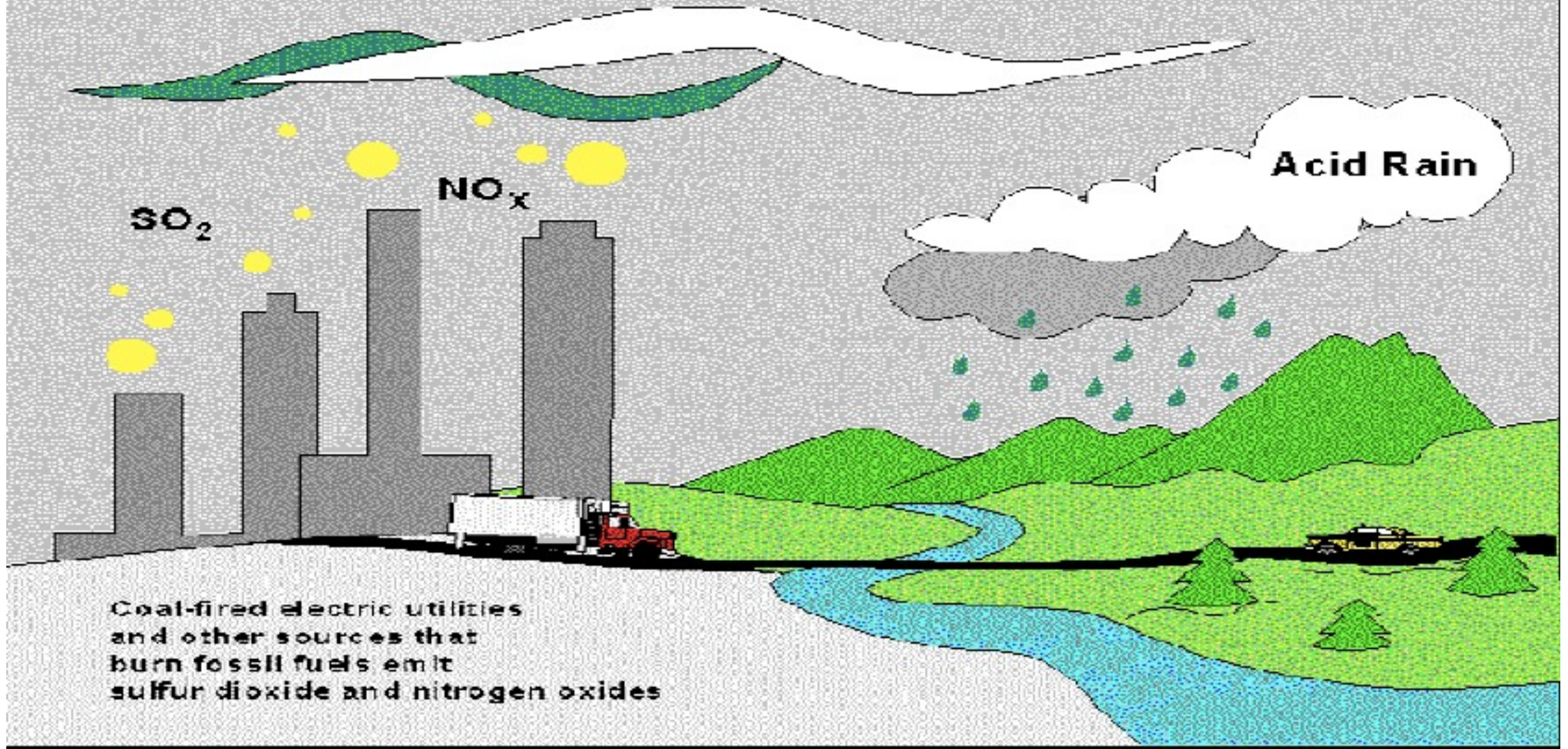
In the presence of water, sulfur trioxide (SO_3) is converted rapidly to sulfuric acid:



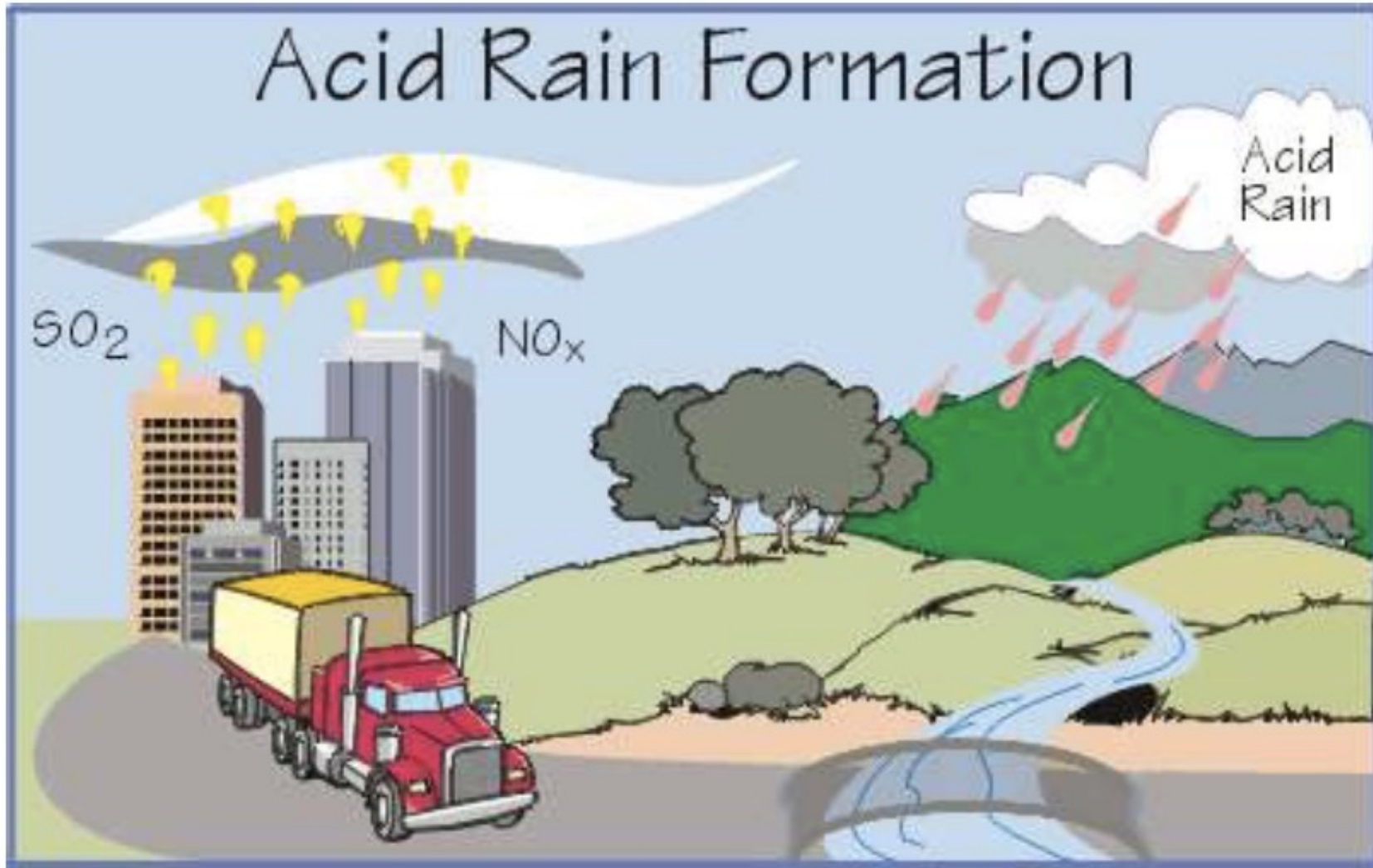
Nitrogen dioxide reacts with OH to form



Acid Rain Formation



Coal-fired electric utilities and other sources that burn fossil fuels emit sulfur dioxide and nitrogen oxides



Formation of Acid Rain

Involves deposition of aqueous acids, acidic gases and acidic salts

- Acid deposition has two parts: wet and dry
 - Wet deposition refers to acidic rain, fog and snow.
 - Dry deposition refers to acidic gases and particles.
 - Half of the acidity in the atmosphere falls back to earth through dry deposition.

Acid rain is a regional air pollution problem.

- Canada and northwestern USA are worst affected.
- Average pH of rainfall recorded in Toronto in Feb 1979 was 3.5. In 1999, fog in Los Angeles had a pH as low as 2.2. Most acidic rainfall in US in Wheeling, West Virginia was 1.4.
- Precipitation of clean atmosphere may have a pH of 5.6

Causes of Acid Rain

- The primary cause of acid rain is the emission of harmful gases and emissions by industrial power plants and factories and to some extent cars as well.
- Burning of fossil fuels lead to emission of gases that gives off oxides of sulfur and nitrogen.
- Burning of gasoline and diesel in cars build the amount of acidified water droplets in the atmosphere.

Origins of Acid Rains

Human activities – primary
source of acid rains

Combustion of fossil fuels
like coal which produce air
pollutants like sulfur dioxide
and nitrogen dioxide

Gases which are at the origin of acid rains are :

Sulphur dioxide



Carbon dioxide



Nitrogen oxide



Effects of Acid Rain

Acid rains have harmful effects on the environment and health of the population. Buildings, national monuments and bridges deteriorate faster.

Damage to natural ecosystem is significant especially considering effects on plants, trees, rivers, lakes, soil and land wherever acid rain falls.

Animals and plants are severely affected. Food sources are reduced. Diseases and mutations may develop and death results in extreme cases.

Deposition Effects



Effects on Human Health

SO₂ and NO₂ that interact in the atmosphere form fine sulfate and nitrate particles that can be blown by the wind over long distances and inhaled by people.

These fine particles easily enter the body causing breathing problems as in asthma, bronchitis and over time can result in skin cancer.

Consequences of Acid Rain

Serious effects are felt in eastern Canada, the Alps, the Appalachians, the US and Japan

Effect on animals and plants – fish can't breathe well; different species die

Ecosystems – water looks transparent because planktons have disappeared.

Corrosion of steel

Harmful effects particularly on the lungs

Impact of Acid Rain

- Acidification of soils:

Acid rain increases acidity of soil, lakes, streams, etc.

Lower pH can mobilize or leach out important minerals and release heavy metals like aluminum, cadmium, lead and others beyond safe limits.

This affects land and aquatic flora and fauna especially fish.

Thousands of lakes across the world have died losing all fish populations and other animal and plant species.

Impact of Acid Rain

- Phyto-toxicity

Directly from excessive concentration of acid and acid-forming gases particularly SO_2 and NO_2

Indirectly from Al_3^- liberated from the soil

Acid rain, acid fog and acid vapors damage the surfaces of leaves and needles and reduce a tree's ability to withstand cold and inhibit plant germination and reproduction.

Tree vitality and regenerative capability are reduced.

Solutions for Acid Rain

- Understand acid deposition's causes and effects: understand how acid rain damages the environment; what changes could be made to air pollution sources that cause the problem
- Use low sulfur coal: amount of sulfur oxides emitted by power plants can be reduced by burning coal with a very low percentage of sulfur present.
- Use scrubbers: scrubbers remove 80-95% of the sulfur oxides; certain types are not capable of removing nitrogen oxides; costly to retrofit in existing powerplants; increase the electric generating costs by 10-15%.

Acid Rain Regime

Lower emissions from fossil
fuels

1990 – Clean Air Act –
tradeable permits

1991 – Air Quality Accord –
US and Canada

1993 – emissions reduced by
30%

Environmental Awareness

1961 – Silent Spring by Rachel Carson

1987 – UN Commission on the State of the Environment → asked people of the developed world to reduce resource consumption and develop a sustainability lifestyle

1992 – Earth Summit – Agenda 21 (encouraged the development of a sustainable world economy)

1992 – World Scientists' Warning to Humanity – earth stewardship

However, there has been little progress by governments and corporation

Implementation=Losses



Thank you.