

Acid Rain, Causes, Mechanism, Sources, Impacts, Controlling Measures

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Acid Rain is an important environmental issue faced all over the world. It not only damages the ecosystem and biodiversity but also impacts human health, cultural heritage and infrastructure. In this article, we are going to cover acid rain, its causes, process, types and impacts.

Acid Rain

- Acid Rain is the formation of precipitation in the form of rain, fog, mist or snow that becomes acidic because of the presence of pollutants in the atmosphere.
- The pollutants responsible for acid rain are sulphur dioxide and nitrogen oxides that combine with water vapour to form sulphuric acid and nitric acid.
- These acids then return to the Earth's surface through rain, snow, or fog, damaging soil, water, vegetation, and man-made structures.
- While normal rain is slightly acidic (pH around 5.6) due to dissolved carbon dioxide, acid rain has a pH much lower than this, often between 4.0-5.0.

Acid Rain Mechanism

The cycle of acid rain works in the following manner:

1. Emission of Pollutants: Fossil fuel burning in industries, vehicles, and power plants releases SO_2 and NO_x into the atmosphere.
2. Chemical Reactions: These gases undergo oxidation and dissolve in water droplets, forming sulphuric and nitric acids.
3. Deposition: The acids fall back to Earth in the form of rain, snow, fog, or dust, leading to acid deposition.

Acid Rain Sources

The sources of acid rain are:

Compound	Natural Sources	Anthropogenic (Human) Sources
Sulphur Dioxide	Volcanoes, oceans, decomposition of organic matter	Fossil fuel burning, coal-based power plants, industrial emissions
Nitrogen Oxides	Volcanoes, lightning, forest fires, organic decomposition	Vehicle emissions, thermal power plants, biomass burning
Formic Acid	Forest fires	Biomass burning
Carbon Dioxide	Respiration, decomposition	Fossil fuels, industrial processes
Carbon Monoxide	Plant emissions (isoprene)	Biomass burning, industries

Acid Rain Chemistry

Acid rain causes the following reactions:

- Sulphur Cycle:
 - $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$ (Sulphurous Acid)
 - $\text{H}_2\text{SO}_3 + \text{O}_2 \rightarrow \text{H}_2\text{SO}_4$ (Sulphuric Acid)
- Nitrogen Cycle:
 - $2\text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_2$ (Nitrous Acid) + HNO_3 (Nitric Acid)

These acids mix with rainwater and fall as acid rain.

Acid Rain Causes

Acid Rain is caused by the following factors:

- Burning fossil fuels in power plants, industries, and vehicles.
- Volcanic eruptions and wildfires releasing natural SO₂ and NO_x.
- Industrial emissions from refineries, cement plants, and chemical factories.
- Biomass burning and agricultural practices.

Types of Acid Deposition

Acid Rain causes the depositions of following types:

1. Wet Deposition

- Occurs when acidic pollutants combine with rain, snow, mist, or fog.
- Common in humid regions with high precipitation.
- Example: Acid rains in Scandinavia caused by industrial emissions in Britain.

2. Dry Deposition

- Occurs when acidic gases and particles settle on surfaces without precipitation.
- Later washed off by rain, causing delayed environmental damage.
- Common in arid or semi-arid regions with less rainfall.

Acid Rain Impacts

Following are the impacts of acid rain:

1. On Soil

- Leaching of essential nutrients like calcium, magnesium, and potassium, making soil infertile.
- Reduced microbial activity and decomposition rates.
- Acidic soils affect crop productivity and forest health.

2. On Vegetation

- Reduced photosynthesis and growth rates.
- Symptoms: Leaf discolouration, premature ageing, stunted growth, and tree death.
- Weakens plants, making them more vulnerable to disease and pests.

3. On Microorganisms

- Disrupts soil microbial balance and reduces bacteria and protozoa, favours fungi.
- Alters decomposition rates and nutrient cycling.
- Increases susceptibility to plant and soil-borne fungal diseases.

4. On Aquatic Life

- Acidic waters lower pH below tolerance levels for fish and amphibians.

- Kills eggs, sperm, and larvae of aquatic organisms.
- Reduces plankton populations, collapsing aquatic food chains.
- Example: Fishless lakes in Canada and Scandinavia due to acidification.

5. On Terrestrial Life

- Indirect effect via food chain disruption.
- Herbivores suffer due to damaged vegetation, cascading impacts on predators.

6. On Humans

- Not directly harmful to touch, but indirectly impacts health.
- SO₂ and NO_x cause respiratory diseases like asthma, bronchitis, and lung cancer.
- Eye, skin, and throat irritation.
- Contributes to ground-level ozone formation, worsening air pollution.

7. On Buildings & Monuments

- Acid rain reacts with limestone and marble, causing structural damage.
- Famous example: Taj Mahal (Agra) turning yellow due to acid rain and pollution.
- Damages heritage structures, statues, and buildings worldwide.

Acid Rain Controlling Measures

Acid rain can be controlled by the following measures:

1. Cleaner Fuels: Use low-sulphur coal, natural gas, or renewable energy and promote solar, wind, and hydropower.
2. Scrubbers: Installs flue-gas desulfurization units in power plants and can remove 90–95% of sulphur dioxide emissions.
3. Catalytic Converters: Fit into vehicles to reduce NO_x and SO₂ emissions.
4. Neutralization: Add lime to acidic lakes and soils to restore pH balance.
5. Policy Measures: Stricter emission standards for industries and vehicles and promotes energy efficiency and public awareness campaigns.
6. International Cooperation: Since acid rain crosses borders, global treaties like the 1979 Geneva Convention on Long-Range Transboundary Air Pollution are crucial.

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