



## Atmospheric Deposition: Processes Ecological Impacts and Global Significance

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### Abstract

Atmospheric deposition is the process by which airborne particles, gases, and dissolved compounds are transferred from the atmosphere to the Earth's surface. It occurs through wet deposition (rain, snow, fog) and dry deposition (settling or direct uptake by surfaces) and represents a major pathway for the input of nutrients, pollutants, and acidic compounds into terrestrial and aquatic ecosystems. These deposition fluxes influence biogeochemical cycles, soil and water chemistry, and ecosystem health. This review describes the mechanisms of atmospheric deposition, its ecological consequences, and the importance of monitoring in the context of environmental management.

**Keywords:** Atmospheric Deposition, Wet Deposition, Dry Deposition, Air Pollution, Nutrients, Acidification, Ecosystem Impacts, Biogeochemical Cycling

### Introduction

Atmospheric deposition refers to the transfer of gaseous and particulate matter from the atmosphere to the Earth's surface. This process is a critical component of global biogeochemical cycling, acting as a conduit for the movement of nutrients (such as nitrogen and phosphorus) as well as pollutants (e.g., sulfur compounds, trace metals) from the atmosphere into terrestrial and aquatic systems. Deposition occurs via two primary mechanisms: **wet deposition**, in which aerosols and gases are scavenged by precipitation and brought to the surface; and **dry deposition**, where particles or gases settle directly onto surfaces without precipitation.

Over recent decades, human activities — including fossil fuel combustion, industrial emissions, and agricultural practices — have increased the concentration of atmospheric pollutants. These changes have led to enhanced deposition fluxes, altering soil chemistry, impacting water quality, and inducing ecological harms such as acidification and eutrophication. Understanding atmospheric

deposition processes is therefore essential for developing effective environmental policies and mitigating the impacts of air pollution on ecosystems [1].

### Mechanisms and Ecological Effects of Atmospheric Deposition

Atmospheric deposition involves complex interactions between aerosols, gases, and meteorological conditions. During **wet deposition**, chemicals in the atmosphere are captured by raindrops or snowflakes and delivered to the surface. This process is influenced by precipitation patterns and the solubility of atmospheric constituents. In contrast, **dry deposition** involves the gravitational settling and direct uptake of particles or gases by vegetation, soils, water surfaces, and built structures.

Deposition fluxes carry a mix of nutrients and pollutants, including nitrogen oxides, sulfur dioxide, ammonia, particulate matter (PM), and trace metals. These inputs can be beneficial — for example, providing nitrogen to nutrient-limited ecosystems — but many pollutants are harmful when deposited in elevated amounts [2].

Atmospheric deposition serves as an important nutrient source for ecosystems, especially in nutrient-poor regions. Nitrogen deposited from the atmosphere (in the form of nitrate, ammonium, and organic nitrogen) contributes to soil and water nutrient budgets, influencing plant growth and productivity. In coastal and marine systems, deposition of nutrients such as nitrogen and iron can stimulate primary productivity by phytoplankton, the foundation of aquatic food webs and global carbon cycling.

However, excessive nitrogen inputs can lead to **eutrophication** of water bodies: the over-enrichment of nutrients that promotes algal blooms, depletes oxygen, and disrupts aquatic food webs. Deposition of phosphorus and nitrogen in particulate matter further modifies nutrient dynamics in freshwater ecosystems [3].

Pollutant deposition — particularly of sulfur and nitrogen compounds — can lead to **acid deposition (acid rain)**, which lowers soil and water pH, mobilizes toxic metals (such as aluminum), and impairs plant and aquatic life. Sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>), largely emitted from fossil fuel burning, are major precursors of acidifying deposition.

Atmospheric deposition also transports **trace metals and particulate contaminants** that can accumulate in soils and sediments. A study of urban regions in India showed that atmospheric deposition significantly determined the nutrient and heavy metal loads in surface runoff reaching rivers, correlating strongly with their concentrations in runoff water [4].

Ecological risks due to atmospheric deposition extend across ecosystems. In forests, excess nitrogen deposition alters species richness and abundance, as shown by studies using epiphytic macrolichens as bioindicators of nitrogen and sulfur deposition stress. Moreover, recent work indicates that particulate deposition affects phytoplankton physiology and community composition in aquatic systems, with both stimulatory and toxic responses depending on the chemical nature of the deposits.

Atmospheric deposition is thus a major driver of ecological change, with implications for biodiversity, nutrient cycling, and ecosystem function [5].

## Conclusion

Atmospheric deposition is a key process linking the atmosphere with terrestrial and aquatic environments through the transfer of nutrients, pollutants, and other chemical species. Wet and dry deposition processes collectively influence soil chemistry, water quality, and ecosystem health. While atmospheric deposition can support productivity in nutrient-limited systems, excess deposition — particularly of sulfur, nitrogen, and particulate pollutants — can lead to acidification, eutrophication, and biodiversity loss. Effective monitoring, modeling, and mitigation strategies are necessary to manage atmospheric deposition impacts, especially in the context of ongoing industrialization and climate change. Continued research is essential to refine deposition measurements, understand long-range

transport pathways, and evaluate ecosystem responses across diverse environments.

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