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PAPER

# GASEOUS EMISSIONS: COMPOSITION, ECOLOGICAL AND TOXIC HAZARDS, TREATMENT METHODS.TECHNOLOGY FOR HANDLING TOXIC AND HAZARDOUS WASTE

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## Abstract

This article examines the ecological and toxic hazards associated with gaseous emissions generated by industrial, transport, and technogenic sources. Particular attention is given to the chemical composition of gaseous pollutants, including carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxides, ammonia, volatile organic compounds, and highly toxic industrial gases. The study analyzes their impact on atmospheric processes such as the greenhouse effect, ozone layer depletion, photochemical smog formation, and acid precipitation, as well as their adverse effects on human health. Modern treatment and mitigation technologies are reviewed, including mechanical and chemical purification methods, adsorption and catalytic oxidation, membrane and cryogenic separation, and biotechnological approaches using microorganisms and microalgae. Special emphasis is placed on Carbon Capture, Utilization and Storage (CCUS) technology, green chemistry principles, industrial ecology concepts, and life cycle assessment (LCA) as key tools for sustainable industrial development. The findings highlight the importance of implementing innovative gaseous emission management technologies to enhance environmental safety, resource efficiency, and sustainable industrial growth in Uzbekistan.

**Key words**: gaseous emissions; air pollution; industrial ecology; greenhouse gases; toxic substances; emission treatment technologies; CCUS; green chemistry; life cycle assessment (LCA); environmental safety

## INTRODUCTION

In today's industrialized society, atmospheric air pollution has become one of the most critical

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issues affecting human health and global ecological balance. In particular, gaseous emissions—chemical pollutants released into the atmosphere in gaseous form—originate from technogenic, transport, and industrial sources. In recent years, scientific and industrial research centers abroad have introduced innovative technologies aimed at reducing, treating, and utilizing gaseous emissions as a resource. These technologies can be applied in the industrial sector of Uzbekistan as well, increasing both ecological and economic efficiency.

Objective of the Article

- To assess the ecological safety of chemical production technologies
- To optimize purification methods in industrial enterprises
- To conduct an in-depth toxicological analysis of industrial emissions
- To implement modern technological approaches for managing hazardous waste

Aerosols and particulate matter are often released together with gases, such as metal oxides, acid droplets, etc.

## III. Ecological and Toxic Hazards

Gaseous emissions released into the atmosphere as a result of human activities significantly affect ecological balance and human health. Their primary ecological risks are manifested in the following areas:

3.1 Impact on the Atmosphere

1. Greenhouse Effect

The greenhouse effect is caused by certain atmospheric gases ($CO_2$, $CH_4$, $N_2O$, and others) that trap infrared radiation, increasing the Earth's surface temperature.

Greenhouse Gases and Their Sources

***Greenhouse Effect***

**Consequences:** Global warming, extreme weather events (heatwaves, droughts, floods), glacier melting, rising sea levels, loss of biodiversity, and reduced agricultural productivity.

**Innovative solutions:** Carbon Capture, Utilization and Storage (CCUS); $CO_2$ absorption using microalgae to produce bioethanol or biomass; smart monitoring systems for real-time tracking of greenhouse gas emissions.

***Ozone Layer Depletion***

Ozone layer depletion is defined as the reduction of $O_3$ molecules in the stratosphere, primarily caused by chlorofluorocarbons (CFCs) and other halocarbons.

**Consequences:** Increased UV-B radiation, higher risk of skin cancer and cataracts, and damage to plants, plankton, and marine ecosystems.

**Solutions:** Replacement of CFCs and halons with eco-friendly alternatives such as hydrofluoroolefins (HFOs), continuous stratospheric monitoring, and evaluation of ozone recovery technologies.

***Photochemical Smog***

Photochemical smog is a cloud of harmful pollutants formed by nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs) under the influence of sunlight. It reduces visibility, irritates the respiratory system, and poses serious environmental and health risks. Major sources include vehicles (especially gasoline engines), paints, varnishes, and industrial solvents.

**Health and environmental impact:** Increased incidence of asthma, bronchitis, cardiovascular diseases, and reduced plant growth rates.

**Innovative solutions:** Electric and hybrid vehicles, selective catalytic reduction (SCR) systems for $NO_x$, biofilter technologies, and smart city systems for smog monitoring and real-time air filtration.

***Acid Rain***

Acid precipitation occurs when sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_x$) react with atmospheric moisture to form sulfuric and nitric acids, which fall to the ground as rain or snow.

**Chemical reactions:**

$$SO_2 + H_2O \rightarrow H_2SO_3 \rightarrow H_2SO_4$$

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

**Ecological damage:**

- Soil acidification;
- Weakening of plant root systems;
- Lowering of pH levels in water bodies leading to fish mortality;

**Таблица 1.** Main gaseous pollutants and their hazards

| Substance | Source | Main Hazard |
|---|---|---|
| CO (carbon monoxide) | Incomplete combustion | Binds to hemoglobin, causes hypoxia |
| $CO_2$ (carbon dioxide) | Combustion product | Causes climate change |
| $SO_2$ (sulfur dioxide) | Fuel combustion, metal smelting | Acid rain |
| $NO_x$ (nitrogen oxides) | High-temperature combustion | Lung diseases, smog |
| $NH_3$ (ammonia) | Chemical plants | Toxicity, damage to vegetation |
| VOC | Paints, petroleum industry | Smog, carcinogenic effects |
| HCl, HF, HCN, $Cl_2$, $H_2S$ | Chemical industry | Highly toxic, corrosive |

**Таблица 2.** Greenhouse gases and their properties

| Gas | Source | Lifetime | Heat Potential |
|---|---|---|---|
| $CO_2$ | Industry, transport | ~100 years | 1 |
| $CH_4$ | Livestock, waste | ~12 years | 25–30 |
| $N_2O$ | Fertilizers | ~120 years | 298 |
| CFCs | Refrigerants | 50–100 years | >1000 |

- Corrosion of buildings and infrastructure (marble, concrete, metals).

**Solutions:** Use of scrubbers and catalytic washing systems, application of low-sulfur fuels, and implementation of energy-efficient technologies.

### Impact on Human Health

Gaseous pollutants significantly affect human health, leading to:

- Acute poisoning (CO, HCN, $NH_3$, $H_2S$);
- Chronic respiratory and cardiovascular diseases (asthma, bronchitis);
- Mutagenic and carcinogenic effects.

## Gaseous Emission Treatment Methods and Innovations

### Mechanical Treatment and Scrubbing

- Cyclone dust collectors and inertial separators;
- Scrubbers for water-soluble gases ($SO_2$, HCl);
- Chemical scrubbing for neutralization of $NH_3$ and $NO_x$.

### Adsorption and Catalytic Oxidation

- Adsorbents such as activated carbon, zeolites, and silica gels;
- Catalytic and thermal oxidation converting $NO_x$, CO, and VOCs into $CO_2$ and $H_2O$.

### Membrane and Cryogenic Methods

- Separation and recovery of $NO_x$ from air streams;
- Selective catalytic reduction (SCR) systems developed in Japan and Germany.

### Biotechnological Approaches

- Microorganisms capable of degrading benzene, phenol, and $NO_x$;
- Biofilters and bio-washing reactors;
- Microalgae for $CO_2$ and $NO_x$ assimilation with bioethanol production.

## Technology for Handling Toxic and Hazardous Waste

### Transportation and Storage

Toxic waste is transported and stored in hermetic containers and designated landfills equipped with hazard warning systems.

### Neutralization and Thermal Treatment

Hazardous substances are neutralized using acid-base reactions, pyrolysis, and plasma incineration to decompose dioxins, PCBs, and phenolic compounds at high temperatures.

### Green Chemistry and Industrial Ecology

Waste recycling as raw materials, closed-loop material and energy flows, and circular economy concepts (e.g., IIT-Bhilai, BASF).

## CCUS Technology – Capture, Utilization and Storage of $CO_2$

- Capturing $CO_2$ and converting it into polycarbonates or urea;
- Biomass production using microalgae;
- Geological storage in depleted oil and gas fields, salt caverns, and basalt formations;
- Major projects: Sleipner (Norway), Petra Nova (USA).

### Life Cycle Assessment (LCA)

Life Cycle Assessment evaluates environmental impacts throughout a product's entire lifecycle, from raw material extraction to disposal. Examples include PET bottles and comparisons between electric vehicles and internal combustion engines.

### Conclusion

Effective management of gaseous and toxic waste is essential for ensuring environmental sustainability, economic efficiency, and social security. The application of green chemistry, biotechnologies, CCUS, industrial ecology, and LCA methodologies in Uzbekistan can significantly reduce emissions, enhance resource efficiency, and support sustainable industrial development. Emerging innovations such as intelligent monitoring systems, IoT-based waste tracking, enzymatic processing, and integration of renewable energy sources further strengthen environmentally responsible production systems.

### Recommended Literature

1. Atmospheric Pollution / N.A. Romanov. Moscow: Chemistry, 2019
2. Industrial Waste Treatment Handbook – Woodard Curran Inc.
3. Green Chemistry and Engineering – Mukesh Doble, Ken Rollins
4. Fundamentals of Environmental Safety – A. Karimov, T. Sattorov. Tashkent, 2023
5. Waste Recycling and Treatment Technology – Ministry of Ecology of Uzbekistan, 2024
6. CCUS and Industrial Applications – Global Energy Institute, 2022
7. Innovative Waste-to-Energy Technologies – IEA, 2023