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# THE ROLE OF GAS PURIFICATION METHODS IN THE CHEMICAL INDUSTRY

**Jumaeva Anora, Qurbonova Madina**
Karshi State Technical University, Department of Chemical Engineering and Biotechnology
Email: anora@qmii.uz

**Abstract.** Gas purification is one of the important processes in industry, energy, chemical production, and environmental protection. Gases released into the atmosphere may contain dust, toxic substances, harmful chemical compounds, and various aerosols. These harmful components negatively affect human health, flora and fauna, and the overall condition of the environment. Therefore, the development and practical application of gas purification technologies play a significant role in reducing environmental problems. In this article, we will provide information about some methods of gas purification.

**Key words:** gas purification, mechanical, physical, chemical, and biological methods, harmful substances.

Gas purification methods are mainly divided into mechanical, physical, chemical, and biological methods. Mechanical purification methods include dust collectors, cyclones, filters, and electrostatic precipitators. These methods serve to separate solid particles from gas streams. For example, cyclone devices separate dust and other solid particles from gas flow using centrifugal force. Filters pass gas through special fibrous or porous materials that capture and retain solid particles[1].

Mechanical Methods (particulate removal, ventilation & scrubbing).

Mechanical methods form the primary “front line” for removing solid particles and large condensates from gas streams. Common devices include cyclones, fabric (bag) filters, cartridge filters, electrostatic precipitators (ESPs), and wet scrubbers such as Venturi scrubbers. Cyclones use centrifugal forces to fling coarse particles onto chamber walls for collection; they are valued for simplicity, low pressure drop, and robustness, but their efficiency declines for submicron particles. Fabric filters (baghouses) provide very high collection efficiencies across a wide particle-size range and remain the industry standard where fine particulate control is required; they do need periodic cleaning (pulse-jet or reverse-air) and proper material selection to withstand temperature and chemical exposure. Electrostatic precipitators charge particles and collect them on electrodes; ESPs excel at treating high-volume flows with low energy penalty for submicron dust but can be sensitive to particle resistivity and gas composition[2].

Venturi scrubbers are a key wet-type mechanical device: by accelerating the gas through a constricted throat and injecting liquid, they produce intense gas-liquid contact and liquid droplet atomization that captures very small particles and some gas-phase soluble species. Venturi systems are particularly effective for removing fine particulate and sticky condensables (tars) and perform well under high temperatures and variable flow conditions. However, wet systems produce a liquid effluent requiring treatment and can consume significant water. In practice, mechanical devices are often arranged as a first-stage cleanup step to reduce particulate load and protect downstream chemical or physical cleaning units (adsorbers, catalysts, membranes). For detailed performance characteristics and design considerations of Venturi scrubbers and mechanical gas-cleaning equipment, consult technical reviews and comparative studies[3].

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Physical Methods (adsorption, membranes, cryogenics)

Physical purification methods are based on separating harmful substances from gases through cooling, condensation, or adsorption processes. During adsorption, substances such as activated carbon and silica gel absorb toxic compounds from gases onto their surface. In the condensation method, vapor-phase components of gases are cooled, converted into liquid form, and then separated. Chemical purification methods are based on neutralizing harmful components in gases through chemical reactions. For instance, during the absorption process, gas interacts with a liquid, and harmful substances dissolve into the solution. This method is widely used for removing toxic gases such as sulfur dioxide and nitrogen oxides. In addition, catalytic purification methods are applied, where catalysts convert harmful gases into less harmful substances or simple compounds.

Physical separation methods exploit differences in phase behavior, surface affinity, or permeability to fractionate gas mixtures without necessarily inducing chemical change. Adsorption — using activated carbon, zeolites, silica, or tailored sorbents — captures VOCs, sulfur compounds, and certain trace species on high-surface-area solids. Adsorbents are regenerable (thermal swing, pressure swing, or purging), making them attractive for cyclic processes such as pressure swing adsorption (PSA) for hydrogen purification or swing adsorption for $CO_2$ capture. Membrane separation has matured rapidly: polymeric, mixed-matrix, carbon molecular sieve, and emerging 2D-material membranes provide compact, modular options for $CO_2/CH_4$, $H_2/CO_2$, and $N_2/O_2$ separations. Membranes offer lower energy requirements for many separations and are easily scalable for decentralized applications, though they can be limited by permeability-selectivity tradeoffs and fouling sensitivity. Cryogenic (low-temperature) separation achieves very high purities — for example, oxygen/nitrogen separation or high-purity $CO_2$ recovery — but is energy intensive and usually reserved for large-scale, high-value separations. In practice, physical methods are often combined: adsorption trains polish streams after particulate removal, membranes remove bulk components before catalytic processing, and cryogenics handle final high-purity steps where warranted by scale and economics. Recent literature highlights advances in membrane materials and hybrid adsorption-membrane schemes that improve overall efficiency.

Chemical Methods (absorption, scrubbing, catalytic conversion)

Chemical cleaning transforms or dissolves target contaminants through reactive capture. The classic example is amine-based absorption for acid-gas removal: aqueous solutions of monoethanolamine (MEA), diethanolamine (DEA), methyl diethanolamine (MDEA), or formulated blends selectively absorb $CO_2$ and $H_2S$ from gas streams; the loaded solvent is then regenerated by heating to release the captured gases and recycle the solvent. Chemical scrubbers using alkaline or oxidative media remove $SO_2$, HCl, and other acid gases by forming stable salts or oxidized products. Catalytic methods — including catalytic oxidation of VOCs and selective catalytic reduction (SCR) of $NO_x$ — convert harmful species into less harmful molecules ($CO_2$, $H_2O$, $N_2$) under controlled temperature and catalyst conditions. Catalytic processes are central in flue-gas and process-gas treatment when thermal incineration is impractical or energy-inefficient. Chemical approaches deliver high selectivity and are well suited to removing chemically active trace species; downsides include reagent/catalyst cost, sensitivity to poisoning by particulates or heavy metals, and the need to treat secondary wastes (spent solvents, salts). Research continues into lower-energy solvent regeneration, robust catalyst formulations, and combined chemical-physical process schemes that minimize waste and energy footprints[4].

Biological Methods (biofilters, bioscrubbers, integrated bio-systems)

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Biological purification methods are based on the decomposition of organic substances in gases using microorganisms. These methods are especially effective in eliminating organic vapors and unpleasant odors from exhaust gases. Biological filters and bioabsorbers are considered environmentally safe and economically efficient technologies.

Biological gas treatment uses microorganisms to biodegrade organic pollutants and odorous compounds into benign end products ($CO_2$, biomass, water). Biofilters — packed-bed systems where a humid, biologically active biofilm grows on a solid support (compost, wood chips, or engineered packing) — are effective for many VOCs and odors and can reach stable efficiencies (e.g., ~70–95% depending on compound and load) with proper design and maintenance. Bioscrubbers first absorb soluble components into a liquid phase and then biologically degrade them in a bioreactor; this configuration can handle higher loading rates and more soluble contaminants. Advantages of biological systems include low operational energy, the avoidance of harsh chemical reagents, and relatively low operating costs. Limitations include sensitivity to temperature, pH, inhibitory compounds, and the need for space and start-up acclimation time for microbial communities. Hybrid systems combining biological treatment with physical or advanced oxidation steps are an active research area to broaden the range of treatable contaminants and to improve resilience. For operational guidance and performance ranges of biofiltration and bioscrubber systems, see recent reviews on biological waste-gas treatments[5;6].

In conclusion, the proper selection of gas purification methods is essential for ensuring environmental safety in industrial enterprises, reducing atmospheric pollution, and protecting human health. The development of modern technologies can further improve the efficiency of gas purification processes.

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