

## CHAPTER 12

# Removal of Industrial Air Contaminants

Industries discharge two types of air contaminants: (1) objectionable solids dispersed in a gaseous waste and (2) objectionable gases dissolved in a gaseous discharge. It falls upon the environmental engineer—with his or her chemical engineering background—to understand these forms of contaminants and design systems for removing both types of contaminants.

Typical examples of the first type include dusts such as coke dust from steel mills, cement dust from cement plants, and fiber dust from pulp and paper mills. The second type includes ammonia as from coke mills, hydrogen sulfide, and sulfur oxides from food processing and paper mills, and organic vapors from paint and plastic manufacturing.

Dust particles not only foul the objects and land on which they are deposited, but also are breathed in by humans and animals causing irritations and consequential disease to respiration systems. Gaseous contaminants more directly interfere with respiratory systems and olfactory organs. Foul odors depict objectionable contaminants whether or not they are proven detrimental to human health.

### Theories and Practices of Suspended Particle Removal

When contaminant particles are present in industrial waste gases, they require removal in order to protect the receiving environment. Treatment of these waste gases containing suspended solids is usually accomplished by passing them through solid bed contactors.

These solid beds can be either stationary or moving and can be in either concentrated or diluted form. Four examples of such bed contactors are described here briefly to provide you with basic background knowledge only.

1. *Dense fixed beds*, which depend on the densely packed solids in the contactor to remove by adsorption the waste gas particles. In this treatment system, the solids contactor is fixed in place and immobile (Figure 12.1A).
2. *Expanded beds*, which move the adsorbing solids about in some degree by either or both gravity or mechanical forces. Such contaminant particulates are typically removed by coming in contact with a slightly moving bed. An example of this treatment system is shown schematically in Figure 12.1B.
3. *Fluidized beds*, in which the adsorbing solids are moved by the impact of the incoming contaminated gases, are an effective and often used system. Such a treatment depends on the difference in forces of the incoming gas and the solid absorbent. Usually the gas flow is upward and the absorbent force is downward—the latter being greater, thus keeping the treatment unit intact. Such a system is shown schematically in Figure 12.1C.

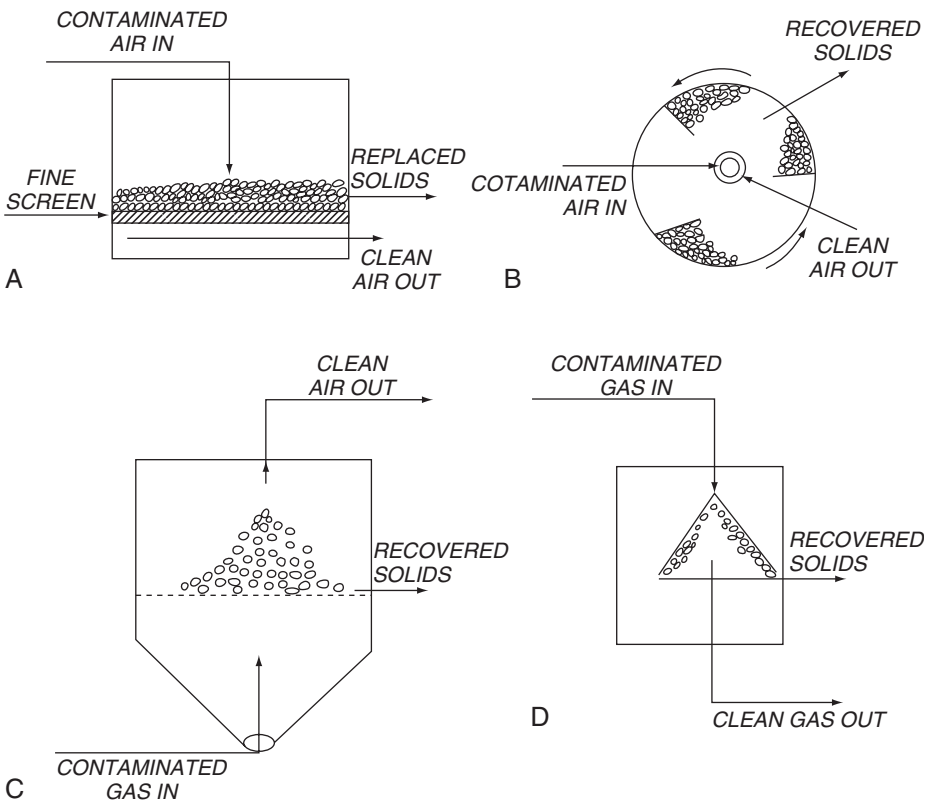


FIGURE 12.1. Treatment of waste gases.

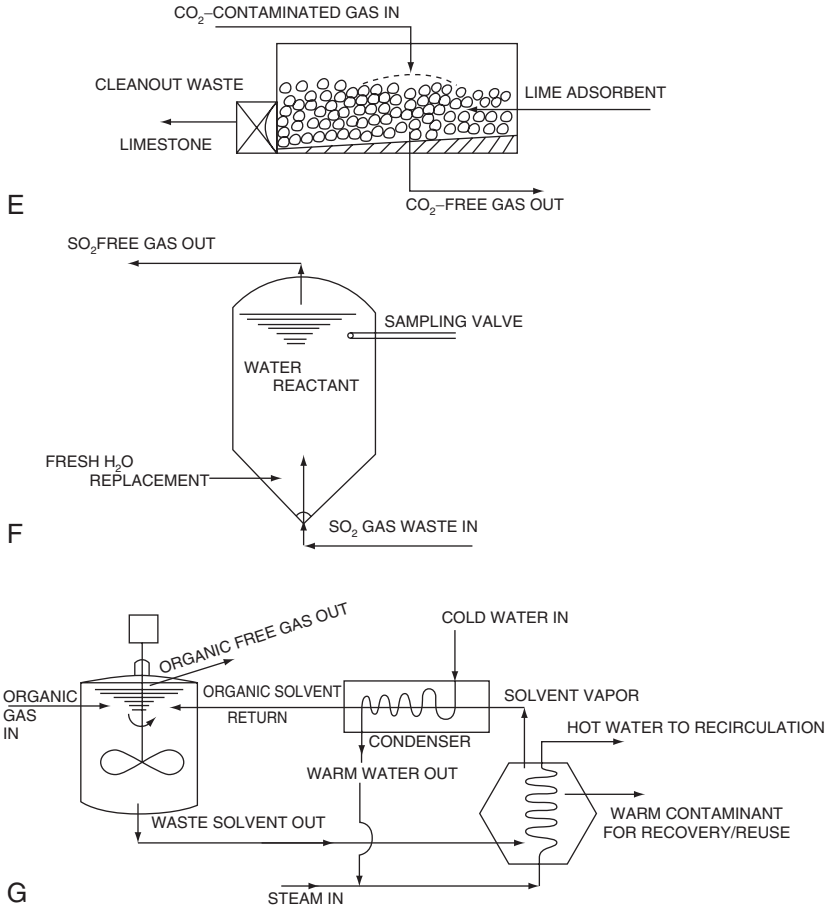


FIGURE 12.1. (Continued)

4. *Dispersed solid system*, in which the density of the suspended system is almost precisely that of the gas phase itself. This is such a dilute system that no bed of solids actually exists and the gas is in reality pressured into a chamber where its velocity decreases and the dispersed solids separate from the gas and are directed towards and collected along the tank or vessel walls. Such a system is presented schematically in Figure 12.1D.

*Objectionable contaminant gases* dissolved in gaseous discharges must also be treated and removed by the industrial waste environmental engineer. Typical of these types of industrial wastes are inorganic vapors such as ammonia (NH<sub>3</sub>), carbon dioxide

(CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), and hydrogen sulfide (H<sub>2</sub>S), and organic vapors such as trichloroethylene (C<sub>12</sub>Cl<sub>3</sub>), phenols (C<sub>6</sub>H<sub>5</sub>OH), and acetone or alcohols.

These gaseous contaminants are generally removed by contact with either solid or liquid reactants. For example, CO<sub>2</sub> is removed by passing the gas through a bed of lime reactant, and the resulting product is limestone (CaCO<sub>3</sub>), while the remainder of the waste gas passes through. Periodically the product, CaCO<sub>3</sub>, is removed and sold or reused and the reactor replaced with fresh lime. Such treatment systems are shown in Figure 12.1E.

Other gaseous wastes such as SO<sub>x</sub>s are removed by passing these gases through liquid reactants, such as water. When the reactant has been completely used in forming sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), it is removed, sold, or reused, and freshwater replaced in the reactor. Such a treatment system is shown in Figure 12.F.

Ammonia gases can be reacted either as in Figure 12.1E and removed as (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub> or as in Figure 12.1F and removed as NH<sub>4</sub>OH.

Organic vapors are retained in reactors with other organic solvents such as benzene or alcohol (depending on the type of organic contaminant). They are later removed from the organic reactor solvent by distillation for recovery and reuse of both the contaminant and the reactor solvent. Such systems are depicted schematically in Figure 12.1G.

In all these second-type systems, the removed and recovered contaminant products must be either sold or reused within the industrial plant to avoid the simple conversion of an air contaminant to a solid or liquid one. For more detailed designs and equipment specifications for all the industrial air contaminant reactors, see Nemerow (2003).

## **Example of Twentieth-Century Air Contaminant Removal**

Heitbrink and McKinnery (1996) reported an evaluation by the National Institute for Occupational Health and Safety (NIOSH) of control techniques for airborne vapors and particulates in tire manufacturing. The mixers studied normally generate aerosols. They found that control of these air contaminants may be accomplished by using local exhaust ventilation or equipment configuration and material substitution.

## **Major Industrial Wastes**

In 1998, I presented in *Strategies of Industrial and Hazardous Waste Treatment* a detailed description of the origin, character, and treatment of all of the major industrial wastes of the twentieth century. The reader is urged to consult this work for specific information concerning these wastes.

These wastes subdivided into eight categories: (1) apparel, (2) food, (3) materials, (4) chemical, (5) energy, (6) radioactive, (7) non-point, and (8) hazardous.

In the following section, I list these same wastes in convenient alphabetical order for your immediate reference. Keep in mind that many of these industries have modified

their processes or eliminated certain products completely since 1998. In addition, new industries have begun production since that time. You can refer to the unnumbered table at the end of this chapter for some of these new industries, as well as Part B of this book.

### **Industrial Wastes Detailed in Nemerow and Agardy (1998)**

#### **Acid and alkali**

Agriculture  
Animal glue  
Asbestos

#### **Bakery**

Beet sugar  
Biological  
Brewery

#### **Cadmium**

Cane sugar  
Cannery  
Caustic (spent)  
Cement  
Chloralkali  
Coffee  
Copper  
Cornstarch  
Corrosion hazardous

#### **Dairy**

Detergent  
Distillery  
Dry cleaning  
Dye

#### **Energy**

E.P. toxic  
Explosive

#### **Feedlot**

Fertilizer  
Fish  
Food  
Formaldehyde  
Fuel and lube oil  
Fuel (radioactive)

#### **Galvanizing and metal plating**

Glass  
Graphic and photographic

#### **Hazardous**

Hospital and laboratory

#### **Ignitable**

Iron foundry

#### **Land farming**

Land and non-point  
Landfilling  
Laundry  
Leachate

#### **Meat packing**

Metal container  
Metal plating  
Mortuary  
Motor

#### **Naval storage**

Nitrogen fertilizer  
Nuclear power

#### **Oils (waste)**

Oil field  
Olive

#### **Paint and printing**

Palm oil  
Pesticide  
Pharmaceutical  
Phenolic  
Phosphate  
Photographic  
Pickle  
Pickling liquor  
Plastic and resin  
Plywood and glues  
Polychlorinated biphenols  
Porcelain enameling  
Power plant  
Pulp and paper

**Radioactive**

Reactive industry  
 Refinery  
 Rice  
 Rubber

**Salts**

Scrubber  
 Silver  
 Soap and detergent  
 Soft drink  
 Spent oil emulsion

Steam power plant  
 Spent solvents  
 Steel mill  
 Sulfides

**Tannery**

Textile  
 Toxics  
 Trihalomethane

**Winery**

Wood furniture  
 Wood preserving

I have added since 1998 the following four wastes:

	<i>Origin</i>	<i>Major Characteristics</i>	<i>Major Treatment</i>
Red bricks (building)	Cleaning of, grinding, mixing, screening and forming of equipment	Minerals	Return to original solids
Waxes carnuba	Semi-liquid filtered matter	Hazardous companies	Landfilled (safe) with solid wastes
Paraffin	Solvent extraction from lube oils	Complex organics	Evaporated for solvent recovery and landfilled
Beeswax	Boiled water discard	Complex organics	Filtered and landfilled

**References**

Heitbrink, W. A., W. N. McKinnery, Jr. Control of air contaminants at mixers and mills used in tire manufacturing. *Am. Industrial Hygiene Assoc.* June;47:312.

Nemerow, N. L. 2003. *Environmental Engineering*, 5th edition, Chapter 6. Hoboken, NJ: John Wiley Publisher.

Nemerow, N. L., F. J. Agardy. 1998. *Strategies of Industrial and Hazardous Waste Treatment, Part 4*, pp. 281–698. Hoboken, NJ: John Wiley Publishing Company.