INDUSTRIAL POLLUTION

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Contents

Summary

Industry contributes various kinds of pollutants to the environment. Different countries in the world are facing different types of industrial pollution problems. Industry produces both traditional pollutants such as organic substances, sulfur dioxide, particulates and nutrients, etc., and newly-recognized pollutants such as dioxin and other specific toxic substances. The pollutants are mainly in gas, water, and solid forms that can cause serious damage to the biosystems. Industrial pollution has attracted a lot of attention. Great efforts have been made to solve the problems. The problems of industrial pollution and their control measures are briefly discussed in this chapter. In recent years, the sustainable development concept has been widely recognized, which has promoted the implementation of integrated management of industrial production. The development of "industrial ecology" aims to provide theories and methods to harmonize the industrial sectors with the biosphere, that may bring solutions of sustainable development to the industry and society.

1. Introduction

Industry plays an important role in the process of economic development in the world. It enhances the economic welfare of citizens and supplies the material goods they consume. The way in which society will develop in the future is largely dependent on how the growth which industry generates is distributed.

Industry is also a major consumer of natural resources and a major contributor to the overall pollution load. Based on OECD (Organization for Economic Cooperation and Development) estimates, it accounts for about one-third of global energy consumption of their member states, and for about 10 percent of the total water withdrawal. The relative contribution to the total pollution load is obviously higher for industry-related pollutants. The industrial sector generates both traditional pollutants (e.g., organic substances, sulfur dioxide, particulates and nutrients) and newly-recognized pollutants (e.g., specific toxic substances). The industrial sector includes a number of diverse activities. As a result, there is a wide range of different resource and environmental impacts created by industry.

Thus, industry has particular environmental responsibilities in terms of such factors as plant location and design, environmental pollution, vibration and noise controls, waste disposal, occupational health and safety aspects, and long-range planning.

Generally, the pollutants from industries are divided into three major categories namely gas, solid and water. There are also some other pollutant forms such as noise and odor. Table 1 shows some pollutant types from different industries.

Industrial sectors	Pollutant forms			
	Gas	Solid waste and soils	Water	Others
Iron and Steel	SO_x, NO_x, HC, CO, H_2S Toxic chemicals	Slag, wastes, sludge from effluent treatment	BOD, COD, oil, metals, acids, phenol, cyanide	Noise, particulate
Textiles and leather	SO_x, HC	Sludge (chromium) from effluent treatment	BOD, solids, sulfates and chromium, dyes	Odor, noise, particulate
Pulp and paper	SO_x, NO_x	sludge from effluent treatment	BOD, COD, solids, chlorinated organic compounds	Noise, odor, particulate
Petrochemicals, refineries	SO_x, NO_x, HC, CO, H_2S Toxic chemicals	Spent catalysts, tars, sludge	BOD, COD, oil, phenols and chromium	Noise, odor, particulate
Chemicals	Organic chemicals	Sludge from pollution treatment and process waste	COD, organic chemicals, heavy metals, solids and cyanide	Odor, toxic chemicals

Table 1. Pollutants from different industries

Industrial pollution control has been paid a lot of attention. Increasing efforts have been made to protect the environment, both in terms of reducing point-source emissions, risk management during chemical use and handling of hazardous waste. New legislation, more stringent emission standards, stricter controls and growing consumer demands for environmentally-sound products have been promoting the implementation of environmental friendly technologies and integrated pollution management strategies.

Recent practices in pollution control tend to move towards the core of industrial operation. Nevertheless, end-pipe treatments played and still play an important role in industrial pollution control.

2. Industrial Pollution Facing Different Countries

The industrial pollution problems faced by different countries worldwide are different. Generally speaking, in developed countries, the pressures created by industrial activates (i.e., the emission of traditional pollutants from iron and steel, metal fabrication and petrochemicals) has grown slowly in recent decades. Other types of environmental problems, e.g., contamination of soil and buildings at closed sites, with subsequent high costs for remedial treatments have received growing attention. In developing countries, the environmental pressure coming from the traditional pollutants created by industries is still very heavy. For both developed and developing countries, the growing technology-based industries, created new problems due to the use of toxic material in their production processes, which can cause soil and water contamination.

2.1. OECD Countries

In developed countries, early in the twentieth century, pollutant emissions to air and water were considerable at production sites, and large volumes of waste material were often dumped in the immediate surroundings of the factories. A classic example is the industrial districts in Northern England, where the fallout of soot put a dark coating cover over the whole landscape. In the Ruhr area in Germany, undesirable amounts of dust fallout from the steel industry as well as large amounts of sewage effluents transformed the river Ruhr into an industrial sewer. In the United States and in Japan, similar situations occurred.

The pollution situation in the OECD countries is now quite different from the previous decades. Treatment measures have been introduced to treat much of the pollution. Wastewater tubes do not end up any more at dead bottoms, trees and vegetation surrounding factories are alive and green, and the surrounding air has cleared up substantially. The efforts in many OECD countries to reduce pollution started in the 1980s, after the need for such efforts became apparent. The discharges of early-identified pollutants have been reduced to a large extent since the beginning of the 1970's, and many environmental problems have been solved.

Industrial growth is commonly regarded as being accompanied by an increase in consumption of energy and raw materials. However, industrial experiences in many countries show that the opposite situation can prevail. Industrial growth may favor environmental protection work and govern research and development, thereby promoting new technologies in industry to further minimize environmental risks. It also provides the necessary financial conditions under which large investments in new technology, necessary for further reducing environmental effects, can be made. As a result, the prerequisites are created for a sustainable industrial development of products with lower requirements for natural resources, and enhanced waste recycling and minimization.

However, the environmental problems have not disappeared in many OECD countries. The local, intense industrial pollution has merely been replaced by regional or global diffuse pollution. Local sources and individual contaminants may be found and identified. Clean, non-contaminated reference areas are still difficult to find. The environmental accidents erupt sometimes. The environmental problems in using the industrial products and used up products are absorbing more concern.

2.2. Eastern European countries

Heavy industries predominate in Eastern Europe, which are often concentrated in specific regions. So far, little concern has been given to environmental impacts of industrialization in these regions. As a result, Eastern Europe now faces very serious industrial pollution problem. However, Eastern Europe also faces a time of change with regard to environmental protection. The big change of the social structure has resulted in the changes of the industrial structure. Heavy industries and relative pollution have been markedly reduced in recent years.

2.3. Developing Countries

The situation with regard to industrial pollution is more heterogeneous and complex in developing countries. The process of industrialization in these countries is far less advanced. Typical industries in these countries are steel mills, mining activities, textile industries, tanneries and pulp and paper industries. Many of these industries are linked to multinational industrial enterprises supplying important raw materials on the world market, to some extent favored by low-paid labor. A large number of the more traditional, small-scale industries are also typical of developing countries. They typically induce severe environmental pollution. On the other hand, technology-based industries have sprouted in some of the developing countries too. Both the traditional pollutants and newly-recognized pollutants function together, which makes environment protection more difficult.

Many developing countries have set aside areas called "industrial free zones" or "export processing zones". These zones are regarded as extra-territorial land from perspectives of, custom regulations, taxation, rules for employment, salaries, working hours, occupational safety and even environmental protection. During the 1980's, some industries unable or unwilling to meet more stringent environmental standards in the OECD countries have moved to "industrial free zones" in many developing countries, which makes the environmental pollution situation in these countries more complex.

3. Industrial Air Pollution

Air pollution emissions can be caused for technical reasons, but may also be caused by unsuitable, worn-out or defective facility components. Figure 1 gives an overview of the origin and causes of air pollution from industrial facilities, showing on the left side those processes where primarily gaseous emissions are generated, e.g., by evaporation, chemical reactions and valve discharges. The most common origins from processtechnological methods of dispersing, sorting, and classifying and other specialized processes are listed at top right.

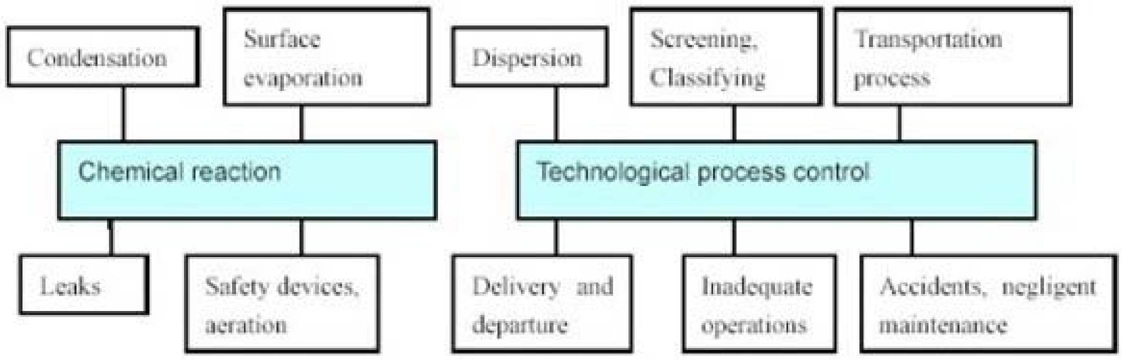

Figure 1. Causes for the generation of industrial air pollutants

3.1 Air Pollution Emissions from Industrial Processes

The major pollutants from industrial emission include gaseous emissions (SO_2, NO_x, etc.) and particulate emissions.

3.1.1 Gaseous Emissions

Depending on the fuel, the SO_2 content of flue gases is 1 to 4 g/m^3; an average size coal fired power plant, with an output of 700MW, produces 2.5 million m^3 of flue gases per hour, emitting about 2.5 tons of sulfur per hour. Compared to power plants, SO_2 emissions from other industrial sources are low and originate primary from the heating of reactors with sulfurous fuels, in roasting processes in the non-ferrous heavy metal and blackening metallurgy and coal enrichment processes (low-temperature carbonization, coking, gasification, etc.). Sulfur dioxide can be oxidized into sulfuric acid by either the "wet" or the "dry" method. A third possibility is the "catalytic" oxidation of soot and dust particles containing heavy metals. This reaction is facilitated by the presence of small droplets of water as fog and these droplets become strongly acidic. The resulting "acid smog" has a particularly deleterious effect on the respiratory system.

Nitrogen oxides are formed in every combustion process and in the production and conversion of nitric acid and nitrates. The most important forms of air pollution from combustion processes are nitrogen oxide (NO) and nitrogen dioxide (NO_2). Mixtures of both oxides are generally summarized as "NO_x". It is customary to report the mass concentrations for NO_x as NO_2 in mg/m^3. Nitrogen dioxide forms from nitrogen oxide through oxidation with atomic or molecular oxygen, ozone, or organic radicals. A special problem is the use of nitrous-containing spent sulfuric acid in super phosphate production, where up to 50% of the nitrogen oxides are released and emitted. At normal temperatures, the breakdown of NO_2 is affected by light (photolysis). As a photochemically very active compound, NO_2 absorbs the sunlight reaching the lower atmosphere at several magnitudes greater than all other gases. This overall reaction is by far the most important trigger of atmospheric radical chain reactions and thus plays a key role in atmospheric chemistry, especially in forming photochemical smog. "Photosmog" also contains a high share of toxic ozone.

Chlorinated exhaust gas is emitted primarily from chlor-alkali electrolysis. Especially critical is the discontinuously occurring "stack chlorine", which is generated for short periods of time in large quantities during startup or shutdown and during malfunctions. Furthermore, during the chlorination of inorganic and organic feedstocks into aluminum chloride, hydrogen chloride, basic detergents, chlorinated hydrocarbons, pesticides, etc., it is possible that up to 30% of the input chlorine is released in the exhaust gas. Non-negligible quantities of hydrogen chloride are released in the drying of potash fertilizer salts.

The scale of health effects from air pollution ranges from irritants to poisons. Causes of diseases of the breathing organs, conjunctivitis, rickets, as well as infections can be collectively related to air pollution. Epidemiological studies have concluded that chronic exposure to sulfur dioxide results in repeated occurrences of sinus infections, respiratory diseases, and breathlessness (emphysema). With respect to the damage occurring to forests today, there is much evidence to suggest that it is caused not only by natural forces, but also primarily by airborne pollutant in dry deposition and/or wet or acid precipitation. The precipitation of the airborne pollutant also can damage the surface water, soil and even further the underground water. The nitrogen dioxides and sulfur dioxides emitted into the atmosphere dissolve and form acids in the water droplets of fog, clouds, and rain. Besides acids (3/4 sulfuric acid, 1/5 nitric acid, and about 1/20 hydrochloric acid), precipitation also contains other pollutants (salts, heavy metals, and organic substances). Air pollution causes damage to historic buildings, to sculptures and stained glass, to industrial and consumer goods, as well as to archived material. SO_2, NO_x and other acid-forming gases, as well as particulates and various photo-oxidants accelerate the natural weathering and aging processes.

3.1.2. Particulate Emissions

Fine particulates are arousing a lot of concern from both scientific circles and the public. Because they not only pollute but also provide huge surface to absorb other pollutant such as heavy metals, toxic organic materials, etc., they may cause many serious health problems and damage the environment. Particulates, or simply particles, is a term that refers to fine solid matter, which is dispersed and spread by the movement of air. Smoke is the dispersion of the smallest still visible solids in a carrier gas and is generated in combustion processes. This finely dispersed matter in the air is generally called aerosol. The most important characteristic of smoke, fog, and dust is their small particle size, between 1 to 0.1μm. Coarser particles settle after a period of time. They are filtered from the air by the nose and the bronchi; finer particulates, such as particles with a diameter below 5μm, are able to enter the lungs.

Particulates are characterized by their mineralogy (lattice structure), their chemical composition, concentration, particle size distribution, and their morphological data. Other important physical characteristics are density, bulk and packing density, angle of slide and repose, abrasion factor, and specific surface. After particulates are generated, they are classified as either primary particulates, which are newly generated particles, or secondary particulates, which are caused by the disturbance of existing particles. In urban areas, secondary particulates can constitute up to 30% of the total particulate load. From the perspective of toxicity, substances like quartz, asbestos, soot, lead, cadmium and vanadium compounds and radioactive particulates deserve special attention. Table 2 lists the important industrial emission sources and particulate type.

Source	Particulate types	Origin, occurrence	S/U
Fertilizer industry	phosphates, urea, potassium chloride, anhydrite, and other sulfates	pulverizing, processing, drying, sintering, granulating, gases	WSCy/Rc
Carbo-chemistry	coal + coke particulates, soot, condensed products	Degasifying, gasifying pulverizing	BP/En
Electro-chemistry	metal + oxide particulates	Electrolysis in the dry method	EP
Calcium-carbide	coke, lime, calcium hydroxide	coke pulverization + drying, lime sintering	Cy/Co
Paint industry	ocher earth, + other particles, heavy metal compound	Pulverizing, dispersing	CyFS
Biocide-industry	insecticides, herbicides, carrier matter	drying, mixing	Cy/Rc
Detergent industry	sodium phosphate, soda, Na-borates	Mixing, dispersing, granulating	Cy/Rc
Rubber and plastics	rubber + plastic particles, talcum, soot; other filler	Mechanical treatment, extracting, dispersing	FS/FM
Smelting	Ores, coke, metal-, metal oxide-, and slag particles	Pulverizing, sintering, throat gas	Cy/Cm
Metal processing	Metal and metal oxide	Converter and smelting furnace, waste gas	Cy/Rc
Foundries	Metal and metal oxide dust, silicates	Smelting furnace waste gas, moulding foundry sand treatment	FS/Rc
Bonding agent and constructio n material	Raw meal and cement dust, rock and mineral dust	Raw material WS extracting, pulverizing, transporting, firing	EPCy/Rc
Ceramics and glass industry	Quartz and silicates, metal and non-metal oxides	Processing + treatment processes WS	FSCy
Wood	Wood dust, sanding	Grinding, sawing,	

processing	and polishing agents	milling, size reduction	Cy/C
Textile industry	Cotton fiber and other textile fiber dust	Treatment (picking, combing), friction	Cy

S = separation: EP = electrostatic precipitator, WS = wet separator Cy = cyclone, FS = filtration separator
U = utilization: Rc = recycling/recirculation, En = Energy generation, FM = filler material, CM = cement manufacture, Co = construction material, C = composting, A = auxiliary filtration material

Table 2. Important industrial emission sources and particulate type

Control methods for industrial air pollutant will be discussed in other articles. (see Technologies for Air Pollution Control).

3.2. Industrial Odor Control

3.2.1. The Problem

Odor is a major factor in the total air-pollution picture because it is easily noticed and frequently the source of complaints. In recent years the problems caused by odor have received a lot of concern. Industrial sources are often considered the main source of offensive odors, and the nature of the company, its raw materials, and the finished products will influence the type of odor produced.

Sensation of odor is an effect caused by odorants when they reach chemo-receptors in the nose. Odor measurements may utilize two different approaches. The identity and the concentration of odorants in the air can be established by appropriate analytical methods. The odor sensation, which is a physiological and psychological effect, can be evaluated using sensory methods that evaluate human responses to the odorous air. In addition, procedures such as the gas chromatogram/odorogram technique may combine both approaches (analytical and sensory) and help in solving some problems.

In a purely analytical approach, the concentrations of know odorous substances in air or an emission are measured. Since many odorants evoke an odor sensation at concentrations as low as 10^{-9} ppb, such measurements may require very specialized techniques. However, analytical data must be interpreted by reference to some target level. Usually the target level is related to the detectability of the odorant by the nose. For example, if a substance begins to smell at a concentration of 10ppb, the analytically determined concentration of 15ppb would possibly be considered odor evoking. In reality, such interpretations are rarely clean cut. An analytical method may focus on some single substance if it is know that its concentration is the prime cause of odor, or that its concentration varies in proportion to other odorants, is found to correlate with the odor of the entire emission, and can be used as an odor index.

Other analytical methods may measure the combined concentration of compounds for chemically related substances. Total reducible sulfur and total aldehyde content are two

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Biographical Sketch

Xianghua WEN is a Professor in Department of Environmental Science and Engineering at Tsinghua University, Beijing, Peoples' Republic of China. She received her Ph.D degree in Environmental Engineering from Tsinghua University in 1991. She teaches Modern Environmental Biotechnology for graduate students. She carries out the research works in the State Key Joint Laboratory of Environmental Simulation and Pollution Control. Her major research fields are in Water pollution control theory and technology and Environmental Chemistry. The on-going projects that she is in responsible for or involved in include: "Membrane Bioreactor for Industry Wastewater Treatment"; "Effect and reinforced mechanism of modern biotechnology in detoxification of pollutants"; "Sustainable Development of Water Resource in Chinese Cities"; "Screening and testing on White-rot Fungi to degrade refractory organics" and etc. She is the author or co-author of about 100 technical papers and research reports.