POLLUTION CONTROL IN INDUSTRIAL PROCESSES

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Summary

Environment pollution accompanies each stage of any industrial process, starting with raw material and fuel production and ending with waste treatment.

Energy consumption plays a key role in every human activity. On the other hand its production is associated with severe pollution of air, soil and water. That is why energy saving, accomplished by any method contributes to reduction of the overall pollution of environment.

The exhaustion of raw materials in nature, the increasing emission of greenhouse gases, the depletion of ozone layer and the severe pollution of underground water and soil prompted modern society to abandon the old fashioned approach of end-of-pipe emissions control. Nowadays the approach of environmentally sustainable industrial development is widely discussed and adopted. It comprises different methods for pollution minimization: to improve efficiency of processing of raw materials; to reduce raw materials input and energy consumption; to re-use by-products; to improve management practices. This approach is demonstrated here using the examples of chemical industries and energy production since they are the most powerful sources of environmental pollution in modern society, compared to all other industries.

1. Introduction

In the nineteenth century, when the technically developed countries (according to the current standards) were few, the production rates and the environmental pollution were not a source of concern. In the twentieth century however, the technical revolution and the resulting economic changes prompted almost the whole world to adopt industrial development as a pattern for prosperity. However, this trend could not be without negative consequences. The extensive industrial development throughout the world lead to huge demand for energy and raw materials, resulting in exploitation of coal, oil and natural gas resources on a scale unseen hitherto. The consequence was generation of enormous amounts of waste and emissions to air and water bodies, overwhelming the capacity of nature to restore the environmental balance. Deforestation, caused by different reasons in different countries, led to massive release of carbon dioxide, the commonest of the greenhouse gases. All this created serious climate changes, which have already been observed. The non-balanced use of certain organic chemicals, like solvents and chlorinated compounds, along with air transport, led to depletion of the stratospheric ozone layer in, menacing the life of the whole planet.

An illustration of the profile of the most important industrial air pollutants in USA for 1997 with their sources of origin is given in Table 1.

Industry Sector	CO	NO_x	PT	SO2	VOC
Metal Mining	4,670	39, 849	173,566	17,690	915
Pulp and Paper	566,883	358,675	111,210	493,313	127,809
Inorganic Chemicals	153,294	106,522	34,664	194,153	65,427
Organic Chemicals	112,410	187,400	16,053	176,115	180,350
Petroleum Refining	734,630	355,852	36,141	619,775	313,982
Rubber and Misc. Plastics	2,200	9,955	5,182	21,720	132,945
Stone, Clay and Concrete	105,059	340,639	662,233	308,534	34,337
Iron and Steel	1,386,461	153,607	87,939	232,347	83,882
Nonferrous Metals	214,243	31,136	24,654	253,538	11,058
Pharmaceuticals	6,586	19,088	4,425	21,311	37,214
Power Generation	366,208	5,986,757	464,542	13,827,511	57,384

Table 1: Air Pollutant Releases by Industry Sector in U.S.A. for 1997 (tons/year) *(Source: Profile of the Pharmaceutical Manufacturing, EPA/310-R-97-005, http://www.es.epa.gov/oeca/sector).*

New efficient and clean technologies and processes, which save raw product and energy, as well as involving by-product use and recycling, are beneficial for environmental protection by reduction of emissions to air, water and soil. At the same time natural resources can be spared for the future. This approach is known as environmentally sustainable industrial development (ESID), leading to reduction of natural resources consumption and to less environmental damage from raw material extraction. ESID leads particularly to lower energy demands and consequently to decrease in fuel consumption and production with less environment pollution, as well as reduction of emissions to all of components of environment and to reduction of waste treatment costs. The ESID approach was formally adopted at the World Summit in Rio de Janeiro in 1992. It is included in the development programs of the United Nations and the developed countries.

Another document of global importance is the Protocol agreed at the Conference in Kyoto

(1997). It sets out commitments to limit greenhouse gas emissions for industrial countries for the period 2008 to 2012. These documents are up-to-date for engineers, scientists and operators to implement technology strategies and public policies that prevent, reduce, or eliminate adverse environmental consequences in chemical industry and metallurgy.

The best way to reduce pollution is to prevent it in the first place. In the waste management hierarchy if source reduction is not feasible, the next alternative is waste recycling, then energy recovery and waste treatment as a last alternative. There are different practices for emission reduction.

Different opportunities to reduce emissions in industrial processes, particularly due to the chemical industries, as the mostly powerfully polluting ones, are presented and discussed in this paper.

2. Petroleum Industry

The petroleum industry includes various activities to explore for, produce, and transport oil and petroleum products worldwide. Besides the production of fuels and lubricating oils, large refineries integrated with petrochemical plants may produce many different synthetic derivatives—from pure chemicals to additives for fuels and lubricants, synthetic polymers, elastomers, etc. However, the world petroleum industry produces around 67 million tons of waste annually. Modern pollution control technologies applied by and developed for the petroleum industry are of great importance, both from the economic and environmental point of view. A comprehensive presentation and discussion on the impact of the petroleum industry on environment and ways to combat the resulting adverse effects is given in *Control of Pollution in the Petroleum Industry*.

2.1 Pollution from Exploration and Production of Crude oil and Natural Gas

Major activities in this branch of the petroleum industry include exploration and well site preparation; drilling; crude oil and gas production, enhanced (secondary) recovery and eventually some on-site processing.

Air pollution from the production of oil and gas is by volatile hydrocarbons in fugitive emissions (mainly methane), as well as emissions from storage and manipulation. Exhaust combustion emissions are generated from compressors, pumps, drill engines and engines of servicing vehicles. Gas flaring is the major source of combustion emissions. The major source of secondary emissions is the water separated from the natural gas and crude oil.

Underground water pollution is usually associated with enhanced recovery and desalting of crude oils. Solid wastes are mainly sludge from the desalting of the crude oil and storage vessels, spent mud, etc.

2.2 Pollution from Storage, Manipulation, and Transportation of Petroleum Liquids

Storage, manipulation and transportation are operations, which are inherent to all branches of the petroleum industry. Air emissions from storage and transportation are mainly evaporative hydrocarbon emissions from manipulation—loading/unloading—and transit losses from storage tanks and tanks of transporting vehicles.

Ballast water from transporting vessels and especially ocean-going tankers is the major source of secondary emissions, but also a major source of marine water pollution. Another source polluting underground water is leaking liquids from pipelines. Solid waste generated in storage and transportation is mainly sludge from the storage and transportation tanks.

2.3 Estimation of Pollution and Control Technologies for Petroleum Processing

2.3.1 Estimation of air pollution

Emissions to air from the petrochemical industry are usually presented as methane (CH_4), carbon dioxide (CO_2) and non-methane volatile organic compounds (VOCs). Table 1 shows that the petroleum industry is the biggest source of VOC emissions.

Storage and handling emissions can be measured directly but are most often calculated. The most widely used control technologies include floating roofs, submerged filling, balancing the vapors from all tanks and collecting them in a separate tank, and condensation of excess vapors.

Combustion emissions can be measured but on a larger scale are usually calculated from the amount and type of fuel burned in the particular burner. Typical control techniques are concentrated on improving the efficiency of combustion and diminishing heat losses. These include new types of burners, flue gases heat recovery, introducing new processes with lower energy consumption, etc. Flaring is used to control pressure and remove gas, which cannot be otherwise used.

Fugitive emissions (equipment leak emissions) are the most difficult to characterize, because they come from an enormous amount of point sources. The control technologies include inspection and maintenance programs, and change of equipment with more advanced seal design modifications.

Process emissions are generated in the process units and are released from process vents. They are most frequently estimated from the material balances of the particular processes.

Gas streams from all refinery processes are usually passed through gas treatment and sulfur recovery units to remove sulfur and recycle them to fuel gas. Particulates are captured in electrostatic precipitators or cyclone separators. Wet scrubbers may be used for catalytic cracking units in the future in order to eliminate catalyst fines.

New developments include production units with reactive distillation, use of oxygen enriched air catalytic cracking, replacing of solvent dewaxing in lubricant production by catalytic dewaxing, bio-desulfurization of oil and oil products and so on.

The water systems of a production or processing site (tanks, ponds, sewer system drains, etc.) are the main source of *secondary emissions.* The main options for their control are diminishing the amount of wastewater and solid wastes and keeping wastewater and solid wastes in closed systems in order to control their release.

2.3.2 Control technologies for water pollution and solid wastes

Many of the wastewater and solid wastes sources are similar in the different branches of the petroleum industry. Refineries provide much more options for regeneration and re-use of effluents.

Some of the main directions in which these options are being further improved comprise decreasing the total amount of water used in refineries, introducing separate treatment for collection and treatment for wastewater, collecting separately and using rain and snow water, development of new, more efficient de-emulsifiers and systems for oil-water separation.

Most refineries generate solid waste in a sludge form, spent caustics, spent process catalysts, filter clay, and incinerator ash. The best solution to the solid waste problem is the reduction of the generated amounts by developing new technologies and processes.

2.4 Concluding remarks

The brief review presented shows that the best way to decrease emissions in the petroleum industry, either in air, liquid or solid, is to improve the economic efficiency of the facility. This means that one has to prevent leaks and non-controlled evaporation, to utilize and to recycle the waste as by-products, and to recover their energy as secondary fuels. Waste disposal is considered the last option and should be minimized.

3. Energy Production from Fossil Fuels

Energy production and energy consumption play a key role in economic development and the health of the environment. The extensive use of fossil fuels began in the middle of the nineteenth century, associated with industrial development.

However, power production from burning fossil fuel led to extremely severe pollution of air, water and soil, through greenhouse gases and by damaging the land. Power generation is the most powerful source of emissions of sulfur dioxide and nitrogen oxides, non-comparable with any other industry (see Table 1).

3.1 Production, transportation and pre-combustion processing of fossil fuel and their contribution to environmental pollution

Coal is a major source of energy for power stations. Almost 40% of the world's electricity is generated from coal—more than twice the proportion from any other fuel. Coal causes environmental problems associated with the release of particulate matter (PM), soot, volatile organic compounds, carbon monoxide, and sulfur and nitrogen oxides.

3.1.1 Coal mining, its impact on environment and technologies for pollution control

The environmental problems of power generation from coal combustion begin with its mining. Coal mining operations are sources of air pollution in the form of methane, coal or rock dust. Water pollutants are suspended and dissolved solids, sulfates, acidity and alkalinity. Acidity derives from oxidation of coal pyrites by the oxygen dissolved in water or contained in the pumped air. The overall effect of these reactions is the conversion of sulfur compounds into sulfuric acid.

Back filling, grading, restoration, re-vegetation and post mining land uses are needed after surface mining.

3.1.2 Pre-combustion cleaning

Pre-combustion cleaning is used to reduce the mineral and ash content in coal. Froth flotation is used for cleaning the fine classes of coal. Desulfurization, even partial, is a very important step in the pre-combustion cleaning of coal. Pyrites are removed (within 30-50%) by flotation. Distillate oils have negligible nitrogen and ash content with sulfur less than 0.3% (wt.). Residual oils contain significant quantities of metals, nitrogen, and sulfur. Waste oils include used crankcase oils from automobiles and trucks, used industrial lubricating oils, and other spent industrial oils (i.e., heat transfer fluids). High levels of halogenated solvents are also often found in waste oil. The most common pre-treatment scheme for waste oil uses sedimentation followed by filtration. Blending of waste oil with a virgin fuel oil is practised frequently and has the same effect as some of the pre-treatment processes.

3.2 Power generation from fossil fuels

There are three main designs of combustion systems in which coal and air can be reacted, classified as fixed bed system, entrained (or suspended) bed system and fluidized bed system. The latter is characterized by sufficiently high velocity of the oxidizing gas to support or “float” the particles without carrying them out of the bed. A pressurized fluidized bed combustor (PFBC) system can drive both a gas turbine and a steam turbine. This arrangement is known as a combined cycle. Coal gasification is one of the clean systems of power generation because sulfur, nitrogen compounds and particulates are removed before the fuel is burned. In an integrated combined cycle with coal gasification coupled with an advanced gas turbine, gas can be cleaned of more than 99% of its sulfur and ash and 90% of its nitrogen pollutants. The gas is burned in the gas turbine. Exhaust heat is used to produce steam for steam turbines. Coal gasification can also take place *in situ*.

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