POLLUTION CONTROL TECHNOLOGIES

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Summary

Environmental pollution is a combined result of natural and man-made (anthropogenic) contributions. This Theme deals with the technologies and equipment available for control of anthropogenic pollution. There are different options for reducing the impact of pollutants but the most cost-effective is to trap pollutants at source. The major sources of man-made pollution are related to engineering activities, such as excavation and processing of raw materials, power generation, transportation, etc. The interdisciplinary engineering efforts for environmental pollution management at source are often defined as environmental engineering. Environmental engineering employs specific methodology of the traditional sciences and their engineering applications (physics and mechanical engineering, chemistry and chemical engineering, mathematical statistics, etc.) in order to describe and solve specific environmental problems.

The first three Topics address the variety of techniques available for minimizing pollution in gaseous emissions. Technology in this area has been developing rapidly. Gaseous emission control systems can generally be divided into those designed to

remove particulates and those designed to remove pollutants, which are emitted as gases. Particulate removal techniques include cyclonic collectors and wet scrubbers, bag house fabric filters, electrostatic precipitators, etc. Gaseous pollutants are separated from the inert air stream through processes, such as condensation, absorption, adsorption, etc. Applied Combustion Science is yielding significant results both in the management of combustion emissions, and as a method for liquidation of pollutants, so the third Topic is devoted to this subject. The first three Topics cover also a necessary amount of chemical engineering fundamentals, needed for better understanding of the principles on which the different control technologies are built.

The Topic on industrial processes reviews the latest pollution monitoring, control and management technologies employed by the major industries – the petroleum industry, power generation, the chemical industries, metallurgy, etc. which are perceived as landmarks of civilization, but are also major contributors to anthropogenic pollution. This topic is an illustration of the specific application of the technologies for control of gaseous emissions discussed in the previous topics, but covers also options for control of the pollution of water and soil, and the pollution control solutions available as part of the different production technologies. Emission control standards and their application within the industry are dealt with in the subsequent Theme.

The final Topic covers pollution control technology within the transportation sector and particularly - techniques for reducing or eliminating vehicle emissions. In contrast to the stationary sources of pollution, which are the object of the previous topic, the sources in transportation are mobile, so their monitoring, control and management require approaches, some of which are different from those for the stationary industrial sources.

1. Introduction

The study of environmental pollution might be divided into three obviously overlapping but somewhat distinct areas:

a) The identification, monitoring and control of the generation of pollutants at their source. This first area includes everything that occurs before the pollutant is released "up the stack" or "out of the pipe".
b) The transport, dispersion, chemical transformation in and removal of species from the environment. This area includes all physical and chemical processes between the point of emission and the ultimate removal from the atmosphere.
c) The effect of pollutants on human beings, animals, materials, vegetation, crops, forest and aquatic ecosystems, etc.

The most effective way to control environmental pollution is to diminish or prevent the release of pollutants at source, which is covered by the first of the above postulated areas. This area is the main object of study of an interdisciplinary effort of scientists often defined as environmental engineering. Environmental engineering employs specific methodology of the traditional sciences and their engineering applications (physics and mechanical engineering, chemistry and chemical engineering, mathematical statistics, etc.) in order to describe and solve specific environmental problems.

The environmental pollution is a combined result of natural and man-made contributions. The natural pollutants result from the cyclic biochemical processes in the biosphere - the bacterial transformations of matter, volcanic and geothermal activity, photosynthesis and the life of animals, etc. The anthropogenic contribution is mainly the result of man's activity for production and use of energy, exploration for and production of raw materials, the industrial transformation of raw materials into useful products and so on.

Air pollution provides a good illustration of the general principles of environmental engineering. Its early history is well documented (see, *Control of Particulate Matter in Gaseous Emissions*). To clean up London's air, polluted by that time mainly by stench and smell of biomass and coal combustion, King Edward I in 1273 even outlawed coal burning exclaiming "…whosoever shall be found guilty of burning coal shall suffer the loss of his head." This is obviously a striking example of an ancient “environmental law”. However, it probably reflects the despair of a ruler not having at his disposal adequate means for controlling pollution. The results of this early fight for a better environment do not seem to have been very different from what we obtain today, because in an “environmental report” entitled "Fumifugium or the inconvenience of the Air and Smoke of London dissipated", written for Charles II, King of England, in 1661 by John Evelyn, one might read: "This coale ... flies abroad ... and in the Springtime besoots all the Leaves, so as there is nothing free from its universal contamination ... and kills our Bees and Flowers abroad, suffering nothing in our Gardens to bud, display themselves or ripen."

Air pollution is usually treated in terms of the monitoring, control and management of the so-called major (criteria) pollutants – CO and CO_2, SO_2 and SO_3, NO_x, particulates and volatile organic substances. These pollutants are released in most natural and anthropogenic processes and are the principal criteria both for air pollution control and for air quality standards. Other pollutants, such as halogenated hydrocarbons, metal aerosols, other toxic and hazard substances, etc. emitted from specific human activities, often termed “specific pollutants”, are the object of pollution control and air quality standards when they are a problem for a particular activity and location.

Air pollutants are typically released as components of an emission, which contains a much greater amount of inert material (air). Within the emission the polluting substances may enter secondary chemical reactions, as the result of which some of the original concentrations may be changed, and new (secondary) pollutants might be created. Because of that, the practical overall environmental impact of the pollutants in a specific emission cannot be estimated only by their individual concentrations and their effect on the environment as individual substances. Chemical reactivity cannot also serve alone as a separate measure for comparison and overall estimation. Possibilities for synergism and antagonism in the adverse effect of an emission may be due also to non-chemical factors. For instance, particulates often serve as carriers of adsorbed pollutants deeper in the human lungs; the fate of a pollutant released from a mobile source (e. g, an aircraft) and from a stationary source might be different and so on. Moreover, pollutants which today have only minor significance, e.g. traces of a substance, released from a vehicle after-burn converter, might become of primary concern when such converters are mounted on all vehicles around the world (see

Catalytic Converters and Other Emission Control Devices).

The above point of view may be spread over, though with some specifics, to the pollution of water and soil as well. In any case, the evolution of any particular pollutant should be closely monitored, so that solutions of unexpected problems might be developed without delay, if needed. Furthermore, any solution to a particular environmental problem for a particular source should be estimated on the basis of its "life cycle analysis" and its impact on other sources. A typical example, discussed in detail in the end of this Theme is the "zero emissions vehicle (ZEV)" concept. An electric vehicle may practically not have polluting emissions. However, its application may involve increasing the emissions of other sources, i.e. in the generation of electricity (see *Zero Emission Vehicles*).

The first three Topics, of the Theme discuss in detail the variety of techniques available for minimizing pollution in gaseous emissions. They provide also a necessary amount of chemical engineering fundamentals, needed for better understanding of the principles on which the different control technologies are built. The Topic on industrial processes reviews the latest pollution monitoring, control and management technologies employed by the major industries which are perceived as landmarks of civilization, but are also major contributors to anthropogenic pollution. This topic is an illustration of the specific application of the technologies for control of gaseous emissions discussed in the previous topics, but covers also options for control of the pollution of water and soil, and the pollution control solutions available as part of the different production technologies. The final Topic covers pollution control technology within the transportation sector and particularly - techniques for reducing or eliminating vehicle emissions. In contrast to the stationary sources of pollution, which are the object of the previous Topic, the sources in transportation are mobile, so their monitoring, control and management require approaches, some of which are different from those for the stationary industrial sources.

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http://www.epa.gov/oeca/sector/ [profiles and reviews of the industries covered in the Theme]

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Biographical Sketches

Bhaskar Nath received his Bachelor's degree in Civil Engineering from the Indian Institute of Technology, Kharagpur (India) in 1960, followed by a Ph.D. from the University of Wales, UK, in 1964. In 1983 he was awarded a D.Sc. degree by the University of London for his outstanding original research (according to citation) in numerical mathematics. In 2001 he was awarded the *Doctor Honoris Causa* (Dr.H.C.) by the University of Chemical Technology and Metallurgy, Sofia (Bulgaria), for his contribution to environmental education.

Professor Nath taught at the University of London for twenty-seven years till 1995. Currently he is Director of the European Centre for Pollution Research (ECPR), London, Executive Director of the International Centre for Technical Research, London, and visiting professor to several major European universities. He is also consultant to a number of UK and US companies.

To date he has organized and participated in eleven international postgraduate teaching and training programs, sponsored by (among others) the Commission of the European Communities and NATO, in Belgium, Bulgaria, the Czech Republic, Hungary, Macedonia, Poland, Romania, and Turkey. On behalf of ECPR, to date he has also organized four major international conferences and fifteen dedicated short courses in various European countries.

Professor Nath's professional interests include elasto-hydrodynamics, numerical mathematics, philosophy, environmental protection, environmental management, environmental education, and sustainable development and related issues. To date his publications on these subjects number over 120, including sixteen books. He has been founder and editor of three international journals, including *Environment, Development and Sustainability*, published by Springer.

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He received his first hands-on experience of ecological problems during compulsory military service as Head of the Fuels and Lubricants Unit of an airbase. His PhD dissertation was on development of replacements for lubricant additives synthesized from the sperm oil, obtained from blue whales. He did a post doc specialization in tribology at the University of Birmingham, U.K. Later he specialized in effective and ecological processing and use of petroleum derivatives at Imperial College, London, the French Institute of Petroleum, and other leading universities.

The scientific and research interests of G. St. Cholakov are centered around petroleum processing and petroleum derivatives – environmentally compatible processes and products, process and product design for the petroleum industry, chemistry of combustion and ecology, etc. He is teaching advanced courses in related academic disciplines – Alternative Fuels and Lubricants, Air Pollution Management, Chemistry of Combustion and Ecology, Additives for Fuels and Lubricants, Computation in Petroleum Processing, etc. In 2002 as an invited lecturer, he gave a course on Chemistry of Combustion and Pollution from Vehicles at The Ben-Gurion University, Israel.

Cholakov has contributed more than 60 papers in refereed international journals and co-edited the Bulgarian edition of Miall's Dictionary of Chemistry. He is member and has served in elective positions in different Bulgarian and Balkan professional organizations. He has been member of the editorial boards of three journals, published in Bulgaria in the English language.