ENVIRONMENTAL QUALITY STANDARDS

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Summary

The purpose of environmental quality standards is to protect quality of life and health by controlling the quantity and quality (mainly in terms of toxicity) of anthropogenic pollutants, emanating mainly from industrial activities, released to the environment. Clearly, in the case of trans-boundary pollution setting and implementing environmental quality standards is contingent upon international cooperation and negotiation, and this can complicate the process and make it time-consuming. The scientific process of setting such standards includes identification of hazards based on epidemiological, clinical and/or toxicological studies as deemed appropriate; and determination of acceptable risk, which is sometimes influenced by marginal abatement costs. These issues are discussed in this contribution with reference to air pollution which is a major cause for concern in many countries as well as globally. The focus of discussion is on the preparation of air quality criteria, and on development of air quality standards and their advantages and disadvantages. Also discussed are the closely related issues of exposure-response relationships, criteria for carcinogenic endpoints, and certain aspects of air pollution control strategy.

1. Introduction

The purpose of environmental health standards is to control hazards caused by the release of certain substances into the environment. The assessment of a pollution hazard should strictly be a scientific process of evaluating probabilities using best available information. When the characteristics of the distribution of a pollutant into the environment and its effects have been determined, it is necessary to carry out a detailed assessment including socio-economic considerations. The socio-economic parameters largely determine the acceptable types of environmental effects and also the measures that may be taken to control pollution. Each country has its own legal framework for making decisions on control measures and for determining whether these should be advisory or mandatory.

There are two main stages in the formulation of public policy decisions to protect health and welfare against environmental hazards:

- *The scientific stage:* This includes hazard identification and characterization, risk evaluation to establish the extent of potential health effects, and hazard assessment to determine routes of exposure and to estimate the number of people exposed to the hazard. At the end of this stage, levels of pollutants that do not cause adverse effects should be determined and necessary safety margins agreed. The resulting figures can then be used as standards in the various national environmental control programs.
- *The administrative stage:* This involves determination of acceptable risk; identification of the population groups to be protected; considerations of human ecology; selection of the control technology to be used; legislation and standards; and economic considerations to determine the costs and benefits of measures to be taken. This stage requires knowledge of the technical, social, financial, legal and institutional implications of the measures to be implemented.

An important step is to set out the procedure to be adopted by the national agencies in choosing the specific pollutants to be controlled from among the many released into the environment. Traditionally this decision has been based on the subjective consideration of a number of factors such as immediate hazard, public concern, and/or feasibility of control. However, most developed countries and international organizations have now adopted systems for setting priorities for more effective guidance. Five criteria, suggested by the World Health Organization (WHO), are usually applied to determine the extent to which a pollutant may pose an environmental hazard. They are severity and frequency of observed adverse effects on human health; abundance of the pollutant in the environment; persistence of the pollutant in the environment; environmental transformation or metabolic alterations of the pollutant; and population exposure.

Often national authorities are forced to make decisions when there is a major local problem. A typical example of this was the mercury poisoning at Minimata, Japan. After this experience other countries around the world attempted to assess their own local conditions regarding mercury with a view to taking appropriate action. In other cases, public opinion focuses attention on an environmental issue to such an extent that it becomes top priority. Also, problems may often be suspected on the basis of chemical similarity between one substance and another that is known to be hazardous.

International co-operation is essential for controlling pollution, especially trans-boundary pollution. A major advantage of such co-operation is the wider availability to the decision-makers of expert reviews of information from many other countries at low cost. Generally, such reviews provide not only internationally relevant suggestions for priority action, but also associated information on the evaluation of health effects; suggested safe levels for human, animal and vegetation exposure; emission data; pollutant concentration in different environmental media, etc. There are formal programmes to facilitate international co-operation in this area, the following among others: the United Nations Environmental Programme, the WHO Environmental Health Criteria Programme, the WHO Regional Office for Europe, the International Register of Potentially Toxic Chemicals, and the International Agency for Research on Cancer.

It is emphasized that, for the sake of coherence and clarity, discussion on environmental quality standards in the following chapters will focus on air quality which is probably the most important area of pollution control. However, it must be kept in mind that analogous pollution control procedures are used in the other fields of environmental control, because the basis of pollution control philosophy is common to the entire spectrum of environmental applications. The usual procedure adopted for developing air quality standards involves the following:

- *Preparation of air quality criteria:* These are based on an analysis of the relationship between air pollutant concentrations and their associated adverse effects. The World Health Organization (WHO) calls these "guides" or "guidelines".
- *Development of air quality standards:* Obtained from air quality criteria, they are pollutant concentrations that we intend to achieve in the immediate future. They may not coincide with our air quality goals, however, because these standards also take into account the feasibility of their achievement within the immediately foreseeable future.

2. Air quality criteria

2.1 Exposure to air pollution

Air pollutants can affect the health of individuals or groups of people over a broad range of biological responses. There are five biological response stages of increasing severity: tissue pollutant burden without other biological changes; physiological or metabolic changes as signs of illness; morbidity or disease; and mortality or death. Some of the stages may occasionally overlap, and there may be a range of responses in each stage.

In any case, severe effects such as death or chronic illness affect relatively small proportions of the population. In very few cases these effects can be attributed directly and solely to pollutant exposure, since in general the role of environmental contaminants in the mortality or morbidity experience of a community is difficult to quantify, and also because many other determinants of death and disease cannot be adequately measured. Other factors may be of diverse origins such as genetic heritage, nutritional status and personal habits. Some of the groups within the population may be especially sensitive to environmental factors like the very young, the very old, and those already affected by a disease. Sensitivity may be temporary or permanent.

Pollutant burdens are tissue residues resulting from pollutant exposure. They are highly specific effects of exposure that can be easily quantified in population studies and may be used as indicators of environmental quality. When the connection between the lower and higher response spectrum can be established, risk of disease associated with physiological changes caused by pollutant burdens can be demonstrated, and the role of pollutant exposure in the total morbidity and mortality experience of a population can be defined.

Information on health impacts of pollutants comes from several health disciplines, mainly epidemiology, clinical research, and toxicology.

- Epidemiology provides studies of population exposure under real conditions. The major advantages of epidemiological studies are that they are made under conditions of natural exposure and so avoid the need to extrapolate data to humans. The major problems are: quantification of exposure, and acquisition of dose-response data from among the many covariates
- Clinical research studies can be used to gather data on either normal or diseased persons with regard to absorption, metabolism, and excretion of pollutants. The advantage of clinical studies is that pollutant exposure is controlled so that improved dose measurements can be obtained. But the disadvantage is that exposure is artificial and cannot be long-term.
- Different response systems are used in toxicological studies, such as whole animals, organs, cells, or biochemical systems. The main advantage of toxicological studies is that it provides maximum response data and more reliable cause-effect relationships. The major disadvantage is that it is difficult to extrapolate animal data to humans.

It is important to verify the coherence of the above three disciplinary approaches and to identify the crosswalks between them. Effects of pollutants on humans can be verified across a wide range of pollutant exposure through animal studies, analysis of metabolic pathways, etc.

The effects of pollutants on human health depend on their physical and chemical properties (duration, concentration and route of exposure) and on their uptake and metabolism by humans. Health effects of an environmental pollutant may be short-lived (acute), or relatively permanent and irreversible (chronic). Acute or chronic effects may occur after a single exposure to a hazardous substance, or from long-term exposure. Acute effects and short-term exposures are less difficult to study than chronic effects or long-term exposure.

Exposure of a population to an individual air pollutant, or to a cocktail of such pollutants, varies according to season, day and hour, depending on changes in ambient pollutant concentration. Mobility of the population, from indoor to outdoor environments and from one residence to another, must also be considered. For this purpose, small-scale instruments for personal monitoring are used in combination with stationary monitors of urban networks. But the method has problems because continuous personal monitoring, needed to evaluate the effect of short-term exposures, is costly and technically complex. Also, equipment for stationary monitoring cannot often be used due to space and/or time constraints, especially to monitor chronic effects.

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Biographical Sketches

Dr. Pavlos Kalabokas obtained his first degree in Physics from the University of Athens, Greece, in 1983, followed by the Masters and Ph.D degrees in Air Pollution Chemistry from the University of Paris VII, France, during 1983-87. The topic of his research was "sampling and analysis of carbonyl compounds in the atmosphere of Paris, France".

He was a visiting scientist to the German Research Center KFA-Julich, Institute of Chemistry of Polluted Atmospheres, during 1987-1988, and to the German Research Center KFA-Julich, Institute of Applied Physical Chemistry, during 1989-1990. During 1991-1993 he was Research Associate at the Laboratory of Meteorology of the University of Athens working on the vertical measurements of tropospheric and stratospheric ozone over Athens. During 1994-1997 he was Research Associate at the Environmental

Research Laboratory of the Greek National Center of Scientific Research "Demokritos" working on the analysis of air pollution data in Athens using atmospheric models.

Since 1997 Dr. Kalabokas has been an elected Researcher at the Research Center for Atmospheric Physics and Climatology, Academy of Athens, studying urban air pollution in Athens; rural ozone levels around Athens; atmospheric pollution around refineries; and air quality in the area of the proposed new airport of Athens (the NTU Athens project).

To date Dr. Kalabokas has published over 65 papers on the above research topics. His other scientific activities include review of papers for international scientific journals on environmental pollution, and review of research projects in the European Union. He is a member of the Greek Committee on Environmental Pollution problems.

Dr. Michael Christolis is a Civil Engineer specializing in environmental science and technology. Currently he is working as a research collaborator at the National Technical University of Athens (NTUA), Greece, on the mathematical modeling of environmental problems. He has so far accumulated twenty years of experience in air quality monitoring, pollutant dispersion modeling, assessment of the impacts of industrial accidents, design of emergency systems, and implementation of the Seveso Directive in Greece.

During 1983-1988 he was the Head of the Laboratory for the Air Quality Monitoring Network for the City of Athens. In 1988 he joined the Computational Fluid Dynamics Unit (CFDU) of the Chemical Engineering Department of the NTUA, working on research projects on the computational modeling of various applications focusing on environmental issues and problems.

Professor Nicholas C. Markatos obtained his Diploma in Chemical Engineering from the National Technical University of Athens, Greece, in 1967, followed by M.Sc, DIC and Ph.D degrees from the Imperial College of Science, Technology & Medicine, University of London, UK, during 1970 to 1974.
In 1983 Professor Markatos was appointed Director of the Centre for Mathematical Modeling and Process Analysis at the school of Mathematics and Scientific Computing of the University of Greenwich, London, England. At that time he was also a visiting lecturer to the Computational Fluid Dynamics Unit of Imperial College as well as working for CHAM Ltd, (Concentration Heat and Momentum, Limited), London, England. At CHAM he worked first as leader of the Aerospace Group (1976) and then, from 1977 until 1984, as Manager of the Applications Team working on various Fluid Mechanical, Thermodynamic and Transport problems.

Since 1974 he has served as technical consultant to many Research Centres, state institutions and industries.

In June 1980 he was awarded the "Certificate of Recognition" by the Inventions Council of NASA.

In 1985 Professor Markatos was elected Professor of Chemical Engineering at the National Technical University of Athens, and in 1990 he was elected Head of the Chemical Engineering Department. In 1991 he was elected Rector of that University.

Professor Markatos' main scientific interest is in the mathematical modeling of Transport Phenomena, Fluid Mechanics, Thermodynamics and Physical Processes like Fluid Flow (Laminar and especially Turbulent), Heat and Mass Transfer, Environmental Flows, Combustion, etc.

He is referee of scientific papers, reviewer of new books, as well as member of the Editorial Board of several international Scientific Journals.

He has published over 100 original scientific papers in international journals and participated and organized many international conferences, seminars and meetings all over the world. Author of two books, he has also published many articles in the popular press on Engineering Higher Education.