SCIENCE OF ENVIRONMENTAL QUALITY STANDARD SETTING

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Summary

Air pollutants can affect the health of individuals or groups of people over a broad range of biological responses. The information on health effects useful comes from several health disciplines mainly epidemiology, clinical research and toxicology. In order to evaluate the air pollution effects on human health the dosage received by a person must be considered, where dosage is defined as the product of the average concentration of

breathed air with the corresponding time. Ideally, guideline values should represent concentrations of chemical compounds in air that would not pose any hazard to the human population. However, the realistic assessment of human health hazards necessitates a distinction between absolute safety and acceptable risk.

Criteria for endpoints other than carcinogenicity are defined by the specification of the lowest-observed-adverse-effect level. Effects estimates for carcinogens do not indicate a safe level and the estimated guidelines represent the risk for cancer occurring. Air quality standards are legal limits placed on levels of air pollutants in the ambient air, during a given period of time. They are not based only on air quality criteria but are also based on a broad range of economic, social, technical and political considerations.

1. Introduction

For the purposes of coherence and clarity, in the following sections discussions on environmental quality standards will focus on air quality, which is a very important area of pollution control. It is to be noted, however, that analogous pollution control procedures are adopted in other fields of environmental control too, because the basic pollution control philosophy is common to the entire spectrum of environmental problems.

The usual procedure for developing air quality standards is as follows:

(a) Preparation of air quality criteria. This is basically an analysis of the relationship between air pollutant concentrations and their associated adverse effects. The World Health Organization (WHO) calls these “guides” or “guidelines”.

(b) Setting of air quality “goals” on the basis of the air quality criteria. The goals are pollutant concentrations that are believed not to produce adverse effects on health or welfare.

(c) Development of air quality standards, also from the air quality criteria. The standards are pollutant concentrations that we intend to achieve in the immediate future. They may not coincide with our air quality goals, because standards also take into account the feasibility of achievement within the immediately foreseeable future.

2. Air quality criteria or guides

2.1 Health effects

In examining the relationship between air pollution levels and the effects of exposure to them, decisions must be made regarding the existence and extent of the cause-effect relationships. The major issues, which must be addressed in assessing the usefulness of cause-effect relationships as air quality criteria, are discussed below:

2.1.1 Spectrum of response

Air pollutants can affect the health of individuals, or of groups of people, over a broad range of biological responses. There are five biological response stages of increasing severity, as shown in Figure 1:

- A tissue pollutant burden not associated with other biological changes.
- Physiological or metabolic changes of uncertain significance.
- Physiological or metabolic changes as disease signs.
- Morbidity or disease.
- Mortality or death.

Occasionally the boundaries between the stages may overlap, while each stage may show a range of responses.

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 or solely to pollutant exposure. Death and disease are results of repeated cumulative risks from sources such as diet, cigarette smoking, physical inactivity, infectious challenges and accidental injury. In general, the role of environmental contaminants in the mortality or morbidity experience of a community is difficult to quantify, because many other determinants of death and disease cannot be adequately measured.

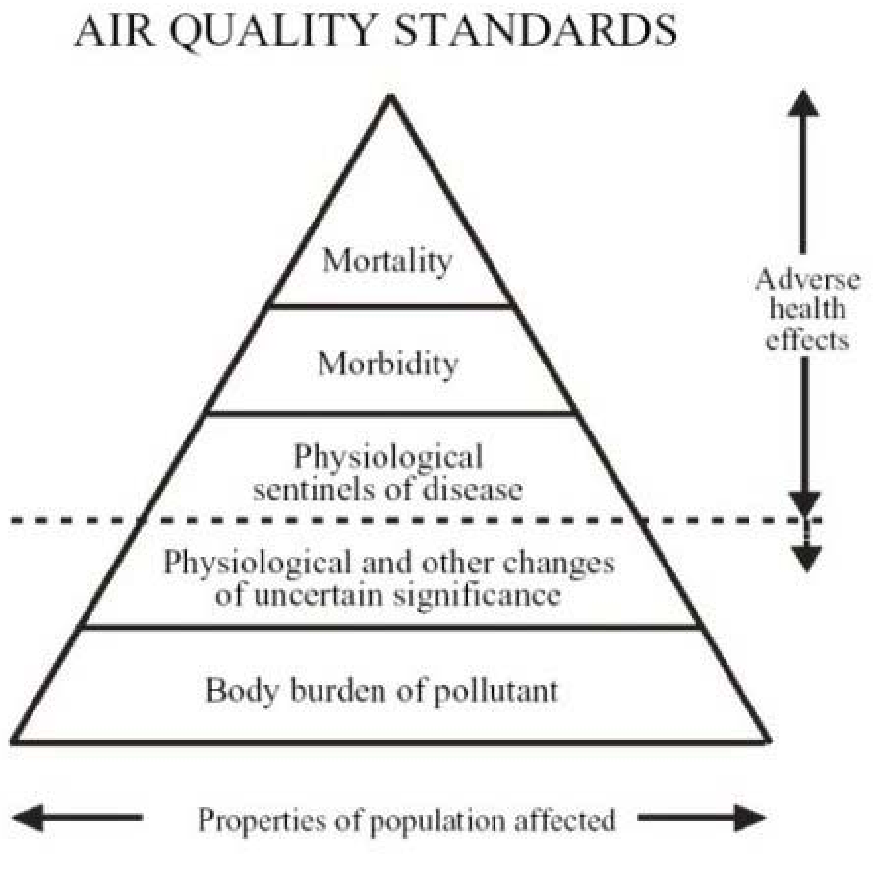

Figure 1. Schematic spectrum of biological response to pollutant exposure.

The lower levels of the response spectrum, shown in Figure 1, are sub-clinical manifestations of pollutant exposure. Larger proportions of the population are affected at these levels.

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

Some 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. Temporarily enhanced sensitivity may be associated with periods of growth, weight reduction, or pregnancy.

In general, diseases result from complex causes rather than simple factors, although environmental pollution may contribute to the complexity. Other factors may be diverse, originating as they do from genetic heritage, nutritional status, and personal habits. Pollutant exposure can alter the severity of disease without altering its frequency.

In order to use such information in the regulatory decision-making process, one needs to distinguish those effects that are considered to be adverse. Such effects include both the aggravation of pre-existing diseases and an increased frequency of a health disorder. In addition, according to preventive medicine, evidence of an increased risk of future disease is considered an adverse health effect.

2.1.2 Sources of information on health effects of environmental pollutants

Information on health effects useful for regulatory decision-making comes from several health disciplines, mainly epidemiology, clinical research, and toxicology.

Epidemiology provides studies of population exposure under real conditions. There are two major advantages of epidemiology: natural exposure; and it is not necessary to extrapolate data to humans. Furthermore, most vulnerable groups of the population can be studied and low-level exposures can be evaluated. The major problems are related to the quantification of exposure, acquisition of dose-response data from among the many covariates, and to the issue of association versus causation.

Clinical research studies are used to gather human data on normal or diseased persons with regard to absorption, metabolism, and excretion of pollutants. They can also be used for in-depth studies of humans accidentally exposed to high levels of pollutants and to identify new parameters and response indicators. The advantage of clinical studies is that pollutant exposure is controlled, and so improved dose measurements can be obtained. The covariates are also well controlled, cause-effect relationships more easily ascertained, and there is no need for extrapolation to humans. However, the deficiency is that exposure is artificial, and so there can be no long-term exposure. Also, there can be real hazard to the exposed person or persons, because only the acute effects are determined.

Many response systems such as whole animals, organs, cells and biochemical systems are used in toxicological studies. The main advantage of studies of this kind is that they yield considerable amounts of response data and more reliable cause-effect relationships. The disadvantage is that, because such studies are based on laboratory tests, they cannot provide complete assurance of dose effects. This is because population exposures cannot be simulated in the laboratory, and because animal data are difficult to extrapolate to humans, especially for estimating thresholds of human response.

2.1.3 Pollutants and human exposure response

The effects of pollutants on human health depend on their physical and chemical properties (such as duration, concentration and route of exposure), on uptake by humans, and on how they are metabolized. Also human biological response to pollutants is a function of occupational, psychological and climatological factors.

Physical and chemical properties of pollutants determine their potential as a health hazard. These properties, including size, density, viscosity, electrical charge, volatility, solubility and chemical reactivity, all affect the absorption, retention and toxicity of pollutants. On entering the environment, many of the pollutants do not retain their original identity because they participate in various reactions along their pathways from source to receptor. These factors determine the toxicity of pollutants at the point of human exposure.

2.1.4 The exposure-response matrix

Duration and concentration of pollutant exposure are measures of the total dosage to humans, and the rate at which it is received can influence response. The health effects of an environmental pollutant may be short-lived (acute) or relatively permanent or irreversible (chronic). Acute or chronic effects may occur following a single exposure to a hazardous substance, or they can result from long-term exposure. In general, acute effects and short-term exposure are less difficult to study than chronic effects or long-term exposure.

2.1.5 Estimation of exposure

Exposure of a population to individual pollutants, or to a cocktail of pollutants, varies according to season, day and hour depending on changes in their ambient concentration. Mobility of the population from indoor to outdoor environments, or from one residence to another, must be also considered. There are difficulties in attempting to estimate the long-term integrated exposure of a population as well as in quantifying personal exposure. For this purpose small-scale instruments for personal monitoring are used either by themselves or in combination with stationary monitors of urban networks. But there are problems with both these approaches. While continuous personal monitoring to evaluate the effects of short-term exposure is costly and technically complex, equipment for stationary monitoring is often dissociated in time and space from measured health effects, especially when chronic effects are to be evaluated.

Studies on disease frequency in a large city or a metropolitan area often rely on exposure estimates based on a few stationary monitoring units that usually do not adequately cover the entire target area. Consequently, conclusions based on such results may imply higher exposures than those actually occurring in residential areas with pollution-related diseases. Furthermore, long-term health impacts of air pollution should be taken into account in assessing the incidence of chronic pollution-related diseases, not just current measurements. This is because, pollution parameters are more than likely to change over time, due to both changing patterns of socio-economic development and pollution abatement measures implemented.

Information needed to deal with these methodological problems is often not available. It is to be noted in particular that the determination of reliable quantitative estimates of exposure is the weakest link in establishing exposure-response relationships, because the development of appropriate criteria levels requires precise data on both exposures and effects. Actions taken on the basis of poorly defined criteria levels may be either too restrictive or not sufficiently robust to protect health.

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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.