National Institute for Occupational Safety and Health, Rockville, MD, USA
Occupational Safety and Health Administration, Washington DC, USA
Commission of the European Communities, Health and Safety Directorate, Luxembourg

Assessment of Toxic Agents at the Workplace

Roles of Ambient and Biological Monitoring

A. Berlin
R.E. Yodaiken
B.A. Henman

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edited by

A. BERLIN, R. E. YODAIKEN and B. A. HENMAN

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EDITORIAL NOTE

The papers in this report have in the main been the subject of minor editing in order to achieve consistency. The discussions required substantial editing to eliminate undue repetition; every attempt was made to adhere to the content and meaning of each contributor. Whenever possible, the English spelling and words are used. The summary report gives an overview of the proceedings.

The editors would like to acknowledge the support given by the chairmen during and after the conference.

CHAIRMEN: M.S. Baram (USA), J. Degimbe (CEC), S. Epstein (USA), F. Pocchiari (I), P. Recht (B), J.T. Wilson (USA).

RAPPORTEURS: N. Ashford (USA), C. Courtoux (F), L. De Boer (NL), J. Froines (US-NIOSH), R. Harris (USA), W. Hunter (CEC), G. Kliesch (FRG), G. Lehnert (FRG), G. Matanoski (USA), P. Recht (B), K. Robock (FRG), K.H. Schaller (FRG), A. Schuster (L), W. Sunderman (USA), A.M. Thiess (FRG), M. Weber (USA).

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ASSESSMENT OF TOXIC AGENTS AT THE WORKPLACE - ROLES OF AMBIENT AND BIOLOGICAL MONITORING

SUMMARY REPORT - A Berlin, R E Yodaiken and D C Logan

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1. INTRODUCTION

1.1 Organisation and aims

This International Seminar, organised jointly by the Commission of the European Communities and the United States authorities (Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health) has brought together more than 150 participants from the Member States of the European Community, from the United States, and also from Greece, Finland, Sweden and Switzerland.

The aim of the Seminar was to examine the roles of ambient and biological monitoring in protecting the health of workers exposed to toxic agents and to define a multidisciplinary approach to this monitoring.

To achieve this aim expertise from the following disciplines, directly or indirectly involved with monitoring, was called upon: medicine, industrial hygiene, nursing, biology, engineering, chemistry, epidemiology, statistics, economics and jurisprudence, and representatives from trade unions, industry and government agencies.

The difference in concepts that each of these disciplines has of monitoring and of its role in the team is fully reflected in the papers.

1.2 Current trends in occupational health and hygiene (as related to monitoring).

The primary purpose of occupational health monitoring is to help achieve a satisfactory working environment and, secondly, to demonstrate that achievement. The increased awareness of occupational health, hygiene and safety in recent years had led, both in the European Community and in the United States, to improvement in working conditions and reduction of

worker exposure to some toxic agents. However, substantial hazards remain, the number of cases of occupational illness due to these hazardous exposures is still high, and new cases will continue to occur if there are no improvements. During the past years investigations have revealed a number of examples of unreported occupational diseases. New problems have appeared with changes related to energy development, biotechnology, electronics, chemicals and so forth.

There is an increasing tendency to develop essentially ambient, but also biological limits and to develop methods of ensuring their implementation, thereby preventing health damage from exposure to toxic chemicals. The introduction of both ambient and biological standards in the United States and in the European Community, and the recognition of the need for such standards by ILO, is an irreversible fact. This has forced all those concerned to pay more attention to the significance of these limits, to their application and to the problem of achieving a common terminology at the international level.

Aspects of monitoring include providing information to help achieve compliance with standards, validating that compliance and accumulating information for later review of the standards.

An appreciation that setting standards requires consultation between the social partners and must take into account socio-economic and political factors is growing. At the same time workers and their representatives (including health and safety professionals) as well as management are increasingly involved with monitoring the application of standards. More access is being gained to ambient and biological monitoring records and therefore it is appropriate for the social partners to become conversant with monitoring techniques. At present there are few provisions for epidemiological follow up to test the adequacy of existing standards and it is becoming clear that new strategies must place more emphasis on toxicological and pharmacokinetic parameters.

Authorities are fully aware that an appropriate combination of ambient and biological monitoring will lead to better protection of workers' health but some uneasiness and some uncertainty still exists on how best to achieve the maximum protection.

Workers are frequently not aware of the hazards associated with substances to which they are exposed, nor of the methods for preventing exposure. Occupational safety and health programmes must therefore ensure that workers are provided with assistance and information about all known or suspected hazards. National health and safety programmes increasingly place emphasis on training and education programmes for employers and workers.

2. DEFINITIONS

The following definitions were developed within the context of the seminar:

Monitoring is a systematic continuous or repetitive health-related activity designed to lead if necessary to corrective actions. Three types of monitoring are defined: ambient, biological and health surveillance.

> Ambient monitoring is the measurement and assessment of agents at the workplace and evaluates ambient exposure and health risk compared to an appropriate reference.
>
> Biological monitoring is the measurement and assessment of workplace agents or their metabolites either in tissues, secreta, excreta, expired air or any combination of these to evaluate exposure and health risk compared to an appropriate reference.
>
> Health surveillance is the periodic medico-physiological examinations of exposed workers with the objective of protecting health and preventing occupationally related

disease. The detection of established disease is outside the scope of this definition.

The definitions of biological monitoring and health surveillance separate components of a continuum which can range from the measurement of agents in the body through measurements of metabolites, to signs of early disease. A problem left unresolved concerns the precise place within these definitions of certain biochemical tests such as zinc protoporphyrin (ZPP), delta aminolaevulinic acid dehydrase (ALA-D), delta aminolaevulnic acid (ALA) in the blood and urine, etc... which are in fact indicators of metabolic effects which have occurred as a consequence of exposure.

3. ROLES OF MONITORING AND PROTECTING WORKER HEALTH

3.1 Ambient monitoring

Ambient monitoring is carried out for different reasons, for example:

determining ambient concentrations in relation to an established legal standard or consensus guideline,

determining the relationship, if any, between the concentrations of agents at the workplace and the health of the workers,

ensuring the effectiveness of control measures,

evaluating the need for controls in the vicinity of specific emission sources,

indicating trends in relation to an improvement or deterioration at the workplace,

providing an historical record.

It was generally accepted by the participants that personal sampling is a better measure of employee exposure than area sampling. For example, samples of air from the breathing zone of the worker give a more reliable estimate of the workers's exposure. It is necessary to utilise a statistical framework to ensure that the sampling scheme is valid; it should also be borne in mind that the cost of individual samples is relatively high.

Considering the many agents which should, and often have to be, monitored, few effective personal monitoring devices are available and it is important to recognise that personal dosimetry is in its infancy. Recognition of potential errors is essential both for compliance with laws and regulations, and for quantitation of dose and dose effect in epidemiological studies.

3.2 Biological monitoring

Biological monitoring measures or evaluates exposure from all routes. It sometimes allows a better evaluation of health risk than ambient monitoring especially in cases where exposure through different routes has to be considered.

Biological monitoring takes into account individual variability, the impact of factors such as personal activity, biological characteristics and life styles of the individual. When applicable, it is a valuable adjunct to ambient monitoring, health surveillance and other medical data. One serious drawback at present is that is is only available for a limited number of agents.

3.3 Examples of workplace hazards

Two inorganic toxic agents, one organic agent and a class of organic toxic agents were selected for discussion. The criteria for selection were that the agents be of considerable concern and provide a wide variety of problems in monitoring.

3.3.1 Carbon monoxide

Monitoring of ambient exposures is difficult due to their episodic and non-predictable nature. Ambient monitoring methods using continuous CO analysers are often inadequate; this can be improved to some extent by using currently available personal samplers or portable analysers. A better assessment of personal exposure could be obtained with the development of chemical badges.

The results from all instruments which measure CO in air are only of value if the need for making them is clearly specified. At present evaluating exposures to CO in air by measuring carboxyhaemoglobin (COHb) content of the blood is limited by the extent to which the subject has acquired CO from other sources (smoking, endogenous CO production by xenobiotic metabolism) and by the effect of physical activity on uptake or expiration of CO.

The ease with which an agent or its metabolite can be determined in a tissue, organ or biological medium depends upon several factors, such as the physico-chemical characteristics of the compound, its toxico-kinetic propeties including its half life, and the target tissue or organ. Since carbon monoxide is a gas, and a target tissue is blood, it seems evident that biological monitoring for carbon monoxide is most valuable in the alveolar air and blood.

Because it is a non-invasive method, determination of CO in alveolar gas as a measure of percent COHb has great advantages, but the method has its limitations. The most precise indicator of CO exposure and of its potential medical significance is direct measurement of COHb. At present gas chromatography is the reference procedure for analysis of CO in blood. The most convenient and simple methods are spectrophotometric techniques,

although they may not be highly accurate at COHb concentrations below 5%.

3.3.2 Cadmium

Preventing acute toxic effects on the lungs can only be accomplished by keeping the airborne concentration of cadmium below a certain level. Ambient monitoring techniques including the use of continuous analyses are available for this purpose. Ambient monitoring may not be sufficient to prevent undue long term absorption of cadmium. Renal dysfunction is the earliest chronic effect believed to occur when Cd concentrations exceed 200 µg/g cortical tissue.

Oral intake of cadmium, personal hygiene habits, great individual variation in the oral absorption rate and non-occupational exposure may significantly affect the cadmium body burden. For estimating the body burden of cadmium and hence the risk of health impairment, biological indicators such as cadmium in blood and in urine may be used. By combining the determination of CdU with CdB, not only recent exposure, but also the cumulative internal dose is taken into consideration. The relationship between cadmium toxicity, renal damage and hypertension clearly needs to be studied further. Atomic absorption spectrophotometry and anodic stripping voltametry are now the preferred methods for determination of Cd in biological material.

3.3.3 Benzene

Benzene is a potent haematotoxin capable of causing aplastic anaemia and acute myeloblastic leukaemia. Considerable attention was devoted to biological monitoring and health surveillance rather than ambient monitoring.

Several methods are currently being developed for the biological monitoring of benzene: benzene in expired air and blood, and urinary output of phenol. The assessment of benzene exposure through measurement in expired air must take into account the complex elimination kinetics.

Headspace chromatography provides a simple and reliable method for the determination of benzene in blood. The measurement of phenol in urine is relatively non-specific and insensitive for the individual assessment of exposure to low levels of benzene in air.

Health surveillance of workers potentially exposed to benzene is currently based on evidence of bone marrow toxicity as well as routine blood examinations.

3.3.4 Aromatic Amines

Aromatic amines includes a large number of substances with widely differing toxicological properties. For the purpose of prevention in the working environment it is appropriate either to restrict the definition of aromatic amines to a homogenous group of compounds or, from a more practical point of view, to draw up a list of specific amines on which attention should be focused.

For many of these lipotropic substances, the skin is the main intake pathway, and therefore ambient air monitoring alone is not sufficient. In view of the carcinogenic effects of many aromatic amines, very sensitive methods of detection are being developed. Indicators of body burden currently used are non-specific total urinary amino-compounds and tests for specific aromatic amines in the urine such as benzidine or its metabolites for which the bladder is a primary target organ.

Primary aromatic amines can be determined by spectrophotometry. More specific methods recently applied employ gas-liquid chromatography, high pressure liquid chromatography and spectrophotofluorimetry.

3.2 Quality of monitoring data

The importance of ensuring the quality of data as an integral part of any monitoring programme was unanimously stressed. However, it was recognised that the amount of emphasis to be placed on standardisation, good laboratory practice and quality control depends on the objectives of the monitoring programme.

The concept of good monitoring practice (GMP) should be firmly established, based on good laboratory practice guidelines currently developed at the international level for the purpose of improving the quality of toxicological data and achieving mutual acceptance of those data. Such GMP should help ensure that self-generated monitoring data can be of direct use to authorities in decision making. Introduction of GMP should not reduce monitoring efforts, only improve the quality.

When monitoring is used for international regulatory purposes, harmonisation (two or more methods giving the same result) and in certain cases, standardisation (an acceptable reference method) of sampling strategies, methods, and analytical procedures have to be achieved within the jurisdictions covered by the specific regulation, in order to ensure uniformity of application of the standard.

To achieve harmonisation, collaborative/cooperative studies have been carried out and a number of quality control programmes established. Such programmes at the international level are particularly important for biological indicators: considering current manpower mobility it would be highly detrimental to workers' faith in occupational health and

safety programmes designed to protect worker health, if the numerical result for the same biological indicator varied with the place of employment or when crossing national boundaries.

The question of the accreditation of laboratories involved in monitoring was raised but not resolved.

The availability of guidelines in GMP, standard methods and quality control programmes will be of help to the worker representatives in evaluating monitoring programmes.

4. ROLES OF THE VARIOUS DISCIPLINES IN MONITORING

4.1 Multidisciplinary approach to monitoring

The physician, the industrial hygienist, the occupational health nurse, the epidemiologist, the analytical chemist, the statistician and the engineer are all members of the occupational health team and share a goal of preventive health care in the occupational setting. Other professionals who play a role in monitoring include economists, computer scientists and lawyers or legal experts.

The engineer has an important role in the multidisciplinary team and the potential to:

- modify processes in such a way as to reduce exposure to toxic products and eliminate or reduce toxic by-products,
- develop and implement appropriate control technologies,
- institute appropriate protective engineering measures for possible emergency situations.

The analytical chemist also has a critical role in the monitoring programme, being responsible for the selection of the appropriate analytical techniques, for careful and accurate measurements of samples, for assessment of new techniques, and for analytical quality control.

For ambient monitoring cost estimates, the economist in consultation with relevant members of the team must calculate capital cost of equipment, labour, maintenance and materials. Fluctuations are primarily associated with personnel and maintenance costs as well as interest rates. Labour costs tend to increase while maintenance costs may decrease with improvements in equipment reliability. For biological monitoring the worktime lost by the workers must also be taken into account. Given the goal of protecting worker health, the economist plays an essential role in workplace monitoring, by helping to achieve cost-effective methods which will add efficiency but in no way compromise worker health.

Computer experts have increasing importance in workplace record-keeping. Ambient and biological monitoring data and health surveillance information are being stored in appropriate compartments for retrieval, analysis and feedback. The computer scientist is also concerned wih assuring that confidential medical information can only be retrieved by specified and authorised personnel. Computerisation of data is important for evaluating the efficacy of such monitoring as well as providing input into research. The role of the computer scientist is also expanding as the science is applied not only to geographically separated corporate facilities but also to link up with social and health services outside industry.

The lawyer's or legal expert's role in the area of ambient and biological monitoring is in the interpretation of statutes regarding the creation, maintenance, storage and access to monitoring data by the worker, members of the occupational health team, and by the social partners. It was noted that degrees of access to monitoring information vary considerably between countries. Access of the worker to his or her individual medical record was discussed in relation to worker access to individual ambient and biological monitoring data. There was universal agreement that such access was of