WORLD HEALTH ORGANIZATION
TECHNICAL REPORT SERIES

No. 535

ENVIRONMENTAL AND HEALTH MONITORING IN OCCUPATIONAL HEALTH

Report of a WHO Expert Committee

WORLD HEALTH ORGANIZATION
GENEVA
1973

PRINTED IN SWITZERLAND

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Geneva, 31 July – 6 August 1973

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ENVIRONMENTAL AND HEALTH MONITORING IN OCCUPATIONAL HEALTH

Report of a WHO Expert Committee

A WHO Expert Committee on Environmental and Health Monitoring in Occupational Health met in Geneva from 31 July to 6 August 1973. Dr B. H. Dieterich, Director, Division of Environmental Health, opened the meeting on behalf of the Director-General. He called attention to the purpose of the meeting, which was to review measures used in monitoring the work environment and workers' health and to make recommendations to governments and to WHO on environmental and health monitoring in preventive occupational health practice. He commented that WHO was paying special attention to the development of occupational health programmes. The Twenty-fourth and Twenty-fifth World Health Assemblies had emphasized the growing importance of developing comprehensive preventive health care for the working populations in all occupational sectors. The Twenty-sixth World Health Assembly, in 1973, had resolved to promote international work in monitoring and control of environmental hazards, including those in the work environment.[1]

1. INTRODUCTION

1.1 Objectives of an occupational health programme

An occupational health programme aims to promote and maintain the highest possible level of health among the gainfully employed upon whom the economic welfare of a community depends. To meet these objectives it is necessary : (1) to identify and bring under control at the workplace all chemical, physical, mechanical, biological, and psychosocial agents that are known to be or suspected of being hazardous ; (2) to ensure that the physical and mental demands imposed on people at work by their respective jobs are properly matched with their individual anatomical, physiological, and psychological capabilities, needs, and limitations ; (3) to provide effective measures to protect those who are especially vulnerable to adverse working conditions and also to raise their level of resistance ; (4) to discover and improve work situations that may contribute to the overall ill health of workers in order to ensure that the burden of general illness in different occupational groups is not increased over the community

[1] *Off. Rec. Wld Hlth Org.*, 1973, No. 209 (Resolution WHA26.58).

level; (5) to educate management and workpeople to fulfil their responsibilities relevant to health protection and promotion; (6) to carry out comprehensive in-plant health programmes dealing with man's total health, which will assist public health authorities to raise the level of community health.

1.2 Reduction or elimination of specific occupational risks

These statements of requirements to meet occupational health goals imply that dependable cause-and-effect relationships are known or can be established between conditions of work and state of health, from which logical preventive measures can be developed and applied to eliminate health risks in industry or to reduce them to acceptable levels. This is especially true of the specific occupational diseases for which a substantial body of scientific and technical knowledge has accumulated, mainly in industrialized countries. Out of this experience have come important data concerning the relationships between the nature, magnitude, and duration of contacts with the causative agents and work situations and the resulting kind and degree of response in man.

The development of this body of knowledge has come not only from laboratory experiments but, to a very considerable degree, from field studies and experience in industry, mining, agriculture, and other occupations. The systematic collection of measurements of actual exposures to the various hazardous agents and work situations and the parallel recording of medical observations on exposed workers has made it possible to demonstrate correlations between level of exposure and degree of health impairment that could be expressed in the form of quantitative dose/response relationships. From these have been derived permissible limits of exposure for a number of hazardous agents.

Systematic application of this knowledge has resulted in a substantial reduction in the occurrence of many occupational diseases. For example, miner's nystagmus has been eliminated where appropriate lighting was provided,[1] and the incidence of disabling pneumoconiosis has been substantially reduced by health surveillance and better dust control in many industries.[2]

The techniques used for measuring the characteristics of the work environment and for determining the biological response characteristics of man constitute the basis of the modern practice of occupational medicine and hygiene. Such practice includes the routine assessment of control measures to ensure that exposure levels are kept within prescribed limits for continued health maintenance or to provide early warning of impending ill health, this indicating the need for additional preventive action. The

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[1] Schilling, R. S. F. (1963) *J. roy. Soc. Arts*, **III**, 933.

[2] Hatch, T. F. (1951) *Amer. industr. Hyg. Ass. Quart.*, **12**, 46.

experience gained so far demonstrates the need for the continuing monitoring of health and the environment in workplaces.

While one of the aims of this report is to provide guidance in the planning and conduct of monitoring schemes and to make recommendations for their implementation in respect of specific occupational health risks, it will also emphasize the need to take account of other health problems of workers, such as the development of ergonomic criteria in matching demand to human capabilities to ensure optimal health and performance. Similarly, the psychosocial characteristics of the work situation must be considered as important determinants of man's function and wellbeing.

2. MONITORING

2.1 Definition and scope

Monitoring has two distinct functions: first, the making of routine measurements on health and environmental indices and the recording and transmission of these data and, second, the collation and interpretation of such data with a view to detecting changes in the health status of populations and their environment. The distinction is important because these functions involve different types of skill. The first requires careful planning and the use of standardized techniques and methods of data collection. The second requires analysis and evaluation, which lead to recommendations for preventive action. It will be possible to broaden the coverage of health surveillance of working populations by making fuller use of technicians and, where available, automated procedures for monitoring. One of the most important aims in current practice is to raise the efficiency of monitoring and to ensure comparability of data from different groups of research workers (and within the same group over a period of time) by standardization of techniques.

An essential part of an occupational health programme is a plan for the continuing hygienic assessment and evaluation of work processes and associated environmental conditions, concurrent with continual health surveillance of the workers. The results must be recorded in a manner that will permit a proper matching and joint analysis of the two sets of data at regular intervals so as to reveal any significant relations that develop between the stresses of work and the health of the worker. In particular, an early warning of health impairment is needed so that appropriate additional protective action can be taken before illness develops.

2.2 Purpose

Monitoring is carried out for the following reasons:

(1) To assess recognized occupational health risks and evaluate their control by (*a*) providing the necessary data to ensure that environmental

protective action is initially taken against health risks and to ensure that workers are placed in jobs suiting their capacities ; (*b*) providing continuing evaluation to ensure that adequate protection is maintained ; (*c*) obtaining an accumulating body of data for epidemiological use to show the comparative effectiveness of the engineering and medical aspects of preventive programmes and, where appropriate, to permit the redefinition of permissible levels of exposure.

(2) To identify occupational health risks not previously recognized so that steps can be taken to control them—for example, by establishing permissible levels of exposure.

(3) To reveal other sources of health risk, especially those associated with stresses that do not cause occupational disease but increase psychobiological vulnerability and possibly contribute to general ill health.

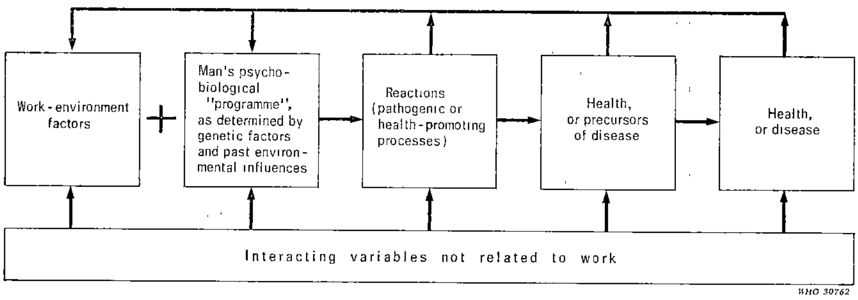
(4) To identify and promote work factors that are beneficial to health.

(5) To provide information on community health problems (not primarily caused by work) through the observation of the gainfully employed, who form a significant part of the general population.

The various levels at which monitoring can take place are shown in Fig. 1 in which the interrelations between occupational environmental factors and man are demonstrated.

While the general aim should be to provide comprehensive routine monitoring of workpeople and their environment, such an ideal may at the present time be beyond the resources of many countries or industries. It should nevertheless be possible to adopt two other approaches—(i) the clinical observation by health personnel of individual workers presenting illnesses found, on inquiry, to be related to specific exposures at work, and (ii) the statistical monitoring of populations, using national and local records of mortality and morbidity to identify hazards in particular

FIG. 1. MODEL OF MAN/WORK INTERRELATIONSHIPS



Monitoring can take place at any or all of the six levels indicated. The combined effect of factors in the work environment and man's psychobiological "programme" determines pathogenic or health-promoting reactions, which may lead either to health or to precursors of disease and ultimately to disease itself. This sequence of events can be promoted or counteracted by interacting variables not related to work.

occupations or groups. Clinical observation and statistical monitoring are useful additional methods of identifying hazards in groups already subjected to fully developed monitoring systems. In many instances, the existing methods of environmental assessment and health examination can be simplified so that monitoring can be carried out at a much lower cost. Information on simple techniques of monitoring should be made available, and further research in the simplification of techniques should be stimulated. A number of occupational health institutions in developing countries have used such techniques for epidemiological investigations of environmental and health conditions at work and have later continued to use them in routine monitoring practice.

3. PRESENT LIMITATIONS IN OCCUPATIONAL HEALTH PRACTICE

Current practices in occupational health, even in the most highly industrialized countries, seldom meet the goals set forth above. In many instances the major emphasis is on the finding of cases of illness and providing the necessary medical care, and true preventive medicine plays only a minor role, if any, in day to day operations. Indeed, it is the practice of general medicine in industry and not the practice of industrial medicine *per se* that characterizes today's efforts.

Medical records, for example, usually provide only separate medical histories on individuals to be referred to when these individuals come as patients. Conceptually, therefore, they do not differ from the records in the office of a physician practising in the community and include little information of the kind that is essential to the practice of occupational health, which must be based on the systematic gathering of parallel data on the conditions of work and the health of the worker.

Thus, the true objectives of systematic monitoring are not often achieved, and when a routine monitoring scheme is adopted it is usually of limited scope—that is to say, it is usually designed to control only a limited number of occupational diseases and often only one. In developing countries, and even in some enterprises in highly industrialized countries, occupational medical services may be absent, especially in small establishments, and the systematic approach of occupational hygiene is usually unknown. As the team approach by physicians and hygienists is rarely practised, it is difficult to relate the conditions of ill health to environmental factors at work. Thus it is not possible to evaluate the effectiveness of environmental control measures. The main causes of these serious limitations are lack of awareness by health planners of the need for occupational health practice and a shortage of trained occupational health personnel. In addition, today's practice rarely includes a systematic consideration of ergonomic and psychosocial factors.

The conditions of health of workers in different parts of the world vary widely, depending *inter alia* on the type of employment and the pattern of disease in the area. A small proportion may enjoy better health than other sectors of the community, but in the world as a whole the majority work under unfavourable conditions. In developing countries the prevalence of communicable diseases is sometimes higher among occupational groups than in the general population.

Although reporting is generally inadequate, field investigations in developing countries often show a high prevalence of occupational diseases. For example, fibrotic pneumoconiosis is as high as 23% in miners and stone cutters in some countries. In others, where large numbers of workers are exposed to vegetable dust in processing hemp, flax, and cotton, a prevalence of 60% of byssinosis and other respiratory diseases has been reported. Poisoning by carbon monoxide has been observed in up to 15% of workers employed in coke production and gas plants. Excessive lead absorption has been found in almost 40% of workers in smelting and battery manufacture. In certain countries occupational dermatoses have been found to affect as many as one third of workers in contact with mineral oils, cement, and other substances. Even in highly industrialized countries the occurrence of occupational diseases is still too high, and additional health problems affecting the gainfully employed include chronic noncommunicable diseases, mental disorders, alcoholism, and drug abuse.[1]

4. CURRENT MONITORING SCHEMES IN THE PREVENTION OF OCCUPATIONAL DISEASE

Monitoring systems are mainly directed towards the prevention of recognized occupational diseases, for each of which a specific causative agent is found in the work environment, usually associated with a particular process or occupation.

Historically there is a reason for this emphasis on specific occupational diseases, since it was their occurrence in almost epidemic proportions that called attention to the greater need for effective preventive action. Because of this overwhelming experience immediate attention had to be given to their control. This explains why the preventive aspects of occupational health have remained so limited in scope. But the successes in this limited field encourage the visualization of a much broader set of objectives for occupational health services and for monitoring.

Since extensive information is already available on the methods used in both occupational hygiene and medical monitoring, the Committee decided

[1] *WHO Chronicle*, 1972, **26**, 537.

to limit its discussions to the major principles on which the techniques of monitoring are based.

4.1 Environmental monitoring

Environmental monitoring (or occupational hygiene monitoring, as it is often known) makes use of an extensive battery of instruments to assess a variety of physical and chemical exposures at work.

The purpose of the procedures used for environmental assessment is to measure the dose of the hazardous agent absorbed by the worker at his place of work. This means that the assessment of the environment is not just an exercise in physical or chemical analysis but has its base in the biological characteristics of man, and the relevance of the results depends on the adequacy of the "biological calibration" of the analytical procedures.

One of the most important aspects of environmental monitoring is that concerned with sampling and measuring techniques. Accurate dose estimations depend on many factors, but particularly the selection of sampling or measuring points and the frequency and duration of sampling or measuring periods. Moreover, account must be taken of the type of hazard being monitored. There is, for example, considerable difference in approach between the assessment of exposures causing immediate illness and the assessment of exposures producing cumulative effects over a long period. In the former case, brief exposures to high concentrations may be the most important index of hazard ; in the latter the level of exposure may best be expressed by time-weighted averages. Personal samplers (i.e., continuous sampling instruments that can be worn by individual workers as they move about) give a better estimate of dose in some instances than do static samplers at stationary sampling points. Particular care must be taken in the use of " spot sampling ", which can lead to substantial errors in estimating exposures. Certain statistical procedures have been proposed for the selection of a proper sampling regimen.[1]

Instruments and analytical procedures are available to determine atmospheric concentrations of a large number of airborne gases, vapours, fumes, mists, and dust particles and to measure other important properties such as the aerodynamic characteristics of dust particles that govern lung deposition. Techniques are also available for the sampling and evaluation of bacteria and other biological agents. Other instruments permit the assessment of a variety of physical stresses such as exposure to excessive heat or cold, high noise levels, mechanical vibration, and inadequate illumination. For other types of contact (e.g., with the skin or by ingestion) different techniques are required. For example, in the control of ionizing radiation, it may be necessary to monitor work surfaces and clothing.

The instruments and techniques used in environmental monitoring range from the simple to the relatively sophisticated, depending on the

[1] Roach, S. A. (1966) *Amer. industr. Hyg. Ass. J.*, **27**, 1.

nature of the relationship between the hazardous agent and the resulting disease. They are selected to yield information on those characteristics of the environment that are known to have particular significance for health and for which dose/response relationships have already been established. Good descriptions of these instruments and techniques are given in several publications.[1]

In some countries there have been important developments in ergonomic practice, and attempts are also being made to describe, qualitatively and quantitatively, potentially harmful psychosocial aspects of the work environment.

4.2 Medical monitoring

Preplacement medical examinations serve the purpose of proper job placement according to the physical and mental capabilities of the worker. They also make it possible to identify persons likely to be vulnerable to certain exposures; for example, those with chronic obstructive pulmonary disease can be identified and excluded from work in dusty occupations. Another function is to provide baseline data that make it possible to measure early adverse effects of exposure in persons at risk. Since there are considerable variations in functional values (for instance, in lung function and blood tests) not only between individuals but in the same individual in the course of time, it may be possible to improve the chances of detecting early deviations from health by following the changes in values from levels established at preplacement examinations in exposed and unexposed groups.

Periodic medical examinations serve five main purposes: (1) to detect early impairment of health; (2) to evaluate the effectiveness of preventive measures; (3) to detect workers showing undue susceptibility to a particular environmental exposure, with a view to their replacement; (4) to reveal trends in the health status of groups of workers; (5) to indicate the need for medical treatment.

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[1] American Conference of Governmental Industrial Hygienists (1972) *Air sampling instruments*, Cincinnati, Ohio (P.O. Box 1937); American Conference of Government Industrial Hygienists (1973) *Manual of analytical methods*, Cicinnati, Ohio (P.O. Box 1937); Gadaskina, I. D. & Filov, V. A. (1971) [*Metabolism and determination of industrial organic poisons in the organism*], Leningrad, Medicina; Lawrence Berkeley Laboratory Report (1973) *Instrumentation for environmental monitoring*, Berkeley, Calif., University of California; Muraveva, S. I. (1969) [*Recent advances in the area of atmospheric chemistry in industry with reference to toxic products*], Moscow, Izdatel'stvo "Medicina"; Singleton, W. T. (1972) *Introduction to ergonomics*, Geneva, World Health Organization; Levi, L. (1972) *Stress and distress in response to psychosocial stimuli*, Oxford, Pergamon; Alekseeva, M. V. (1963) [*Determination of atmospheric pollution*], 2nd ed., Moscow, Medgiz; Manu, P. & Nicalescu, T. (1971) *Occupational medicine*, Bucharest, Editura Medicală; Lazarev, I. V. (1963) [*Harmful substances in industry*], 4th ed., Leningrad, Goshmizdat, 2 vols.; Lazarev, I. V. (1969) [*Harmful substances in industry*] (companion volume), Leningrad, Izdatel'stvo "Himija".

While the ultimate aim should be to institute such examinations generally throughout industry, it may be necessary in countries with limited resources to concentrate on those industries in which the hazards are greatest. Even where full resources are available it is common practice to arrange for the periodicity of the examinations to conform to the degree of risk to the worker himself and to others, the age structure, and the susceptibility of the group. Furthermore, high priority has been given to preplacement and periodic examinations for persons performing special types of work such as airline pilots, road transport drivers, and food handlers, upon whose fitness the health and safety of others depend. Medical examinations have also provided the opportunity for health education in respect of both specific and general risks.

Such examinations utilize the particular diagnostic procedures and the additional physiological, biochemical, and other tests that are required to demonstrate the presence of health impairment, if any, and its extent and severity. Their specificity and sensitivity depend on the depth and detail of knowledge of the cause-and-effect relationship in question and on the extent to which various monitoring systems have been evaluated, discarding the less reliable for the more reliable techniques. In the monitoring of lead workers, use is made of clinical signs and symptoms of lead absorption [1] such as levels of porphyrins, delta-aminolaevulinic acid and aminolaevulinate dehydratase.[2] In hearing conversation programmes,[3] temporary threshold shift (TTS) of hearing acuity is used as an early indicator of permanent threshold shift (PTS). The lowering of phagocytic activity of leucocytes has been cited as an early effect of exposure to benzene.[4]

Acute change in ventilatory capacity during the first shift in the working week [5] is recommended to be used as a predictor of permanent change in workers exposed to certain vegetable dusts. The iodine-azide test on urine has been developed as a simple early measure of absorption of and susceptibility to carbon disulfide.[6] Thus the examinations in current use are often quite refined and reveal response to the hazardous agent well before the onset of diagnosable illness. Sometimes, however, the diagnostic index may identify the presence of health impairment only a short time

[1] Joint ILO/WHO Committee on Occupational Health (1969) *Permissible levels of occupational exposure to airborne toxic substances*, Geneva, World Health Organization (*Wld Hlth Org. techn. Rep. Ser.*, No. 415).

[2] Classified as enzyme EC 4.2.1.24 in: International Union of Biochemistry (1965) *Enzyme nomenclature*, Amsterdam, Elsevier.

[3] International Standards Organization (1971) *Acoustics : assessment of occupational noise exposure for hearing conservation purposes*, Geneva (ISO Recommendation R.1999).

[4] Volkova, Z. A. (1972) Unpublished observation.

[5] Permanent Commission and International Association on Occupational Health, Subcommittee on Byssinosis. *Report*. In : *Proceedings of the XVII International Congress on Occupational Health, Buenos Aires, 1972* (in press).

[6] Vasak, V. (1963) *Pracov. Lék.*, **15**, 143.

before the development of disabling illness. In other cases, indices of impairment preceding disease may not be used because of lack of awareness, lack of experience, or lack of appropriate instruments. This is particularly so with regard to symptoms of mismatching between man and job—for example, low back pain resulting from faulty equipment design, and neurotic and psychosomatic disorders provoked by inadequate training or inappropriate shift-work schemes.

As with environmental assessment, there are important statistical considerations in the design and conduct of medical surveillance programmes. These programmes have two different objectives—the assessment of the health of individual workers, and the evaluation of responses in a group of workers whose exposures vary in magnitude. In the first case periodic examinations are needed in all exposed workers at a frequency commensurate with the dynamics of the disease. Practical considerations may require that the examination be limited in extent and duration. For the group evaluation, on the other hand, more detailed examinations are required, perhaps at different intervals of time, and appropriate samples of the total population should be selected for examination, with proper representation in the different categories of exposure levels (including controls). The design and conduct of such studies must be carefully coordinated with the concurrent assessment of environmental exposure, and both the medical studies and the environmental assessment should be subjected to expert scrutiny to ensure the fulfilment of the statistical criteria for obtaining dependable relationships.

4.3 Complementary roles of environmental and medical monitoring

It must be emphasized that the two approaches—measurements of environmental exposures and health assessment of exposed workers—should not be regarded as alternative procedures. They are, in fact, complementary and should be carried on in parallel to ensure the proper management of the occupational health maintenance programme. This is especially true when dealing with newly recognized hazards for which the dose/response relationships are not fully known.

While emphasizing this need for joint monitoring programmes, the Committee recognizes that there may be circumstances that do not permit them, and it then becomes necessary to give greater emphasis to one or the other.

There is no general agreement on the relative importance of environmental and medical monitoring. Some would rely entirely on environmental exposure limits, or insist on the air quality inside the workroom being the same as outside and argue that the workers should not be used as sampling devices. Others believe that the only meaningful index of hazard is " absorption " and that it makes little difference what the stress levels are in the work environment as long as workers are protected through periodic health examinations.

The environmental monitoring of physical and chemical agents may be emphasized when the hazard is a specific one for which a permissible exposure limit is known and when occupational hygiene personnel are available. Medical monitoring, on the other hand, should be emphasized as the main tool for evaluating environmental control measures and is the only means for detecting total health effects. When occupational hygienists are not available, complete dependence must be placed on medical monitoring, which may, however, be expanded to include consideration of environmental factors.

Other factors to be considered when choosing between environmental or health monitoring are as follows : (i) the level of risk, (ii) the number of subjects exposed, (iii) the latent period between exposure and onset of ill effects, (iv) variations in individual responses, (v) exposure by routes additional to inhalation, and (vi) the range of fluctuations in exposure. Continuous environmental monitoring is necessary if the effects of exposure are serious or acute, if there is a danger of sudden high exposure, if the population at risk is large, and if the permissible limit is a ceiling value.

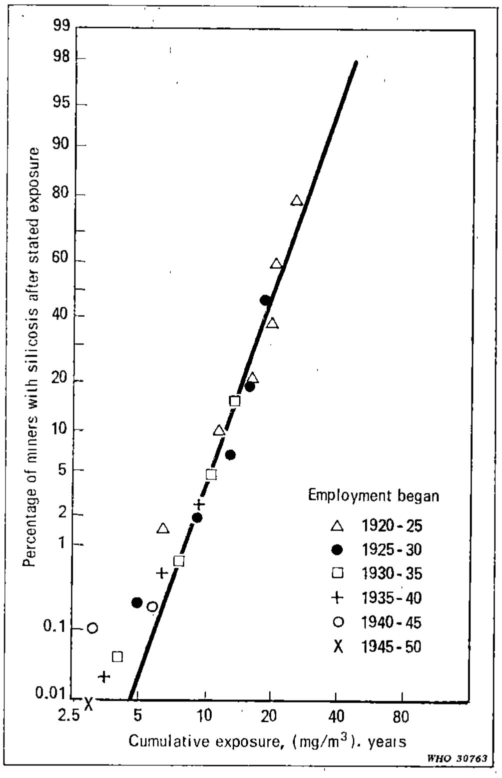
4.4 Statistical monitoring

In addition to the statistical procedures mentioned in section 2.2, statistical monitoring at the plant level also comprises the review at regular intervals of collected data on the health and environmental exposure of occupational groups. The main objective of these reviews is to evaluate the adequacy of preventive measures and occupational health criteria, including permissible exposure levels.

The evaluation of preventive measures depends on the reliability of the collected data, which in turn is determined by the diagnostic methods used to measure the presence or absence of disease, by the adequacy of environmental assessment, and by the duration of time over which workers have been exposed. It is necessary to ensure that representative samples of exposed workers are examined at appropriate intervals.

The statistical requirements for evaluating permissible exposure level are obviously more extensive since the need is to establish a quantitative dose/response relationship over a range of doses above and below the critical cut-off level. For example, from an accumulation over many years of medical records on cohorts of miners entering employment in the South African goldmines in successive periods after 1920 and a parallel record of decreasing levels of dust exposure over the same period, it has been possible to construct a graph showing the relation between the cumulative dose of dust with years of exposure (concentration $\times$ duration of exposure) and the increasing probability of radiological lung changes representing the earliest stage of silicosis (see Fig. 2). The benefits of progressive efforts to

FIG. 2. RELATIONSHIP BETWEEN DOSE (DUST CONCENTRATION × YEARS OF EXPOSURE) AND PROBABILITY OF DEVELOPING FIRST-STAGE SILICOSIS AMONG MINERS IN SOUTH AFRICAN GOLD MINES



From : Hatch, T. F. (1951) *Amer. industr. Hyg. Ass. Quart.*, **12**, 46

reduce the dust level are seen in this figure. Of workers who entered the mines in 1920, 20% had acquired first stage silicosis by 1935. Owing to a substantial reduction in dustiness, however, those who started work in 1935 showed only 2% at the first stage silicotic level after an equal period of employment—a tenfold reduction in risk. From such a relationship a level of exposure can be selected to keep the probability of occurrence of the first evidence of health impairment at whatever level is needed to achieve the desired results in disease prevention. For example, the figure suggests that, to limit the probability to 1 in 100, the dose must be kept below 8 (mg/m^3) · years, so that, for a working period of 30 years, the dust concentration must be kept below 8/30 mg/m^3, i.e., 0.27 mg/m^3. A correspondingly lower level would have to be maintained to accomplish a higher health objective, say, a probability of 1 per 1000 after an equal work period.

Statistical monitoring has also been extended in two directions beyond the limited scope of occupational disease prevention as outlined above.

Firstly, records gathered primarily for other purposes such as the population census and death registration,[1] pension schemes, social security data,[2] and insurance company and hospital records[3] have proved useful in identifying and quantifying previously unrecognized hazards such as lung cancer and mesothelial tumours in asbetos workers,[4] excess of death from coronary heart disease in viscose rayon workers,[5] cancer of the respiratory system in the chromate industry,[6] and pulmonary tuberculosis among workers in an axe factory.[7] Recent evidence of the teratogenic effects of certain compounds indicates a need for inquiry into the possibility of certain industrial exposures having such effects. Statistical monitoring in various industrial regions or cities might reveal an association between stillbirths (and also live births with congenital defects) and the mother's occupation.

Secondly, comparison of rates of sick absence and of attendance for medical aid in a number of similar establishments can provide a basis for identifying hazards and for evaluating the relative effectiveness of health programmes. However, since sickness absences and the seeking of treatment are sometimes conditioned by factors other than health status, such comparisons must be made with caution. Absence from work may occur for a variety of reasons, apart from illness severe enough to cause unfitness. In so far as it represents a withdrawal from work it may be used as an index of negative attitudes and may lead to the identification of various causes of psychosocially induced stress in working populations. Absenteeism (absence without certified sickness or injury) may be a partial indicator of low job satisfaction and of social problems outside work. At present most of the work done in this field is concerned with demonstrating that mental illness and negative attitudes are major causes of lost time, and there are few examples of using indices of mental health or negative attitudes in the actual monitoring of adverse psychosocial factors. For example, the ratio of nonmedical to medical reasons for attendances at the health department may be used as an indicator of psychosocial problems.

There is a need for guidelines for occupational health practitioners on methods of detecting, estimating, and managing psychosocial stress at work.

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[1] Collis, E. L. & Greenwood, M. (1921) *The health of the industrial worker*, London, Churchill.

[2] Mancuso, T. F. & Coulter, E. J. (1959) *Amer. J. publ. Hlth*, **49**, 1525.

[3] Schilling, R. S. F. (1973) *Occupational health practice*, London, Butterworths.

[4] Newhouse, M. L. & Thompson, H. (1965) *Ann. N.Y. Acad. Sci.*, **132**, 579.

[5] Tiller, J., Schilling, R. S. F. & Morris, J. N. (1968) *Brit. med. J.*, **2**, 407.

[6] Machle, W. & Gregorius F. (1948) *Publ. Hlth Rep. (Wash.)*, **63**, 1114.

[7] Drury, W. H. (1921) *US Publ. Hlth Service Reports*, **36**, 159.

5. FUNDAMENTAL AIMS OF OCCUPATIONAL HEALTH MONITORING

The fundamental aims of occupational health monitoring are to measure all the stressors encountered at work and to assess the overall health status of employees. The stressors to be measured include not only physical, chemical, and biological hazards but also such factors as adverse psychosocial conditions and the poor adaptation of work processes and tools to human capacities. Furthermore, monitoring should be carried out with a view to detecting the positive aspects of work, which play an important part in health promotion. Unfortunately, knowledge of factors beyond the normal industrial hazards is far from complete, and a good deal of research will be needed before practical monitoring systems can be devised to cover them. At present, therefore, efforts must be concentrated on improving existing monitoring systems in order to promote the health both of the gainfully employed and of the community at large. This may be done by extending the system of monitoring so as to :

(1) strengthen further the preventive action against occupational health hazards ;

(2) identify unrecognized health hazards ;

(3) determine how variation in individual susceptibility influences the response to adverse working conditions ;

(4) determine in what ways conditions of work add to or lessen the burden of general ill health in working communities.

5.1 Strengthening of preventive action against occupational health hazards

There are four important aspects of prevention that demand particular attention : (1) the choice of medical examining procedures for the detection of precursors of disease and early health impairment [1] well in advance of the development of actual disease, (2) the improvement of methods of environmental and biological monitoring,[2] (3) the adequacy of current levels of permissible exposure to hazardous agents or the need to establish lower levels to ensure full health protection, and (4) the extension of knowledge concerning ways in which simultaneous or successive exposures to two or more hazardous agents combine to produce a greater or different effect on health than is produced by their independent toxic actions.

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[1] Early detection of health impairment is defined by the Committee as the detection of disturbances of homoeostatic and compensatory mechanisms while biochemical, morphological, and functional changes are still reversible.

[2] Biological monitoring is taken to mean, in this report, the measuring of levels of hazardous agents or their metabolites in biological materials to provide quantitative evidence of absorption and retention of the hazardous substance in the body, reflecting the magnitude of external exposure.

Detection of early health impairment

This is needed to give advance warning of potential ill health so that further protective action can be taken to ward off the impending illness. It follows that the usual medical criteria for distinguishing between a state of health and one of ill health are not good enough ; the types of examination must be selected to reveal functional changes that, while not in themselves manifestations of illness, show kinds and degrees of impairment that are predictors of impending ill health. Recent advances in techniques of medical examination have made it possible to monitor large numbers of workers at low cost.

Improvements in environmental and biological monitoring

More sensitive medical examination procedures must be accompanied by an improvement in the techniques of environmental measurement in order to ensure a comparable degree of refinement in assessing the various forms of stress at the workplace. The two must be of equal quality if together they are to yield a dependable relation between conditions of work and man's health.

The primary need is to secure the best possible estimate of the magnitude of the effective doses of the hazardous agent to the exposed individuals. The level of an environmental agent at a given workplace often varies in time owing to differing rates of release. The total operating cycle may be made up of several different steps of unequal duration, in the course of which the rate of release of the agent may range from a peak level down to zero. Also, the respiratory rate of a worker will vary with changes in energy expenditure and thus alter the rate of intake of airborne contaminants. In this respect the effect of altitude is also important. There may be modifications in the operating process over time with corresponding changes in the generation and release of the agent. Finally, individuals move from one job to another with accompanying changes in the nature and/or magnitude of exposure.

In the face of all these variables, what constitutes an effective dose rate to the exposed individual ? In the simplest terms, for stresses that act acutely over a brief period, the peak level may be most significant ; for those that act slowly on man over a long time, an average weighted daily exposure is usually calculated. The simple assumption that level and duration of exposure have equal weight has been reasonably supported for a number of exposures, such as exposure to silica-bearing dusts (effective dose = concentration × time).[1] There is, however, need for a more detailed examination of the response to many other kinds of agent.

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[1] Flinn, R. H. et al. (1939) *Publ. Hlth Bull. (Wash.)*, No. 244.

Some of these difficulties may be overcome by using personal sampling instruments attached to the individual or by using the man himself as the sampler. The personal sampler gives an average value of the concentrations at each exposure level. The personal film badge to monitor radiation exposure and the personal sampler of airborne contaminants are the best known examples. When the man himself is used as the " sampler ", concentrations of substances (e.g., carbon monoxide or solvent vapours) in expired air are proportional to the intake concentrations of these substances.[1] Levels of dissolved substances in blood and urine reflect their body burden as shown particularly in the case of heavy metals.[2] Man, of course, samples the airborne agent at his own respiratory rate and in proportion to his duration of stay in areas of different concentration levels of the hazardous agent, thus giving an average concentration properly weighted by both of these factors.

Using man as a biological monitor may or may not give a better estimate of magnitude of exposure than direct measurement of environmental concentration, depending on how well the measured internal concentration reflects the magnitude of the effective dose in critical organs or sites within the body. For carbon monoxide and other metabolically inert gases and vapours, the venous blood concentration (equivalent to concentration in exhaled air) is a better measure of effective exposure than is the external atmospheric concentration, but the blood or urine content of dissolved metals generally represents only a very small fraction of the total body burden and is not necessarily proportional to the effective dose to the critical site. Thus, for such substances, dose/response relationships and permissible limits of concentration in the blood or urine must be derived in the same systematic way as are the relationships between external exposure levels and human response, with full recognition of the uncertainties introduced by variable mobility of the total body burden between the fluids and fixed tissues of the body. Studies of biological levels of different toxic agents in the human body following exposure to these agents have yielded information on a number of different substances,[3] but it is recognized that further research in this area is required.

A particular problem arises in the assessment of exposures to aerosols containing particles of varying sizes. There are great differences in the

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[1] Stewart, D. *Monitoring industrial exposures to gases and volatile compounds with breath analyser.* In : *Proceedings of the XVII International Congress on Occupational Health, Buenos Aires, 1972* (in press).

[2] Stokinger, H. E. *Rationale for the use of biological threshold limits.* In : *Proceedings of the XVII International Congress on Occupational Health, Buenos Aires, 1972* (in press) ; Yamaguchi, S. et al. (1971) *HSMHA Health Reports*, **86**, 904.

[3] Stokinger, H. E. *Rationale for the use of biological threshold limits.* In : *Proceedings of the XVII International Congress on Occupational Health, Buenos Aires, 1972* (in press) ; Schilling, R. S. F. (1973) *Occupational health practice*, London, Butterworths, pp. 107-8.

way in which the respiratory system deals with particles of different sizes,[1] and there is considerable size selection in the dust deposits in nasal chambers, along the airways, and in the alveoli. Moreover, dusts often show variation in composition with size of particle, resulting in different compositions of the deposits in the upper and lower respiratory tract. Thus, to assess the risk of dust exposure, distinction is made between these two fractions. For this purpose it is now customary to use a two-stage sampling instrument.

Atmospheric sampling and subsequent analysis of a mixture of gaseous contaminants often prove difficult owing to the mutual interference of the various substances. Appropriate selective absorbers may be required to circumvent this difficulty, and when analytical procedures such as gas chromatography are used such interference does not occur. Advanced occupational hygiene technology also facilitates the monitoring of variations in level of physical and chemical environmental factors.

Permissible limits of exposure to hazardous agents

Permissible limits are now accepted as essential guides to the control of a number of occupational risks, but they need continuous reappraisal. The prescribed limit is adequate if there is no evidence of significant health impairment among the workers who are thus protected, provided periods of exposure have been long enough to reveal the long-term as well as the more immediate responses to the stress. This means that routine observations must continue even when the accumulating data fail to show evidence of ill health.

Even when dose/response relationships have been defined and agreed upon by various countries through international organizations such as WHO, countries may differ in their interpretation of permissible levels. The permissible level of a substance may be taken at a point in the dose/response curve that would prevent the earliest demonstrable change from normal behaviour. Alternatively, for economic and social reasons permissible limits may be set at a higher level, namely, to prevent diagnosable illness, or at an intermadiate point between these two, so that the response would be kept below the level of detectable health impairment.[2]

The whole question of permissible levels has to be approached as a problem in epidemiology utilizing special studies in selected establishments as well as the findings from routine monitoring.

Study of combined health effects

It is common to encounter two or more different hazardous agents or situations simultaneously at the workplace or in succession as work pro-

[1] Hatch, T. F. & Gross, P. (1964) *Pulmonary deposition and retention of inhaled aerosols*, New York and London, Academic Press ; Fuchs, N. A. (1964) *The mechanics of aerosols*, New York and London, Academic Press.

[2] Hatch, T. F. (1972) *Bull. Wld Hlth Org.*, **47**, 151.

gresses. Thus, their combined effect must be evaluated. Exposure to multiple stresses may lead to additive synergistic or antagonistic effects, or, on the other hand, the stresses may act independently.

Questions concerning multiple exposures can be only partly answered by animal experiments. This is especially true when searching for an understanding of the effects of exposure to a hazardous agent at the workplace combined with a weakening of the individual's capacity to withstand stress resulting from his life outside the place of work. Inadequate nutrition, for example, may aggravate the risk of exposure to harmful agents. In the toxicology laboratory, however, every effort is made to standardize the test animals to minimize variability in response to the test agent. Thus, animals are selected from a given breed, standardized for age and sex, housed under controlled conditions, and maintained on a standard diet. These conditions are quite unreal compared with those under which people live, and for this reason (among others) great caution has to be exercised in drawing upon the animal findings to predict man's behaviour in response to the same agents. In many countries a relatively poor nutritional status and low level of health in the population can be factors of great importance in determining the magnitude of the health risk at the workplace. Therefore, the final answer must come from the systematic recording and quantitative evaluation of the health experiences of workers subjected to such multiple causes of ill health. Some of the consequences may be too subtle to be revealed by a routine monitoring scheme and will have to be investigated on a more formal epidemiological basis. For example, factors such as smoking and pollution outside the work environment can complicate the relationship when establishing permissible levels.

5.2 Identification of unrecognized health risks at the workplace

There are reasons to believe that many noxious exposures have not yet been identified as being related to human disease. This is particularly the case when there is a long time lapse between the exposure and the onset of disease, the consequence being that the disease may appear many years after the patient has left the hazardous working place.

Many of the chemicals encountered in industry are known to induce cancer in animals and may be similarly carcinogenic to man. Moreover, it is known that some occupations are associated with an increased risk of cancer even though the agents responsible have not been identified. It is, however, not clearly understood whether agents that cause specific diseases will, at low concentrations (perhaps below the permissible level), produce other pathological conditions with a longer incubation period. There is some evidence from animal experiments that chemicals having acute toxic effects at a certain dosage may lose this effect at lower doses but that the lower doses may instead have long-term carcinogenic effects.

In such situations, adequate biological and environmental monitoring of exposures may or may not produce immediate results, depending on the latent period between exposure and effect, but it will provide the indispensable background information for the epidemiological studies of long-term effects.

In the further search for other possible health risks at the workplace, more consideration should be given to man/job relationships that do not fall into the category of physical, chemical, or biological hazards. Other factors, such as ergonomic and psychosocial factors,[1] are extremely important for the successful matching of job demands and human capabilities. The principles of ergonomics may also be applied in the analysis of work processes and the identification of the anatomical, physiological, and psychological demands that these processes impose upon the human operators. Such analysis leads immediately to the proper design of the work environment. It has been suggested that the allocation of function between man and machine is governed by four criteria :

" (1) relative abilities : this demands a knowledge in relative terms of which tasks men are basically suited for and in which tasks machines are better employed ;

(2) cost/value : the relative cost in terms of acquisition, selection, training, subsistence and insurance for men *versus* capital investment and depreciation for machines ;

(3) the integrated task : this involves the recognition that men are only available as integrated units, and given that a man must be present for certain purposes he may as well do certain other tasks that could be done by machines were it not for the availability of the man. In addition, the man as a human being requires a task that is integrated in the sense that it is worth doing and makes use of his abilities ;

(4) graded tasks : in large systems it is not desirable that all tasks should be of equal difficulty. Members of the available working population always vary in their levels of ability, skill and seniority, and a good design will make use of this variety." [2]

There is not yet a well established body of procedures to ensure adequate matching between man and job, whether for the identification and quantitative assessment of the more subtle demands that are imposed on workers by the job requirements or for the measurement of man's capacities to deal successfully with these demands. Efforts in ergonomics and in the area of psychosocial stresses remain largely in the research phase, in which parti-

[1] Levi, L., ed. (1971) *Society, stress and disease*, Vol. 1, London, Oxford University Press.

[2] Singleton, W. T. (1972) *Introduction to ergonomics*, Geneva, World Health Organization, p. 140.

cular problems are studied in isolation from the total relationship between conditions of work and man's health. The need is to bring these new approaches into the main stream of occupational health and make them a part of the monitoring system.

5.3 Variation in individual susceptibility and tolerance

Individuals without demonstrable health impairment vary in their inherent biological capacities to withstand the stresses of life. Because of a variety of selective processes (e.g., genetic, physiological, social, educational, economic, and environmental) different population groups and different ethnic groups may also vary in their levels of resistance. There is, for example, in certain respects a progressive lowering of health status as the population group shifts from the professional/managerial class through various levels of skilled and semiskilled workers to the category of unskilled labourers ; and it is of particular significance that such differences are seen in both husbands and wives.[1] This suggests that the differences are characteristic of socioeconomic rather than of occupational groups. In consequence, individuals within such selected groups may exhibit quite different kinds and degrees of response to a given environmental stress. This difference can range all the way from a seriously disabling reaction in those with the lowest biological strength to little more than a transitory irritation or annoyance in the most highly endowed. Environmental stresses of sufficient magnitude may overwhelm the individual, whatever his strength, and thus hide variations in susceptibility, but, as a level of minimum exposure to the external stress is approached, the relative strengths of the exposed individuals become increasingly important and finally dominate the agent-host-disease relation. At such time, clearly, the primary emphasis in a preventive programme must shift from the agent to the host.

Because of this inherent variability in vital endowment and consequent range in the probability of ill effects from a given work situation within a given population, the degree of required protection has to be set to protect the exposed population at some acceptable probability level commensurate with the seriousness of the health risk. Consequently, the needs for health protection will vary from one population group to another, and this fact should be borne in mind in the design of monitoring and preventive programmes for different groups. A number of occupational health institutions in developing countries have recognized these needs and are engaged in research programmes in this area.

There is another source of variation in ability to withstand stress, however, which does not come within the " normal " category, namely, the

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[1] Great Britain, Registrar General (1958) *The Registrar General's Decennial Supplement, England and Wales, 1951*, London, H. M. Stationery Office.

loss of resistance on account of a previous or present illness or state of chronic disability. An individual with long-standing cardiovascular disease, for example, is especially vulnerable to heat or other extra demands on his circulatory system. One with cardiorespiratory disease falls victim to an added stress in the form of a respiratory irritant. Such handicapped subjects can respond to environmental stress in a manner quite outside the range of normal variation from the average dose/response curve, and it is doubtful whether they can be dealt with properly by viewing them merely as individuals of unusual susceptibility in the general population. They should be recognized and treated separately. In some workplaces this is done by making sure that they are not put on jobs that tax them unduly. There will be no great difficulty in discovering such individuals in advanced states of disability, but it may be less easy to recognize earlier levels of impairment, even when the impairment is sufficient to render the worker less resistant to stress.

In certain economic situations and in times of labour shortage, optimum placement may not be possible and the handicapped will be found working in undesirable conditions. The possible existence of such individuals in the working population should be recognized and receive proper consideration in any monitoring system.

An occupational health monitoring system should, as far as possible, take these characteristics of human variability into consideration in the selection of items (environmental and human) to be included in the record. Such monitoring schemes should therefore include health examinations before job placement, periodically afterwards, and following sickness or injury, particularly for occupations that carry potential health risks.

5.4 Interaction between work and general health of the gainfully employed

It is to be expected that the level of health among those who are regularly employed in an established industrial organization will be higher than that in an unemployed group, equivalent in certain characteristics such as age, sex, and race, when the latter category includes a high proportion of those who are unfit for work. However, even the unemployed who are fit for work are likely to be less healthy than their contemporaries at work because the latter may have the advantages of in-plant health services, higher economic standards, and other positive contributions that come from being employed. There are also differences in health status between populations in different occupations and industries. These differences may arise as a result of persons with certain health characteristics being attracted to particular jobs; for example, the higher incidence of duodenal ulcers among business executives and foremen compared with other occupation groups may be due to these jobs attracting the type of man who drives himself hard.[1] Differences in health status between two occupational groups may also occur because the two kinds of work demand quite different educational standards.

It is necessary to make a clear distinction between these differences and another type, in which an increase in the level of general illness over that expected in a given population has been imposed by occupational stresses. The stresses may contribute directly to the overall prevalence of illness or they may act as agents that aggravate the seriousness of established illness.

In the first case, corrective action should be directed both to the workers and to the work stresses, and positive benefits (such as the correction of malnutrition, the treatment of schistosomiasis, and the provision of recreational facilities) should be introduced that will offset to some degree the inherent deficiencies brought by the workers to their jobs. In the second case, however, the prospects for better health protection will come directly from the identification and removal or modification of the hazardous component at work. It is important to emphasize the possibility that the well known hazardous physical, chemical, and biological agents that cause specific organ damage or disease could act below the established permissible levels of exposure to aggravate existing diseases affecting the same organ or physiological system in the body. If a problem exists it is revealed only in the form of a statistically significant excess in the occurrence of some disease that is found commonly in the general population, such as chronic cardiovascular disease.

5.5 Further goals in monitoring

To achieve the goals outlined at the beginning of this report, consideration should be given to psychosocial and ergonomic factors as well as to physical, chemical, and biological agents, and those engaged in occupational health monitoring should seek to establish the relationships between these additional work factors and the probability of disease. In controlled experiments, suspected stress factors can then be removed from the environment and the change in subsequent health experience noted. The anticipated relationships here are more complex than is the case with the specific occupational disease hazards. Not only are the statistical requirements much more complicated but new questions are raised concerning the additional items that should be measured to give a more complete assessment of the total situation at work and outside. In the absence of specific disease, it is necessary to decide what to measure to determine the worker's health status and assess the potential of the stress factors for ill health as well as to evaluate the possible beneficial effects of work. Attempts have been made in certain industries to quantify these beneficial effects by comparison

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[1] Doll, R. & Avery Jones, F. (1971) *Special Report of the Senior Medical Research Committee*, No. 276, London, H. M. Stationery Office.

of absence rates, job satisfaction, and quality and quantity of performance. The Committee recognizes that knowledge in this area is incomplete.

One risk in extending the coverage of the monitoring system in this way is that too many variables of uncertain meaning will be included in the record, resulting in diffuse data from which no significant relationships can be derived. It is necessary, therefore, to use great care in the selection of items to be measured and recorded, keeping the statistical requirements always in mind. It would be advisable to start with the most obvious needs and to progress gradually to the more complex patterns and relationships.

Despite these difficulties, broader monitoring schemes are needed. In the industrialized countries they will supplement and extend existing occupational health efforts, and in the developing countries they will ensure a broader base on which to build their programmes from the beginning.

In working with specific occupational diseases it has proved easy to elucidate the dominating environmental and human factors, and it is tempting to continue along the same limited lines. The total health of man, however, cannot be broken down into separate compartments. It is unrealistic to deal with work factors independently of the strengths and weaknesses of the worker himself and without consideration of his living conditions. This is the reason why the objectives of an occupational health programme must be broadened to deal with the total pattern of relationships between conditions of work and man's health.

6. USE OF OCCUPATIONAL HEALTH MONITORING IN PUBLIC HEALTH

Since public health practice is directed mainly to the health problems common to population groups rather than to individuals, there is need for regular access to such groups for large-scale epidemiological studies, for early case findings, and for attack upon the problems by a mass approach. The large fraction of the adult population that is gainfully employed constitutes such a group, and ready access to them is made possible by the fact that they assemble each day in their places of employment where they may be more easily reached than at home and where medical observations upon them may be made and recorded. Such records, prepared in a standard manner, provide invaluable data to public health authorities.

The possibilities of more effective public health action through cooperative efforts between occupational and community health services are thus readily envisaged and are being realized in a number of countries. In the Netherlands, for example, a cooperative study of coronary heart disease in a large number of workers is being conducted by the Ministry of Health and twelve occupational health services.[1]

[1] Bonjer, F. H. (1973) *Hartbulletin*, **4**, 71.

Much the greater proportion of sickness occurring among working people is simply a part of the common pattern of illness characteristic of the general population. This is often true even in industrial establishments having well defined health hazards. The causes of such illness are found away from the workplace. It follows that the occupational health programme must devote much attention to these common forms and sources of ill health if it is to make any serious attempt to reduce the total sick absence rate and to provide significant health benefits for the majority of workers. This responsibility is shared, of course, with the general public health authorities.

The analysis of the daily experience in occupational health departments permits the discovery of incipient illness (especially important with such diseases as tuberculosis) and the early recognition of epidemic outbreaks, while the frequent contacts between individual workers and the occupational health staff reveals evidence of malnutrition and poor home conditions. In addition to providing information on prevailing community health problems, periodic medical examinations also offer many opportunities for the effective health education of workers and (through them) their families.

Experience in industry helps to strengthen community efforts to improve environmental health because many of the pollutants that contaminate the air, water, food, and soil in urban areas are generated by industrial processes and are encountered in workplaces, often in greater concentrations than are usual outside.

The occupational physician and hygienist may extend their monitoring systems to the community outside the workplace in order to maintain continuous observation of the pollutants emitted and to evaluate, in collaboration with the public health authorities, the effects of such pollutants on community health. This is well exemplified by epidemiological studies revealing neighbourhood effects produced by local industry, such as the occurrence of mesothelial tumours,[1] chronic beryllium disease,[2] and Minamata disease.[3]

National health programmes in any country are in a position to improve and widen the scope of their work and increase their effectiveness by utilizing occupational health resources. In too many countries, however, occupational health manpower is working in isolation from national health services, and this is especially serious in some developing countries where the health personnel serving the workers (on full- or part-time basis) constitutes a major part of the total health manpower.

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[1] Newhouse, M. L. & Thompson, H. (1965) *Brit. J. industr. Med.*, **22**, 261.

[2] Stokinger, H. T., ed. (1966) *Beryllium—its industrial hygiene aspects*, New York, Academic Press.

[3] Takeuchi, T. (1967) *Pathology of Minamata disease*, Kumamoto University Press.

7. OCCUPATIONAL HEALTH MONITORING AS AN EPIDEMIOLOGICAL RESEARCH TOOL

The accumulating data on the health of workers and the change in their health status with time together with parallel data on conditions of work and the various stresses at the workplace provide essential material for continuing epidemiological research, which will not only lead to a better understanding of health problems in industry but will reveal important relationships in medicine in general.

As occupational health efforts bring about a significant reduction in the more simple health risks associated with chemical, physical, and biological agents, there will be a shift of emphasis to a new area concerned with more subtle and complex relations in which the characteristics of man himself will assume greater importance. More highly mechanized and automated processes will come into use in industry, removing the operator from direct contact with hazardous agents and giving him new responsibilities. There will be less risk of direct poisoning but greater exposure to a variety of psychological and physiological demands in his new role as a controller of a mechanized process, taking readings from instrument dials, interpreting their meaning, and taking the proper action to keep the process functioning at maximum efficiency. In the ultimate automated process, psychological stresses will greatly outweigh physiological ones, and much greater attention will have to be devoted to matching the demands of the job and the capabilities of the operator. Good matching will be essential both to the health of the operator and to the productivity and efficiency of the man/machine system.

Occupational health monitoring offers opportunities of developing a better understanding of the chronic degenerative diseases and of other diseases of special concern to aging people. In the absence of recognized external causative agents, there has been little opportunity for primary preventive action against chronic diseases, and control efforts have had to be confined largely to early case finding and appropriate medical care.

It is clear that large-scale controlled epidemiological studies are required to demonstrate the significant relationships between environmental and host factors and resulting disease, and, since time itself is an important dimension in the etiologies of chronic diseases, it follows that these studies must be prospective and not retrospective. Industry offers unique possibilities for such long-term studies, utilizing the information derived from a systematic continuing monitoring scheme that has for a major purpose the discovery of significant relationships between host characteristics and conditions of work.

On the assumption that the probability of occurrence of degenerative diseases depends on genetic factors and the influence of past events (malnutrition, poor home environment, previous illness, etc.) the only prospect of altering the probability would appear to be to take some positive action that offsets the established genetic or other weakness that the individual brings to his adult life. Therefore, it is interesting to speculate on the possibility that work performed in completely satisfactory conditions might be found to have beneficial effects that would serve as positive contributors to health and thereby make up for genetic or other handicaps. If such effects exist, only careful epidemiological studies will reveal them.

8. GUIDELINES FOR MONITORING

In the Committee's view, there are three basic levels at which monitoring can be carried out in preventive occupational health practice—at the national or regional level, at the plant level, and at the level of specific hazards.

The guidelines given in this section refer to specific occupational health risks and the monitoring of the more obvious environmental hazards. Nevertheless, it should be stressed that the monitoring of working populations offers opportunities for determining the broader influence of work factors such as heat, hours of work, shift systems, and psychosocial stresses. For this broader concept of monitoring, guidelines are not yet sufficiently developed to be given as examples, but they should become available through further research.

8.1 Monitoring at national or regional level

The conditions of health of the working population in a country, or in a productive region within the country, can be assessed by means of a survey, which will provide a basis for the planning and organization of occupational health services. The survey should enable the health authority to formulate objectives in occupational health, to establish long-term as well as immediate priorities to meet these objectives, and to determine the organizational requirements and physical facilities required for the programme. It will also ensure the most effective use of existing resources, such as trained personnel and equipment, and will provide a baseline against which the effectiveness of preventive action may be measured by subsequent monitoring.

The occupational health effort should be part of an overall national health policy and should be properly coordinated with other health programmes. Since workpeople constitute a major part of the total adult population, the findings from a national inventory of their health problems will contribute much of the information needed to determine the policy for overall community health protection. It will also help to justify financial allocations to occupational health programmes.

During an initial assessment of this kind it is not usually possible to examine all workplaces or to determine the health status of all workers. However, in certain countries, a national inventory can be developed from a variety of sources, such as government data on social security, occupational diseases, and accidents, records collected by industry, and actual surveys. In many countries the only way of obtaining this information may be to carry out a survey based on a sample of the industries, chosen to give a proper statistical representation of the total work population and of the different kinds of industries and occupations. Methods of examination and analysis must be carefully standardized to ensure internal consistency and comparability of the data accumulated from the different establishments. Examples are given of surveys specially designed to determine occupational health needs :

In the USA, between 1936 and 1939, an occupational health survey[1] was made in 15 States by the United States Public Health Service. It included nearly 17 000 plants employing 1.5 million workers. The sample was considered to be representative of industrial conditions in the whole country and it was used as the basis for recommendations for future action by industry and official agencies. In 1972, a National Occupational Hazards Survey was undertaken by the National Institute for Occupational Safety and Health, utilizing standardized survey procedures. From this stratified sample of some 5000 manufacturing establishments, it will be possible to make a national projection of the potential occupational health hazards in the USA and an estimate of the work populations potentially exposed.

In Great Britain, after the Second World War, the Factory Department of the Ministry of Labour undertook two pilot surveys to assess the extent of the need for such services. One of these surveys was made in the town of Halifax.[2] It drew attention to unsatisfactory working conditions and the need for better occupational health services in a town with nearly 29 000 workers employed in 760 factories.

In Egypt, in 1965, a health insurance scheme including the provision of comprehensive health care for industrial workers was undergoing its first trial in the city of Alexandria. To help plan this new scheme, which was to cover approximately 92 000 industrial workers mainly employed in 152 plants with more than 50 workers, a survey[3] was made of the processes and materials used and of the potential hazards and safety and health services existing in 101 randomly selected plants. At the same time, medical examinations were carried out on 5.3% of the workers, stratified according to the type and size of the industry, records being made of their medical, occupational, and social histories, smoking habits, history of parasitic infestations, and past occupational injuries. The survey revealed a high prevalence of respiratory, digestive, rheumatic, eye, and skin diseases,

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[1] Bloomfield, J. J. et al. (1940) *Publ. Hlth Bull. (Wash.)*, No. 259.

[2] Great Britain, Ministry of Labour and National Service (1958) *Industrial health : a survey in Halifax*, London, H.M. Stationery Office.

[3] El Batawi, M. A. (1972) *Industr. Med. Surg.*, **41**, 18.

which were probably due in many instances to occupational exposures, including disorganized feeding at work.

Similar types of study are being carried out in some developing countries, with WHO assistance. In Thailand the activities of the Occupational Health Division of the Ministry of Health have been planned following a study of representative samples of workplaces and working populations in Bangkok and Samudprakarn.

The information obtained by surveys at the national or regional level may be used for the initial planning of occupational health services, but there should be further monitoring at regular intervals at this level to identify gaps in the overall provisions for occupational health care and to determine new health problems.

8.2 Monitoring at the plant level

To protect the health of workers employed in a particular industrial enterprise, it is necessary to monitor the plant as a whole. In contrast to the general nature of the national survey, monitoring at the plant level is much more detailed, its objectives being:

(1) to determine the nature and magnitude of all known health risks within a particular plant for which a given occupational health staff have primary responsibility,

(2) to evaluate the adequacy of protective measures against these risks,

(3) to discover other possible risks, previously unrecognized, for which control measures are required,

(4) to facilitate the organization of an occupational health programme, and

(5) to make critical evaluations, at regular intervals, of the effectiveness of different phases of the programme (i.e., environmental and medical) and to measure the progress made in health protection.

The monitoring programme is carried out by occupational hygienists and physicians, assisted where necessary by experts in other disciplines, and it must be employed routinely to ensure continued health protection and to identify and take prompt action against newly introduced hazards. In short, a routine monitoring scheme is a fundamental part of the occupational health programme and a necessary step to gain and maintain full command over the health problems of working people. It must be carried on in whatever degree of detail is necessary to reveal all the essential information, which itself depends on the degree of complexity of the health problems in the particular factory, mine, or other establishment concerned. The needs are very much simpler in a quartz-grinding mill, for example, where silica is likely to be the dominating hazardous agent, than in a large chemical plant producing or using a variety of toxic materials capable of producing many different ill effects in man.

8.3 Monitoring for specific hazards

Monitoring for specific hazards includes monitoring the exposure of each worker to specific agents (acting singly or in combination) and monitoring a prevailing condition of ill health, which might be a specific occupational disease such as pneumoconiosis or a nonspecific disease such as hypertension or coronary heart disease, where working conditions may play a part in causation or aggravation.

The complexity of the measurements needed to establish a reliable dose/response relationship and to arrive at a proper estimate of the magnitude of health risk for a given exposure varies widely from one hazardous substance to another and even with the circumstances of contact with a given agent. These variations must be fully understood in order to set up appropriate monitoring schemes for assessing the risks from different agents. The following examples will help to illustrate the problems encountered, but for a full and formal investigation it is necessary to consult the standard textbooks on the subject.

Silicosis

Silicosis is a fibrotic disease of the lungs caused by the cytotoxic action of free silicon dioxide, which results in fibrosis and impairment of pulmonary function. The silicosis risk increases with the free silica content of the inhaled particles, the dust concentration, and the duration of exposure.

Of the airborne particulate matter inhaled, only a fraction of the finer particles will penetrate to the alveoli, where the damage occurs, and of these a still smaller fraction will be deposited and retained to produce the tissue damage. Even for this selected fraction (perhaps no more than 1–2% of the quantity of dust inhaled) the degree of tissue response and physiological impairment will depend on the fineness of the particles. For silica-bearing rocks, moreover, the mineralogical composition of the airborne dust usually varies with particle size,[1] ranging (for some sedimentary sandstones) from more than 90% silicon dioxide in the coarsest particles down to less than 5% for particles smaller than 2 micrometres, which mainly represent the lung deposit. Since silicosis generally develops slowly over many years, it is the long-term exposure, averaged over months and even years, that best represents the magnitude of the effective dose. This means that a few atmospheric samples taken over brief periods will not give data relevant to long-term exposure.

From these considerations, it is clear that no simple correlation exists between the total dust concentration in the outside air and the magnitude of the effective dose at the critical site in the lungs. Thus, it is not a simple matter to estimate the varying degrees of silicosis risk for different circum-

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[1] Drinker, P. & Hatch, T. F. (1954) *Industrial dust*, 2nd ed., New York, McGraw-Hill.

stances of exposure to silica dust, although there may be a reasonably stable relationship with the atmospheric concentration arising from a single process where some of the other factors will be constant, as, for example, with the wet pneumatic drilling of granite rock.

The problem becomes simpler when high exposures are encountered because of the overwhelming role of simple dust concentration in determining the magnitude of hazard. Other factors are submerged, and good correlation is found between atmospheric dust concentration, percentage of free silica in the dust, and duration of exposure on the one hand and magnitude of lung damage as revealed by radiography on the other.

This was the case in all the early efforts to control health hazards in trades involving exposure to silica-containing dusts. In the series of studies carried out by the United States Public Health Service on granite cutting,[1] pottery manufacture,[2] and hard-rock mining [3] useful dose/response relations were established and the beneficial consequences of systematic dust control and medical surveillance were demonstrated despite the relatively simple methods employed to measure the magnitude of exposure and to assess ill health (silicosis and silico-tuberculosis) in the exposed workers. It must be recalled, however, that the objectives at that time were also relatively limited : to delay the onset and progress of the well defined lung changes seen in silicosis and to eliminate the disabling forms of the disease.

As exposure levels are lowered, however, other variables (including individual susceptibility) become increasingly important and may eventually dominate the relationship. When this happens, the monitoring scheme must be refined accordingly. The dust sampling procedure, for example, must better imitate the size-selective characteristics of the human respiratory system and the mineral composition and atmospheric concentration must be determined from the fraction of inhaled dust that will be deposited and retained in the alveolar spaces. More sensitive physiological measures of pulmonary function and more refined reading and interpretation of chest X-ray films are necessary to diagnose and measure the extent of the early impairment that precedes silicosis.

In some countries a very high silicosis risk may still be found, resulting in frank respiratory disability and early death. In attacking these gross problems, the immediate objective should perhaps be as limited as it was in the early attempts at dust control in other countries, thus permitting the continued use of simpler monitoring methods. It would not be wise to persist in this policy, however, for experience in other countries has shown that the overlong use of simple methods delays recognition of the change in the nature of the hazard as dust control advances.

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[1] Russell, A. E. et al. (1929) *Publ. Hlth Bull. (Wash.)*, No. 187.

[2] Flinn, R. H. et al. (1939) *Publ. Hlth Bull. (Wash.)*, No. 244.

[3] Dreessen, W. C. et al. (1942) *Publ. Hlth Bull. (Wash.)*, No. 277.

Carbon disulfide poisoning

Acute and subacute poisoning by carbon disulfide, which can cause central and peripheral neurological disturbances, has long been recognized as a risk among viscose rayon workers. More recently, evidence has accumulated from a number of studies that long-term exposure to carbon disulfide may cause or accelerate atherosclerotic changes. Of particular importance has been the significant excess of deaths from coronary heart disease observed among viscose rayon workers both in the United Kingdom [1] and in Finland.[2] These studies have stimulated epidemiological investigations of working populations exposed to carbon disulfide, which are carried out with the aim of detecting early adverse effects on the cardiovascular system. Monitoring systems for viscose rayon workers have thus been broadened to include not only screening tests for neurological and psychological disturbances but also for chest pain, increased blood pressure, electrocardiographic changes, and raised blood lipid levels.

It must be emphasized that monitoring is a dynamic, not a static, system and must be subjected to continuous reappraisal to provide the best available methods of surveillance. A monitoring system suitable for European workers may not be suitable for workers in other parts of the world. For example, in a comparative survey planned for viscose rayon workers in Egypt and England, the examination of the former had to include details of parasitic infections that would have been irrelevant to the latter.

In Japan, a study of viscose rayon workers and controls carried out some years ago revealed that renal disease was nearly four times as frequent in men with more than 10 years' exposure to carbon disulfide as in the controls and in men with shorter exposure.[3] Thus the routine monitoring of workers exposed to carbon disulfide in Japan was designed to include renal function tests but not the measurement of blood lipid levels, since at that time no significant difference had been found in this respect between exposed workers and controls. Some of the relevant data to be recorded for the biological monitoring of workers exposed to carbon disulfide are given in the Annex.

This unfolding of the complexity of acute and long-term effects from carbon disulfide exposure emphasizes the danger of adopting a standardized approach. Monitoring systems have to be designed to deal not only with newly recognized risks but also with particular national and local conditions, and there must be continuous reappraisal of permissible limits derived from the biological and environmental data collected routinely in workplaces.

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[1] Tiller,, J., Schilling, R. S. F. & Morris, J. N. (1968) *Brit. med. J.*, **2**, 407.

[2] Hernberg, S. et al. (1970) *Brit. J. industr. Med.*, **27**, 313.

[3] Goto, S. & Hotta, R. (1967) *The medical and hygienic prevention of carbon disulphide poisoning in Japan.* In : *Toxicology of carbon disulphide : proceedings of an international symposium, Prague, September 15th–17th 1966*, Amsterdam, Excerpta Medica, p. 219.

Carbon monoxide poisoning

In contrast to the previous examples, for which the monitoring requirements became increasingly complicated as more subtle ill effects were found at lower levels of exposure, the relationship between the dose of carbon monoxide and the physiological response in man has remained basically the same as lower levels of exposure were shown to elicit responses not previously recognized.

This is because carbon monoxide acts only within the red cells to produce carboxyhaemoglobin, which lowers the level of oxygen transport by the blood, the ill effect arising in consequence of the reduced oxygen supply to other tissues. The circulating blood is the only site where the carbon monoxide reacts with the body, and, as refinements are made in techniques of observation to reveal increasingly subtle effects, the quantitative dose/response relationship continues to be expressed basically between percentage of carboxyhaemoglobin in the blood and the response, at whatever level it occurs.

The biophysical laws governing the respiratory uptake of carbon monoxide are straightforward and permit the direct calculation of relationships between constant atmospheric concentration and blood level for different respiratory rates and periods of exposure. The relationship is more complicated when the air concentration varies, but the significant consequence of the exposure is the build-up of carboxyhaemoglobin in the blood, and this is easily derived at any time from the measured carbon monoxide concentration in the terminal portion of the exhaled air. From this measurement too, a hypothetical average air concentration can be calculated that will be biophysically equivalent to the varying exposure to which the individual was exposed.

Thus, no matter how low the tolerable level of carboxyhaemoglobin may be set to protect exposed workers, the biological monitoring of exposures by means of regular sampling and analysis for carbon monoxide in exhaled air should be carried out as a supplement to environmental monitoring. It is particularly valuable when atmospheric concentrations of carbon monoxide vary in time, making it difficult to derive a physiologically correct exposure level from the varying air concentrations. In such cases, the environmental concentrations serve more to guide the design of protective measures and to assess the effectiveness of ventilation or other control measures than to monitor the hazard itself.

8.4 Procedures for monitoring

A monitoring scheme is organized and developed in logical steps as described in the following sections.

(1) *Preliminary survey*

The first step is to conduct a general survey to obtain initial information pertaining to the plant, its technological processes, the age and sex distribution of the employees, and the health, safety, and welfare provisions (see Annex, Example 1). This information is intended to give a general indication of the scope of the health problem and to lay the groundwork for planning the next step in the survey.

(2) *Observational survey*

The preliminary inquiry is followed by a more detailed visual inspection of the plant and processes to note specific kinds and locations of hazardous exposures, later to be evaluated by a quantitative assessment of exposure and of the adequacy or inadequacy of control measures. These observations enable decisions to be made on such matters as the kinds of sampling instruments needed, the number and location of sampling stations, the required frequency of sampling, and the kinds of measurements required to determine the operating characteristics of exhaust ventilation systems and other control measures.

This survey is essentially a visual one made by an individual familiar with the type of industry, especially the properties of its raw materials, products, and by-products and their significance to health, and with training and experience in occupational hygiene. In a large undertaking, apprentice occupational hygienists may be employed on this work as a part of their training, under the supervision of a senior staff member. The survey follows the processes through the plant from raw materials to finished products and should be conducted in company with a qualified plant man who can explain the details of processes and operations.

(3) *Occupational hygiene survey*

The definitive environmental investigation, commonly called the occupational hygiene survey, has as its purpose the quantitative evaluation of all significant exposures and the assessment of control measures. At least four basic principles may be laid down for the quantitative evaluation :

(*a*) Measurements must be made at all workplaces where individuals or groups of workers are exposed to obvious or suspected hazardous conditions. If there are many similar workplaces, measurements should be made in a representative selection.

(*b*) Sufficient numbers of samples must be taken, and in order to obtain an overall assessment of exposure they must be taken at intervals properly chosen to encompass all phases of the work cycle and at locations covering the entire work space.

(*c*) Agents taken into the body by inhalation require " breathing zone " samples to estimate respiratory intake. When the airborne agents are in the form of aerosols, account should be taken of the influence of aerodynamic size on respiratory intake and pulmonary deposition. Skin exposure may be measured by means of absorbing patches worn by the workers. Contacts with hazardous chemicals by mouth must be assessed. All measurements must be made in such a way as to maximize the hygienic significance of the exposure. To assist in the design of control measures, other samples are required at locations near the principal points of generation or release of the agent.

(*d*) For those conditions in which previous research has established that man himself is the best sampler for measuring exposure, care must be taken in the collection of blood, urine, or expired air in order to avoid contamination of the sample.

The techniques of environmental surveys, such as the choice of air sampling instruments and the quantitative analysis of collected samples, are too numerous to give in detail but the references given in the footnote on page 12 of this report contain more extensive discussions of instruments, analytical methods, principles of sampling, and interpretation of results.

The quantitative evaluation of conditions of work must take full account of the design and operational efficiency of control devices. The assessment of an exhaust ventilation system, for example, must include not only its present effectiveness but the probability of its continuing to operate effectively. It must thus be carefully examined for constructional strength, adequate pipe velocities to ensure transport of collected dust, and provision for regular inspection and maintenance of the fan, air cleaning equipment, and ventilation ducts.

(4) *Combined occupational hygiene and medical survey*

The fourth step in the health evaluation survey is to assess the health status of each individual in the exposed population and to match it against the environmental exposure.

This is the most comprehensive of all health surveys, carried out by occupational hygienists, physicians, and other specialists and often requiring weeks or even months to complete. Medical examinations have to be extended to include many special observations and tests, including chest X-rays, blood examinations, and a variety of biochemical and other tests to provide the necessary diagnostic information required to identify and measure the extent of particular occupational diseases and other evidences of ill health.

Specially designed forms are used for both environmental and health examinations to meet particular needs. Examples of the types of information to be obtained for evaluating the specific hazards of noise and carbon disulfide are given in the Annex. Additional data forms covering, for example, the analysis of air samples or on-the-spot measurements of heat or noise exposures are added to each plant survey sheet. The results of medical examinations are systematically recorded, and forms for specific biological, radiographic, and other tests, are attached to the general medical record of each worker. These forms should be designed in accordance with statistical methods to permit tabulation and the drawing of sound conclusions, and their usefulness in practice should be tested in advance of the study. Periodic monitoring should be instituted thereafter, and where new variables appear they should be readily detected and investigated.

The results must be recorded in a manner that will permit a proper matching and joint analysis of the two sets of data and allow comparison with other surveys.

(5) *Routine monitoring*

The surveys outlined above are for an initial assessment of the health problems in a particular plant. They permit the hygienist to plan the necessary occupational health programme, an essential part of which will be a routine medical and environmental monitoring scheme.

Medical monitoring varies in character according to the nature of the work and its associated hazards. Nevertheless, there are certain data essential for all types of examination—date of birth, sex, race, civil state, number of dependents, occupational history, medical history, present illnesses, and clinical findings in respect of the various organ systems (see Annex, Example 2). To these are added special tests for the early detection of specific harmful exposures—for example, audiometry to evaluate the hearing of those exposed to harmful noise levels or employed in jobs where speech communication is particularly important; lung function tests for those exposed to the risk of pulmonary disease; and tests for early signs of abnormalities in the cardiovascular system and the central and peripheral neurological systems for workers exposed to carbon disulfide.

Methods of medical surveillance need to be continuously reappraised, old methods being discarded for new ones that provide more sensitive or more specific indices of early departures from health.

In occupational medical surveillance, it must be recognized that single exposures may cause a wide variety of physiological responses and types of health impairment and also that a single disease entity like coronary heart disease or chronic obstructive pulmonary disease may be causally related to a variety of environmental and personal factors. Medical monitoring is, in fact, an exercise of an extremely complex nature.

Environmental monitoring, too, must be designed to identify all sources of stress, especially those not commonly recognized in the routine practice of occupational hygiene. There are two directions in which inquiry must be extended. Firstly, an attempt should be made to discover aggravating factors that may increase the level of risk from well known hazards—for example, the magnifying effect of heat on the toxicity of various chemicals [1]

[1] El Batawi, M. A. (1959) *Effect of environmental temperature on intoxication by inhaled chemicals having different physiological action*, Pittsburgh, University of Pittsburgh; Baetjer, A. et al. (1960) *Arch. environm. Hlth*, **1**, 463.

and the part played by inhaled particles in accentuating the effect of irritant gases in the lungs.[1] The possible additive effect of psychosocial stresses on individuals exposed to other agents, such as manganese, that affect the central nervous system requires investigations.[2] Secondly, there is a need to include within the purview of occupational hygienists a deeper understanding of man-machine relationships and of methods of making quantitative statements of job demands on the worker, expressed in terms that can be matched against parallel statements of his anatomical, physiological, and psychological capabilities and limitations obtained in the course of preventive medical appraisal.

From these routine monitoring systems an accumulating record can be developed of the magnitude of the worker's exposure to hazardous work conditions and of his parallel health experience. In practice, such records may not be obtainable for every individual separately, but groups of workers engaged in a common occupation may be followed medically in relation to the exposure characteristics of the occupation.

The frequency with which both environmental and medical examinations should be made depends on two principal factors—the dynamics of the disease process and variability in exposure.

The frequency of examinations has to be higher for acute than for slowly developing diseases, and even continuous environmental monitoring may be needed to ensure full command over certain hazards. In contrast, because of the long exposures involved in slowly developing diseases (e.g., silicosis) provided that well designed and properly maintained control systems are in operation, the frequency of environmental monitoring can be reduced to monthly or even annual checks and medical examinations may be similarly spaced out to annual or biennial periods.

The schedule for routine monitoring must also take account of manufacturing processes in which hazardous agents are released cyclically. The handling of hazardous materials in a " batch " process of manufacture, for example, with a sudden release of the contaminant in large amounts when mills or reaction vessels are filled and emptied, presents a markedly different pattern of exposure from that seen when a continuous process is employed in which exposure to the materials extends over a longer period but is at a much lower rate. Production of chemicals in enclosed equipment will present little hazard when the reaction vessels are maintained with good seals. The major risk will occur when the process is shut down for cleaning and repair. For this reason, maintenance workers require special monitoring facilities because they may be exposed to a variety of toxic agents intermittently and at exceptionally high levels. At other times

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[1] Amdur, M. (1961) *The effects of aerosols on the response to irritant gases.* In: Davies, C. N., ed., *Inhaled particles and vapours*, London, Pergamon Press.

[2] Levi, L., ed. (1971) *Society, stress and disease*, London, Oxford University Press.

accidental leaks and other emergencies will cause concern, and where such possibilities exist frequent inspection of the equipment itself will be of particular importance.

8.5 Information to be obtained from monitoring

Examples of the kind of information that might be obtained during monitoring (*a*) at the national or regional level, (*b*) at the plant level, and (*c*) for specific hazards are given in the Annex to this report. The forms to be used for recording the information will vary not only with the type of survey but also with the availability of special data-handling equipment, and since the utilization of new data-handling techniques is expanding rapidly no attempt is made in the Annex to illustrate any specific format.

9. CONCLUSIONS

1. Occupational health practice provides unique opportunities for monitoring both environmental conditions at the workplace and the health status of the gainfully employed—a major part of the population. Such monitoring provides a comprehensive approach to the prevention and control of the health problems of the working population. Problems not readily apparent can also be discovered and controlled. For optimum effect, both parts of the monitoring programme must be conducted as an integrated effort ; either alone is less effective.

2. In revealing previously unrecognized health problems, comprehensive occupational health monitoring may yield further benefits by furnishing clues to the causation of disease and thus contributing to a more effective public health effort. Monitoring may offer a unique opportunity to identify etiological factors in diseases of multiple causation and in dealing with other health problems such as alcoholism and drug abuse in workplaces.

3. Health planners in many parts of the world are insufficiently aware of the fact that the health problems of the gainfully employed need urgent attention.

4. Monitoring is an essential part of occupational health practice in both developing and industrialized countries. An initial monitoring effort provides a baseline against which subsequent changes in work conditions and health status can be evaluated ; it is one of the main tools available to the health authorities for recognizing the kind and magnitude of health problems in the general population, thus providing the basis for developing an effective health programme making the best use of available resources. The extension of monitoring to include ergonomic and psychosocial factors is possible and desirable, and the report indicates some ways in which this may be done.

5. At present, occupational health personnel, both in developing and in industrialized countries, need further education and training to

carry out the broader aspects of the programmes of preventive occupational health monitoring and care outlined in this report. Since general health personnel are often involved with the health problems of working populations, particularly in small enterprises and agriculture, they too need education and training in occupational health.

6. Through the use of simple methods and observational techniques, comprehensive monitoring programmes like those outlined in this report can be adapted to the needs of countries where occupational health resources are scarce. These countries should not be deterred from starting monitoring programmes. Besides the reduction that they will bring about in occupational diseases, such programmes will give the health authorities greater control over the diseases common to the general population affecting a group of great economic importance—the gainfully employed.

7. It is necessary to educate both management and workers to promote the introduction and expansion of occupational health services and monitoring programmes, since mainly by these means can working conditions and the health of workers be improved.

Work is one of the most significant manifestations of the productive existence of man. Through the proper adjustment of work demands to human capabilities and needs, it can offer unique opportunities for health promotion through physical activity, work satisfaction, mental gratification, and sense of achievement.

10. RECOMMENDATIONS

1. Governments should initiate (or stimulate), support, and strengthen the operation of comprehensive monitoring programmes (both environmental and medical) in all occupational groups so as to prevent and control the health problems of the gainfully employed. WHO should assist and advise Member States in these efforts.

2. In order to carry out effective monitoring programmes, governments should promote and develop education and training in occupational health for all health personnel serving working populations. Training in occupational health should also be provided for all other health personnel (including health assistants) who are likely to participate in occupational health monitoring.

3. Detailed guidelines should be produced, with WHO assistance, for carrying out comprehensive monitoring of workers' health to meet the different needs and resources of industrialized and developing countries.

4. Attempts should be made through WHO to reach agreement on methods of establishing permissible limits of hazardous exposures at work and permissible concentrations of hazardous agents in human organs.

Further international efforts, including meetings of investigators, are necessary to coordinate this work and to explore areas requiring further research.

5. To establish fully effective occupational health programmes in developing countries, governments should, in planning industrial development, take account right from the start of the projected goals of occupational health monitoring as presented in this report, recognizing that occupational health should be a preventive health service of a comprehensive nature that goes beyond the limits of controlling specific occupational diseases. All countries should develop the epidemiological approach of environmental and health monitoring in workplaces as an integral part of the total health programme.

6. Governments, institutions, and other interested bodies should carry out evaluative studies of monitoring systems in occupational health, including, where possible, cost/benefit assessments.

7. At an early stage in promoting monitoring, methods should be developed to standardize the information to be collected by occupational health personnel so that the information derived from different sources is comparable.

8. WHO should assist Member States, particularly the developing countries, in preparing national inventories of conditions of occupational health, which will be used in the planning and implementation of appropriate occupational health programmes and provide a baseline against which the effectiveness of further monitoring can be measured.

9. In order to fill existing gaps in knowledge relative to occupational health monitoring, WHO, in collaboration with governments and interested institutions, should stimulate and coordinate research efforts in such areas as :

(*a*) the development of monitoring procedures and methods for measuring exposure to multiple noxious agents and work situations and for evaluating the resulting combined effects,

(*b*) the formulation of criteria to determine different degrees of early health impairment,

(*c*) the evaluation of the beneficial health effects of various working conditions, and

(*d*) the development of methods of detecting and evaluating individual susceptibility and adaptive capacity to specific work stresses.

10. WHO should collect and evaluate methods for the early detection of health impairment in the gainfully employed and for the assessment of physical, chemical, biological, and psychosocial stress factors at the workplace, with a view to the international standardization of monitoring procedures.

Annex

INFORMATION TO BE OBTAINED FROM SURVEYS AND MEDICAL EXAMINATIONS

Example 1. Type of information obtained from preliminary surveys

This example lists the type of information that is particularly applicable to monitoring at the national or regional level. It may be supplemented by data obtained during more detailed surveys.

PLACE OF WORK

Name and address

OFFICIAL CONTACT

Name and title

DATE AND TIME OF SURVEY

EMPLOYEES

Demographic data, e.g., number, sex, age, employment status, arrangement of working hours

PROCESSES

Description, including raw materials and intermediate and end products

POTENTIAL HEALTH RISKS

List by process, including population exposed and information on any prior measurements of risks ; e.g. :

chemical agents such as toxic aerosols and liquids

physical agents such as excessive temperature, noise, radiations, inadequate illumination

biological agents such as infected materials handled

ergonomic and psychosocial factors such as machine design, methods of payment, joint consultation, lines of communication

Other risks requiring specific evaluation (indicate and attach relevant forms)

CONTROL MEASURES AVAILABLE

Indicate, with assessment of condition and efficiency, e.g., total enclosures, ventilation, machine guards, personal protective devices

SANITARY FACILITIES

Drinking water, washing facilities, locker rooms, toilets, eating and recreation areas, methods of disposal of wastes, including solids, liquids and aerosols

HEALTH AND SAFETY PERSONNEL

Description, numbers employed (full and part time)

Health personnel—e.g., physicians, hygienists, nurses, assistants, first aid attendants

Safety personnel—e.g., safety supervisors, safety engineers

HEALTH AND SAFETY FACILITIES

Health facilities—e.g., hospitals, health departments, dispensaries, first aid stations, first aid kits, ambulances, records

Safety facilities—e.g., safety equipment (general and personal), records

HEALTH AND SAFETY PROGRAMMES

Health programmes—e.g., pre-employment, periodic and special medical examinations; routine and special environmental and monitoring programmes; counselling and education; frequency of visits by health personnel to workplace; supervision of sanitary facilities; types of reports made

Safety programmes—e.g., counselling and education; inspections (routine and special) other than accident investigation; accident investigations; emergency procedures; types of reports made

CONCLUSIONS

General findings, recommendations, follow-up

Example 2. Type of information obtained from medical surveys

This example gives the type of information obtained during the medical monitoring of individual workers. Where specific hazards are known to exist, the information should be supplemented by a special diagnostic test of the kind illustrated in Example 3 of this Annex.

PERSONAL DATA

Name, identification number, sex, date of birth, address, workplace (plant and department)

SOCIAL HISTORY

Education, marital status, family size, living conditions

OCCUPATIONAL HISTORY

Present occupation—duration, hours of work, shifts, degree of responsibility, potential hazards and unusual job demands (as stated by the worker), his/her opinion of job

Previous occupations—date of first employment, types of employment, potential risks and duration of each job

FAMILY MEDICAL HISTORY

Relevant diseases, e.g., infections, tuberculosis, mental illness, and cardiovascular diseases

PAST MEDICAL HISTORY

Previous illnesses and operations, including any ill health or disability related to employment

PRESENT MEDICAL HISTORY

Present complaints or symptoms including endemic diseases

Personal habits—smoking, alcohol, and drugs

CLINICAL EXAMINATION AND ASSESSMENT OF CAPACITIES

Weight, height and other anthropometric data

Examination of organ systems for defects and for assessment of capacities, e.g.:

- vision—acuity and visual fields
- hearing—audiometry
- cardiovascular system—blood pressure, exercise test, and electrocardiography
- blood—haemoglobin cell counts and platelets, lipids, monitoring tests for toxic agents in blood
- respiratory system—chest X-ray, lung function tests, monitoring tests for toxic agents in exhaled air

renal and urinary tract—urinalysis, cystoscopy, monitoring tests for toxic agents in urine
skin—allergy tests
psychological assessment

CONCLUSIONS

Recommendations concerning work capacity and restrictions regarding exposure to hazardous agents or other work situations
Follow-up

Example 3. Type of information obtained from monitoring a specific hazard

Since the work conditions and specific hazards vary greatly from one establishment to another, it is not possible to use a single environmental survey form in all cases. The items of information listed in this example illustrate two specific hazards : (*a*) noise and (*b*) carbon disulfide.

(*a*) NOISE

Environmental survey

PLACE OF WORK

Name and address

DATE AND TIME OF SURVEY

EMPLOYEES

Demographic data, e.g., number, sex, age, employment status, arrangement of working hours

PROCESS

Description and layout

SOURCES AND TYPE OF NOISE

By department and specific workplaces
Mechanical characteristics : energy distribution by frequency
Pattern of noise : continuous, intermittent (duration, intervals), impact

MEASUREMENT OF NOISE

Position of noise source relative to the worker
Position of instrument for each measurement
Overall noise level (A, B, or C scales on noise meter)
Octave band analysis
Other noise analyses in special instances
Type of instrument used and calibration

EXISTING NOISE CONTROL MEASURES AND PERSONAL PROTECTIVE EQUIPMENT

CONCLUSIONS

Statement of magnitude of noise problem

Medical survey

PERSONAL DATA

Name, identification number, sex, date of birth, address, workplace (plant and department)

SOCIAL AND OCCUPATIONAL HISTORIES

Details of hobbies such as music, shooting, home workshop, driving
Previous exposures to noise at other workplaces

FAMILY MEDICAL HISTORY

Deafness in family

PAST MEDICAL HISTORY

Past complaints and conditions, e.g., ear, nose, and throat operations ; use of drugs such as salicylates and streptomycin and other antibiotics

PRESENT MEDICAL HISTORY

Effects of common cold on hearing ; difficulty with breathing from nose ; pain in ears ; tinnitus ; discharge ; complaints of impaired hearing and duration of impairment

CLINICAL EXAMINATION

Nose, sinuses, pharynx, ears (including discharge and wax plug or other masses), condition of external meatus and drum, discharge from middle ear

AUDIOMETRIC EXAMINATION

Time since last noise exposure
Hearing in decibels at specific frequencies
Audiometer calibration record

CONCLUSIONS

General findings from medical examination

JOINT APPRAISAL

Comparison of environmental and medical data, and overall conclusions regarding noise hazard

RECOMMENDATIONS

Additional environmental controls required
Use of personal protective equipment

FOLLOW-UP

(*b*) CARBON DISULFIDE

Environmental survey

PLACE OF WORK

Name and address

DATE AND TIME OF SURVEY

EMPLOYEES

Demographic data, e.g., number, sex, age, employment status, arrangement of working hours

PROCESS

Description and layout

SOURCES OF EXPOSURE TO CARBON DISULFIDE AND HYDROGEN SULFIDE

By department and specific workplaces
Patterns of release (continuous, intermittent, etc.)

MEASUREMENT OF EXPOSURES

Type and location of sample, description of sampling instrument
Duration of sample collection, volume of air sampled
Analytical methods (and possible sources of error)
Concentration
Calculation of time-weighted average concentration (show method of calculating)

DESCRIPTION OF EXHAUST VENTILATION SYSTEMS AND OTHER ENVIRONMENTAL CONTROL MEASURES

CONCLUSIONS

Summary statement of magnitude of exposures to carbon disulfide

Medical survey

PERSONAL DATA

Name, identification number, sex, date of birth, address, workplace (plant and department)

SOCIAL AND OCCUPATIONAL HISTORIES

Details on previous exposures to toxic chemicals at other workplaces

FAMILY AND PAST MEDICAL HISTORY

Central and peripheral nervous diseases, mental illness, and cardiovascular diseases in family and in worker

PRESENT MEDICAL HISTORY

Present complaints or symptoms including endemic diseases
Personal habits—smoking, alcohol, and drugs

CLINICAL EXAMINATION

As in Example 2, with special emphasis on cardiovascular and central and peripheral nervous systems and psychological assessment

SPECIAL TESTS FOR CARBON DISULFIDE INTOXICATION

Serum lipid levels, renal function excretion tests, urine analysis for 17-ketosteroids, and iodine-azide test

CONCLUSIONS

General findings from medical examination

JOINT APPRAISAL

Comparison of environmental and medical data, and overall conclusions regarding health hazard from carbon disulfide

RECOMMENDATIONS

Additional environmental controls required
Use of personal protective equipment

FOLLOW-UP