

SURVEILLANCE IN OCCUPATIONAL HEALTH

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A definition of surveillance is as follows: “surveillance (ser-vâ'lens) noun. 1. Close observation of a person or group, especially one under suspicion. 2. The act of observing or the condition of being observed” (*The American Heritage Dictionary of the English Language*, 3rd edition, Houghton Mifflin Company, 1992).

The term “surveillance” is derived from the French word meaning “to watch over”. In public health, surveillance was originally developed as part of efforts to control infectious diseases, but the principles of surveillance can potentially be applied to other problems such as chronic diseases (for example, cancer and coronary heart disease), social problems (for example, drug addiction), and the threat of bioterrorism.¹

Surveillance is a core activity in the practice of occupational health. Two broad groups of surveillance are commonly performed—hazard surveillance and health surveillance. While the focus of the former is hazards at the workplace, the latter type of surveillance pertains to the health of a person or group of workers. Both have important roles in occupational health practice and are complementary.

The focus of this paper will be on chemical and biological exposures and related diseases. In many countries, occupational health concerns include psychosocial and ergonomic issues in the work environment and related problems and adverse health outcomes. These issues will not be addressed in detail in this paper, but surveillance programmes for such concerns have been developed, for instance, in Nordic countries.

HAZARD SURVEILLANCE

Hazard surveillance has been defined as “the process of assessing the distribution of, and the secular trends in, use and exposure levels of hazards responsible for disease and injury”.² For this type of surveillance to be considered, a clear “exposure–health outcome” relation must already have been established. The surveillance of hazards should result in action to reduce exposure in workplaces where indicated. This will eventually reduce the disease burden arising from hazardous exposures.

Hazard surveillance can be incorporated into part of an existing national or regional system used for other purposes, for example, registries of usage of toxic substances or discharges of hazardous materials, or information collected by regulatory agencies to check for compliance. One example of this is the carcinogen registry in Finland.³ Regulatory authorities in many other countries have registries of factories or work processes.⁴ Another approach is to have exposure surveys or inspections. In some countries such as the USA, periodic national occupational exposure surveys are conducted.¹ This is often based on a representative sample of defined workplaces or processes.

Another method of hazard surveillance is the recording of hazardous occurrences in specific occupational groups, such as needlestick or sharps injuries among health care workers.⁵ At the individual workplace, computer software packages containing exposure databases, can be used to assist in hazard surveillance.

There are several advantages and benefits of hazard surveillance. Firstly, the surveillance of hazards eliminates the need to wait for disease to occur before taking steps for prevention. This is a considerable advantage, as many occupational illnesses take time to develop.

Secondly, the activity of identifying single hazards is generally easier than the detection of disease. Diseases, which have long latent periods, may also have multifactorial aetiologies—thus diagnosis can be complex. The focus on hazards ensures a direct attention to preventable causes of the disease.

However, while monitoring of individual hazards is easier to implement, integrated exposure databases and surveillance systems for combined exposures potentially offer a greater promise for improving health and safety at work.⁶ As not every exposure results in disease, hazardous situations would be expected to have a higher frequency of occurrence. This allows an opportunity to monitor trends or observe emerging patterns in exposure to workplace hazards. The information can be used to predict or project future disease burdens where prevention is not adequate.

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Confidentiality of health information may pose a threat to public health surveillance.⁷ But unlike health surveillance, in hazard surveillance confidentiality of records that infringe on individual privacy is not an issue. However, there could be a practical difficulty with hazard surveillance in dealing with confidentiality of trade secrets and propriety information on the amount and composition of chemicals used in different industrial processes.

HEALTH SURVEILLANCE

Health surveillance can either take the form of periodic clinical and/or physiological assessment of individual workers, or the public health review of the health status of groups of workers. For the individual, the rationale is to detect adverse health effects resulting from occupational exposures at as early a stage as possible, so that appropriate preventive measures can be instituted promptly. This is a form of secondary prevention. The findings from health surveillance can be used to indicate the absence of a significant hazard, the adequacy of control measures, individuals at increased risk, baseline medical data, benchmarks for preventive action, and opportunities to provide health education. Another function is to quantify the incidence and prevalence of occupational and work related disease.

The criteria for health surveillance are:

- (1) If it is not possible in practice to further reduce exposure to a known hazard—for example, in situations where the presence of the hazard is essential or inherent to the work process, and no other feasible alternatives are available. There may be an ethical dilemma involved in considering what constitutes an essential part of an industrial process versus the extent of acceptable risk to those who have to be exposed in the course of their work.
- (2) If the relation between the extent of exposure required to produce a health effect is not well defined, as in exposure to sensitizers and carcinogens. For sensitizers, a level of exposure may be required to sensitize an individual, but the triggering dose necessary to elicit an effect in those already sensitized may be very small and much lower than the sensitizing dose. For carcinogens, it is uncertain what long term effects may ensue at the cellular level from exposure to small amounts of a known carcinogen. The body's defence mechanisms may be able to eliminate cellular effects from exposure to low doses of carcinogens, but the dose which results in a change that initiates the carcinogenic process irreversibly is often not well determined.

Defined groups of persons with specific short term exposures have been placed under long term health surveillance for possible health effects. In some instances, the long term health effects of the specific hazard are unclear. A current example is the health surveillance of soldiers who were exposed for a short period to depleted uranium during their combat operations.⁸

In practice, there may be legislation requiring health surveillance, or there may be pressure to initiate health surveillance because of concerns related to unique circumstances of exposure, case reports of clusters of disease, or media and political attention.

Confidentiality of health surveillance data is an important issue. The person who administers the surveillance programme has responsibilities to the employee, the employer, and national statutory bodies, and this often gives rise to conflicts of interest. Guidelines on how such conflicts may be overcome for the information to be used effectively can be obtained from ethical codes, such as those produced by the

American College of Occupational and Environmental Medicine, or the Faculty of Occupational Medicine in the UK.

Clinical and physiological assessments

Periodic clinical and physiological assessment of specified groups of individual workers may be performed to detect early effects of exposure to occupational hazards. The screening procedures could include symptom review, clinical assessment, medical examination, special investigations, and determination of immune status.⁹ The principle is for exposed workers with early subclinical changes to be removed from further exposure so as to reverse the early changes. The surveillance programme should be based on good evidence that the changes are indeed reversible. Periodic chest *x* ray examinations to detect pulmonary effects from exposure to asbestos and other fibrogenic dusts may identify the presence of fibrosis, but the prospects for reversing the changes even on cessation of further exposure are poor. As such, there is doubt as to whether periodic *x* ray examinations have any material benefit for such workers.¹⁰ It is essential that where health effects are detected during such surveillance, the workplace exposures should be reassessed, and control measures further improved.

Symptom review involves enquiry of the experience of relevant symptoms from exposure to specific occupational hazards. Clinical assessment is performed to decide whether these symptoms are likely to be due to workplace factors. This process takes into account the nature (for example, physical, chemical, mechanical, biological, psychosocial) and extent of workplace exposure and other concurrent exposures at work and home, and involves consideration of the differential diagnoses. For example, a case of peripheral neuropathy in a middle aged worker could result from occupational exposure to *n*-hexane, and/or diabetes mellitus. A practical alternative to regular symptom enquiry is to provide a list of relevant symptoms and/or signs to exposed workers, and instruct them to report experience of these health effects for further clinical evaluation. For example, workers exposed to workplace asthmagens can be given a symptom list that includes chest tightness, wheeze, breathlessness, and nocturnal cough. The process can be extended to self examination, as in the case of electroplaters exposed to chromic acid examining their hands for the presence of "chrome ulcers".

Pre-employment examinations are sometimes advocated as a means of providing baseline information for occupational health surveillance. In many countries, new employees undergo pre-employment medical examinations as a matter of convention. In practice, the main focus of such examinations appears to be not necessarily as a pre-placement procedure, but often for assessing the current state of general health, or for medical insurance purposes. In addition, there may be national regulations that stipulate pre- and periodic medical examination for specific occupational groups.

Statutory health surveillance

Statutory periodic medical examinations, for workers exposed to prescribed hazards, is another form of surveillance that is practiced in many countries. The requirements vary between countries. For example, in the United States, OSHA (Occupational Health and Safety Administration) standards require employers to provide employees with access to medical screening examinations when they are exposed to substances such as those listed below in table 1. There is also a requirement that records should be maintained for the duration of employment plus 30 years, and access of the employee

Table 1 Agents for which occupational exposure requires medical surveillance (OSHA standards)

2-acetylaminofluorene	Ethylene oxide
Acrylonitrile	Ethyleneimine
4-aminodiphenyl	Formaldehyde
Inorganic arsenic	Hazardous waste
Asbestos	Lead
Benzene	Methyl chloromethyl
Benzidine	Ether
Bis-chloromethyl ether	Alpha-naphthylamine
Coal tar pitch volatiles	Beta-naphthylamine
Coke oven emissions	4-nitrobiphenyl
Cotton dust	N-nitrosodimethylamine
Dibromochloropropane	Noise
3,3'-dichlorobenzidine	Beta-propiolactone
4-dimethylaminobenzene	

Source: Baker and Matte.¹¹

to his or her personal records should be granted on request.¹¹ Availability of records for epidemiological studies is often given as a reason for retaining records for a period after cessation of occupational exposure. This requirement also applies to occupational health surveillance records in the UK. In practice, it is difficult to be certain of the quality and completeness of these records, and hence their use for epidemiological studies may be limited.

In the UK, statutory medical examinations can only be performed by "appointed doctors". These are physicians appointed under specific regulations, by the government department responsible for occupational health and safety (the Health and Safety Executive). In countries such as Singapore, there are similar provisions for statutory medical examinations to be only undertaken by designated physicians with recognised further training in occupational health. Specific clinical/physiological tests are prescribed for workers exposed to each of the hazards (table 2). The results have to be kept for five years from the date of the examination.

There is a continuing need for periodic audit and review of required procedures so that the process continues to produce benefits for those under surveillance, and that new research

findings are taken on board. Thus, surveillance procedures such as the items listed in table 2 should be subject to periodic critical review.

There is recent published evidence supporting medical surveillance of workers exposed to diisocyanates. Surveillance and intervention resulted in reduction of incidence, symptom duration, and hospital admissions for occupational asthma in this exposed group.¹² There are also recent publications on the surveillance of workers exposed to other occupational hazards, for example, vibration¹³ and pesticides.¹⁴ The European Parliament has just published its minimum health and safety requirements for workers exposed to hand-arm and whole body vibration and included in its directive provisions for health surveillance.¹⁵ Whether required by law or recommended as guidelines, the continuation of some of the prescribed surveillance procedures should be justified and supported by published evidence for their efficacy and absence of harmful side effects. In the UK, the use of periodic x ray examinations for occupational health surveillance was subject to critical review. The consensus view was that chest x ray examinations should be removed from statutory requirements for such surveillance, and only be performed where there was a clear clinical indication.¹⁰

Biological monitoring and biological effect monitoring

Biological monitoring is sometimes included as a screening procedure under occupational health surveillance. However, the purpose of biological monitoring is to detect the presence of a toxicant or metabolite in a biological sample (an indicator of exposure) rather than detect an early health effect. Hence, according to our definitions, it fits in more with hazard surveillance instead of health surveillance.

The term "biological effect monitoring" is used to refer to some early indicator of a health effect, for example, a detectable change in a biochemical parameter. Unlike "biological monitoring" which indicates the extent of exposure, "biological effect monitoring" shows an early effect, and hence rightly belongs under health surveillance. For example, the use of blood lead (Pb) levels for biological monitoring serves to determine the extent of exposure to lead in an exposed person. Biological effect monitoring, for example, measuring

Table 2 List of prescribed hazards and specific medical tests required for workers exposed to these hazards (Singapore)

Prescribed hazard	Medical test(s) required
Arsenic and compounds	Pre-employment and annual early morning urine arsenic level, pre-employment liver function test, and chest x ray examination
Asbestos	Full size chest x ray examination (pre-employment and once in 36 months)
Benzene	Pre-employment and annual haemoglobin, full blood count, peripheral blood film, and mid-week end of shift urine phenol
Cadmium and its compounds	Pre-employment and annual blood cadmium, urine β_2 microglobulin
Compressed air (frequency depends on working pressure)	Pre-employment and annual audiometry, lung function test, x ray examination of shoulder, hip and knee joints, electrocardiogram (for those >35 years), pre-employment chest x ray examination
Cotton	Pre-employment and annual lung function tests: FEV ₁ and FVC
Lead (inorganic) and its compounds	Pre-employment and six monthly blood lead and haemoglobin levels
Manganese and its compounds	Pre-employment and annual early morning urine manganese
Mercury and its compounds	Pre-employment and annual early morning urine mercury
Noise	Pre-employment and annual audiometry
Organophosphates	Pre-employment and six monthly red blood cell acetylcholinesterase
Perchloroethylene	Pre-employment and annual mid-week end of shift urine trichloroacetic acid, pre-employment liver function tests
Free silica	Full size chest x ray examination (pre-employment and once in 36 months)
Trichloroethylene	Pre-employment and annual mid-week end of shift urine trichloroacetic acid, pre-employment liver function tests
Vinyl chloride monomer	Pre-employment and annual liver function tests

Source: *Guidelines for designated factory doctors*, 3rd edn. The Factories (Medical Examinations) Regulations, Singapore, 1997.

Table 3 Examples of molecular biomarkers measured in occupational health

Molecular biomarkers	Application	Study population
Exposure marker PAH-DNA adduct	Workplace and community exposures and exposure to cigarette smoke, and risk of lung cancer	Foundry workers Coke oven workers General community in industrial areas
Early effect markers <i>p53</i> tumour suppressor gene or its protein product	Specific fingerprint mutation in certain gene codon and risk of liver, breast, lung, and oesophageal cancer	Radon exposed miners, vinyl chloride monomer workers General population with environmental exposure to aflatoxin B1
H-ras and K-ras gene or its protein product	Increased risk of various cancers, e.g. lung, liver, and bladder	Firefighters, hazardous waste workers, foundry workers, vinyl chloride monomer workers
Host susceptibility markers CYP1A1 polymorphism NAT2 polymorphism	Increased risk of lung cancer with exposure to benzo[a]pyrene Increased risk of bladder cancer	Foundry workers Workers exposed to arylamine and hydrazine

free erythrocyte protoporphyrin (FEP), and urinary delta amino laevulinic acid (δ -ALA) detects an early effect. These measure the direct effect of lead on haem synthesis. Other examples of biological effect monitoring are the measurement of serum cholinesterase levels in workers exposed to organophosphate pesticides, and the detection of specific low molecular weight urinary proteins among cadmium exposed workers.

Molecular biomarkers as indicators of susceptibility

Technological advances in molecular biology over the past two decades have produced sophisticated techniques for the study of the role of specific exogenous agents and host factors in causing ill health. These advances have resulted in the development of newer molecular biomarkers for exposure, response, and genetic susceptibility. They include measurements for structural gene damage, gene variation, and gene products in cells and body fluids, for example, oncogenes and tumour suppressor genes, DNA adducts, gene products and genetic polymorphisms, and metabolic phenotypes in exposed populations.

Several studies have shown an association between environmental exposures and various molecular biomarkers (table 3). There are limitations in using individual molecular biomarkers for assessing health risk.¹⁶ The use of genetic tests to identify susceptible workers raises issues of ethics, individual privacy, right to work, and the relevance of such tests. For example, the availability of a method for detecting a human leucocyte antigen (HLA) gene that is associated with an increased risk of chronic beryllium disease, has led to interest in using this marker for pre-employment screening. The occupational groups for which such screening is proposed are those required to handle beryllium based materials in their work. However, the low positive predictive value of the test indicated a considerable limitation for advocating its use in pre-employment screening.¹⁷ Most diseases of occupational and environmental origin are multifactorial in aetiology. A combined approach that examines several factors simultaneously, can improve the understanding of disease mechanisms, and clarify the role of identifying molecular biomarkers in occupational risk assessment.

Steps in setting up a specific occupational health surveillance programme

Baker and Matte¹¹ proposed steps in designing and implementing an individual health surveillance programme in the workplace. A summary is shown in the box.

- ▶ Steps 1, 2, and 3: These refer to exposure assessments and risk assessments for target organ damage. "Screenable" health effects are those that can be detected during the pre-clinical phase and where intervention at this stage is more beneficial than during later stages of the disease.
- ▶ Step 4: The development of action criteria in response to medial test results is important. Guidelines by consensus groups, such as the Biological Exposure Index (BEI) of the ACGIH, and OSHA standards are available for selected indicators. Unfortunately, such guidelines are limited and may be inconsistent. Criteria to be applied for each test should be appropriate in the local context.
- ▶ Steps 5 and 6: Standardisation of test procedures and quality control, provision of information to employees about the tests, and confidentiality of results should be ensured.
- ▶ Steps 7 and 8: Interpretation of the test results should be based on several factors, including the predetermined action level criteria, and exposure data for the individual (including possible non-occupational exposures). Abnormal results should be reconfirmed.
- ▶ Steps 9, 10, and 11: Removal of the employee from further exposure may be necessary, and there may be legal provisions to safeguard wages and benefits in the event of job transfer due to such a reason. Employees themselves should be notified of the results, in addition to statutory notifications (where applicable). As screening tests may not provide a definitive diagnosis, further medical evaluations may be indicated, including referral to the appropriate specialist.
- ▶ Steps 12 and 13: The work environment of the employee with an abnormal screening result has to be re-evaluated. If

Steps in designing and implementing an occupational health surveillance programme

1. Assessment of workplace hazards
2. Identification of target organ toxicities for each hazard
3. Selection of test for each "screenable" health effect
4. Development of action criteria
5. Standardisation of data collection process
6. Performance of testing
7. Interpretation of test results
8. Test confirmation
9. Determination of work status
10. Notification
11. Diagnostic evaluation
12. Evaluation and control of exposure
13. Record keeping

(from Baker and Matte¹¹)

necessary, measures should be implemented to reduce the exposure to safe levels. In addition to medical recordkeeping, records of notifications, as well as exposure evaluations and resulting environmental modifications, should be kept. In addition, consideration should also be given to:

- (a) The requirements, procedures, and interpretation of findings for health surveillance as specified by national legislation.
- (b) Responsibility for continuation of health surveillance after cessation of exposure, especially for conditions with long latency.
- (c) Determination of whether additional or special surveillance should be started after specific events, for example, following a chemical incident or a natural disaster.¹⁸

PUBLIC HEALTH SURVEILLANCE

In the context of occupational health, public health surveillance is a set of activities that is usually undertaken by government departments within their respective jurisdictions to monitor and to follow up occupational diseases and injuries. There are several reasons for this type of surveillance. Information on incidence and prevalence of occupational disease and injury provides a sound basis for prevention and control. The data allows for the analysis of trends, in order to determine research and control priorities and strategies, and to evaluate the effectiveness of interventions. Public health surveillance can also lead to discovery of new associations between occupational agents and accompanying disease.

Notification of occupational diseases as an outcome of health surveillance

Most countries require the statutory notification of occupational diseases and publish a list of notifiable occupational diseases. Notification may be required following the confirmation of definite disease, or in some countries, on the basis of suspicion of occupational disease. In the latter, the process of notification can result in the confirmation of individual cases of occupational disease and/or the identification of additional cases. Identification of confirmed index cases should lead to active case finding in the same workplace among workers with similar exposures. The onus for notification usually rests with a medical practitioner or with the employer. Mandatory notification from laboratories is required in a number of countries,¹⁹ but there is substantial variation in reporting requirements by country, and even in territories and states within countries.

The sentinel health approach²⁰

Rutstein and colleagues²¹ introduced the concept of sentinel health event as “a case of unnecessary disease, unnecessary disability, or untimely death whose occurrence is a warning signal that the quality of preventive or medical care may need to be improved”. This concept was extended to occupational health surveillance, and the term sentinel health event (occupational) was introduced to refer to “an unnecessary disease, disability, or untimely death which is occupationally related and whose occurrence may:

- (a) provide the impetus for epidemiologic or industrial hygiene studies, or
- (b) serve as a warning signal that materials substitution, engineering control, personal protection, or medical care may be required”.²²

Besides the notification of occupational illness, public health surveillance can take the form of national or industry based surveys. An example of a governmental survey is the annual

Bureau of Labor Statistics (BLS) Survey of occupational injuries and illnesses (BLS annual survey).²³ These surveys have been conducted by the US Department of Labor since 1972. Other data sets that can be examined for public health surveillance are:

- ▶ Mortality from diseases that have a strong link to occupational/environmental exposures, for example, mesothelioma and asbestos exposure.
- ▶ Occupational injuries among hospital based admissions²⁴ and discharges.
- ▶ Workmen’s compensation data.¹¹ These data tend to underestimate the true number of cases, as cases of long latency may be excluded, especially if illnesses develop after exceeding the “time to claim” legal requirements. However, the data are usually obtained from cases that have been investigated fully, and would tend to be those of confirmed occupational aetiology, with adequate information on occupation of the claimant and circumstances leading to the development of the disease.

CONCLUSION

The prime purpose of surveillance in occupational health is prevention. Surveillance in occupational health practice covers both the periodic assessment of workplaces for evaluating hazards, and the periodic examination of individuals to detect early reversible ill health. Surveillance data can inform of trends or emerging patterns in workplace hazards and illnesses. To be effective, surveillance has to be followed by preventive action and evaluation of the effectiveness of intervention.

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QUESTIONS (see answers on p 633)

(1) Which of the following statements regarding hazard surveillance are true?

- (a) Procedures for hazard surveillance are aimed at detecting early reversible health effects.
- (b) A limitation of implementing hazard surveillance in some countries is the requirement for maintaining confidentiality of individual medical records.

(c) A purpose of hazard surveillance is to evaluate the extent of exposure to workplace hazards.

(d) Documentation of needlestick injuries in hospital staff is an example of hazard surveillance.

(e) Registries with information on use and exposure to carcinogens can form part of a hazard surveillance scheme.

(2) Which of the following statements regarding occupational health surveillance are true?

(a) Periodic review of symptoms is a relevant procedure for health surveillance.

(b) Periodic chest x ray examinations are an essential part of health surveillance of workers exposed to asbestos because of the potential for reversibility of fibrogenic effects if detected early by use of radiology.

(c) Health surveillance should be performed where residual exposure indicates a potential risk to health.

(d) Exposure to sensitizers and carcinogens are two examples where health surveillance should be considered.

(e) In some countries, there is legal provision for health surveillance for defined occupational exposures to be performed only by designated physicians.

(3) Which of the following statements regarding biological effect monitoring (BEM) are true?

(a) BEM assesses the proportion of workers with a specific genetic effect at a defined level of exposure to a hazard.

(b) BEM uses analysis of a biological sample to determine the amount of a specific metabolite of a compound to which a worker is exposed.

(c) Measuring the level of urinary delta amino-laevulinic acid in workers exposed to inorganic lead is an example of BEM.

(d) Determination of serum cholinesterase levels in workers exposed to organochlorine pesticides is an example of BEM.

(e) Periodic lung function tests are an important component of a BEM programme for workers exposed to asthma causing agents.

(4) Which of the following statements are true?

(a) Pre-employment screening for a human leucocyte antigen (HLA) gene associated with an increased risk of berylliosis is advocated because of its high positive predictive value.

(b) Peripheral neuropathy can result from occupational exposure to n-hexane.

(c) Workers exposed to asthmagens should be asked about their experience of breathlessness, nocturnal cough, wheeze, and chest tightness.

(d) The availability of medical surveillance may contribute to a reduction in the severity of cases and number of compensation claims for occupational asthma from exposure to isocyanates.

(e) A sentinel health event (occupational) includes the occurrence of a major chemical incident that exposes the community to a mixture of unknown chemicals.