

HAZARDS MANAGEMENT, MONITORING OF THE WORK ENVIRONMENT AND THE IMPLEMENTATION OF STANDARDS

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Summary

Occupational Hygiene or Industrial Hygiene, as it is often known, is the science of recognizing, evaluating and controlling the risks in the workplace with the aim of preventing ill-health at work. Throughout this chapter the primary focus is on the management and measurement of chemical substances but it should be borne in mind that the range of occupational hazards extends beyond chemicals and includes biological agents (bacteria, viruses, fungi, endotoxin and other microbiological matter) and physical agents (noise, light, vibration, ionizing and non-ionizing radiation). Where chemicals or substances are referred to, the text should be able to be extended to the wider situation where the exposure is to a biological or physical agent.

1. Hazard and Risk

The terms hazard and risk are often used interchangeably to describe danger in the workplace but the whole basis of occupational hygiene revolves around the ability to identify what is hazardous, quantify the degree of risk and then manage the risk appropriately. Hazard therefore should be understood as the potential of an agent to cause harm to health while risk is the likelihood or possibility of that harm occurring. Exposure to a material is the activity that links hazard and risk. If a person does not come in to contact with hazardous material then it poses no risk.

The ability of a substance to harm will vary from a minor irritation through to major injury or death and so there is a need to consider the type of harm when characterizing the hazard. The harmful effects may be acute (causing an immediate reaction, such as coughing or burns) or chronic (causing longer-lasting and often delayed effects such as asthma or cancer). The harm caused can also be considered in terms of reversibility. Cancer or genotoxic effects may be irreversible while respiratory tract irritation may be resolved within a short time following removal from the exposure.

While the media often confuse the two terms and use 'hazard' when they mean 'risk' it is useful to look at the following examples to ensure that the difference is understood. Firstly, consider the worker who handles a large drum of chemical 'X' that can cause burns to the skin. In this case the hazard is the chemical X that can cause harm in the form of acute, severe burns to the skin and so it may be considered to be highly hazardous. The risk is the likelihood of the harm occurring and will depend on how the worker handles the drum. If the drum is sealed and the filling process is well controlled with no contamination on the exterior of the drum then it is likely to be a low risk activity. Where the drum is open and full, and requiring transport by hand over a considerable distance then the risk may be categorized as high. A second example might be the testing of large engine components at high speed in an enclosed chamber. One of the hazards may be the high levels of noise that are generated causing noise-induced hearing loss if the worker is subjected to these levels repeatedly. The risk is the likelihood of deafness occurring and in this case the risk may be categorized as low due to the enclosure of the task and the use of sound barriers to prevent the exposure of the worker.

As can be seen from these examples, a risk assessment is required to take account of the nature of the hazard and the type of harm the hazard can cause, combined with the likelihood of a harmful exposure taking place. It thus involves a process of hazard identification, exposure assessment and a method to compare the assessed exposure with health-based limit values that enable quantification of the potential for the material to harm health. The exposure assessment process needs to consider not only typical, day to day tasks but also more exceptional exposure situations such as maintenance and accidents and may also need to extend beyond the direct workforce to the wider public and those visiting or living near to the worksite.

2. Hazard Identification

Identifying hazards in the workplace is the first key step in protecting workers' health. Without knowing which substances are used or produced it is impossible to undertake a program of assessing the exposure of workers to these agents, assessing the risks to health and then implementing control measures to prevent harm occurring.

Understanding the processes within a workplace such as a factory is essential in locating where chemicals or other hazards may be used. Data from those involved in purchasing raw materials is often particularly useful, as may be information from those involved with the final products that are sold or transferred out from the factory. Chemicals or hazardous substances that are produced or are the by-products of production should also be considered and these may be identified through conversations with managers or site foremen.

While much information can often be gathered prior to any visit to a site through telephone and email exchange, there is nothing to beat a hands-on, walk-through survey to identify the hazards that need to be considered. Historic materials that are no longer used but are leaking from a store room or changes to raw materials that the foreman or manager were unaware of often only become apparent during a visit to the shop-floor or in discussions with the workers involved in the process of interest.

The next step in hazard identification should involve compiling a list of chemicals (and by-products) found in the workplace. This is often helped by the existence of a Safety Data Sheet (SDS). These are required under legislation in most countries and as part of the Globally Harmonized System (GHS) for the classification, labeling and packaging of substances and mixtures (see *Occupational Safety*). The SDS will provide a range of information relating to the hazard potential of the material and how best to use it in a safe manner in order to reduce the risk to health. If the SDS is not available then the container or package should provide the contact details of the supplier who is obliged to provide a copy of the SDS.

By-products including any dust, vapor, mist or process fume, and catalyst materials can be more difficult to identify and may require the help of a process or chemical engineer. Similarly, physical and biological agents may not be immediately obvious without observing the workers perform their tasks and enquiring about maintenance or other less regular activity. Physical agents including noise and vibration, heat and cold, lighting and exposure to direct sunlight should all be included in the list of hazards. Biological agents may be used in the production of some materials or may be inadvertently generated particularly where cooling systems or water tanks are used. Once again, discussion with shop floor workers and union representatives about which materials they use, how they use them and what they perceive to be the hazards can be invaluable in terms of identifying hazards. A final step to consider in the hazard identification process may be a review of human resource data. High staff turnover within a particular section may indicate an especially unpleasant or harmful part of the factory in which to work.

3. Exposure and Exposure Routes

Exposure can be defined simply as contact between a person and a material within a given environment. As explained in the first part of this chapter, exposure is the link between hazard and risk. When there is no contact or exposure between the hazardous substance and the individual, there is no risk. The process of understanding and quantifying exposure is central to occupational hygiene and forms much of the basis of risk assessment and identifying the need for control. Exposure assessment can be simple in terms of identifying workers as 'exposed' or 'unexposed' or can be more complex, involving quantitative measures of a person's exposure in terms of the concentration of a gas or vapor in the air the worker is breathing or by defining how much dust or liquid deposits on the skin. The duration of exposure can also be important and the averaging time of the measurement should be expressed when discussing exposure. Most occupational exposure assessments relate to a work-shift and therefore average the measurement made over an 8-hour period. Some materials which can cause acute or life-threatening health effects may be measured over much shorter time-periods such as 10 or 15 minutes while others have instantaneous levels that should not be exceeded.

The route of exposure also needs to be considered. There are 4 main routes by which a material can interact with or enter the body. These are: inhalation, where the dust, gas, vapor or mist is breathed in to the airways and lungs; dermal or skin exposure where the material is deposited on the skin and is either absorbed through the skin or causes a local effect directly on the skin; ingestion where the workplace hazard is inadvertently taken in to the mouth and swallowed; and injection where a sharp object pierces the skin and introduces the hazard directly in to the body. The relative importance of the different exposure routes will vary depending on the toxicity and target organ of the chemical being used and the task being performed. Inhalation is likely to be the main route of exposure where fine, dusty material or fibers such as asbestos are being used. In these cases the inhaled exposure can lead to respiratory health effects due to the deposition of the material in the lungs. For solvents the inhaled and dermal routes are generally of most importance. Solvents can be absorbed systemically through inhalation in to the lungs but can also be absorbed in to the blood directly through the skin. In situations where respiratory protection or masks are worn to reduce the quantity of solvent inhaled, the exposure on the skin that can take place during washing with solvents or immersion of the hands in tanks of solvent cleaning materials can lead to considerable health effects. Inadvertent ingestion can be an important route in industries where metals are used such as lead acid battery manufacture. Ingestion of pharmaceuticals in production facilities or in patient treatment can also be important, as can the ingestion of pesticides during preparation or spraying activities. Injection is rare in the workplace but is a substantial concern in health-care work where accidental injection of pharmaceutical agents or infectious material can occur.

4. Measuring Exposure

The science of occupational hygiene has led to the development of a range of methods for quantifying exposure in the workplace. Standardized methods for the measurement of a wide variety of inhalation exposures are available. Measurement methods for skin exposure are less well developed but there are now a number of internationally

recognized ways of assessing exposure via the dermal route. Ingestion and injection exposures are rarely quantified and little is often known about how these contacts occur.

Measuring exposure within a workplace involves three main steps. The first step involves identifying what type of sampling is required. It may be necessary to undertake a rapid assessment to identify if a situation is life-threatening and in such cases different methods to those required to assess compliance with an exposure limit are used. The second step involves the collection of the sample or data and the third step involves analysis of the sample or data. The analysis step is commonly performed by a laboratory rather than by an occupational hygienist, but it is useful to know the common methods used to be able to understand the limitations of the result or the advantages and disadvantages of different approaches.

For inhalation exposure the measurement methods can be grouped in to either personal exposure or static (also known as area) exposure monitoring. Personal monitoring is carried out by attaching the sampling equipment to the worker for them to wear whilst carrying out their normal duties and tasks. Generally this involves a small pump attached to the belt and a short length of tubing linking the pump to a sampling head or tube positioned within the breathing zone of the worker. Air is drawn through the sampling head or tube by the pump, at a known rate. The breathing zone is an area within 30 cm of the worker's nose and mouth. In some cases sampling may occur by passive sampling rather than the pumped or active sampling described here. Passive sampling uses the process of diffusion to collect a mass of chemical on to a collection substrate and is commonly performed by attaching a badge- like item within the breathing zone of the worker.

Area or static sampling is similar but involves placement of the measuring device at a fixed location within the workplace. Area sampling is often used to identify the effectiveness or lack of effectiveness of control measures or to identify leaks or emissions from a system. It generally cannot be used to compare to a workplace exposure limit.

Most exposure assessment involves gravimetric methods whereby a physical sample of the substance is collected on a substrate, for example a filter or an activated charcoal tube. By analyzing the mass of the material on the collection substrate and dividing this by the known volume of air sampled (the sampling rate multiplied by the duration of sampling), it is possible to produce an exposure concentration in, for example, milligrams per cubic meter of air (mg/m^3). For gases or vapors the concentration is often expressed as parts per million (ppm) of air and there are simple equations available to allow conversion between a mass concentration of mg/m^3 and a ppm equivalent. Personal gravimetric methods are the gold-standard of exposure assessment and are the sampling methods defined by most regulatory bodies when defining how exposure should be measured for comparison with statutory occupational exposure limits. Samples usually take some time to analyze as they have to be returned to a laboratory for processing and analysis.

Standard methods that describe both how to do the sampling and the analysis of the sample are available from a number of sources. The UK Health and Safety Executive

(HSE) publishes all of their Methods for Determination of Hazardous Substances (MDHS) series on their website while the US National Institute of Occupational Safety and Health (NIOSH) detail all of their methods in the NIOSH Pocket Guide for Chemicals- also available as an online tool.

Direct reading instruments offer faster, though usually less accurate data on exposure. Colorimetric detector tubes are a quick and cheap method of determining concentrations of chemicals at a given moment in time. These substance-specific tubes are used with a small hand-held, bellows-style pump to draw air through the tube a set number of times. A chemical reaction between the contents of the tube and the substance in the air will produce a color change that can be used to provide an indication of the likely exposure concentration range. More advanced direct reading instruments using infra red analyzers or light scattering technology can be employed to gather real-time data on exposure levels and such methods are particularly useful in examining variation in exposure by task over a work-shift.

Dermal and ingestion exposure routes can be quantified by using wiping or patch methods to assess how much of the material is on the skin or around the mouth and perioral area but these methods are much less standardized than the approach to inhaled hazards, and have generally only been applied to research studies to date.

Biological monitoring is an additional approach to assessing exposure that involves the measurement of the substance or its metabolites in a biological fluid such as blood, saliva or urine. Biological monitoring provides a measure of how much of the material has been absorbed in to the body but this integrated method does not allow the identification of the exposure route (inhaled, dermal, ingestion, injection) or even the exposure pathway involved (occupational, diet, environment, non-occupational). Biological monitoring is often used to assess the exposure of workers handling heavy metals such as lead, or those who work with pharmaceuticals or pesticides.

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Biographical Sketch

Dr Semple is Associate Professor at the University of Stirling in Scotland where he carries out research and teaching on the health effects of indoor air pollution, tobacco control, and occupational hygiene. He has over 20 years experience of translational research focused on air quality measurement and interventions relating to second-hand smoke, biomass fuel smoke and workplace inhalation hazards.

Dr Semple is the author of over 150 research publications cited over 3600 times, and one of the editors of the text-book 'Monitoring Health Hazards at Work' (translated in to Chinese, 2012). He has a successful teaching program with supervision of 14 PhD students with a further 3 currently in progress. His recent research program has had a significant impact on public health policy to reduce exposure to second-hand smoke in Scotland. He was the chief Investigator of the BHETSE study which was seminal in examining how Scotland's smoke-free law impacted on air quality and workers' health. This work was adapted for use in England and Wales, used as an international example of how to examine the effects of legislation designed to improve public health, and is now cited in MRC guidance for the evaluation of natural experiments. Dr Semple established the Scottish Smoke-Free Homes Research Network to bring practitioners and academics together in 2015. He has been involved in a wide range of international collaborations with academics, policy makers, public and third-sector organisations including: Action for Smoking & Health Scotland, the University of Edinburgh, Liverpool School of Tropical Medicine, University Putra Malaysia, Makerere University Uganda, the International Union Against Tuberculosis and Lung Disease, Imperial College London, NHS Lanarkshire and the British Lung Foundation.