PART 1

1 Introduction
CHAPTER 1

1 Occupational Hygiene and Risk Assessment

1.1 Introduction

“When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind...”

Lord Kelvin, Popular Lectures and Addresses

Scientists have always known that measurement is fundamental to making accurate statements about the world around us. The pioneers of occupational health were also enthusiastic about measuring exposure, even when this involved considerable effort to get reliable data. In recent years, it has become less fashionable to rely on measurement data and we have seen the development of sophisticated computer-based systems to estimate exposures, or health and safety professionals rely on their judgment to come to a conclusion about the risks in a particular situation. We support these approaches but we also recognise that which was clear to Lord Kelvin more than 100 years ago: measurements can provide a precise, reliable and objective description of a situation that is generally superior to the alternatives.

The science of human exposure encompasses assessment and control of exposure to hazardous agents that arise from work, in the home or elsewhere in the environment. It does not really matter whether you want to measure the exposure to diesel engine exhaust particulate of someone working as a truck driver or the exposure of someone else in the street where the truck is unloading: the underlying science is the same. Where differences do arise, they are in relation to who has responsibility to manage the exposures and what legislative regime applies. Occupational health professionals are concerned with establishing and maintaining a safe and healthy working environment. Occupational hygienists are the occupational health professionals who are focused on the prevention of ill health by intervening in the workplace to eliminate or reduce exposures to hazardous agents. There are other occupational health and safety specialists who may deal with different aspects of health and work, for example occupational physicians and nurses, safety advisors and ergonomists. However, no matter what the specific expertise of the
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individuals they should all be aware of the principles of occupational hygiene to help them in their job.

Hazardous agents may be chemicals, loud noise, unseen radiations or many other things. The discipline of occupational hygiene groups hazardous agents into three categories: physical, chemical or biological agents. Psychological stressors are generally seen as being outside the remit of occupational hygiene. Physical agents include noise, vibration, electromagnetic radiation, ionizing and non-ionizing radiation, excessively hot or cold environments and abnormal atmospheric pressures. Chemical agents include harmful dusts, liquids, gases and vapours. Biological agents include bacteria, viruses and other materials of biological origin that are harmful to health. For convenience chemical and biological agents are often grouped together as substances hazardous to health.

The basis for occupational hygiene is the link between exposure to a hazard and the risk of illness arising from that exposure, where the ‘hazard’ is the potential for harm and the ‘risk’ is the chance that that harm may arise in a particular situation. In general, it is assumed that the higher the exposure someone experiences, the greater the risk to their health. Figure 1.1 shows an
idealized exposure–response relationship for a hazardous agent, which epitomizes the causal link between these two measures. The point at which the line cuts the horizontal axis is the threshold for this particular agent and exposure less than this value will not cause any adverse effects. It is clear that limiting the exposure below the threshold will prevent anyone becoming ill and in these circumstances an occupational exposure limit (OEL) should ideally be defined at this point; i.e. it is a health-based OEL. Note that in this book we use the term OEL to refer in a general way to limit values for exposure.

In practice, the setting of occupational exposure limits is more complex than the identification of a simple unambiguous threshold, but the general principle of restricting exposure below some value, to ensure risk is minimised, is still valid. In some cases we cannot identify whether the exposure–response relationship contains a threshold below which the hazardous agent has no effect; i.e. the exposure–response line passes through the origin on the graph. The main types of hazardous agents that may be in this category are carcinogens that act on the structure of DNA – so-called genotoxic carcinogens. Also, people express a range of different susceptibilities to hazardous agents and although in theory, there may be a threshold for a given agent it may be that some individuals will still be affected at lower exposures. For example, someone with asthma may react to quite low concentrations of an irritant gas when others do not experience any ill effects. Finally, there may be factors that make it impracticable to set a limit at a threshold, for example it may not be technically or economically feasible to restrict exposure to the level of a low threshold and society deems that the benefits from production or use of this material outweigh the health risks from the exposure.

There are many systems that are in place to derive OELs: some are based on national legislation and are used to enforce the law in the workplace; some are national or international advisory limits without any direct link to legislation and some are international limits with the intention of harmonizing practice. In Great Britain, there is a system for workplace exposure limits (WELs) for substances hazardous to health, which are linked to the legal provisions of the Control of Substances Hazardous to Health (COSHH) regulations. Each country in Europe has its own limits, but the European Union has set uniform minimum standards for OELs for some hazardous substances through the efforts of the Scientific Committee for Occupational Exposure Limits (SCOEL), which aims to identify health-based OELs. The European Commission then uses the scientific advice from SCOEL to make proposals for indicative occupational exposure limits based only on the scientific advice given or binding limits where socioeconomic or technical feasibility factors are taken into account in the decision. International bodies provide advisory limits for radiation and other physical agents, and these may then be incorporated into national legislation or guidance.

Harm may be caused by exposure to a hazardous agent. The degree of harm depends on the hazardous properties of the agent, the intensity and duration of exposure and the person’s response to the exposure. Exposure is
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conventionally characterised by two independent factors: the intensity of the exposure and the duration of the individual's exposure. For chemicals, where the person inhales the substance, the intensity is usually the average concentration of that substance in the air breathed into the nose or mouth. In the workplace, concentration is generally measured in terms of the mass of the hazardous substance per cubic metre of air, for example mg m\(^{-3}\), or in parts of the substance by volume per million parts of air, i.e. ppm. However, the units of exposure should really be something like mg m\(^{-3}\) h, i.e. the product of intensity and duration, but it is conventional to express exposures in units of concentration only and to make the duration a standard period, normally either 8 h or 15 min. So for example, a painter exposed to 10 mg m\(^{-3}\) of toluene for 4 h out of an 8-h shift would have an exposure of 40 mg m\(^{-3}\) h but we would normally say that the painter's 8-h average exposure was 5 mg m\(^{-3}\), i.e. 40/8 = 5. If the exposure is to be assessed over a 15-min period then the sample is normally collected for this duration. In the case of our painter, the 15-min exposure might be measured on a number of occasions partway through the shift when it was judged the exposure level was highest.

If exposure is measured by collecting a number of samples over an 8-h period then it is conventional to take the average of these, allowing for the different duration of each sample – this is called a time-weighted average (TWA). For example, we could have measured the painter's exposure during the first hour when she was preparing the job, for the next 3 h when she was painting and then for the final 4 h when she was doing paperwork in the office. The results from this monitoring are shown in Table 1.1.

The 8-h TWA exposure level \(E_{8\text{-h TWA}}\) is calculated by multiplying each exposure level in the table by the corresponding duration, summing them all and then dividing by the total duration (i.e. 8 h). Mathematically this is written as

\[
E_{8\text{-h TWA}} = \frac{\sum_{i=1}^{n} E_i t_i}{8}
\]

where \(E_i\) are the exposure levels, \(t_i\) the durations and \(n\) the number of samples collected over the 8 h. If you calculate the 8-h TWA for the results in the table you will see that it is also 5 mg m\(^{-3}\), i.e. (4 \times 1 + 12 \times 3 + 0 \times 4)/8 = 40/8 = 5.

For hazardous substances, exposure may occur by several different routes; i.e. the substance may enter the body by inhalation, by ingestion, by injection or by passing through the skin. For most chemicals the science was

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration of sample (h)</th>
<th>Exposure level (mg m(^{-3}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Painting</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Paperwork</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>
originally developed to address problems from inhalation, principally because this was considered the most important route for the majority of substances. This means that for the other routes of exposure the measurement methodologies and the concept of an OEL are less coherently developed. Also, for physical agents there are differences in the units of measurement and in the approaches used to obtain a measure of exposure, but again these issues are dealt with in the later sections of this book.

1.2 Hazard and risk

We saw earlier that a hazard is a situation that has the potential to cause harm to a person, e.g. exposure to toxic chemicals, absorption of energy transmitted as microwaves or exposure to loud noise. Risk is the possibility of that hazard causing harm to a particular individual or group of individuals in a given time period. Hazard and risk can be expressed in words, numbers or any other way, as long the information is meaningful. However, it should be clear that if you cannot come into contact with a hazard, i.e. you are not exposed, then the risk is zero.

The type of harm that may occur is an important aspect of a hazard. As each hazard may cause a range of harm, from minor injury to death, the type of harm must be specified. For example, exposure to a substance may carry a risk of causing respiratory tract irritation or cancer, and it is obvious that the latter consequence would be the more serious outcome. This is partly because cancer is a life-threatening illness and irritation is generally a nuisance, and partly because once the cancer has been initiated it tends to be irreversible whereas the irritation will mostly cease soon after exposure has ended.

In assessing risk, care should be taken to ensure that possible accidental exposures are properly considered and there is not just a focus on routine conditions. Accidental exposures may include spillages, activities such as cleaning and maintenance, which can disturb deposited material making a hazardous substance airborne again, entry into confined spaces that contain hazardous substances without proper protective equipment, and wearing contaminated personal protective clothing. Rules that prohibit eating, drinking, smoking, applying cosmetics, nail biting and so on can help prevent substances hazardous to health entering the body by inadvertent ingestion. Advice about washing and showering can reduce the risk from dermal exposure.

1.3 Risk assessment

Risk assessment is the process of making decisions about the acceptability of the risk and the need to take precautionary or protective measures. Risk assessments are part of the wider systems designed to ensure effective management of health and safety in the workplace, but they are a key component that is necessary for the protection of health.
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The outcome of a workplace risk assessment is usually expressed in terms such as the *risks are acceptable*, the *risks are unacceptable* or the outcome of the *risk assessment is uncertain* and further information is required to arrive at an appropriate conclusion. One would generally start by making a qualitative assessment of the risks by using all of the relevant available information. For example, if a laboratory technician is using a very small quantity of a low-toxicity liquid in a fume cupboard while wearing appropriate protective gloves then it will almost certainly be the case that the risks from handling the chemical are acceptable, and any further investigation would be unnecessary. In contrast, people working in a factory where the noise levels were so loud that you cannot hear someone next to you talking are probably exposed to unacceptable risks to their hearing and the most important thing to do is ensure that a suitable noise control strategy is implemented as soon as possible. However, it may be necessary to obtain some simple quantitative data to arrive at a satisfactory conclusion or it may be that measurements of exposure are needed to convince management that the risks are unacceptable and that they need to take action. This type of data may be obtained by measuring exposure.

Any measurements need to be interpreted in terms of risk and for most situations the OEL provides the best way of doing this; exposures above the limit being unacceptable. Where there are no published OELs then a more considered approach is needed to evaluate the risks and in these circumstances it will be necessary to seek the advice of an occupational hygienist or other relevant scientific or medical expert.

1.4 The stages of a risk assessment

1.4.1 Identify the hazard

Workplace risk assessments are best carried out with the cooperation of the relevant managers and workers. They will have access to the sort of information that is needed to come up with an appropriate conclusion and they will also be able to help identify possible solutions where the risks are considered unacceptable.

The first stage in risk assessment is to define the scope and state which area, task or activity is to be assessed. You may choose to start by drawing a hazard map of the area, or a flow diagram of the tasks or activities to be assessed. Check that you have covered all relevant activities including cleaning, breakdowns and maintenance. Then list the physical, chemical or biological hazards associated with each activity, taking care to consider process-generated agents and remembering to identify accidental exposures. Examine the workplace layout and the process to identify where different hazardous agents may interact and make a note of the environmental conditions such as air temperature, humidity and general ventilation. It is often useful to seek out published information from trade associations, regulators, e.g. the Health and Safety Executive (HSE) or other reputable information sources.
Risks that are reasonably foreseeable should be noted and some preliminary decisions taken on their significance. The risks judged to be insignificant should be noted to indicate that they have been considered but the significant ones will require more attention.

1.4.2 Decide who might be affected and how
List all types of personnel who may be exposed to the hazards, including how many people are in each group, the split by gender and any other relevant demographic information. Some workers such as new and young workers, new or expectant mothers and people with disabilities may be at particular risk and there may be specific legal obligations in respect of them.

It is usual to identify work groups or types of employees such as process workers, maintenance workers, welders, office workers and so on, and non-employees such as contractors, customers or neighbours. If appropriate, you should also record more specific job titles represented in each group.

1.4.3 Evaluate the risks
Identify the possible types of harm that could be realised, for example whether there is a chance of acute or chronic effects. Then make an estimate of the exposure that the identified groups of workers and non-workers may experience.

The sorts of things that need to be considered here are the following:

- Who is carrying out the work;
- What work processes and equipment are used;
- What methods of work and materials are used;
- What are the frequency and duration of operations;
- What conditions are there in the work environment, including the presence of general ventilation, lighting and other factors; and
- Are there any legal or good practice requirements specific to the activity?

In deciding whether there is adequate control, you should also consider the principles of good practice for the control of exposure to substances hazardous to health as laid down in the COSHH regulations. These principles, which can be extended to physical agents, are the following:

- Design and operate processes and activities to minimise emission, release and spread of substances hazardous to health.
- Take into account all relevant routes of exposure: inhalation, skin absorption, injection and ingestion, when developing control measures.
- Control exposure by measures that are proportionate to the health risk.
- Choose the most effective and reliable control options to minimise the escape and spread of substances hazardous to health through the workplace.
- Provide suitable personal protective equipment, in combination with other control measures, where adequate control of exposure cannot be achieved by other means.
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- Check and regularly review all control measures for their continuing effectiveness.
- Inform and train all employees about the hazards and risks from the substances with which they work, and the use of control measures developed to minimise the risks.

There is no easy way to estimate the exposure once you have assembled the information about the work task. In some cases, it is possible to argue that the risks are acceptable because of observations made during the information gathering process. For example, if the noise levels are sufficiently low as to not interfere with communication, if there are no signs of dust being emitted from a powder transfer workstation, if the hand tool does not appear to vibrate during use then we may eliminate possible unacceptable risks from noise, chemicals and vibration, respectively. In some situations it may be possible to draw upon your previous experience with similar processes in other workplaces.

Hazards with risks judged to be insignificant should be noted to indicate that they have been considered. For example, in a workroom where the temperature is 25–30°C, there is little chance of any serious risk from heat strain, but the conditions may contribute to the discomfort of workers, particularly if they are engaged in manual work or need to wear protective clothing that limits their ability to lose heat. However, if the risk is judged to be unacceptable, then protective measures are required. The best approach is to identify what control measures are needed and then compare these against the measures that are being taken. Where there is uncertainty some exposure monitoring may be necessary and these data can then be compared with an appropriate limit value.

1.4.4 Take preventative and protective measures

If the risk is unacceptable then measures are required to either prevent or control the risk. Where control measures are being taken then you must check that they are reducing the risk to an acceptable level. It may be helpful to check the controls are functioning as originally installed and are regularly maintained. If they were initially judged adequate then regular maintenance and testing will help ensure continued control.

It is often appropriate to think about whether it is possible to modify the process to eliminate some or all of the hazardous agents. For example, by replacing a welding process where hazardous gases and fumes are emitted to a system involving bolts to join the metal pieces. However, one must always be alert to changes that just alter the hazard without really reducing the risk. In the example mentioned earlier, there may be no real advantage if the bolts were fixed using power tools with associated exposure to noise and vibration. For hazardous substance there is also the possibility of moving to a less hazardous material or to a material that gives rise to a lower emission into the work environment.
Special consideration should be given to personal protective equipment (PPE) worn by operators, particularly where the equipment is heavy or difficult to wear, as this may not be worn correctly. It is often asserted that PPE should be ‘the last resort’, i.e. that PPE should only used if it is not possible to achieve adequate control by other forms of intervention, and it is a requirement of the British health and safety regulations that PPE should be used in this way.

Whenever a control measure is introduced, its effectiveness should only be checked by objective measurements or observations. These checks could include using methods such as dust lamps, smoke tubes, direct reading dust monitors, photoionization detectors or sound level meters.

There is an increasing base of information available about good control practice and the types of control measures that should be implemented on specific work processes. A number of guidance sheets have been published by the British HSE for hazardous substances as part of the COSHH Essentials initiative (www.COSHH-Essentials.org.uk). This type of information provides a guide as to the level of control that is needed to ensure the risks are properly controlled.

1.4.5 Record the significant findings

At the end of the risk assessment process, you must be in a position to demonstrate that the assessment was suitable and sufficient. In particular, that:

- A thorough investigation was made;
- You asked those who might be affected by the hazards for their input;
- You considered all the significant hazards;
- The precautions that were put in place were reasonable and the resultant risk was low.

If the current controls are insufficient to properly control the risk then further measures must be introduced. Any recommendations for further control measures should be identified in the written record of the assessment.

In our view, it is good practice to always record a risk assessment, although if there is a small number of people exposed and the hazard is relatively slight then it may not be necessary to make an extensive written record of the assessment.

1.4.6 Review the assessment regularly and revise it if necessary

Risk assessments must be reviewed at suitable intervals or if there has been an important change to the work process or work environment. If any cases of injury and ill health are identified amongst workers on a process then the risk assessment should be immediately reviewed to ensure that it is still valid.
1.5 Who should carry out risk assessment

To undertake a risk assessment you need to have an appropriate level of training, knowledge and experience. Some regulations or official guidance specify that the risk assessment should be undertaken by a competent person, but you should assume that competence is required by everyone undertaking this type of work. However, the level of competence may vary from one situation to another, and for example someone assessing the risk in a large petrochemical site will need to have a greater level of competence than another individual assessing the risk for an office environment. A competent person must be able to recognise their own limitations and when they need further assistance from someone more experienced. This may involve assistance from within the company or external advisors, experts or consultants. Usually, larger companies have specialists such as safety professionals, occupational hygienists and engineers to assist; smaller organisations will need to outsource such advice.

References and further reading


The Scientific Committee on Occupational Exposure Limits (SCOEL) provides scientific advice to the European Commission to underpin regulatory proposals on exposure limits for chemicals in the workplace. Available at http://ec.europa.eu/social/main.jsp?catId=153&langId=en&intPageId=684.

More information on good control practice techniques is available at HSE’s COSHH Essentials website. www.coshh-essentials.org.uk/.

HSE’s COSHH website provides information about the regulations and how to comply with them, plus a list of WELs. www.hse.gov.uk/coshh/.

HSE information about the calculation of exposure with regard to the specified reference periods, with examples. Available at http://www.hse.gov.uk/coshh/calcmethods.pdf.