RSC | Advancing the Chemical Sciences

Environment, Health and Safety Committee
Note on:
WHY DO WE WORRY ABOUT CHEMICALS?

Everything is made of chemicals. Every chemical can be dangerous if used in the wrong way. Equally, every chemical can be used safely if controlled in the right way. Chemicals can and do bring great benefits to society. It is up to the relevant stakeholders to strike the right balance between the benefits of using a particular chemical and the resources that are required to control it.

Introduction

People have many concerns about chemicals. The Royal Society of Chemistry is an independent learned and professional body that promotes the science of chemistry. The Society believes that some of the concerns people have about chemicals are legitimate and some are well founded. However, the Society also believes that chemical risks can be adequately controlled – and usually are – and that without chemicals modern life would not be possible. The Society also believes that controlling chemical risks and balancing them against the benefits for society is complex and poorly understood by most people. This Note attempts to open a constructive discussion on this issue.

People know that chemicals have caused harm despite assurances from experts. For example, man-made chlorofluorocarbons (CFCs), which were very good for the uses that they were originally intended, were later found to cause damage the ozone layer. Thalidomide and some other drugs have also caused terrible harm to individuals. It is easy for experts to claim that testing and controls are now better and that such problems can not occur nowadays. However, similar assurances were given at the time and people today are aware of this.

Life today would be impossible without chemicals and the products made from them. Every chemical can be dangerous, whether it is man-made like bleach, or is naturally occurring like asbestos. Nonetheless, many dangerous chemicals are used every day. Because we are careful with them, they seldom cause harm and most of the problems that do arise are the result of misuse.

The chemicals produced by the chemical industry are used to make a wide variety of products such as plastics, paints, medicines, detergents, cosmetics and many other materials. Such chemicals have to be properly controlled. We have to protect workers who handle them and people who use them. We also have to prevent chemicals from being released into the environment in quantities that might cause damage. However, if we simply ban a chemical because it might have hazardous properties, even though the exposure can be controlled, then we stand to lose all the potentially useful things that could be made from it.

Why can't we simply classify chemicals as 'safe' or 'unsafe'?

This is a complex question that needs to be answered in stages, starting with the clarification of the terms that we use.

'Chemicals'

Most people use the word 'chemical' to mean only man-made (synthetic) substances produced by the chemical industry. This is reinforced, to a large extent, by most dictionary definitions of a 'chemical'. However, the universe is made up of chemicals. Air, water, rocks, minerals, coal, oil, salt, natural gas, plants and animals are all made up of chemicals. From these naturally occurring materials, a wide range of other chemicals are manufactured including petrol, diesel, plastics,

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vitamins, cleaning materials, medicines, cosmetics, iron and other metals, paint, inks, dyestuffs, pesticides, sugar, etc. All chemicals, whether they are natural or man-made obey exactly the same laws of chemistry and physics. Whilst people understand that everything is made up of chemicals, they do not always associate 'chemicals' with products manufactured from chemicals.

'Safe'

There is a perception that all naturally occurring chemicals are good or 'safe' and that man-made chemicals are 'unsafe'. This is simply not true. For example, water is critical to the support of life but we can drown in it or it can poison us if we drink too much of it. Some plants are edible but many, including some fungi, naturally contain poisonous chemicals which can kill us if we eat them. On the other hand, man-made medicines, such as aspirin, have beneficial properties if used in small quantities but can be fatal in large doses.

Although there is a public demand to have chemicals that are 'safe', the above examples demonstrate that it is not always possible to have chemicals that are absolutely safe at all times and in all possible situations. Therefore, rather than describing chemicals as 'safe' or 'unsafe', it is more appropriate to consider chemicals in terms of 'hazards' and 'risks'.

Hazard and Risk

The words 'hazard' and 'risk' have their own meanings that are quite different and not interchangeable.

Hazard is the potential for something to cause actual harm (injury or damage). For a chemical, the hazard is related to its intrinsic and individual properties such as flammability, corrosivity and toxicity.

Risk is the likelihood that the hazard will cause actual harm. It is a function of hazard and exposure. This means that if the likelihood of exposure to a hazardous chemical is extremely low or unlikely, then the risk associated with that chemical will also be very low. For a chemical to cause harm requires exposure to its hazardous properties in concentrations likely to be harmful to health and the environment.

While it is imperative to protect health and the environment it is not possible to design out all risks over the life cycle of chemical substances and products. While the RSC supports the search for safer alternatives it must be remembered that chemical substances generally do not pose a single risk and in fact have a risk profile. Therefore in the search for less harmful substitutes with equivalent functionality and utility, care must be taken to ensure that a reduction in one risk is not replaced by an increase in another. Furthermore, the search for safer solutions should be based on the principles of sustainability.

We all know that the main hazard associated with petrol is its flammability. If petrol is poured from a can close to a naked flame the risk of ignition and fire is high. The potential for injury to people in the vicinity and damage to nearby property is also high. On the other hand, if petrol is dispensed from a garage pump directly into the tank of a car with no flames or other sources of ignition in the vicinity, the risk is low - but not zero.

In the above examples, the hazard concerned was the flammability of petrol. However, chemicals usually have more than one hazard. For example, petrol is poisonous as well as flammable. The reason we focus on its flammability is that this is the most likely hazard to cause a problem in real life (e.g. due to misuse or carelessness). Petrol is just one example of the many hazardous substances that are used safely every day. This can make it difficult for chemists to understand why many people demand that chemicals should be completely 'safe'. On the face of it, this demand seems absurd. However, on digging deeper, some real concerns emerge as shown below.

Balancing risks and benefits

Chemists recognise that substances – whether natural or man-made - can be dangerous when used in the wrong way. However, they also appreciate the benefits of chemicals. Unfortunately, many people see only the dangers of chemicals and forget, that without them, we would be unable to make the products we take for granted and without which modern life would be impossible. For example, without chemicals we would not have plastics, aspirin, antibiotics, cosmetics, silicon chips, cleaning products, modern fabrics and dyes and indeed most of the materials that we enjoy and depend on.

The problem we face is how to balance the risks from chemicals, which may be significant, against their benefits to society. We strike this sort of balance in many other areas of life. For example, car accidents kill thousands of people and aeroplanes occasionally crash. However, we do not 'ban' driving or flying. Instead, we control them with laws and training, and we improve their safety with better technology. Why should chemicals be any different?

What's different about chemicals?

In fact, there are important differences between risks from chemicals and risks from other sources.

First of all, much of the public concern about chemicals focuses on the potential of chemicals to cause ill-health, a property of chemicals known as 'toxicity'. This term is used to cover both:

- immediate or acute effects such as poisoning where you swallow a substance or breathe it in or get it on your skin and are affected soon after, and
- long-term or chronic effects such as cancer where you may be exposed to a material today, or over a period of time, but are not affected until much later (e.g. developing cancer twenty years or more after breathing asbestos dust).

There is no simple catch-all test for toxicity. By and large, we need to be aware of the effects that may be caused in order to test whether the chemical causes it, and if so, at what dose. Properly planned tests will look for most of the possible effects. However, occasionally there may be effects that are difficult to detect with present knowledge and which may only be discovered once the substance is in use. For example, we do our best to test the toxic side-effects of medicines, with lengthy clinical trials, before we can use them but occasionally we do not identify all the side-effects. This does not mean we ban all new medicines. Instead, we look at the risks and benefits and if we judge that the risks are small while the benefits to patients are large, then we will probably go ahead and use the substance with arrangements for reporting any side-effects that may be observed and for taking action on them.

A further complication is that toxicity usually depends on the species, exposure route and amount involved. A chemical may have relatively little effect on man but may be toxic to wildlife, or vice-versa. For a particular species, e.g. man, the effects of a chemical usually vary with 'dose' i.e. the amount you are exposed to. Unlike an aeroplane crash say, there is generally a level below which a chemical causes no perceptible harm. For example, we are all exposed to highly toxic chemicals called polyaromatic hydrocarbons every time we make toast. However, we do not usually worry about these because the amount involved is so small that we regard it as 'safe'.

In man, the 'safe dose' for salt (sodium chloride) is quite high whereas it is much lower for say sodium cyanide. However, the principle is the same. Once we know the safe level of a chemical we can control it, taking account of its effects on man, other species and the environment. In other words, we can make sure that man and other species are not exposed to more than a fraction of the 'safe dose'. We can do this, for example, by setting limits to the amount that workers are exposed to or the amount that is allowed to get into rivers or into the air. In general, these amounts are will vary because we apply different criteria and 'safety factors' to take account of the different situations. However, the principle is the same. Even so, some groups such as children may be more sensitive than the rest of the population to particular chemical substances. Heightened sensitivity among these groups is usually taken into account when calculating the tolerable risk and the efficacy of chemicals.

Dealing with uncertainty

Although we understand the dangers of flying and driving, we may not understand the reasons why a particular aeroplane crashes. However, we know that aeroplanes falling onto built up areas is an ever present danger, albeit a remote one and we know the effects to expect if it happens. Chemicals are rather different. While we know a lot about the effects of chemicals on man, other species and the environment, they may have hazards that we do not find out about until it much later because we simply do not know what to look for in advance. CFCs are a good example. They were used as refrigerants, to extinguish fires and as propellants in aerosols and were hailed as a great step forward because they were of low toxicity and non-flammable. At the time no one imagined they would damage the ozone layer and so that possibility was not considered or tested. Nowadays, knowledge has moved on and we can predict the effects of CFCs. While scientists constantly strive to increase our knowledge and understanding of chemicals, we cannot guarantee that some chemicals in use now may not be shown to have unpredicted hazards in the future.

Accepting that there have been mistakes in the past, the potential for as yet undiscovered hazards, the likelihood of human error, the difficulty of establishing 'safe' doses and safety factors and all the other confounding issues, it is little surprise that many people are worried about chemicals. It is also understandable that many demand the banning of all chemicals with a serious hazard. This may be reasonable if we have 'safer' alternatives or we are prepared to forego the benefits of the chemical concerned. However, this is seldom the case. Often alternative chemicals are not available or if they are they may have different hazards that are just as bad or even worse. Usually a chemical is only made and sold if it has a significant benefit. If we want to have that benefit we usually have to control the chemical rather than banning it or replacing it. As with flying and driving, control can be achieved by introducing laws and rules and/or by improved technology. However, as with aeroplanes and cars these may not always be entirely perfect.

In principle, we can use a hazardous chemical safely by containing it in an enclosed system. Of course, there is always the risk of escape, (e.g. as a result of human error or mechanical failure) - chemical accidents, like the one at Bhopal, have killed large numbers of people. In some cases, benefits are judged to outweigh the risk, for example where highly radioactive materials are used in nuclear power stations but contained using multi-barrier enclosed systems. In other cases, complete containment would be impractical, too expensive, or not worth even the low risk of an escape e.g. CFCs which cause serious damage to the ozone layer. However, the nature of their uses (e.g. in sprays) means it would not be practical to keep them enclosed systems. Therefore, they have been banned. This means that for many applications we have had to revert to using older alternatives which may be flammable and toxic. As a society we accept that it is worth putting up with these hazards because we want the products and the flammability and toxicity are less serious and more easily controlled than damage to the ozone layer.

How can claims about chemicals and their risks be evaluated?

When new chemicals are discovered, extensive tests are usually undertaken to determine their properties, including those relating to toxicity. As shown earlier, despite these tests, there are examples where chemicals have been taken into use only for unexpected adverse effects to appear later. There are also occasions when claims are made about new adverse effects of a particular chemical or a group of chemicals. When this occurs, it is important that a detailed investigation is undertaken to validate the claims.

As a starting point for investigation, scientists normally try to answer the following series of questions:

- Is the claim based on anecdotal information?
- Is the claim based on objective scientific experiments or observations?
- Has the claimed effect been widely observed?
- Is exposure to the chemical always followed by the claimed effect?
- Does there appear to be a relationship between the level of exposure to the chemical and the severity of the effects?
- Does the effect occur in the absence of the chemical?
- Is there a plausible explanation of how the chemical could produce the particular effect?
- Does the evidence presented fit the known facts or data?

Depending on the answers to these questions, it may be appropriate to undertake further research or tests to improve the understanding of the properties of the particular chemical. This will allow decisions to be made as to whether any additional actions are needed to control the use of the chemical concerned.

Conclusions

The modern world could not function without chemicals. If chemicals were not considered to be beneficial to society they would not be manufactured and sold. If we want those benefits at a reasonable cost then we have to accept that there may be some risks. We need to strike a balance between the risks and benefits and control the risks with laws and better technology. Banning chemicals simply because they have certain hazards, when they could be used perfectly safely with the right controls in place, may result in society losing many useful products on which it relies.

Chemists are working hard to provide better materials and a better understanding of the effects of chemicals on man, other species and the environment. However, balancing the risks and benefits of chemicals is not just a matter for chemists, or for any other single ‘stakeholder’ such as the chemical industry.

The Royal Society of Chemistry believes that the public and other ‘stakeholders’ should be fully involved in striking the right balance and in calling decision-makers to account. For example, the Royal Society of Chemistry is one of the organisations represented on the ‘UK Chemical Stakeholder Forum’, a government body that brings together environmental groups, industry, and others to discuss the risks and benefits of chemicals and to advise the Government on the best balance between them.

In order to develop consensus all parties concerned need to understand that we live in an imperfect world. Scientists are not infallible. New problems can always surprise us and old problems may sometimes be more serious than we had realised. In most cases, the best we can do is to investigate the likely hazards, weigh the risks and benefits, and if the benefits justify proceeding, put in place suitable measures to control the risks.

Further Reading

Royal Society of Chemistry 'EHSC Note on What is a Poison?', (2009)

Royal Society of Chemistry 'EHSC Note on Why do we worry about Perfumes?', (2007)

Royal Society of Chemistry 'EHSC Note on Why do we worry about Brominated Flame Retardants?', (2007)

Royal Society of Chemistry 'EHSC Note on Why do we worry about Dioxins?', (2007)

Royal Society of Chemistry 'EHSC Note on Why do we worry about Phthalates?', (2008)

Royal Society of Chemistry 'EHSC Note on Potency of Chemical Carcinogens', (2004)

Royal Society of Chemistry 'EHSC Note on Harmful Effects of Chemicals on Children', (2004)

Royal Society of Chemistry 'EHSC Note on Reproductive Risks of Chemicals at Work', (2006)

Royal Society of Chemistry 'EHSC Note on 'LD50' (Lethal Dose 50%)', (2007)

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