We don't do that – it's not safe any more!

Peter Borrows

An over-cautious approach to health and safety is inhibiting good science teaching. The CLEAPSS School Science Service aims for a balanced view.

Safety in perspective

Teachers often express the view that over-emphasis on health and safety is inhibiting good science teaching, especially for the 14–19 age group. This concern is sometimes reported in the national press, which, of course, teachers read. That, in turn, reinforces their view: it must be true if it was in the *Observer*! (e.g. *Observer*, 1996). There are many myths about particular chemicals or procedures being banned. Of course, teachers must obey the law and, in the very unlikely event of their employer having banned something, they must respect that ban. But there are very, very few such bans.

Sometimes, I suspect, teachers use health and safety as an excuse, when what they really want is a quiet life – and who can blame them, given the pressures of league tables, Ofsted and the like? Certainly a shortage of money may be a problem. If the safety spectacles are so badly scratched that you cannot see through them or you develop a headache when wearing them, then perhaps it is safer to adopt practical work that does not require eye protection.

ABSTRACT
There are many myths about practical activities being banned or discouraged. Too much good science is being lost as a result. Teachers do need to develop an understanding of health and safety principles, and teach their students, for example, that more dilute solutions are less hazardous. In many cases, what is safe depends as much on the nature of the class as on the chemical or procedure being used. Properly funded curriculum development projects can – and do – identify and deal with potential health and safety problems.

There is no doubt that class sizes, both pre- and post-16, have increased in recent years. Over-crowded classes, where pupils cannot carry out practical work without being a danger to their neighbours, put teachers under stress – and that, of course, is a health and safety issue.

When I run courses for heads of department, we sometimes look at case studies of accidents and incidents. Rather too often, participants suggest that the school or college should not have had a particular chemical, for example, silicon tetrachloride, because it isn't specified in the syllabus. I find it rather frightening that teachers only want to use that which is specifically named. This leads to a rather Orwellian view that if it isn't in the syllabus, it must be banned. Silicon tetrachloride certainly needs to be handled with care but experienced teachers should be able to use it safely and thereby enrich their teaching.

What we need is a balanced view of health and safety. We cannot eliminate all risks or have absolute safety. Eating is dangerous. You may get food poisoning. You may choke on a fish bone. You may be allergic, for example, to the nuts used in the food. You may become obese. However, not eating is even more dangerous, for you will surely die! Interviewers on the media often ask '*Is it safe?*' This is a stupid question, because the answer can never be '*Yes*'. There is always the possibility of something going wrong. The best you can do is to say '*It is safer than it was*' or '*It is safe enough*'.

Salt is an essential component in our diet, yet excess salt contributes to high blood pressure. There was even one tragic case a few years ago where a mother killed her 4-year old son by feeding him quantities of salt (*Guardian*, 1997a). Salt can kill – but we don't ban the use of sodium chloride in science, nor indeed as a product sold to the general public.

Similarly with caffeine. Look at its Material Safety Data Sheet and you might well wonder whether this is a chemical suitable for use in schools and colleges. Yet few of us can get through the day without our fixes of caffeine, whether from tea, coffee or cola drinks. There, the solution is so dilute as to present no significant hazard, although there is a very rare medical condition known as caffeinism, brought on by excessive consumption of such drinks (e.g. 1 gallon of tea per day for 20 years) (*Guardian*, 1997b). It is really very important to teach students (and their teachers) that the hazard from a chemical depends on its concentration. Solid sodium hydroxide is CORROSIVE (and thus, for example, likely to cause permanent damage to the eye), as are aqueous solutions at concentrations of 0.5 mol dm^{-3} and above. Between 0.05 and 0.5 mol dm^{-3} solutions are IRRITANT and below 0.05 mol dm^{-3} LOW HAZARD. Many courses require students to be taught about health and safety but the variation in hazard with concentration is rarely taught or examined. Unfortunately, authors of practical texts are equally guilty as they often refer to 'dilute' sodium hydroxide, for example, which is just not precise enough. In general, where there is a choice, the law requires the safest alternative to be used. Hence, in this case, the most dilute solution which actually works should be used, but this is rarely specified by the author.

Often, a risk assessment will require that personal protective equipment (PPE) be worn. Certainly, the eyes are very vulnerable and need a good level of protection, but it is not necessarily the case that gloves are such a good idea. Some chemicals are potent sensitizers and others are toxic by skin absorption. On the other hand, wearing gloves may lead to careless and clumsy behaviour and there is widespread allergy to latex (which is a major problem in the NHS). Gloves (preferably nitrile rather than latex) are necessary when handling open radioactive sources (so that in the event of a spill any contamination is removed when the gloves are removed). They are also necessary when handling phenol. Not only does this cause burns (the effects of which are not immediately apparent) but it is also TOXIC BY SKIN ABSORPTION and the phenol crystals tend to clump together in the bottle, making them difficult to remove and increasing the possibility of hand contamination. The hazard is significant and the likelihood of something going wrong is appreciable; hence there is a major risk which needs to be controlled.

Banned chemicals?

I sometimes issue a challenge to teachers: tell me what exciting bit of practical work you used to do and I will show you that you can still do it, perhaps with rather more precautions than was the case 30 years ago. There are many myths and misunderstandings about banned chemicals (Borrows, 1993). One of the few substances which was used routinely in the past and which is no longer available is benzene. Originally banned in the UK under the COSHH (Amendment) Regulations 1992, this cannot be used except for scientific research or industrial production. So you cannot legally nitrate benzene – but I never found this particularly exciting, and there are plenty of other things you can nitrate, such as methyl benzene-carboxylate (benzoate). The ban on using small amounts of benzene may seem slightly illogical, given the amount of petrol (which typically contains 1–2% benzene) that is sloshed around on garage forecourts. It is important to stress that it is only benzene, C_6H_6, which is banned: the rumour-mongers seem to believe anything with a benzene ring in the molecule is banned. This is simply untrue: phenol, phenylamine or naphthalene are all perfectly legal. They are hazardous in different ways and it may well make sense to find safer alternatives where these exist, but they are not banned.

Chlorinated hydrocarbons present two different problems. Some are toxic or suspected carcinogens and some damage the ozone layer. The ozone-depleters, including, for example, tetrachloromethane (CCl_4) and 1,1,1-trichloroethane (CH_3CCl_3), can no longer be purchased, nor can they be used in 'diffusive applications'. Although not ozone-depleters, trichloroethene ($CHClCCl_2$) is toxic and there is limited evidence of carcinogenic effects for trichloromethane ($CHCl_3$). If used at all, these need to be in an efficient fume cupboard but, where possible, it is best to find a safer alternative. Therein lies the problem: there is no universal alternative; each use needs to be considered individually (CLEAPSS, 2003). For some solutes, dichloromethane (CH_2Cl_2) or cyclohexane (C_6H_{12}) are good solvents. In other cases, volasils such as octamethylcyclotetrasiloxane ($(CH_3)_8Si_4O_4$), or proprietary hydrocarbon mixtures such as Lotoxane or Evolve (see end) may be used.

As a final example, consider the use of dichromates(VI) and chromates(VI). These are very toxic by inhalation. They are category 2 carcinogens (i.e. should be regarded as carcinogenic in humans) and may cause cancer by inhalation. The evidence for this comes from industries where there is likely to be high levels of exposure to airborne contaminants, for instance when handling powdered pigments (inhaling dust), welding stainless steel (inhaling fumes) and electroplating (inhaling bubbles bursting at the electrodes). Such exposure routes are not at all plausible for a sixth-former titrating iron(II) solutions or oxidising ethanol, although due care should be exercised as sensitisation may be caused by skin contact. On the other hand, in the ammonium dichromate(VI) volcano chromium(III) oxide is formed. This is not hazardous in itself but it is plausible that some unreacted ammonium dichromate(VI) might be carried into the air with the chromium(III) oxide and inhaled. Thus, if the decomposition is to be carried out it should be either in a fume cupboard or in a vessel fitted with a mineral wool plug to prevent particles escaping.

Banned biology?

The CLEAPSS Helpline (available free to members) took over 6600 calls last year. Almost every day there were enquiries as to whether, for example, year 10 pupils are allowed to watch hearts or kidneys being dissected. These products are available from supermarkets for human consumption. Why should pupils not be allowed to see them dissected, or, better still, dissect the organs themselves? A ban on eating brain and associated tissue from cows (because of CJD concerns) suddenly metamorphoses – in people's minds – into a mistaken ban on dissecting hearts.

For a few years the then Department for Education advised schools not to take cheek cell samples. This was purely advice; there was no statutory instrument put through parliament to give it the force of law, although most LEAs acted upon the advice and put (temporary) local bans in place. As employees are obliged to cooperate with their employer on health and safety matters, teachers were then obliged to respect such bans. However, the advice was issued before the COSHH Regulations were implemented in 1988 and the Management of Health and Safety at Work Regulations in 1992. These regulations introduced risk assessment as a concept and this proved to be empowering to science teachers. Once a risk assessment for cheek cell sampling is carried out it becomes clear that there are safe strategies for doing this activity. They are only safe if teachers are aware of them and students implement them. In some schools, with high staff turnover or under-qualified or inexperienced staff, a head of department might well decide that, because of communication difficulties or problems of student behaviour, the risk is too great. But a different decision could reasonably be made in the school down the road, or, indeed, in the same school next year. As a result of changed DfEE advice (DfEE, 1996), almost all LEAs rescinded their previous bans, provided that schools carried out a risk assessment. The main factors in this would be teacher knowledge of a safe procedure and a judgement about student behaviour.

Similarly, for blood sampling. There are safe procedures (e.g. available from CLEAPSS for members) but the risk is obviously greater than with cheek cell sampling. Thus a school or college needs to be more certain of the answers. Some LEAs have not rescinded bans on blood sampling; others permit it only in A-level contexts. In general, regulations require employers to use the safest alternative which achieves the desired ends. Using time-expired blood from a blood bank (where it will have been screened for HIV) is safer than students using their own blood. On the other hand, using a stranger's blood is inherently less motivating than using your own, so there can be an educational justification.

Boring physics?

Many teachers seem to be afraid of radio-isotopes. They prefer to show videos or use CD-ROMs. But students find the clicking of a Geiger counter or observing a track in a cloud chamber fascinating. Where else can you experience the effects of a single atom? The sealed sources generally used in schools and colleges are very safe. You could be exposed to more radiation by standing at the smoke alarm counter in your local DIY superstore or by flying to Spain from the UK four times than in carrying out a typical school demonstration.

Mercury has some unique properties (a liquid at room temperature, a good conductor of heat and electricity and a high density) which give it a special place in physics teaching. Or at least, should give it a special place. Sadly, some schools and colleges seem to have been frightened off using mercury in recent years or believe its use is discouraged (by whom?). Certainly, mercury is hazardous: it is toxic, a cumulative poison and any spills must be cleared up efficiently. Perhaps teachers were careless with it in the past, although CLEAPSS surveys of some ten thousand laboratories in the past 20 years have shown mercury concentrations well below HSE limits in all but a tiny handful of laboratories and even they did not exceed the limit. Even so, teachers need to handle it with care. For example, if demonstrating how to make a mercury barometer, all the work needs to be carried out over a non-metallic tray to contain any spills; the room should be well ventilated and mercury surfaces left exposed to the atmosphere for the minimum time. Teachers should remove gold or silver rings and preferably wear protective gloves.

Despite their reservations about handling radioactive sources or mercury, physics teachers can be surprisingly blasé when it comes to electricity. For example, Teltron tubes will have a metal pin, which may be connected to a HT-supply using a 4 mm plug. However, the plug will have to be put on backwards, leaving another metal pin projecting, live at a high potential and capable of delivering a dangerous current (mA) – an open invitation to an accident. A simple risk assessment would suggest appropriate control measures: shrouded connectors. Most physics teachers claim to have experienced a significant electric shock at some point in their career, which rather suggests they are not observing suitable safety precautions. We still hear of teachers carrying out a demonstration of the high voltage transmission line, with exposed conductors live at 230 V. In the 1980s half a dozen teachers experienced severe electric shock during such demonstrations. The Health and Safety Executive (HSE) warned employers (LEAs and the governors of independent establishments) of the dangers and suggested safer procedures. These appear in section 12 of the CLEAPSS *Laboratory handbook* (CLEAPSS, 2001). We believe the HSE would probably prosecute the employer or head of department if there were a further accident leading to significant injury.

Project and investigational work

For a number of years, the Salters' A-level chemistry syllabus has required candidates to carry out an individual investigation. Nuffield A-level biology similarly required a project. Often, these activities involve novel chemicals or unusual procedures, for which model risk assessments cannot be found in those sources commonly used in education, such as the CLEAPSS *Hazcards* (1995–2003) and *Laboratory handbook* (2001) and *Safety in science education* (DfEE, 1996). In such situations, most education employers will require special risk assessments and we at CLEAPSS are happy to provide these for our members, given reasonable notice. In practice, special risk assessments often require many hours of research in the library, on the Internet or in the laboratory – and sometimes all three. They cannot be rushed. Moreover, we do not encourage calls directly from students. Sometimes, it appears as if we are being asked to carry out students' projects for them! On other occasions, students are so unclear as to the procedure they are going to carry out – quantities, concentrations, voltages, apparatus, etc. – that it is not possible for us to carry out a risk assessment. Generally, it is better for the teacher, lecturer or technician to help them clarify their ideas in discussion, and then for the member of staff to contact us.

Over the years, CLEAPSS has taken many calls about these projects and only very rarely have we found it necessary to suggest that a particular activity would be inadvisable. One project we did reject had been inspired by a student's work experience in an industrial laboratory. He wanted to boil various materials with hydrofluoric acid in a fume cupboard. Whilst fume cupboards capable of containing a hydrofluoric acid digestion are available, the average school fume cupboard would disintegrate rapidly. Schools are often surprised that we do not automatically reject the use of hazardous and apparently high-risk chemicals such as cyanides. On investigation, it is usually the case that the student only needs to handle very small volumes of quite dilute solutions. Technicians prepare the solution. Of course many factors need to be taken into account by the school or college in customising the model risk assessment to its own situation. Where will the solution be kept between lessons? How will the solution be disposed of after use? How big is the class? How well will the teacher be able to supervise the activity? How experienced is the teacher? How reliable is the student? Projects which are entirely suitable in some contexts may be quite unsafe in others.

Applied science

From September 2002 an applied science GCSE has been available. The concept is undoubtedly a good one: to better motivate young people by showing them the applications of science in the world of work. This may involve some novel practical work, or at least may involve 14-year-olds carrying out activities previously reserved for the sixth-form or higher education. Some of these do not present a problem. However, activities which are safe when carried out by 15 or so A-level students supervised by an experienced teacher may be much less safe when carried out in a crowded class of 30 much less experienced and less motivated students, supervised by a teacher with little experience or expertise in the topic who may be a specialist in a completely different branch of science. One example is flaming inoculation loops and glass spreaders in microbiology. Given the number of accidents over the years caused by ethanol fires, the proximity of ethanol and Bunsen flames in a crowded classroom, perhaps occupied by students presenting behavioural problems and certainly lacking much practical experience, gives cause for concern. But usually some adaptation of the procedure avoids the most hazardous activities.

Part of the problem with GCSE applied science is that it is simply a syllabus, without the infrastructure of a fully developed course. Salter's chemistry and Nuffield biology, on the other hand, were well-resourced, properly trialled projects.

The future

The revision of the science National Curriculum in 2005 will lead to changes. Already, trials for one interesting development, *Science for the 21st Century*, are under way. Like Salters' and Nuffield, this is a properly funded project, which is being trialled before being made more widely available. There is an excellent chance that any serious safety problems will be identified and resolved. The course should be both exciting and safe.

The investigations carried out for GCSE under the guise of attainment target 1 have become very stereotyped. How many millions of students have measured how the rate of the reaction between acid and sodium thiosulfate varies with temperature or concentration? Surely, to call this an investigation is a potential breach of the Trade Descriptions Act? There have been suggestions that when the curriculum is revised in 2005 more genuine investigations should be encouraged, but at present teachers would be rightly fearful of how moderators might view something novel. Genuine investigations would prove something of a challenge to teachers with limited subject expertise in large, overcrowded classrooms. Producing hundreds or thousands of special risk assessments per year could prove a problem for CLEAPSS too! But with thought and planning, perhaps there are ways around this. After all, we don't want spurious health and safety concerns to interfere with good practical science.

Sources

Lotoxane is available from Griffin Education and Evolve from Timstar or Breckland Scientific Supplies.

References

Observer (1996) Colour magazine. Sceptics' corner: Teaching science should be a risky business. 17 November.

Guardian (1997a) Mother killed son with salt. 18 June.

Guardian (1997b) Tea 'trip' swayed army man's mind. 11 June.

Borrows, P. (1993) That's banned, isn't it? Some safety myths in science. *School Science Review*, **74**(269), 51–54.

CLEAPSS (2003) *L195, Safer chemicals, safer reactions*. Uxbridge: CLEAPSS.*

DfEE (1996) *Safety in science education*. London: HMSO.

CLEAPSS (2001) *Laboratory handbook*. Uxbridge: CLEAPSS.*

CLEAPSS (1995–2003) *Hazcards*. Uxbridge: CLEAPSS.*

*Also available on CLEAPSS (2004) *Science publications CD-ROM 2004*. Uxbridge: CLEAPSS.

Note that CLEAPSS publications are only available to members, although at the time of writing this includes every LEA in the UK (outside Scotland) and the vast majority of independent schools, post-16 colleges and teacher training establishments. Contact the CLEAPSS School Science Service, Brunel University, Uxbridge, UB8 3PH or visit the website at: www.cleapss.org.uk.
E-mail: science@cleapss.org.uk

Peter Borrows is Director of the CLEAPSS School Science Service and a member of the ASE's Safeguards in Science Committee. He was formerly a head of science in a large inner city London comprehensive school and a science adviser.