Safety Alert

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Unpredictable science experiments

Science experiments can, and do, serve many valuable and essential functions in engendering inquiry, providing skills and acquiring knowledge that are essential to student learning. However, 'fun' experiments involving explosions or pyrotechnic effects used to demonstrate science concepts can have unintended and dangerous consequences. These activities are often researched online, resulting in the selection of activities that offer spectacular outcomes, yet translate into limited learning experiences.

Poorly selected and managed activities can be quite disastrous – when things go wrong, they tend to go very wrong. Engaging students in the excitement of scientific discovery must be balanced by appropriate curriculum choices and risk minimisation strategies.

Issue

There have been a number of incidents at schools involving explosive or pyrotechnic science experiments. These activities all resulted in physical injuries to both staff and/or students. Experiments have included:

- dry ice or liquid nitrogen in sealed (soft drink) bottles
- large pieces of reactive metals (sodium) added to water
- production of contact-sensitive chemicals (touch powder) and
- reactions that produce a smoke bomb effect (e.g. glycerine or nitrate based reactions).

Irrespective of the theory demonstrated or the methods used, the outcome is the same – an explosive or pyrotechnic effect is produced through the uncontrolled release of energy.

Why is it an issue?

Any activity involving the sudden and violent release of chemical energy creates an unacceptable risk to both students and teachers. While risk assessments were undertaken in all of these activities, investigations showed that these incidents occurred as a result of:

- a lack of understanding that experiments that involve *a practical effect by explosion or a pyrotechnic effect* are NOT permitted (*Explosives Act 1999* (Qld), Sch 2; Guideline for Managing Risks with Chemicals in DoE Workplaces, s4.8.3).
- a misconception that the use of commercially available risk assessment software is equivalent to the DoE curriculum risk management (CARA) process and therefore suitable for identifying hazards associated with processes involved in high risk activities;
- a lack of evaluation of the educational benefit of the activity in relation to the risk;
- a failure to explore/manage the unpredictable nature of the activity before demonstrating it such as:
  - taking note of the obvious hazards and risks observed in online research
  - conducting a trial of the activity to identify potential hazards and issues with work processes
  - controlling the scale of the reaction by limiting reactive products
  - neglecting to consider how to manage the experiment should it *not* work.

What can you do?

When undertaking science curriculum activities:

- Carefully consider the character and purpose of your activity. If it can be reasonably considered to be explosive or pyrotechnic, the activity cannot proceed.
- Schools are required to use approved departmental processes for managing high and extreme risk curriculum activities as per the Curriculum Activity Risk Assessment (CARA) procedure. A chemical CARA template is provided here.
- School-based or commercially available risk management programs must meet or exceed CARA requirements for high and extreme risk levels in order to provide an adequate risk management plan. Schools should note that there are currently no *endorsed* risk assessment software packages under the department's procurement arrangement (apart from OneSchool and ChemWATCH) because they do not meet the department's risk management criteria.

- Any activity involving the uncontrolled release of chemical energy remains high risk regardless of control measures. This is because the potential risk for serious injury is likely should control measures fail. Extreme risk activities involving chemicals are not permitted as the risk is uncertain and not effectively controlled.
- Trial high risk experiments by the activity leader before being demonstrated so as to identify and manage all risks associated with the activity (i.e. managing foreseeable risk).
- Examples of activities prohibited under the [*Explosives Act 1999* (Qld)] include:
  - **Any reaction that occurs in a sealed vessel** where pressure build-up causes the containing vessel to rupture. These types of experiments effectively manufacture an improvised explosive device because there is no way of predicting the timing, trajectory, duration or size of the discharge once the device is filled and sealed. For example:
    - Dry ice or liquid nitrogen sealed in bottles
    - Generation and/or expansion of gases or ignition of flammable vapours in sealed vessels.
  - **Reactions that produce deliberate pyrotechnic** e.g. thermal decomposition of nitrates excluding small scale flame tests **or smoke bomb effects** e.g. spontaneous redox reactions; the ammonium dichromate volcano; 'cannon fire'.
  - Dry-ice propelled film canisters (or other such containers) are not to be used. Containers propelled by dry ice require handling of the ice and produce variable results based on the size of the ice used and the strength of the lid seal. As such, they may launch before all the ice sublimates. This risk spraying pieces of dry ice over participants.
  - Film canister (weak acid-base) rockets are permitted as launch predictability can be managed through the use of known reagent volumes.
- The production of explosive products (<100g; e.g. touch powder) is not prohibited under the Act. However, it is very strongly discouraged as the potential for serious injury is likely given the highly unstable nature of the product. Residues, storage and disposal also present serious risks.
- Demonstrations of **combustion reactions** (e.g. H_2, O_2 gas combustion) are permitted as long as they demonstrate combustion, not explosion; otherwise they will fall within the explosives definition of the *Explosives Act 1999* (Qld). Staff are to carefully consider this distinction before proceeding.
  - The 'cornflour bomb' or dust explosion in a tin has been used to show the effect of surface area on the rate of chemical reaction. The rapid combustion of the cornflour (or any similarly finely divided product) causes an explosion and blows the lid off the tin resulting in a fireball and a projectile (lid). This style of activity is not permitted.
  - Ignition of flammable vapour in containers to launch a cork or other projectile is not permitted.
  - Hydrogen and oxygen gas combustion is permitted in small volumes.
  - Water propelled, air burst and hydrogen bottle rockets are permitted. The legislation does not cover these types of rocket propulsion; only solid fuel rocket motors. However, as with all activities, the educational value of the activity must outweigh the risk associated with the activity before it is permitted.
- Demonstrations of highly exothermic reactions (e.g. thermite redox reaction) are permitted by experienced staff only; however, the volume of reactants is to be restricted to the lowest practicable amount. This will control the intensity and duration of the reaction so as to minimise any sustained pyrotechnic effect, spitting, fuming or splashing resulting from ejection of products from the reaction vessel. Do not deviate from the requirements of standardised experimental procedure.
- Alkali metal in water reactions are permitted at small scale only. Metal pieces are not to exceed 4mm x 4 mm x 4mm in size and only one piece is to be used at a time.

Using alternative teaching resources including online video resources in lieu of these activities is encouraged; however, safety is often not a prime consideration for those performing the activity. Careful screening of resources, combined with appropriately guided pre-and post-activity discussions will assist to discourage hazardous experimentation by students, and help to prevent injury should they be undertaken outside the school environment.