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The Buncefield Accident and the Environmental Consequences for Fuel Storage Sites and other Sites in the UK, Regulated under the Seveso Directive

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In December 2005 there was a major explosion and fire at the Buncefield fuel storage depot, located about 25 kms north of London. Fortunately nobody was killed but over 40 people were injured and there was extensive damage to property. Some of the tank bunds failed during the fire leading to the release of fuel and fire-fighting foam which caused pollution of the soil and groundwater. Buncefield was an upper tier establishment under the UK Control of Major Accident Hazards (COMAH) Regulations, which implement the requirements of the Seveso II directive. The pollution of groundwater exceeded the threshold for reporting the environmental impact to the European Union.
In the seven years since the Buncefield accident, the COMAH Competent Authority (CA) comprising the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA) and the Health and Safety Executive (HSE) has worked with the UK fuel storage industry to implement the lessons learned. This paper describes the accident and the progress that has been made, including:

- The causes of the Buncefield accident and details of the subsequent prosecution;
- The environmental consequences including the continuing remediation of groundwater;
- The work done to develop a containment policy that defines the standards for upgrading fuel storage sites and the use of semi-quantitative risk analysis to assess the environmental risks;
- The progress that has been made implementing the containment policy;
- The actions taken by the CA to improve its performance as a regulator under the Seveso directive;
- Accidents at warehouses that have raised similar concerns about fire water containment.

By the end of 2011, all of the fuel storage sites had an action plan, agreed with the regulators, for improving their containment to meet the standards set in the containment policy. The oil refineries are expected to have similar plans in place by 2013. These actions will take up to 15 y to complete.

1. The Buncefield accident and the environmental consequences

1.1 Causes and environmental consequences

The accident on 11th December 2005 was caused by the failure of a level gauge during the filling of a petrol storage tank, which resulted in petrol overflowing from the roof of the tank into the bund. The weather was calm which allowed a large vapour cloud to form and 40 min later there was a massive vapour cloud explosion (VCE) followed by a fire involving over 20 tanks in 7 separate bunds. The fire burned for four days and the fire service applied 68 million L of water and 786,000 L of foam concentrate containing perfluorooctane sulphonate (PFOS) which is bio-accumulative, persistent and toxic. Several of the concrete bunds failed during the fire, releasing fuel and fire water that flowed off-site. About 33 million L of fire water were recovered after the fire and the rest soaked into the ground, polluting the soil and groundwater. The explosion and fire destroyed most of the fuel storage site as well as industrial and domestic properties off-site, including a major office block. Although over 40 people were injured there

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were no deaths, largely because the accident happened early on a Sunday morning when there were very few people in the area.

The fire was investigated by a joint team of Inspectors from the HSE and EA. Five companies were prosecuted and found guilty in July 2010 with fines and costs exceeding £9.5 m (€10.7 m). The economic cost of the accident has been estimated at around £1 bn (€1.1 bn). A report describing the causes of the accident is available on the HSE website (COMAH CA 2011).

The pollution of groundwater in the chalk aquifer below the site exceeded the 1 hectare threshold for reporting the environmental impact to the European Union under the Seveso directive. The aquifer is used for drinking water supply and a public water supply borehole 3 kms from the site had to be closed down. The polluted groundwater is now being pumped out through several boreholes and treated to remove fuel and PFOS. This remediation work is costing £1 m (€ 1.1 m) a year and will have to continue for many years.

Figure 1. Buncefield, Aerial picture of fire and smoke plume (Photographed by Chiltern Air Support Unit)

1.2 The lessons learned

The UK Government set up a Major Incident investigation Board (MIIB) which produced several reports on the causes of the accident and made a series of recommendations about the future operation and regulation of fuel storage sites in the UK (MIIB, 2008).

We described the immediate environmental consequences of the Buncefield accident and the lessons learned in a previous paper (Whitfield and Nicholas, 2008). In this paper we are focussing on how those lessons have been implemented. Buncefield is a typical UK fuel storage site, built in the 1950s and 1960s so the lessons learned from the accident are directly applicable across most of the UK fuel storage industry. The issues of particular relevance to environmental protection are:

– The accident scenario used by operators in their COMAH safety reports was usually a single tank fire. Buncefield showed that a multiple tank, multiple bund fire was a realistic "worst case" scenario. Operators had therefore failed to assess the large volumes of fuel and fire water that would have to be managed during a major accident;
- Operators did not recognise that tank bunds are safety critical items of equipment. Many bunds were not designed, built or maintained to the standards considered as good practice at the time of the accident. The presence of pipework penetrations and lack of fire resistant bund joints meant that many bunds would fail during a prolonged fire;

- Operators failed to identify the pathways by which fuel and contaminated fire water could reach sensitive environmental receptors such as rivers and groundwater. Very few sites had a tertiary containment system that could keep fire water on the site in the event of a bund failure.

2. Setting the containment standards for fuel storage

2.1 The regulators and industry working together

The CA and industry formed the Buncefield Standards Task Group (BSTG), to develop practical solutions that would implement the recommendations of the MIIB. One of the early outcomes was an agreed list of "quick wins". These were simple measures to reduce the consequences of a major fire, for example ensuring that bund joints and pipework penetrations were sealed with modern waterproof and fire proof sealants and joints were protected by metal plates. Most operators responded by installing the "quick wins" quickly but the CA had to issue COMAH improvement notices against one operator (an American owned multinational oil company with several UK sites) to make them to comply. The BSTG was superseded by the Process Safety Leadership Group (PSLG) which continued the collaboration between the regulators and industry. The PSLG final report, (UK HSE, 2009) provides detailed guidance on the technical and managerial measures necessary to control the risks of operating fuel terminals.

2.2 The containment policy

The CA reviewed more than 100 sites where a Buncefield type accident could occur and identified that a significant number of them would need to carry out work to bring their containment systems up to modern standards (COMAH CA, 2007). In June 2007 the CA consulted on a draft containment policy that proposed standards for upgrading existing sites, including:

- Primary containment, to prevent tanks being overfilled, such as installing high integrity overfill protection systems with independent high-high level alarms and automatic shut-off for valves or pumps;
- Secondary containment to be provided by impermeable bunds. This would necessitate lifting the walls of some large tanks to allow the installation of impermeable membranes and new tank bases;
- Tertiary containment systems capable of storing fire water on site in the event of a major fire that might include a complete bund failure.

The CA identified that the containment policy would apply to 95 COMAH fuel storage sites, containing 2,200 tanks, of which 690 tanks contained petrol or similar highly volatile hydrocarbons. It was assumed that all of the petrol tanks and 10-25 % of the other tanks would require upgrading to improve primary containment at a cost of around £500,000 (€560,000) per tank. Also about 600 tanks would require upgrading to improve secondary containment at a cost of around £720,000 (€810,000) per tank. The total cost of the policy was estimated to be £650-950 m (€ 730-1,070 m) spread over the 20 years it would take to complete the work. The containment policy was published in February 2008 (COMAH CA, 2008)

2.3 Reducing the risk of tank overfill

The highest priority for the protection of people and the environment was to reduce the likelihood of similar tank overfills that might lead to a VCE. Industry agreed with the CA that high integrity overfill protection systems should be fitted to petrol storage tanks, to achieve at least a Safety Integrity Level 1 (SIL1) level of protection. The functional safety standard BSEN 61511 (2004), combined with general risk assessment principles as detailed in the ISO 31000 (2009) risk management series was used to carry out risk assessments on loss of primary containment to determine if SIL 2 or further layers of protection were required, as described by Fanelli (2012). In many cases the risks from overfill leading to a VCE are dominated by risks to people, and ensuring these are acceptable has driven SIL determination. In some cases, where there are more sensitive environmental settings and fewer people are present the site environmental risk has dominated the SIL determination. In most cases, SIL2 overfill protection has been or is being fitted to petrol storage tanks.

2.4 Reducing the risk to the environment

The risks of a Major Accident to the Environment (MATTE), was considered by the UK Government when the COMAH regulations were introduced (DETR 1998). The proposed criteria for determining environmental tolerability took a similar approach to the UK HSE principles that risks should be reduced to As Low As Reasonably Practicable (ALARP). This methodology identifies three tolerability areas: Intolerable; Tolerable if ALARP (TifALARP) and Broadly Acceptable, representing the risk posed to an individual environmental receptor from the whole establishment. These risk criteria made many assumptions and related only to the aquatic environment. The CA is currently working with industry to develop a revised set of environmental risk criteria and is due to complete this work in 2013.

A new development during the risk assessment process was the extent to which environmental risk was included in the SIL determination. The assessments considered the probability of failure of mitigation measures such as secondary and tertiary containment especially during large scale and prolonged fires. For example the risk of a MATTE from Figure 2 is (a) + (b) = 1.4 x 10^{-4} incidents y^{-1} for a single tank. This can be reduced by reducing the frequency of a tank overfill (failure of primary containment) or by installing other risk reduction measures such as tertiary containment. Figure 2 uses a frequency of tank overfill of 2 x 10^{-3} incidents y^{-1} which is a typical value for a tank without a safety instrumented system (SIS). Upgrading the tank by installing an overfill protection system to achieve SIL 1 would reduce the frequency of overfill by a factor of 0.03 giving a MATTE frequency of 4.2 x 10^{-6} incidents y^{-1} which might be regarded as being TifALARP. Upgrading the tank by installing an overfill protection system to achieve SIL 2 would reduce the frequency of overfill by a factor of 0.003 giving a MATTE frequency of 4.2 x 10^{-7} incidents y^{-1} which might be regarded as being broadly acceptable. One issue this process has highlighted is the lack of generally agreed tolerability criteria for the environment, and in particular whether the tolerability thresholds apply to the consequences of individual hazardous events or the sum of all the scenarios that might affect the whole establishment.

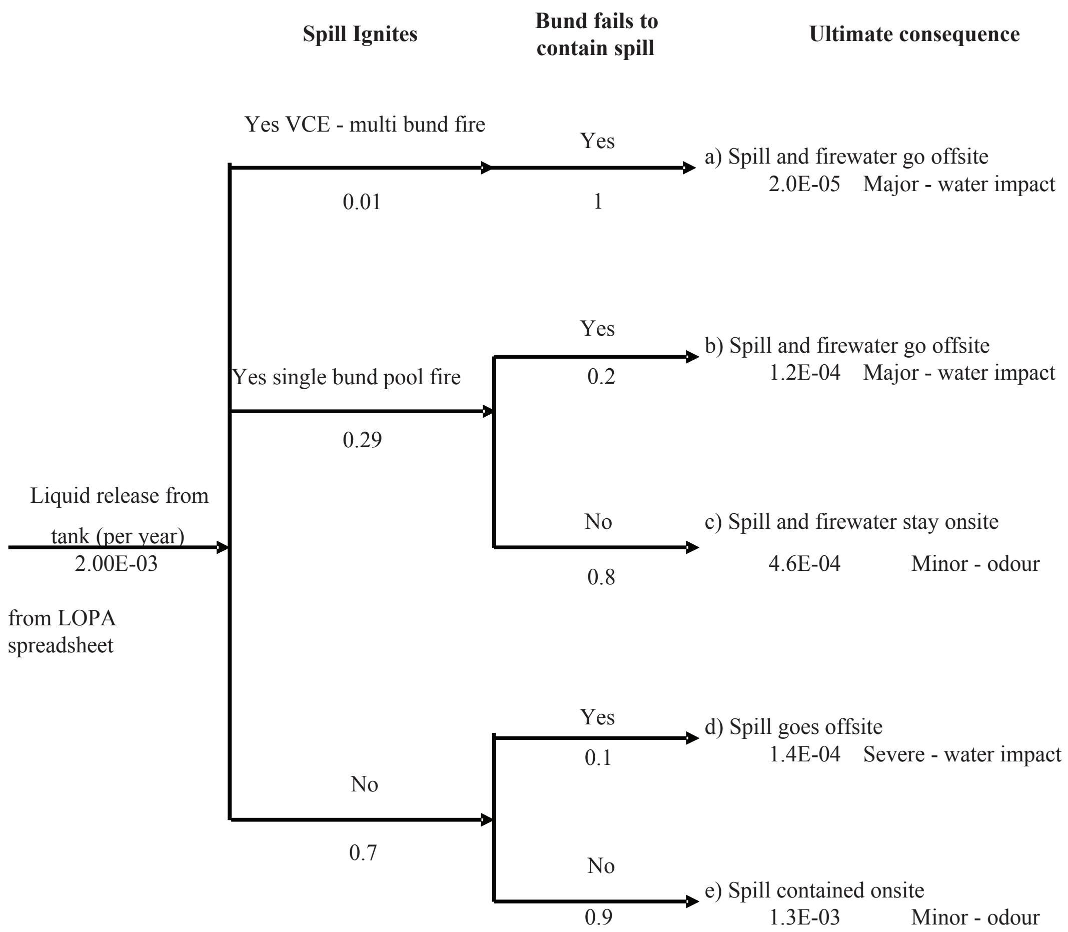

Figure 2.Event tree including probabilities, for the failure of secondary containment following a petrol tank overfill, on a tank without an overfill protection system on a site without tertiary containment

3. Implementing the containment standards for fuel storage

3.1 Implementation at fuel storage sites

By mid-2011 there were still eight fuel terminal operators who had not assessed their sites and submitted containment policy improvement plans to the CA. They were given several months to comply or face enforcement action. Eventually by the end of 2011 only one operator (an American owned multinational oil company with several UK sites) had failed to submit a plan, so the CA issued COMAH improvement notices to ensure that the work was completed. The slow progress by a small number of operators was regrettable considering how many operators had already started work on their improvement plans.

3.2 Implementation at oil refineries

Some of the UK oil refinery operators have argued that they need more time to carry out detailed site specific risk assessments to determine what improvements are necessary. They have been given until the end of 2012 to submit their plans to the CA. Refineries have encountered several significant problems with the containment policy, including:

- For primary containment, the cost of installing high integrity overfill protection systems is very high because there are multiple tank filling pipeline routes, each of which requires a large and expensive Remote Operated Shut-Off Valve (ROSOV). By contrast a typical fuel storage site only has 2 or 3 feed pipelines so only requires 2 or 3 ROSOVs;
- For secondary and tertiary containment, the semi-quantitative method shown in Figure 2 generally gives a broadly acceptable risk for the consequences of a single tank overfill that might lead to a fire and bund failure, provided that a safety instrumented system for tank overfill protection and additional measures such as tertiary containment are installed. However, on a site with hundreds of tanks the risk posed by the whole establishment may be hundreds of times higher and additional measures may need to be taken to avoid the risk being regarded as intolerable.

4. Actions taken by the regulators to improve their performance

The MIIB (2008) report recommended a number of improvements to the CA so that it would be more effective as the Seveso directive regulator. The CA carried out a review of its operations in 2007-08 to take account of the MIIB recommendations and the COMAH regulatory experience it had gained over the previous nine years. The outcome of the review was known as “COMAH remodelling” and the changes were brought into effect in April 2008. These included:

– The assessment of COMAH safety reports was too slow, with the CA making repeated requests for further information so many assessments took over a year to complete. A new procedure was introduced to complete assessments in less than a year and deal with any residual issues as part of site inspections;
– The EA had more than 100 Inspectors who were carrying out IPPC and Seveso directive inspections. Consequently each Inspector was spending about 5 % of their time dealing with Seveso issues and this was too little to maintain their expertise. The solution was to reduce the number of Seveso Inspectors to about 20 experts with each spending about 40 % of their time on Seveso work. Reducing the number of Seveso Inspectors has the additional benefit that it is practicable for them to meet several times a year with head office staff to review implementation issues, exchange ideas and receive training etc.;
– The CA introduced a system of strategic priority topics for inspections. The system is intelligence led with the Site Inspectors identifying problems that are analysed by head office staff, discussed with industry and become the basis for setting inspection priorities. The CA issues guidance on each topic and the inspection programme typically lasts about two years with every upper tier site being inspected and assessed. The Buncefield accident led to the development of loss of containment (primary, secondary and tertiary) as a priority topic on all COMAH sites, not just fuel storage sites handling petrol. Other priority topics have been: ageing plant; management systems and emergency plans. Strategic priority topics allow Inspectors to carry out in-depth inspections and the system has been well received by the site operators.

5. Accidents at other sites involving containment issues

Many of the environmental protection issues highlighted by the Buncefield accident are not unique to fuel storage sites. In recent years the UK has seen a number of serious fires at manufacturing and distribution installations, with COMAH warehouses being of particular concern. In some cases the fire has resulted in firewater runoff entering watercourses and causing serious harm. This issue is not unique to the UK – the

European Environment Agency (2010) reviewed a decade of industrial major accident data and concluded that the main threat to ecosystems is contaminated firewater, which may pollute surface water or groundwater.

Fire at Biolab, Andoversford 2006

Biolab operated a factory and warehouse, packing and storing swimming pool and water treatment chemicals. These were classified as oxidizing and dangerous to the environment (R50 very toxic to aquatic organisms) making it a COMAH lower tier establishment.

The fire on 6th September 2006 started in the production area when a 1,000 kg bag of sodium dichloroisocyanurate dihydrate was being emptied by a screw conveyor into hoppers on the upper floor. The equipment had been running for about an hour when smoke was seen rising from the auger tube of the screw conveyor. The fire alarm was raised and the factory unit was evacuated immediately without incident. As the Fire Service arrived on site the white smoke changed colour, followed very quickly by a fireball 20 metres high. The fire was contained within the factory building which was completely destroyed and chemicals were released following the rupture of Intermediate Bulk Containers (IBCs). Fire water (with a pH of 1) entered the River Colne and more than 2,500 fish were killed over a 6 km stretch of the river. The EA estimated that the river will take four to seven years to return to pre-incident condition. There was an almost total loss of the chemical inventory and the accident was reportable to the European Union because of the loss of inventory exceeded 5 % of the upper tier threshold.

The fire appears to have started inside the polypropylene tube of the conveyor, probably due to the mechanical heating of the sodium dichloroisocyanurate dihydrate and the fire escalated when the chemical reached its thermal decomposition temperature. The lessons learned from the accident included:

- The UN classification of the sodium dichloroisocyanurate dihydrate as an oxidizer does not appear to give an accurate description of the reactive nature of the chemical and possible hazardous conditions. If it were classified as a self-reactive it would be limited to transport in packages of 50 kg or under, rather than be available, as it is, in 1000 kg 'big bags'.
- Mitigation measures to prevent the run-off into watercourses appear to have been inadequate. The operator was unaware of the full layout of the drainage system and how their inventory could get into the watercourse;

Biolab was prosecuted by the CA in 2010 and fined £66,000 (€ 74,000). The factory is now closed and chemicals are no longer stored on the site.

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