

IDENTIFYING AREAS IN WHICH ENVIRONMENTAL IMPROVEMENTS CAN CONFLICT WITH SAFETY REQUIREMENTS FOR CHEMICAL PLANT DESIGN AND OPERATION

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The 1990's has seen a massive increase in environmental awareness in society as a whole and in the chemical industry in particular. New legislation and internal policy requirements have encouraged companies to invest heavily in new processes, technologies and working practices which remove or minimise environmental impacts. Plant designers and operators must, however, still ensure that any measures taken to improve environmental performance do not cause unforeseen safety problems. This paper identifies areas where safety and environmental considerations may conflict and suggests methods to avoid conflicts where this is possible. Areas where compromises have to be made are also highlighted.

Keywords: environment, safety, fire.

1. INTRODUCTION

The tree collapsed onto the tank farm and breached the tank containment. The energy of the impact led to ignition of the highly flammable contents and the resulting fire caused extensive damage and environmental pollution. At the incident investigation, managers started to ask why this hazard had not been detected and removed. 'We had to plant the trees to shield the tank farm from the local housing estate because the local council were worried about the visual impact of the tank farm. The trees were only small when we planted them and nobody noticed that they'd grown so rapidly' came the reply.

An operator fell from the cat ladder while he was taking air emission samples from the scrubber outlet. This happened in the early hours of Sunday morning when the plant was de-manned. He wasn't found for several hours, by which time his injuries had worsened. The resulting injuries forced him to take early retirement due to ill health. The company had been legally obliged to undertake 24 hour monitoring but nobody had questioned the risks that this had created for the staff who had to collect the samples.

The reaction started to get a bit feisty. Procedures had not been followed and two doses of reactant had been added in error. The internal temperature started to rise uncontrollably and then the relief system operated. 'I'm glad we upgraded the pressure relief system to that new standard' thought the plant manager. Little did he know, but his problems were only just beginning. Although the relief system had protected the plant successfully, it had created another equally serious problem. Large quantities of toxic odorous vapour had been released and had formed a toxic cloud which was drifting towards the nearby old people's home. The residents all had to be evacuated causing great personal distress and resulting in three people being kept in hospital for observation. After the accident, the local people lost faith in the ability of the company to operate safely and cleanly.

All of these incidents are fictional but could clearly happen if operating companies and Regulatory Authorities fail to take a holistic view when balancing safety, health and environment (SHE) priorities. Most plant designs and operating philosophies require balances to be made between the conflicting constraints of major hazard safety, operational safety, environmental impact, health impact and asset protection requirements. Any compromises which are made have to be carefully thought out and must be justifiable. Reasonable efforts need to be made to remove hazards and impacts using inherent SHE principles before final decisions are made. This paper identifies some key areas where safety and environmental requirements are in conflict, proposing techniques for minimising these conflicts where this is practicable. It could be used as an input to a lifecycle project review process but may need further development to suit the needs of particular industries.

2. CATEGORIES OF SAFETY AND ENVIRONMENTAL CONFLICTS

The following four broad categories of conflict have been identified :

(i) environmental improvements which reduce day-to-day environmental impacts but increase major accident hazard safety risks.

(ii) environmental regulatory requirements which could increase major accident hazard safety risks.

(iii) environmental improvements which reduce day-to-day environmental impacts but increase operational safety risks.

(iv) safety features which cause environmental impacts.

3. ENVIRONMENTAL IMPROVEMENTS WHICH INCREASE MAJOR ACCIDENT HAZARD SAFETY RISKS

3.1 PROCESSS CONTROL

Plant automation can significantly improve process performance, maintaining key parameters within their design limits. This, in turn, should minimise environmental impacts from the plant. If the automation system is not carefully planned, serious safety issues may arise. Operators may spend less time on the plant and would then be less likely to detect process problems using their judgement. It may not be possible to fully automate all plant operations such as sampling, catalyst addition, initiator addition and waste disposal, making it difficult to achieve clear and managed control. This in turn could lead to human error.

An automated plant is also subject to complex common mode failures caused by system designers, software engineers, production operators, software bugs and hardware errors. It is essential that a structured approach such as draft international standard IEC61508 (IEC, 1998) is followed to manage the automated plant throughout it's lifecycle. This will ensure that critical safety functions are identified and are robust.

It is also possible to over-automate plants, making them unnecessarily complex. Each new instrument will create a potential leak source. If hazardous chemicals are being handled, a balance has to made between the need for process information and the increased leak frequency that will result.

3.2 CLEANING EQUIPMENT

A lot of water is undoubtedly wasted on many chemical plants through vessel washing. This can create large volumes of liquid effluent. Water usage can be optimised to minimise water usage and hence minimise resource consumption and environmental impact. It is, however essential that :

(i) potentially reactive residues are completely cleaned from vessels to avoid the risk of subsequent thermal runaways.

(ii) vessels are completely cleaned of chemicals which may be incompatible with materials which are subsequently added to the vessel.

(iii) any cleaning agents do not have the potential to cause temperature rises in vessels or fires inside vessels.

3.3 ABATEMENT SYSTEMS

End-of-pipe abatement systems are being installed on many older plants because they represent the only practical means of meeting new environmental air quality standards. They can, however, introduce or increase fire risks on plants which are connected to the abatement systems.

3.3.1 SOURCES OF IGNITION

Incinerators and flares act as a near continuous ignition source. They are normally sited in areas of the site where there is a low risk of a flammable atmosphere being present. Large uncontrolled flammable gas releases may still have the potential to drift over the ignition source from a distant release point to produce a Vapour Cloud Explosion (VCE).

3.3.2 FIRE HAZARDS

On a smaller scale, carbon bed absorbers have a tendency to overheat and catch fire if they are not managed and maintained properly. A fire could start in a carbon bed and spread to other vulnerable areas.

3.3.3 MECHANISMS FOR FIRE SPREAD

If flammable vapours are fed to the abatement system, internal fire risks are normally controlled by a combination of measures to ensure that gases are always outside their flammable range, inerting systems and control of ignition sources. None of these measures are foolproof and there will always be at least a small internal fire risk, particularly during plant upset or abnormal operating conditions. If several plants feed to a common abatement system via connected headers, there is a real risk of massive fire spread through the feed lines and back into plant vessels. A small upset in one plant may then have the potential to create a serious accident in connected plants. Designs using flame and explosion arrestors can minimise the risk of internal fire spread but this fire risk should never be overlooked when specifying or designing common vent abatement systems.

3.4 CONTAINMENT

Secondary containment systems using bund walls are installed around many chemical tanks and vessels to prevent uncontrolled chemical spills which could affect the adjacent environment and to limit the pool size and consequences of any accidental chemical releases,

If bund containment systems are not carefully designed, they can increase the following safety risks :

(i) high bund walls, especially around equipment which has a high frequency of small leaks, can lead to flammable vapour accumulation inside the bund. The vapours cannot disperse efficiently and could create a flash fire or weak explosion if ignition occurred.

(ii) tank farms are sometimes split into a number of individual bunded areas. These bunded areas are sometimes linked using preferential spillways to maximise containment capacity for worst case events. If the tank farm handles flammable materials and tanks which are vulnerable to BLEVEs (Boiling Liquid Expanding Vapour Explosion) or violent explosions when subjected to fire attack, such systems could significantly increase tank farm fire risks if they are not carefully designed.

(iii) if plant areas are fitted with excessive bund walls to minimise spill areas, it will be difficult for operators and maintenance staff to safely access bund areas and carry equipment into them.

Some plants and storage areas could be equipped with containment systems which do not rely on bund walls. The ground could be sloped to a catch pit or the area could be surrounded by drains which feed to a catch pit. The disadvantage of these design options is that large pools would develop if spills overflowed the drains or the catch pit was full. They are also often impractical for existing plants.

3.5 EMERGENCY RESPONSE PRIORITIES

In fire situations, response teams are faced with the conflicting priorities of trying to safeguard human life, property and the environment. The last two objectives may not always be compatible. Property damage will be minimised by using large volumes of fire fighting water and foam. This then creates an aquatic environmental impact from the subsequent firewater run-off. Consideration must now be given to adopting a ‘let it burn’ philosophy where the impacts of firewater run-off would be severe. In essence, the asset is deliberately sacrificed to minimise the amount of applied firewater that is used. The air pollution from the fire is tolerated because it is considered to be less environmentally damaging than the water pollution from the firewater run-off.

The best way of managing this problem is to minimise the fire frequency by carrying out fire risk assessments for vulnerable areas and ensuring that appropriate fire prevention and protection systems are installed in these vulnerable areas.

3.6 NOISE ATTENUATION

Some industrial equipment, such as compressors serving gas fired power stations, is inherently noisy. Noise can be attenuated by enclosing the structures housing the power plant with sheeting. This creates a confined volume around equipment which contains highly flammable gases. Small leaks may not disperse due to the still conditions within the enclosure. Gas accumulations could then occur. Ignition of this gas cloud could lead to a flash fire or a Vapour Cloud Explosion (VCE). This would be a serious event.

The plant designer has to strike a balance between the basis of safety for the plant and the need to minimise noise pollution from the plant. This is normally achieved by taking all reasonable measures to reduce noise at source by equipment design and selection and by locating noisy equipment in areas which produce the lowest offsite noise impacts. If the equipment is enclosed, it may be necessary to install some combination of high reliability gas detection systems inside the enclosure, forced ventilation systems, fast action emergency shutdown systems and explosion relief systems.

3.7 VISUAL IMPACT MINIMISATION

Chemical plants can be visually intrusive, dominating local landscapes. This is caused by a combination of the size and shape of buildings and structures, the height of structures and plumes from stacks and other release points. The highest structures are normally discharge stacks. The higher the stack, the more efficiently the emitted vapours will disperse. Vapours will be emitted during normal operation, foreseeable upsets conditions (such as start-up and shutdown) and emergency situations. Poor dispersion could cause offsite toxic major hazard impacts during emergency situations. A balance therefore has to be made between the need for minimising visual impacts and obtaining efficient dispersion from the stack.

3.8 PROMOTING LOCAL ECOLOGY

Encouraging wildlife to inhabit areas around chemical sites can help to protect local ecological systems. Animals can, however, cause damage to vulnerable equipment by burrowing underground and undermining the stability of foundations and by gnawing through cables. The resulting damage could lead to a serious accident if the foundations for critical equipment subsided or if the cables formed part of a safety system. Care should therefore be taken in establishing wildlife areas close to vulnerable plant and equipment.

Table 1 summarises the environmental improvements which could increase major hazard risks.

Table 1 Environmental Improvements And Major Hazard Risks.

Ref	Issue	Cause	Potential Problems	Risk Reduction Options
3.1	PROCESS AUTOMATION	Operators not on plant.	Failure to detect incidents.	Regular plant inspections.
		Partial automation excludes some tasks.	Operator confusion.	Consider human factors when defining control philosophy.
		Common mode failure.	Plant fails to a dangerous state.	Use standard for plant automation.
		Over-instrumentation.	Increase leak frequency.	Optimise instrumentation at design stage.
3.2	EQUIPMENT CLEANING	Residues left in vessel.	Runaway reaction.	Optimise cleaning procedures.
		Fire caused by cleaning agents..	Fire spread.	Risk assessment of materials before use.
3.3	ABATEMENT SYSTEM FIRES	Flares and incinerators act as ignition sources.	Vapour Cloud Explosion (VCE) or flash fire.	Careful location of plant in low risk areas.
		Fires in carbon bed absorbers.	Fire spread.	Regular maintenance and good management.
		Common vents.	Fire spread.	Avoid or design carefully.
3.4	CONTAINMENT	High bund walls.	Fire or explosion following ignition.	Avoid high walls in vulnerable areas.
		Connected bund overflows.	BLEVE or explosion.	Direct overflows away from high risk tanks.
		Excessive bund walls.	Operator injury.	Design bunds for safe access.
3.5	EMERGENCY RESPONSE	Environmental threat outweighs asset value.	Asset damage and fire spread.	Fire risk assessment. Fire prevention and protection measures.
3.6	NOISE ATTENUATION	Shielding creates a confined space.	VCE.	Noise reduction at source. Equipment location. Safety systems for VCE..
3.7	VISUAL IMPACT	Emission stacks.	Toxic release.	Minimise plant upsets.
3.8	ECOLOGY	Damage to cables and foundations.	Loss-of-containment.	Discourage wildlife close to vulnerable areas.

4. ENVIRONMENTAL REGULATORY REQUIREMENTS WHICH COULD INCREASE MAJOR ACCIDENT HAZARD SAFETY RISKS

4.1 LANDSCAPING

Chemical plants often tend to dominate local landscapes because of the height, shape, size and colour of their constituent buildings. Visual intrusion can be softened and minimised by careful plant layout and by landscaping around the plant perimeter. Older plants will often be constrained by historic layout decisions. Local planning authorities will therefore often stipulate that landscaping features should be included as a condition of granting planning permission for developments.

Whereas the objective of these conditions is sound, great care needs to be taken in implementing them to avoid the following major accident hazard risks :

(i) small trees are planted but they grow over the years to reach a considerable height. A tree collapses and falls onto vulnerable process equipment, leading to a loss-of-containment (LOC) incident with potentially serious consequences.

(ii) small tress grow to become taller than adjacent plant structures. The tree is hit by lightning and causes a fire which spreads to affect adjacent process areas.

(iii) trees grow and their root systems undermine the foundations of adjacent structures or affect the soil stability (by altering the soil moisture content) causing critical equipment to subside with the risk of LOC.

(iv) vegetation grows by the site boundary and is ignited by people on the other side of the site boundary, which is outside the control of the operating company. The fire or embers from the fire cause the fire to spread to affect equipment which contains chemicals.

(v) earth mounding is unstable and washes onto plant areas during a heavy rainstorm, damaging transfer pipes and causing a LOC incident.

(vi) leaves from trees block critical plant containment drains or accumulate on site roadways leading to a vehicle skid and a potential LOC incident.

These hazards are often not identified because they occur as an afterthought to the original plant design and are imposed by a third party, the Local Planning Authority (LPA). The operating company often incorrectly assumes that the LPA has fully understood the short and long term consequences of the planning conditions and fails to challenge them.

Risks are best managed by minimising the visual impact of the plant at the design layout stage of the project (if this is possible), ensuring that any design features comply with appropriate design standards and good practice (such as soil stability and lightning protection), treating vegetation as a hazard and ensuring that the landscaping complies with the standards for separation distances which are being used for the project. Trees may need to be reduced in height by pruning at regular intervals during the plant life cycle. Tree and shrub species can be specially selected to minimise tree heights, length of root systems and foliage loss in autumn.

4.2 PUBLIC ACCESS TO ENVIRONMENTAL INFORMATION

There is an increasing trend towards open government. Information which used to be treated as being confidential to operating companies and Regulatory Authorities must now be filed on public registers and may ultimately be posted on the internet. This measure does achieve the objective of obtaining greater public scrutiny of company performance but is based on the premise that public scrutiny will be benign and not malicious.

Problems may arise when this philosophy is applied to installations which have major accident hazard potential. Major accidents are thankfully relatively rare in the United Kingdom (UK) chemical industry. Published guidance on risk tolerabilty (HSE, 1992) suggests that risks will be considered to be As Low As Reasonably Practicable (ALARP) if they are within the range of 10^{-6} to 10^{-4} per year and will be considered to be broadly acceptable if they are lower than 10^{-6} per year. These risks are currently believed to be dominated by technological and management system failures. Many plants are vulnerable to sabotage - a risk which is very difficult to control.

Under recent legislation such as COMAH (COMAH, 1999), many of the UK's highest risk chemical plants will now have to provide information about their most vulnerable operations. Used maliciously, this information could serve as a route map of how to create a major accident. In the past, the industry has not published information in this format, making it harder for individuals or organisations to identify plant vulnerabilities. Malicious use could be associated with mentally unstable individuals or with terrorist organisations. Credible terrorist threats still exist in many European countries, including the UK. Whereas terrorist threats may be regarded as an issue which is relevant to national security, other causes of sabotage could still lead to extremely serious accidents involving flammable, explosive or toxic chemicals with unpleasant local impacts on people and the environment.

Great care is therefore required when publishing information about the UK's most hazardous installations. If sufficient care is not taken, there is a real risk that sabotage may become a dominant cause of major accidents in the chemical industry. Risks attributable to technological causes and management system failures can be managed to ensure that they are extremely low. One accident in a major hazard facility which was aided or caused by publishing sensitive information in the public domain could significantly alter the risk profile of the industry, promoting sabotage to one of the dominant risks.

It is, however, important that operating companies act responsibly and do not use secrecy as an excuse for operating plants which have major accident hazard risks without fully exploring opportunities to develop inherently safer products and processes.

Table 2 summarises the environmental regulatory requirements which could increase major hazard risks.

Table 2 Environmental Regulatory Requirements And Major Hazard Risks.

Ref	Issue	Cause	Potential Problems	Risk Reduction Options
4.1	LANDSCAPING	Tree collapse.	Loss-of-containment (LOC).	Remove trees which could fall on plant.
		Lightning strike on tree.	Fire.	Remove trees which are too close to plant.
		Roots undermine foundations.	LOC.	Selection of plant species.
		Scrub fire.	Fire spread.	Compliance with separation distances.
		Mound collapse.	LOC.	Stabilise mounds.
		Drains blocked or vehicles skid due to leaves.	LOC.	Selection of plant species.
4.2	PUBLIC INFORMATION	Malicious use of information.	Major accident.	Careful disclosure of information.

5. ENVIRONMENTAL IMPROVEMENTS WHICH INCREASE OPERATIONAL SAFETY RISKS

5.1 TALL STRUCTURES

End-of-pipe air emission abatement systems generally have to be located at a greater height than surrounding plant and buildings to ensure that any released vapours are effectively dispersed in the environment. Access is required to these structures during installation, for maintenance and to take or verify environmental emission data.

Operators must therefore work at heights when carrying out these operations. There are risks associated with the sampling procedure, falling down or off ladders and becoming stranded in an isolated plant area if an incident occurred on another area of the plant. Risks are particularly high when the plant is de-manned, such as on weekend night shifts. It may take some time to detect accidents and there may be fewer personnel to man the site emergency crews. Even higher risks exist when sampling is carried out by external bodies and at short notice. They will not be familiar with the plant and may only receive a short local induction to the site.

These risks can be minimised by carefully considering operator access for construction, sampling and maintenance when the plant is laid out. This may be very difficult to achieve on older plants. The frequency of random external monitoring outside normal working hours should also be minimised if operational risk levels are to be minimised. Due to the nature of the monitoring requirements, this is not within the control of the operating company.

5.2 FIREWATER CONTAINMENT LAGOONS

Firewater run-off has the potential to cause major damage to the aquatic environment. Approaches to managing these risks have been published by the UK National Rivers Authority (now the Environment Agency) and the UK Health & Safety Executive (UK HSE) - (HSE, 1995 & NRA, 1994). Many solutions rely at least in part on using dedicated firewater run-off lagoons. These deep pits are normally empty and are used to contain any run-off in a dedicated area before it can reach vulnerable aquatic systems.

The lagoons are often in unpopulated areas of the site. People still need to visit the lagoons for visual inspections, monitoring and maintenance. If anybody fell into a lagoon, they could injure themselves in the fall, be exposed to polluted water or even drown. The accident may not be detected quickly and there may be a lack of alarm buttons in the immediate area for summoning emergency assistance. These lagoons therefore need to be protected as a confined space and facilities must be provided to allow operators to exit the lagoon if they did fall in and to summon emergency assistance.

5.3 PLANT LIGHTING

There are two major environmental problems associated with chemical plant lighting systems : visual nuisance and energy consumption. Illuminating a chemical plant draws attention to the plant from a wide area during the hours of darkness causing the plant to dominate the local landscape. Lighting also uses electricity and increases the energy consumption of the plant. It may be tempting to remove lighting or install switches or sensors to optimise the lighting in plant areas which are rarely used. Care must be taken to ensure that operators are able to see clearly when they are working on plant and can find and use escape routes if rapid plant evacuation is required.

Table 3 summarises the environmental improvements which could increase operational safety risks.

Table 3 Environmental Improvements and Operational Safety Risks.

Ref	Issue	Cause	Potential Problems	Risk Reduction Options
5.1	TALL STRUCTURES	Operator falls during sampling operation.	Operator injury.	Minimise off-peak sampling. Design structures for safe access. Monitor operations.
5.2	FIREWATER LAGOONS	Operator falls into lagoon.	Operator injury.	Provide fencing, escape route and alarm call points.
5.3	PLANT LIGHTING	Poor lighting.	Operator injury.	Minimum lighting requirements met for occupied areas.

6. SAFETY IMPROVEMENTS WHICH CAUSE ENVIRONMENTAL IMPACTS

6.1 ASSURING PROTECTION SYSTEM RELIABILITY

A design standard such as draft international standard IEC61508, ' (IEC, 1998) is normally used for specifying and operating Safety Related Systems (SRS) on a chemical plant. Critical aspects of the system specification include reliability and test interval requirements. If a system is activated, an environmental emission may occur and / or system start-up may be required. The plant's environmental performance is often not optimal at start-up and shutdown. Abatement systems may be less efficient, additional waste streams may be created and additional emissions may be generated. To minimise the environmental impacts from the plant, the number of shutdowns and start-ups should therefore be minimised.

If the plant design was to be purely optimised for safety performance, the SRS's could be based on one-out-of-two (1oo2) or one-out-of-three (1oo3) voting logic using redundant instrumentation or controllers. This unfortunately produces a high spurious trip rate, causing the plant to shut down frequently with consequent operational and environmental impacts. Different SRS loop configurations, such as two-out-of-three (2-o-o3) voting logic, provide different balances between the need for high safety reliability and low spurious trip rates. Careful consideration therefore needs to be given to balancing the safety and environmental reliability requirements for each Safety Related System.

6.2 COMMISSIONING AND TESTING

The performance of Safety Related Systems can only be properly validated by system testing under conditions which mimic real plant conditions as closely as possible. If full testing is not performed, there will always be an element of uncertainty about whether the system will perform acceptably in a real situation.

The test and commissioning procedures often give rise to environmental impacts such as:

(i) Volatile Organic Compound (VOC) emissions during gas detection system tests using sample pots. The samples may also be odorous depending on the chemical which is being sampled.

(ii) Aqueous effluent generation during active fire protection system testing. If fixed water deluge systems are operated in a plant area, they will wash out any chemicals which have accumulated on plant floors or drip trays. As the rate of application of water is usually high, local effluent drains may be overwhelmed, leading to a risk of by-passing the local effluent systems and causing an aquatic environmental impact.

(iii) Foam generation when testing foam / water deluge or bund foam pouring active fire protection systems. Foam will enter the site effluent systems and may have an adverse impact on biological effluent treatment systems. This can lead to aquatic environmental impacts if the effluent streams are not carefully managed. Foam also has a tendency to aerate, particularly if wind speeds are high. The foam will then drift around the site and may affect offsite areas. Although environmental impacts are minimal, the foam will create a visual nuisance impact to neighbouring populations.

6.3 PRESSURE RELIEF

Pressure relief systems are designed to protect process equipment from under and overpressure effects in the event that automated or procedural process control systems fail, causing an upset condition to develop.

If they operate, chemical containment is lost where the upset occurred. Historically, many relief systems have been designed to relieve to a safe area which is normally outdoors. Upset conditions are assessed as being rare events and the consequent environmental impacts have been tolerated.

The extent of any environmental impacts will depend on the characteristics of the particular upset scenario but may be significant. Typical impacts may include releases of VOCs, ecotoxic vapours, odorous materials or highly toxic reaction by-products. The conditions giving rise to the impact may not always be rare events in practice.

It is therefore essential that the basis of design for pressure relief systems takes account of potential environmental impacts. This may involve a fundamental process change to remove the relief scenario, designs based on complete containment of the process upset using systems with higher pressure ratings, measures to provide additional containment facilities such as dump tanks and measures to minimise the frequency of relief scenarios such as improved process control systems.

6.4 MATERIALS

Some materials which are used in fire protection systems to improve plant safety are known to be or suspected of being harmful to the environment. In particular, halon systems are in wide use for protecting areas such as control rooms. These systems used to contain Chlorinated Fluorocarbons (CFC), materials which have a high Ozone Depletion Potential (ODP). Replacement materials which are less harmful to the environment have been developed but they still produce a residual environmental impact.

Flame retardants and fire fighting foam are also commonly used in fire protection systems. By-products from flame retardants are suspected of being contaminated with dioxins, a highly potent toxic material. Fire fighting foams are harmful to the aquatic environment due to their ecotoxic properties and their potential for causing discolouration of water courses.

These materials continue to be used because the benefits of their ability to prevent fires and minimise fire damage are considered to outweigh the problems associated with environmental damage during production, commissioning, testing, false alarms and real fire situations. It is important to remember that the environmental impacts of large industrial fires are often severe and significant air and water pollution damage can ensue.

Research efforts are currently focussed on identifying new materials which can provide an acceptable level of fire safety but which are less harmful to the environment.

6.5 EQUIPMENT MARKING
It is often important to clearly mark important safety systems on chemical plants. For example, escape routes are often highlighted using bright fluorescent paint. This creates a local impact for plant operators but inevitably creates a visual impact from offsite areas. The bright paint will often draw the viewer's attention to the plant, giving the chemical plant prominence in the local landscape. This is particularly true for escape routes which are at the top of tall plant structures.

6.6 SECURITY
Plant security systems often use Closed Circuit Television (CCTV) systems. Individual cameras must be located above vulnerable areas so that they provide adequate security coverage and avoid hazardous plant areas, where they could act as an ignition source.

Cameras which are located on buildings or existing structures normally have a negligible environmental impact but those which are located on standalone towers will affect views from offsite areas. Cameras are often positioned to cover the site boundaries, as these are high risk areas. Some visual environmental impacts will therefore be created by these cameras.

Table 4 summarises the safety systems which could cause environmental impacts.

Table 4 Safety Systems And Environmental Impacts.

Ref	Issue	Cause	Potential Problems	Risk Reduction Options
6.1	RELIABILITY ASSURANCE	High false trip rate.	Effluent emissions or waste generation.	Reliability optimisation.
6.2	COMMISSIONING AND TESTING	Tests use ecotoxic or odorous materials.	Effluent generation or offsite nuisance.	Optimise test programme to minimise impact.
6.3	PRESSURE RELIEF	Vent emission of ecotoxic material.	Offsite air pollution.	Full risk assessment covering all relief scenarios and ultimate impacts.
6.4	MATERIALS	Fire protection materials which are harmful to the environment.	Effluent generation or contribution to global environmental impacts.	Research into new materials.
6.5	EQUIPMENT MARKING	Visual impact of brightly painted structures.	Visual pollution.	Avoid or conceal tall structures where possible.
6.6	SECURITY	Visual impact of CCTV towers.	Visual pollution.	Use existing structures where possible.

7. CONCLUSIONS

This paper has identified a wide range of potential conflicts between environmental and safety requirements for chemical plant design and operation. These include issues associated with engineering design, control philosophies, operating practices, fire protection, spill containment, abatement systems, emergency response, landscaping and visual impact.

Many of these potential conflicts can be resolved by using a structured team based approach to plant design. Safety and environmental issues need to be identified early in the design process so that they can be properly addressed. A holistic view must be taken so that a balanced design is produced that satisfies all requirements: environmental, safety, health, major hazards and financial.

Careful application of the principles of inherent SHE through the plant’s life will help to remove or reduce many conflicts as will a careful and thorough examination of the full consequences of decisions which affect the plant. This should include consideration of how hazards may develop over time (such as when new landscaped areas are created).

All environmental issues need to be identified at an early stage in the concept design for the plant. These issues need to be assessed with the same rigorous approach that is used for addressing safety issues. The best plant designs are likely to occur when safety and environmental issues are treated together and with equal importance.

Operating companies must be particularly careful when assessing requirements that are imposed by Regulatory Authorities. These requirements may not always satisfactorily address safety and environmental issues in a holistic manner and may be overly focused on one individual legislative requirement. If these requirements are made late in the project design cycle (such as planning conditions from the Local Planning Authority), there is a particularly high risk that mistakes will be made.

An ideal plant would have no conflicts between safety and environmental priorities. Real plants will have conflicts. These conflicts need to be assessed and careful decisions need to be taken to avoid designing clean but dangerous plants or safe but dirty plants.

8. ACRONYMS

SHE	Safety, Health and Environment
LOC	Loss Of Containment
LPA	Local Planning Authority
UK HSE	UK Health & Safety Executive
UK	United Kingdom
IEC61508	Draft international standard IEC61508.
SRS	Safety Related System
VOC	Volatile Organic Compound
CCTV	Closed Circuit Television
CFC	Chlorinated Fluorocarbons
ODP	Ozone Depletion Potential
VCE	Vapour Cloud Explosion
BLEVE	Boiling Liquid Expanding Vapour Explosion

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