HSE process safety communication – explosion in an anaerobic digestor plant

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Summary

This paper details a catastrophic explosion at an anaerobic digestion plant, caused by the ignition of flammable gases in a buffer tank during hot work. The incident resulted in life-altering injuries to two workers and highlighted serious deficiencies in hazard identification, risk assessment, and contractor competence.
Key failures included an inadequate DSEAR assessment, outdated process diagrams, and poor management of change. The report emphasises critical lessons for the anaerobic digestion industry and broader sectors, including the need for accurate hazard studies, robust safety systems, and active operator engagement in risk management.

Keywords: Anaerobic digestion, flammable gases, DSEAR risk assessment, hot work, process safety management.

Description of the incident

The company operated an anaerobic digestor to recycle food waste in Colwick, Nottingham. In September 2017 a blocked pipeline was being removed with a grinder by two employees in a mobile elevated working platform (MEWP). Both suffered life changing injuries as a result of the basket being violently bounced when the flammable atmosphere in the buffer tank ignited and it lifted, contacting the basket. One worker lost his leg and the other spent two months in hospital.

Figure 1 illustrates the anaerobic process. The liquid being recycled back into the process was essentially reseeding the slurry, and beginning the digestion process earlier than anticipated (the initial phases of the digestion process can lead to hydrogen being evolved as well as methane). This is common practice to save on fresh water, and acceptable if flammable hazards are included in the risk assessment.

The buffer tanks, which had atmospheric vents, had not been emptied prior to the incident: Figure 2 illustrates the buffer tanks and ingress of air.

Issues identified included:

- process diagrams were not accurate
- a hazard study failed to identify flammable hazards upstream of digester
- the DSEAR risk assessment was inadequate, and
- a Safe System of Work for hot work was inadequate.

When the grinder sparked, ignition of the flammable gases occurred and the expanding ignited gases forcibly ejected the slurry out of the bottom of the tank (see Figure 3) where the clamp arrangement, the weakest point of the vessel construction, had given way (Figure 4). The buffer tank remained in the air for nine seconds before landing on the electrical board building (Figure 5). It was fortunate that the tank did not hit other people or process plant.

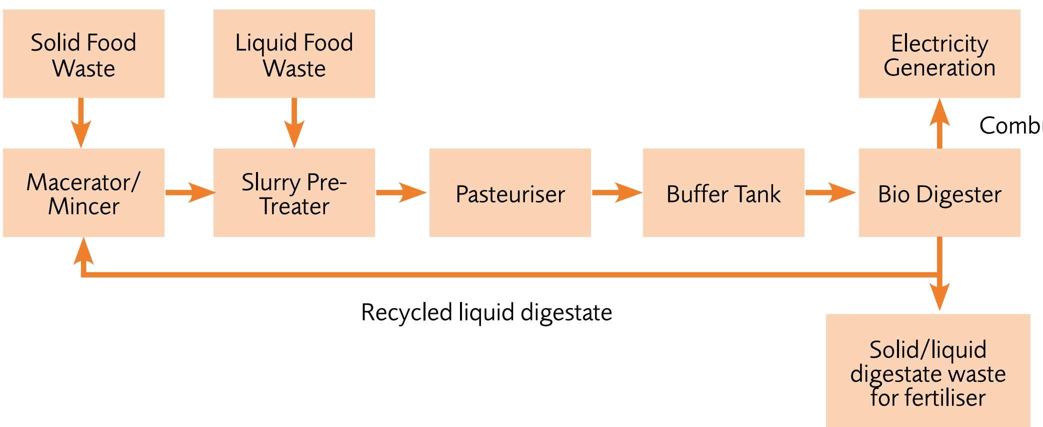

Figure 1 – Outline of the anaerobic digestion process

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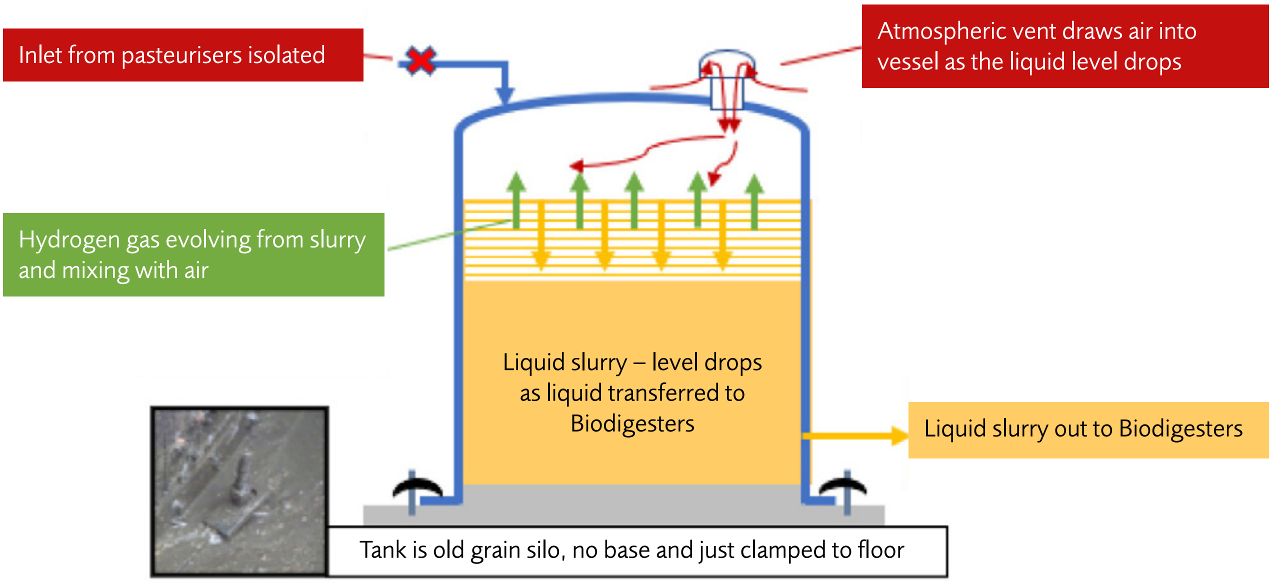

Figure 2 – The buffer tank, once isolated, now showing ingress of air

Causes of the incident (direct and safety management systems failures)

Failure to identify hazards

The risk assessment carried out by a consultant failed to identify flammable hazards upstream of the digester. Consequently, the company did not know that flammable gases existed in the buffer tank. As a result, the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) risk assessment was inadequate and the Safe System of Work (Permit to Work) for hot work was not considered or used. Inadequate risk assessments or DSEAR assessments effectively allowed gaps and failures to remain undetected in a system i.e. latent failures. This meant that an incident became likely because no-one was aware of these gaps and deficiencies.

Competence

The DSEAR assessment was carried out by a consultant, but the assessment had a range of serious deficiencies and was not fit for purpose. The consultant had only undertaken a one-day training course (Introduction to DSEAR) and was not experienced in identifying the flammable risks at a site using microbes to generate large quantities of biomethane. The company failed to manage and challenge the consultant on their assumptions and assertions, i.e. be an intelligent

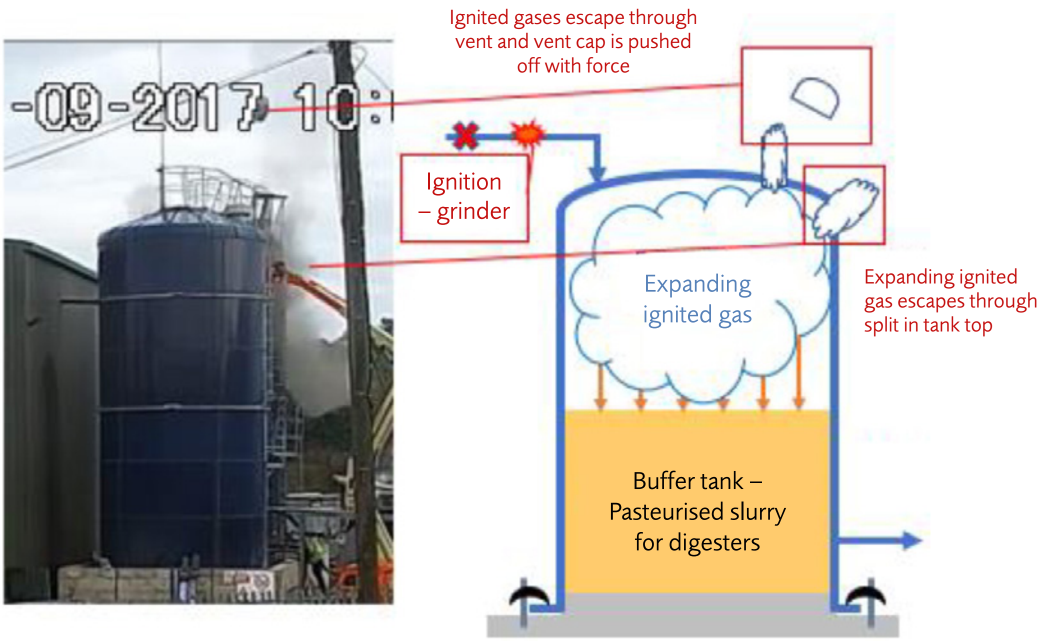

Figure 3 – The buffer tank – flammable gases ignited & expanding internally

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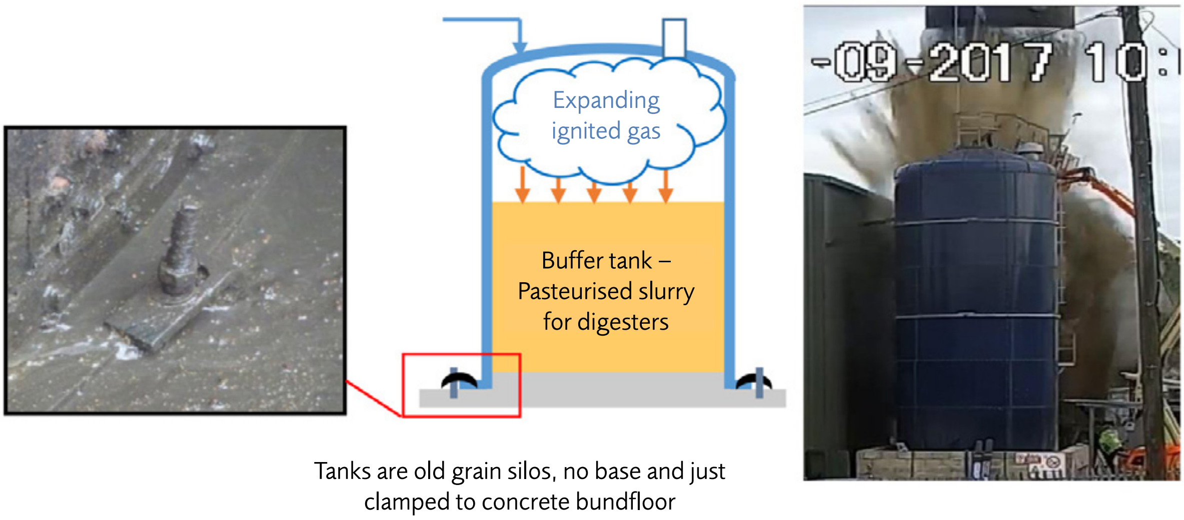

Figure 4 – The buffer tank 'take off'

customer. Site operators should not take things on face value — the legal duty to ensure safe site operations remains with the site operator and cannot be passed to consultants. HSE guidance *Managing contractors: A guide for employers HSG159* is aimed at small to medium businesses in the chemical industry and has a checklist of questions to ask contractors or consultants.

Lessons to prevent a reoccurrence

Lessons specific to the anaerobic digestion industry

- **Flammable atmospheres can occur in vessels and pipework other than the digester itself e.g., pre and post digester.**
  Always assume there is the potential for transfer of flammables when vessels are connected to each other, and methane is known to be present in at least one. A cautious approach should always be taken to make sure the atmosphere is safe. Do not assume a pipe / vessel is gas free — always check before carrying out work. This is essential if the work involves heat or other potential sources of ignition.
- **Methane is not the only flammable gas generated in the AD process.**
  Post incident testing of material from the buffer tank showed that the predominant gas initially produced by the bacteria in the tank was hydrogen, not methane. Hydrogen is lighter than air and is more likely to accumulate near the top of any vessel. Hydrogen has a wide flammability range (typically 4-77% by volume). When ignited hydrogen shows higher overpressures, faster flame propagation and is more prone to detonation than methane. In other words, hydrogen presents a higher risk which is harder to control than the risks from biogas (predominantly methane). These considerations should have formed part of the DSEAR assessment.
- **Use of 'black water'.**
  Recycling the 'digestate' liquid (black water) back to the start of the maceration process is acceptable, provided the site operator understands the possible impact of this process (e.g., the potential for reseeding the reaction). A suitable and sufficient risk assessment should have considered the likelihood that black water can accelerate the reaction processes and that flammable substances are more likely to be present early in the process.
- **Pre-digestion pasteurisation.**
  It was assumed by the site operator that pasteurisation would greatly reduce the microbiological activity within the degrading food waste in the tank, making it safer to keep it there in a holding tank ahead of main digestion. In fact, pasteurisation is intended to reduce the levels of pathogenic microorganisms in the feedstock and not to eradicate all microbiological components. Post incident tests on the feedstock slurry from the buffer tank detected vast numbers of viable microorganisms (both aerobic and anaerobic bacteria). The waste had remained extremely bio-active, even after earlier heat treatment at 70°C.

Lessons applicable to all industries

- **Management of Change.**
  The buffer tank was a repurposed grain silo bolted to a concrete base. Where vessels are repurposed, risk assessment should determine that they are fit for purpose and whether any modifications are required, such as fitting pressure or fire relief.
- **Reviewing and updating plant design records.**
  The risk assessments were also undermined by outdated process and instrumentation diagrams (P&ID) which did not reflect the plant "as built". The risk assessment and DSEAR assessments were based on a plant layout which did not exist. Operators must ensure that diagrams and process documentation is kept up to date and reflects reality.

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Figure 5 – The final landing position of the buffer tank at the site

- **Hot work.**
  This is a high-risk activity in all industries with flammable substances, including AD plants. This is made clear in paragraph 321-322 of the DSEAR Approved Code of Practice (ACoP): "Hot work on or in any plant and equipment (including containers and pipes, e.g. storage tank, drum, cylinder, silo, pipeline, fuel tank etc) remaining in situ that contains or may have contained a dangerous substance is classified as high-risk activity and will require a Permit to Work system to be put in place."
- **Use of inert atmospheres.**
  A suitable safe system of work for carrying out hot work should include appropriate methods for making the tank gas free or inerted. Schedule 1, Regulation 6(8) of DSEAR outlines the general safety measures that ought to be considered, including use of inert atmospheres. The option chosen will depend on the risk assessment. Standards exist for cleaning vessels/tanks containing flammables; although these are aimed at the petroleum type sites, with large storage tanks (Energy Institute Model Code of Safe Practice IP16), the same principles will apply. Typically, the vessel is emptied, washed down/filled with an appropriate cleaning fluid (e.g. water) and emptied, then gas tested to ensure the flammables are removed, with ongoing monitoring because material can be held upon the internal walls even after washing.
- **Site operators must genuinely engage in the risk assessment process.**
  Whilst there were deficiencies in the competence of the consultant to undertake the DSEAR and HAZOP assessments, the quality of the resulting reports was further compromised by a lack of engagement by the site operator in the assessment process.
- **Obtaining regulatory approval prior to alterations.**
  Modifications to the process were not clearly communicated to the Environment Agency, and permission was not sought or obtained for deviations from the original design and operation of the plant as authorised by the environmental permit.
- **Maintaining permit compliance.**
  Whilst the operator had an environmental management system and associated operating procedures, these were not being followed, audited or reviewed and updated.

Enforcement outcome

Two Prohibition Notices were served immediately, with multiple Improvement Notices and Notices of Contravention for occupational safety issues.

The UK Health and safety Executive undertook a joint investigation with the Environment Agency (breach of permit conditions). On 22 November 2024, BioDynamic (UK) Limited were fined £304,500 (HSE Fine £297,500) costs £229,988 awarded (HSE costs £57,900).

In conclusion

This incident is a clear reminder of the importance of ensuring that key elements of a process safety management system are in place and functioning well. Without effective identification of hazards, sites will be unlikely to properly provide the necessary controls for safe work. Without good management of change procedures, process changes can bring unforeseen hazards which can subsequently bring vulnerability to sites. Without good competency management, mistakes can be made which have tragic consequences. The incident details, prosecution and sentencing outcomes in this case are shared here to encourage learning across industry for prevention of future related incidents.

References and Guidance

1. *DSEAR Approved Code of Practice (ACoP) L138 – available to download for free from the HSE website*
2. *Managing contractors: A guide for employers HSG159*
3. *Energy Institute Model Code of Safe Practice Part 16 – Guidance on tank cleaning.*
4. *'The Practical Guide to AD' – Anaerobic Digestion and Bioresources Association*
5. *BS ISO 19388:2023 – Sludge recovery, recycling, treatment and disposal – Requirements and recommendations for the operation of anaerobic digestion facilities.*
6. *BS EN ISO 24252:2022+A11:2023 – Biogas systems – non-household and non-gasification.*
7. *'Guidelines for the safe use of biogas technology' – German Biogas Association, www.biogas.org*

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