Biogas -Process safety challenge

Ashok Thingore, Process safety manager, Thames Water, Clearwater Court, Reading, RG18DB

Thames Water is the largest water and waste water treatment service provider in UK. As well as receiving and treating water, Thames Water is also in the fore front of adopting different types of waste water treatment technologies. Some of these include; simple biogas, gas to grid (bio methane), fat oil and grease and AER (Advance energy recovery- pyrolysis). In 2017/18 Thames Water produced 293 GWH of electricity from renewable sources including sludge treatment, wind and solar.

A typical Thames Water sewage treatment plant will consist of; grit screens, primary settling tanks, aeration process, and secondary sludge treatment and digestion process.

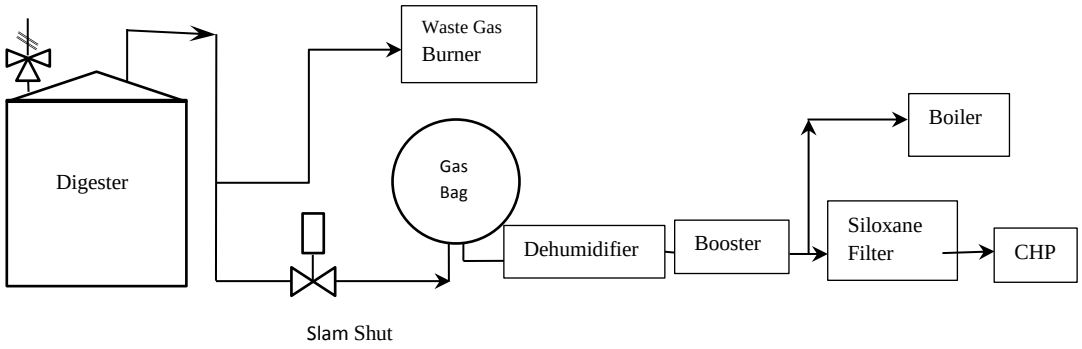
The sludge from the small capacity sewage treatment plants are usually taken to the sewage treatment works where biogas is produced from sewage waste by means of the digestion process. Depending on population in the catchment area, the sewage treatment plant may have a biogas plant in addition to the sewage treatment process.

The sewage digestion process is mainly an anaerobic process (in absence of oxygen). Biogas produced by this digestion will mainly consist of methane (60-65vol. %), carbon dioxide (30-40vol. %), saturated water vapours, hydrogen sulphide (150-2000ppm) and other traces of impurities. Biogas combined heat and power (CHP) project has a distinct advantage in terms of utilising biogas to generate electrical power and utilise heat in the process. It also helps to reduce methane gas released into the atmosphere, by means of converting it to CO_2 (carbon dioxide) which causes less damage to environment.

Biogas combined heat and power projects (CHP) help in generating electrical power but comes with additional hazards. Some of the hazards include; fire due to methane, toxicity due to presence of hydrogen sulphide, a corrosive environment due to moist carbon dioxide and risk of any major sludge spills due to digesters holding liquid sludge.

Any biogas plant at Thames Water will typically consists of one or many; digesters, condensate pots, gas bags, gas boosters, gas dehumidifier, siloxane filter, CHP engine and waste gas burners.

The block flow diagram illustrates overall biogas plant.



As Thames Water is one of the oldest water and waste treatment service provider in UK, it is unsurprising that the sewage digestion process has evolved over a period of decades, hence the different types of digester designs across the sites. The different designs can be classified as floating roof, membrane roof and fixed roof type digesters. Also, some digesters are in metal construction and some are in concrete construction. Each digester type has its own capex, advantages, disadvantages and safety concerns,

Biogas CHP projects are still considered to be in early evolving stages of the life cycle. There are different challenges at various stages of the biogas asset life cycle which include challenges in design, operation, maintenance, inspection and testing.

Process safety risk assessments help in understanding the importance of different safety barriers and its effect on overall plant safety if these barriers are weak in design. Failing/weak safety barriers could lead to poor plant safety management, therefore it is very important that all risks associated with biogas asset are well understood and robustly managed.

On sewage treatment works, any failure of process safety barriers can easily lead to a fire hazard, toxic and flammable gas release. If any of these events are not mitigated on time, they can eventually turn into a catastrophic event leading to loss of human, damage to environment or loss to business.

Weak or total loss of control on process parameters or equipment failure will lead to gas release. Uncontrolled or unmanaged hot work or electric spark will then be a source of ignition leading to fire or an explosion.

Corporate commitment and process safety

At Thames Water, the corporate policy statement sets out the commitment to zero incident, zero harm, and zero compromise keeping assets and people safe and healthy.

It is the intention of the process safety risk assessment to identify any gaps in design, operation or maintenance which need to be mitigated in order to achieve the triple zero safety commitment set by Thames Water. Process safety is a combination of engineering and management skills; therefore a process safety risk assessment tool was developed.

Process safety risk assessment

In order to understand the process safety risk, an in-house process safety risk assessment model was developed by process safety with help of the health and safety team. The model developed was based on semi-qualitative method of analysis, which covers various elements of design, operation, maintenance and testing of biogas asset. Each element was further categorised into high, medium and low risk, based on site audits and findings. Table 2.1 provides the details and basic principals in which risks are categorised into low, medium and high.

Table 2.1 Risk level and description

RISK	Description
LOW	Design, operate and maintenance is safe and meets required risk limits.
MEDIUM	Design, operate and maintenance issues are identified. Action to be considered for improvement
HIGH	Weakness in design /operate /maintenance testing inspection such as to report a high /unacceptable risk for an asset The resolution of this risk requires immediate or urgent attention.

At Thames Water, biogas safety risk assessments revolve around creating awareness about biogas safety risk, at the same time as assessing the process safety barriers to provide some risk indications.

In order to make it easier for the operating personnel to understand the process safety risk assessment, a team based risk approach is explained. In this approach, a football team is subdivided into defined group roles (forward, midfield and defenders), which is compared with the design, operate and maintain of the asset life and impotence of the each roles and its contribution as a team will provide a strong safety barrier. The hazards are represented as opponent who needs to be defeated. Each player in the team represents individual safety barriers. This is illustrated in the following table.

Table 2.2 Process safety – A team work

The process safety risk assessment is only limited to the biogas section of the sewage treatment plant. Barriers such as gate security, control room ergonomics, occupational health or functional safety are excluded from this risk assessment study. However, the principle of risk assessment can be extended to other parts of the asset as well if required.

Design, Operate and Maintenance Safety Barrier

The process safety risk assessment of any biogas asset can be easily carried out by means of review and audit of various process safety barriers. Their findings can be categorised in high, medium and low risk. The stronger the barrier means the lower the risk rating and conversely, the weaker the barriers means the higher the risk rating for an individual risk barrier. The following section covers details of safety elements.

Design safety barrier

The following are some of the major process safety design barriers for an operational biogas plant. There could be more safety barriers within the design stage in the project life of an asset, but in this paper to keep is more precise, only the key process safety barriers are listed as:

- As built P&ID
- HAZOP
- Site Operating manual
- DSEAR
- Process safety data
- Change management control

As built P&IDs carry key information of the project and are very important in terms of any future expansion or modification required to be done. They are the basic building block for the change management procedure. Good “as built” information makes change management much easier to understand.

HAZOP close out is also a very important part of the design safety as it helps in understanding the various digestion processes upset and how it is mitigated in design phase.

Operation safety barrier

The following are some of the process safety operation barriers for a biogas plant. There could be more operation safety barriers in the entire life of the project but in this paper only the key process safety barriers are listed as:

- Skills and competency
- Communication and cooperation
- Roles and responsibility
- Alarm management
- SimOps (simultaneous operation)
- Permit to work
- Safety critical element
- Emergency response plan
- Fire safety drill

The operation barrier revolves around the way communication is carried out at biogas sites among the operating team. This could be simple toolbox talks, weekly/monthly meetings or daily logs and how the safety concerns and mitigation plans are raised in these meetings.

Alarm management is the key communication between the operating persons and the process equipment via human machine interface (PC+PLC or SCADA).

Permit to work / SimOps assessments provide information on the way communication is made with third party or contractors in order to carry out work safely. Process safety risk assessments help in understanding this method of communication, identification of any gaps and development of a plan to mitigate them.

Maintenance safety barrier

The following are some of the process safety maintenance barriers for biogas plant. There could be more maintenance safety barriers in the entire life of the biogas project but in this paper only the key process safety barriers are listed as:

- Digester inspection and testing
- Gas bag testing
- PVRV(pressure vacuum relief valve) testing
- Slam shut valve testing
- Gas bag earth test
- Waste gas burner testing
- Fire safety audit
- Plant preventive maintenance

- Gas detectors testing
- Noise issue
- Critical spares

The maintenance safety is about identifying safety critical elements and how well these are maintained, inspected and tested. Some of the safety barriers are not very well defined about the test procedure or test frequency, hence process safety risk assessment provides an opportunity to have a holistic view for the tests that are in place and if any such test needs any improvement or any change in test procedure to improve safety.

All these safety barriers are audited based on the certain criteria and allocated high, medium or low risk rating. An example of this can be seen in Table 3.1 below.

Table 3.1 Typical audit finding and risk rating is for illustration purpose

P&ID	There are no P&IDs available for the modified section of the plant	High
Alarm management	There are lots of alarm (more than 50/shift) hence managing of alarm needs to be further investigated hence rated as Medium.	Medium
Digester Inspection	Digester Inspection completed in 2018 hence rated Low	Low

Once all the safety barriers are audited and risk rated, based on number of high risk element and total number of elements, the % high risk can be calculated. Any new asset will have challenges with design and operation and as the asset ages, the maintenance related risk will increase hence age related factor is applied to get the realistic asset risk rating.

Biogas asset age factor

Once all the safety barriers are risk rated, according to the site audit, an asset life factor is applied based on the age of an asset. As the asset becomes matured it requires more maintenance to operate reliably and safely, hence why asset beyond the design life has a higher age factor percentage. Whereas, for the relatively new asset, higher age factor % are applies on design and operations. Table 4.1 provides % contribution of design, operation and maintenance at different stages of asset life.

Table 4.1Asset life and age factor

Asset Life based risk rating	Design Safety	Operational Safety	Maintenance Safety
Asset good as new < 2yr	25%	60%	15 %
Asset within ½ design life	20%	50%	30%
Asset more than1/2 design life	15%	25%	60%
Asset beyond design life	10%	10%	80%

Identification of gaps in safety barriers, assessment of these safety barrier gaps and any mitigation plan to bring risk within as low as practically possible, helps in creating awareness about the process safety barriers and the importance of the process safety assessment itself.

The heat map of different risks at different sites can be graphically presented to the different corporate meetings to raise the process safety concern in a timely manner.

Process safety risk heat map

The process safety barriers, its audit outcome on each safety barrier and age factor can be communicated to the corporate and senior leadership in the form of a heat map. A typical heat map with risk distribution is illustrated in Table 5.1.

The process safety risk heat map is a dynamic representation. As and when the actions are closed the high risks can be reduced to either low or medium. In contrast, cases such as delay in inspection, or incomplete site data can increase the site process

safety risk, The process safety risk heat map can be updated monthly and presented meetings, or can be web based to enable it to be directly accessed by relevant persons to have ready information on process safety risks.

Table 5.1 Process safety risk heat map

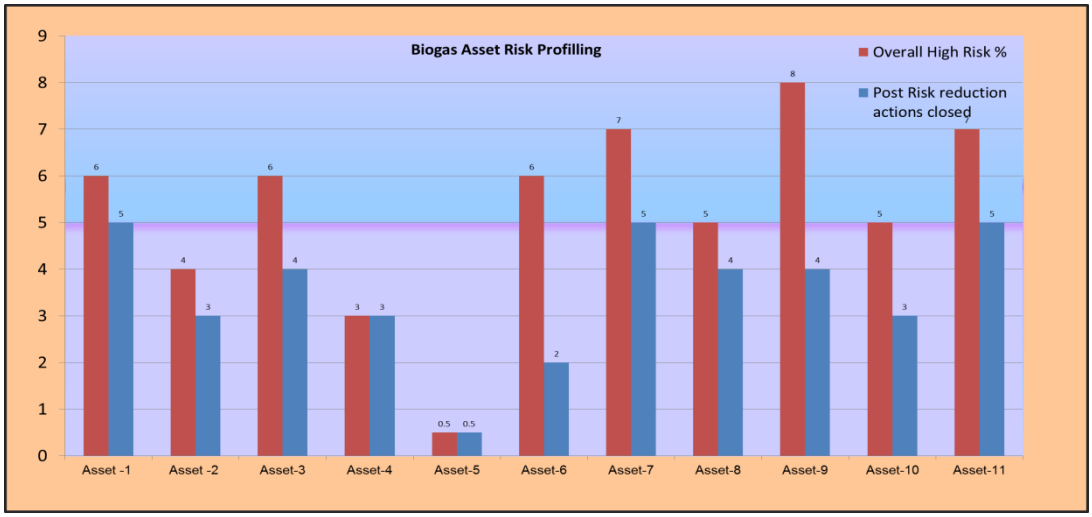
Thames water - Asset	Design									
	Piping & Instrument Diag.(P&ID) As Built	Site Operating Manual-In place	HAZOP -Last Done	HAZOP Updates	Cause and Effect, Safety Interlocks ,control Philosophy,Procedure including ICA control	Process Safety Data available at site	Risk Register maintained	Zoning/ DSEAR Drawing	Emergency Response Plan	Change Management Register
Asset -1	Medium	Medium	Medium	Medium	High	Medium	Low	Low	Low	High
Asset -2	Medium	Medium	High	Medium	Medium	Medium	Low	High	Low	High
Asset -3	Medium	Low	Medium	Medium	Medium	Low	Low	Low	Medium	High
Asset -4	Medium	Medium	Low	Low	Medium	Medium	Low	Low	Low	Medium
Thames water - Asset	Operate									
	Skill and Competancy	Roles and Resposibility	Reactive checks - control after event	Alarm Management	Change Management Register	Any Fire drill or Mock test Conducted	List of safety Critical Elements	Emergency Evacuation Drill	No of Leaks reported /year	Muster Point and Escape Route well maked
Asset -1	Low	High	High	Low	Low	Low	High	High	Low	Low
Asset -2	Low	Low	Low	Low	Low	Low	Medium	Medium	Low	Low
Asset -3	Low	Low	Medium	Low	Low	Low	Medium	Medium	Medium	Low
Asset -4	Low	Low	Low	Low	Medium	Low	Low	Low	Low	Low
Thames water - Asset	Maintenace Inspection and Test									
	Digester Inspection - overdue	Gas Bag /Holder Inspected/Elec safety	PVRV For Digester -1 tested	Flare Monitering and Testing	Slam Shut Tested	Corrosion Monitoring System	Critical Spare Maintained	Maintanace Plan Register	Condensate / Seal Pot	Fire Risk assesment
Asset -1	High	High	Low	Low	Low	Medium	High	High	Medium	Low
Asset -2	Low	Low	Medium	Low	Low	Low	Low	Low	Low	Low
Asset -3	Low	Low	Low	Low	Low	Low	Low	Low	Low	Medium
Asset -4	Low	Low	Low	Medium	Medium	Low	Low	Low	Low	Low

Asset wise process safety risk assessment–graphical representation

Apart from the process safety risk assessment heat map, the process safety high risk for different sites can be represented on a bar graph as illustrated in 6.1. The bar graph indicates high risk % of different sites and provides criteria for the risk reduction programme.

Process safety risk mitigation requires proper planning and funding, hence a typical risk rating target of say 5% can be set for the initial risk reduction program and all the sites above this value can be prioritised for site risk reduction programme. The Graph 6.1 represents typical initial high risk and high risk after reduction programs actions are completed.

Graph 6.1 Asset and high risk percentage



Process safety high risk and asset funding priorities

The high risk barrier, which is collected from process safety risk heat map or high risk asset graph, indicates the areas of weak barriers which need to be mitigated on an urgent basis. If a number of high risk barriers are present then these high risk barriers can be selected on priority or all can be selected in risk reduction program depending upon the availability of funding.

Process safety risk assessment helps in identifying areas of concern and also helps in synchronising asset funding with process safety risk so that funding can be effectively utilised. Process safety risk assessments also provide operating personnel with a clear understanding of dynamic risk associated with biogas digestion process due to presence of flammable and toxic gas.

Conclusion

It is very important for every biogas asset to have a risk assessment covering the entire life cycle of biogas asset. The risk assessment technique in form of audit requires complete understanding of the barriers in place and their importance. Well-kept information helps in reactive control or response when unlikely incident happens.

The understanding of process safety barriers clearly help in creating process safety culture, align funding to high risk and creates safety as a team culture to help to achieve the corporate commitment of zero harm, zero compromise and zero incident.

Glossary

Acronym	Meaning
AER	Advance Energy Recovery
CHP	Combined Heat and Power
DSEAR	Dangerous Substances Explosive Atmosphere Regulations
HAZOP	Hazardous Operability
P&ID	Piping and Instrumentation
PC	Personal Computer
PLC	Programmable Logic Controller
PVRV	Pressure Vacuum Relief Valve
SCADA	Supervisory Control And Data Acquisition
SimOps	Simultaneous Operation