# Toxic Gas Detector Array Evaluation

Steve Forster, Technical Director, Graham Tickle, Principal Consultant, Folake Akinnusi, Senior Consultant, ESR Technology, 202 Cavendish Place, Warrington WA3 6WU, UK

A new approach, giving a quantified and cost effective solution for evaluation of toxic gas detector arrays has been developed. Current flammable gas detector coverage mapping methodologies and guidance do not adequately address the persistent industry wide problem of detection of highly directional high-pressure toxic gas jets.

Available techniques based on the current BP Fire and Gas Detection guidance are well known to inadequately address this problem, while full CFD modelling tools are time consuming and very expensive to apply.

The approach presented here has been applied to an existing onshore high-pressure sour gas plant to assess the toxic gas detector array coverage. The plant analysed has a toxic component carried in the primarily flammable gas streams, so that in the context of the problem considered, flammable gas detection could be used as a proxy for toxic gas.

In the analysis presented here, the evaluation proceeded as follows:

- Specification of releases of concern (based on QRA approaches and concentration levels of concern at a vulnerable location);
- Derivation of gas dispersion "footprints" associated with the releases of concern;
- Evaluation of the performance (coverage) of the existing gas detector array in terms of the percentage of releases detected by the array.

The outcome of the application was:

- An indication of the coverage of the existing array for potential releases;
- An indication of the optimum positioning for additional gas detectors to improve the performance of the array.

This methodology has then been implemented within ESR Technology's proprietary fire and gas mapping software: DELOS (Detector Location Optimisation Software).

The implementation is promising as a basis for development of an improved methodology for evaluation and optimisation of existing arrays, and in the design of new toxic gas detector arrays.

Further development of this methodology will be discussed including evaluation and presentation of confirmed gas detection (two out of N) coverage and its use as a basis for automatic executive control action.

## Introduction

The placement of toxic gas detectors for the protection of off-installation personnel has traditionally been based on heuristics, with no prescriptive rules on when and where to place gas detection equipment. This has led to a situation where toxic gas detection philosophies may be poorly defined by the designers, mistrusted by the operators, and potentially deemed as not fit for purpose by the regulators.

Gas detection guidance documents from regulatory bodies such as HSG176 (HSE 2004), OTO 93 002 (HSE 1993), and those commonly used in the petrochemical industry such as the BP Technical Practices GP 30-85 (BP 2009) concentrate on criteria and location metrics for the detection of flammable vapour clouds with sizes that may result in Vapour Cloud Explosions (VCEs) of sufficient magnitude to cause serious damage or injury, with little or no guidance applicable to toxic vapour clouds. Assumptions implicit to the flammable gas methodologies used in these documents, are that all flammable clouds are spherical, within a plant module, and close to the release source.

These types of releases are adequately addressed by analysing the gas detector coverage in terms of 'geographic coverage', which is defined by the ISA technical report on fire and gas system effectiveness (ISA 2010) as "the fraction of the geometric area (at a given elevation of analysis) of a defined monitored process area that, if a release were to occur in a given geographic location, would be detected by the release detection equipment considering the defined voting arrangement."

The proposed methodology described here has been developed to address the issue of releases which result in significant hazards in the far field that are toxic rather than flammable, are highly directional and which disperse outside the plant structure as a plume away from the release location.

The methodology is based on 'scenario coverage', which is defined as "the fraction of the release scenarios that would occur as a result of the loss of containment from items of equipment of a defined and monitored process area that can be detected by release detection equipment considering the frequency and magnitude of the release scenarios and the defined voting arrangement" (ISA 2010).

## Methodology

The methodology is based on an analysis of the hazards present on the installation, and the vulnerable locations which these hazards may impact upon. This requires information on the process conditions (temperature, pressure, flow rates, inventories), and the toxicity of the material which may be released in terms of exposure limits such as specific level of toxicity (SLOT) (HSE 2018), or acute exposure guideline levels (AEGLs) (NASEM 2016). These together allow calculation of the critical release scenario (leak size) for the given process conditions, which is the scenario that will just affect the vulnerable location.

A hazard identification exercise is carried out for each plant unit, and a set of process conditions are chosen that are representative of that unit, along with a maximum credible leak size. The largest credible leak scenario is then modelled using a gas dispersion model such as DRIFT (ESR 2013) or PHAST (DNVGL 2017). If the largest credible scenario is insufficient to affect the vulnerable location, then there are no releases of concern from this process unit, and it is not considered in the detector analysis.

If the largest credible leak scenario can affect the vulnerable location, then further dispersion modelling is carried out to identify the critical release scenario, by reducing the leak size (release rate) until the maximum toxic effect range is equal to the range to the vulnerable population. This is identified as the critical release scenario for that particular plant unit. In a study where multiple plant units are being analysed, each unit will have its own critical release scenario.

The critical release scenario is then used to analyse the detector coverage. Releases smaller than the critical are not considered, as these will not affect the vulnerable location, whilst larger releases are assumed to have a ‘footprint’ that is at least as wide at a given range, and so will be at least as easy to detect; in practice they would be expected to have a wider ‘footprint’ over most ranges and therefore be less likely to pass through the gaps between detectors.

Each plant unit is tested in turn against the array of point gas detectors to determine the probability that the critical release defined for that unit will be detected at one, or more than one, of the detector locations. The results are plotted graphically, to give a visual indication of the detection probability and whether a release would be picked up by one or more detectors. This data is also presented numerically as a percentage coverage for each plant unit.

Based on the results of the analysis, the location of the individual gas detectors can be modified and reviewed to optimise the detector coverage.

## Implementation

The methodology described above has been implemented in the ESR Technology detector location optimisation software (DELOS). DELOS is a 2D/3D fire and gas mapping tool that optimises the number and location of fire and gas detectors, presenting its results graphically as coverage plots and numerically as coverage percentages. For toxic gas mapping, the source location for the unit may be defined as either a single point, or as an area. An extended source area (e.g. a plant area) is treated as a sum of point sources distributed over the area.

A typical plot showing the results of an area source detector coverage assessment are shown in Figure 1 below. The gas detector probability plot is obtained by associating the detection probability with the area of angular range for each detector and summing the probabilities.

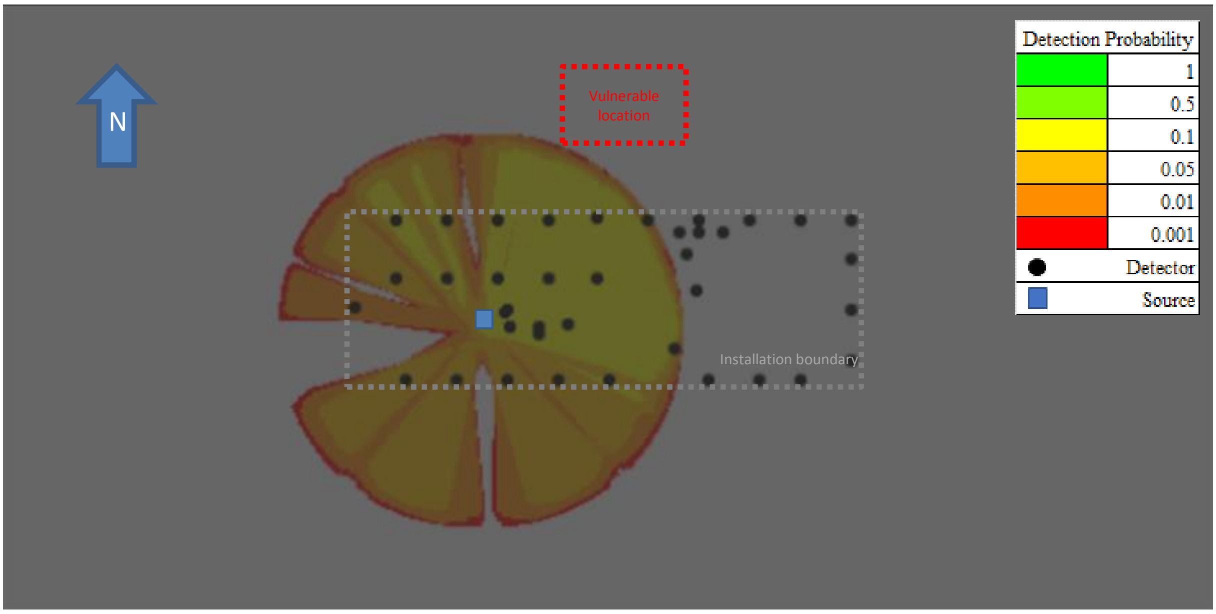


Figure 1: DELOS gas detector probability of detection plot

The effect of using an area source can be seen in the figure above, where the ‘gaps’ in which the probability of detection is not recorded (are zero) are not radial, but narrow with distance from the source. The plot shows the highest probabilities of detection to be in the northeast quadrant where the detector density is the greatest, and the lowest to the west, where releases in a large segment would go undetected.

Analysis of the gas detector layout would suggest that the coverage could be improved by adding additional 'boundary detectors' on the western edge of the installation, however, if there are no vulnerable locations in that direction, this may be unnecessary.

Where gas detector arrays are used for executive action, voting systems may be employed, such that a single detector activation gives an alarm, and multiple (two out of 'N') alarms will result in executive action such as a process trip or emergency shutdown.

A plot showing the results of a detector count field assessment for the same array as Figure 1 are shown in Figure 2 below. The gas detector count field calculates the number of detectors that can simultaneously detect the cloud footprint. This calculation determines the field in a similar way to the gas detection probability field, but includes extra logic to count the number of detectors that can simultaneously detect the cloud.

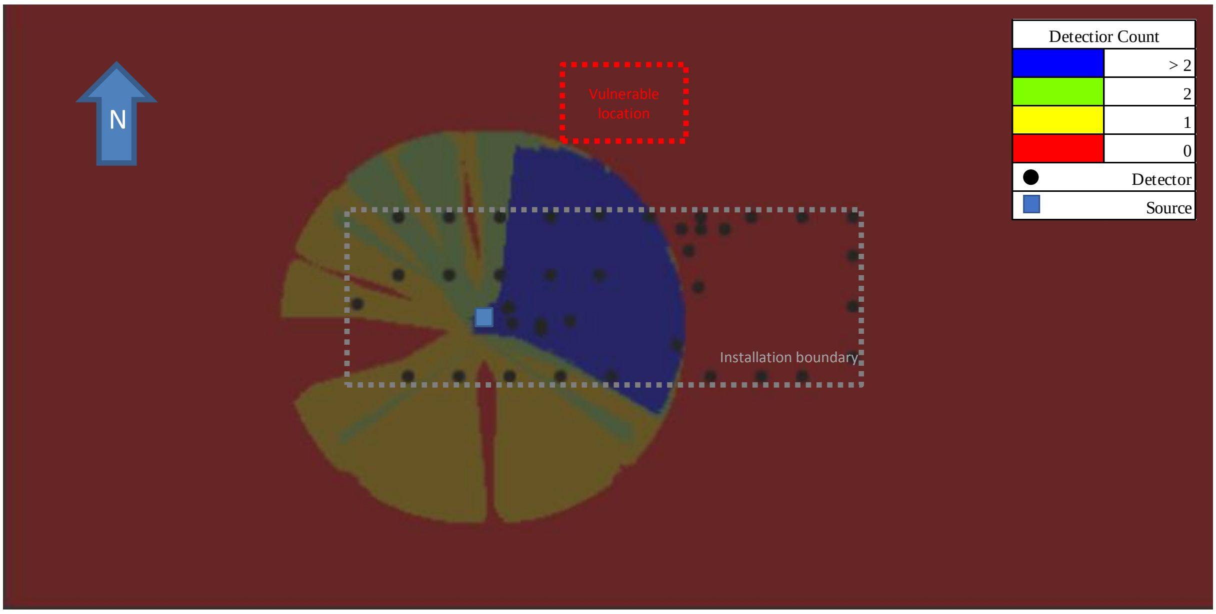


Figure 2: DELOS gas detector count field plot

The above figure shows that critical releases in the direction of the vulnerable location would result in at least two of the detector array (green or blue) alarming, so it may be feasible to link the gas detection system to the shutdown systems for protection of the vulnerable location. Releases in the directions towards the southwest would be unlikely to result in two or more detectors going into alarm.

## Discussion

Use of empirical dispersion models such as DRIFT (ESR 2013) or PHAST (DNVGL 2017) for modelling free field releases allows a relatively rapid assessment of gas detector arrays which may be used around major hazard installations.

For analyses such as scenario based detector mapping that combine the results of many impact zones, the accuracy in definition of the impact zones that techniques such as computational fluid dynamics (CFD) can offer does not greatly affect the overall results of the analysis for the free field higher pressure (momentum driven) releases considered. This is primarily due to the initial turbulent jet, which has been assumed to be relatively unaffected by the wind direction or meteorological conditions.

The methodology described has been developed from a spreadsheet based method which was used for evaluation of a toxic gas detector array implemented on an installation which handled high pressure sour hydrocarbon gas. The results obtained allowed the gas detection philosophy to be better defined, with a well understood numerical basis, allowing the effectiveness and coverage of the system to be determined.

## Conclusions

Current flammable gas detector coverage mapping methodologies and guidance do not adequately address the persistent industry wide problem of detection of highly directional high-pressure toxic gas jets. To address this issue, an approach, giving a quantified and cost-effective solution for evaluation of toxic gas detector arrays, has been developed.

Using a scenario based approach, an array of point gas detectors can be evaluated to determine the probability that critical releases will be detected at one, or more than one, of the detector locations. This allows consideration of the toxic (and flammable) effects of releases on locations and populations outside of the plant unit and installation from which they originated, which methods that rely only on the "geographic coverage" concept cannot.

The approach presented here has been successfully applied to an existing onshore high-pressure sour gas plant to assess the toxic gas detector array coverage. The analysis provided information on which segments of their boundaries achieved their coverage criterion, and allowed advice to be given on where additional detectors would improve the level of coverage.

The methodology described has been implemented within ESR Technology's proprietary fire and gas mapping software, DELOS, to plot results graphically and provide a percentage coverage for each plant unit.

## References

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