QUICKFN – A LESS RESOURCE INTENSIVE METHODOLOGY FOR DETERMINING THE MAGNITUDE OF SOCIETAL RISKS AT MAJOR ACCIDENT HAZARD INSTALLATIONS

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This paper describes a methodology developed to provide an indication of the magnitude of societal risks using FN curves at and in the vicinity of a major accident hazard installation. Using the proposed methodology, named QuickFN is an alternative to the traditional approach of calculating 'full' FN curves and is significantly less resource intensive. The 'right-hand' (high N, low F) part of a FN societal risk curve can be closely replicated by inclusion of fewer scenarios and hazard sources than the full set typically used when calculating societal risks.

KEYWORDS: quantitative risk assessment; major hazards; societal risk; methodology

INTRODUCTION

It is normally accepted that the best available technology for studying societal risk is full scope application of quantitative risk assessment. Such studies lead to a relationship between the number of fatalities (N) that can follow a major accident, ranging from 1 to some maximum value (N_{max}) and a frequency (f) at which that number of fatalities is estimated to occur. This relationship, or more usually the corresponding relationship involving F, the cumulative frequency of events having N or more fatalities, is usually presented as a graph with log-log axes. However the technique is time consuming and requires a high level of technical capability.

The Health and Safety Executive (HSE) has recently published a methodology[1] developed to provide a rough but rapid indication of the magnitude of societal risks at and in the vicinity of a major accident hazard installation. This methodology has been named ARI_{COMAH} (the COMAH Approximate Risk Integral). Although coarse, the use of this methodology requires only the frequency of the 'worst-case' scenario and the maximum number of persons harmed.

Experience with the application of ARI_{COMAH} has indicated, that for cases with large N_{max} from a uni-directional event, the method for predicting the frequency of N_{max} tends to consistently overestimate the result, increasing with increasing N_{max}. As ARI_{COMAH} is only used as a screening and ranking tool the absolute value of the result is not an important factor. However a more accurate method is needed for assessments where the absolute value is of importance, for example where risk reduction options are being considered. Such a method should not rely on the accurate estimation of the frequency of N_{max}.

The purpose of this paper is to identify the requirements of an intermediate societal risk tool that could provide improved 'resolution' compared to ARI_{COMAH}, and would be less resource intensive than the calculation of 'full' FN curves. It has been determined that the 'right-hand' (high N, low F) part of a FN societal risk curve can be closely replicated by inclusion of fewer scenarios and hazard sources than the full set typically used when calculating societal risks. If a close approximation is made, then the 'left-hand' (low N, high F) part of the societal risk curve can be extrapolated. Inclusion of fewer scenarios and hazard sources is likely to significantly reduce the resources needed to estimate societal risks.

ASSESSMENT BASIS

The study was based on typical representations of two types of installation identified as presenting major accident hazards. For each installation a 'full set' of hazard sources were included, judged representative of such installations.

The installations are summarised as:

(a) A chlorine installation (road tanker delivery to 2 × 80 tonne tanks and supply to manufacturing plant); and
(b) An anhydrous hydrogen fluoride installation (road tanker delivery to storage tanks and use at elevated temperature and pressure in a manufacturing plant).

In general, the hazard scenarios covered releases of toxic gas from vessels, road tankers and pipework that disperse under the influence of the wind. The types of release can be summarised as:

(a) vessels: catastrophic 'instantaneous' release, and releases from 50 mm, 25 mm, 13 mm and 6 mm effective diameter holes;
(b) pipework: full guillotine failure, and releases from 25 mm and 3 mm effective diameter holes, together with releases from flanges and valves; and
(c) road tanker: releases from coupling.

The base case for the chlorine installation requires 51 scenarios and 7 hazard sources to be included to determine the full FN curve, and similarly 69 scenarios and 21 hazard sources are required for the hydrogen fluoride installation. Determining the data for this large number of hazard sources and scenarios can often be a difficult task requiring intensive resource.

The consequence harm envelopes for the release scenarios were calculated using parameterised equations for wind/stability classes, B2, D2, D5 and F2, for three levels of harm (LD01, LD10, and LD50). The parameterised equations were derived from data generated by RISKAT[2], a risk assessment tool incorporating dense gas dispersion models, and used internally by HSE. The chosen wind/stability classes are representative of the typical weather experienced in the UK. The probability that the wind blows from a certain direction in each time period, for each wind/stability class was based upon probabilities derived from Meteorological Office data from an anonymous weather station in the UK.

The surrounding populations covering a 30 km × 30 km area (centred approximately on the site) were represented in three different ways, as follows:

(a) high detail: the population represented by an inner 6 × 6 km square made up of a grid of 200 × 200 m square population cells and the outer portion of the 30 × 30 km square area made up of a grid of 1 × 1 km square population cells;
(b) medium detail: the population represented by a 30 × 30 km square area made up of a grid of 1 × 1 km square population cells; and
(c) low detail: the population represented by a background population density of 63 persons per km^2 together with 31 population blocks or polygons, with each population block having a number of persons uniformly distributed within it.

To calculate the societal risks, the release scenarios, associated frequencies of occurrence, the dimensions of the consequence envelope of harm for each set of weather conditions, together with the wind/stability class probability data were entered into the proprietary risk summation software package *RISKPLOT GRAPHIC*[3].

BASE CASE RESULTS

A total of 6 base cases were created, relating to the two idealised installations, set in three population representations. The base cases represent inclusion of the 'full set' of hazard sources and scenarios.

In general, the societal risk results for a chlorine installation (in this case, road tanker delivery to 2 × 25 tonne tanks and supply to a manufacturing plant) is illustrated in Figure 1. It can be seen that the societal risk results (FN curve) for 'high', 'medium' and 'low' detail population representations are broadly similar for 'high N'. There is greater deviation of the FN curve for 'low N' – 'high F'.

With regard to this, and acknowledging that improved methods for determining more accurate representations of population sets are under development (which should offer a level of precision similar to the high detail representation used here), it was therefore decided that only the high detail population representations would be considered further.

The base cases and high detail population sets were used to develop FN curves by systematically removing scenarios from the base cases. Changes in weather representation were not considered. Up to 16 tests were performed for each base case. The test case that

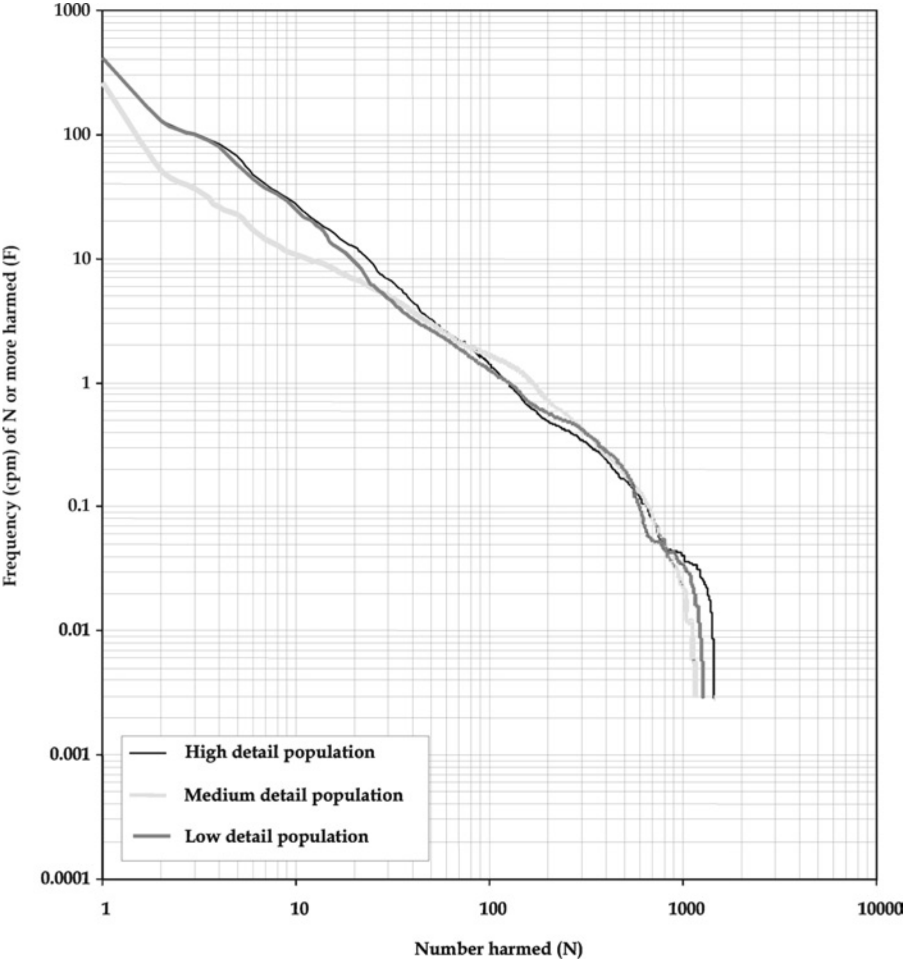

Figure 1. Chlorine installation: societal risk results as a function of population representation

best represented the ‘right-hand’ (high N, low F) part of the societal risk curve of the corresponding base case was selected as the ‘representative case’.

From analysis and inspection of these cases, it was judged that a suitable approximation to the societal risk curve could be achieved in the region where the number harmed (N) is greater than 10% of the maximum number harmed (N_{max}). Therefore the ‘right-hand’ (high N, low F) part of the societal risk curve represents the region where the number harmed (N) is in the range $0.1 \times N_{max}$ [N [N_{max} and the 'left-hand' (low N, high F) part represents the range $N < 0.1 \times N_{max}$.

The assumption used in the ARI_{COMAH} methodology is that the 'left-hand' part of the FN curve can be approximated by a line with a slope of -1 on a log-log scale, and this assumption was used here. Therefore the 'left-hand' part of the societal risk curve was extrapolated by drawing a straight line through the point ($0.1N_{max}$, $F_{0.1Nmax}$) with a gradient of -1 when plotted on a log-log scale.

RESULTS

For the chlorine installation (road tanker delivery to 2 storage tanks and supply to manufacturing plant) the representative case (that is, those cases which most closely replicated the FN curve for $0.1 \times N_{max}$ [N [N_{max}) only required inclusion of the following 5 scenarios:

(a) release from a 50 mm effective diameter hole in the liquid space of storage vessel;
(b) release from a 25 mm effective diameter hole in the liquid space of storage vessel;
(c) release from a 13 mm effective diameter hole in the liquid space of storage vessel;
(d) catastrophic release from the storage vessel (full capacity); and
(e) catastrophic release from the storage vessel (half capacity).

All the other scenarios relating to liquid releases from tanker operations and pipework, and vapour releases from the vessel spaces were not required.

The societal risk curve for the representative case is illustrated in Figure 2 and was the same as that of the base case for values of N in the range $0.1 \times N_{max}$ [N [N_{max}. Furthermore, the societal risk curve for the representative case was similar to that of the base case for values of N in the range 200 [N [$0.1 \times N_{max}$.

The extrapolated societal risk curve (for values of N in the range N [$0.1 \times N_{max}$) lies somewhat lower than that of the base case. Therefore the extrapolated curve underestimates the societal risk in this region. It is judged however that this is a reasonable approximation to the base case.

For the hydrogen fluoride installation, the representative case replicated the base case by only including the following 12 scenarios, namely:

(a) catastrophic release from the 9.9 tonne storage vessel (full capacity, 9.9 tonne);
(b) release from a 50 mm effective diameter hole in the 9.9 tonne storage vessel;
(c) catastrophic release from the 72.9 tonne storage vessel (full capacity, 72.9 tonne);
(d) release from a 50 mm effective diameter hole in the 72.9 tonne storage vessel;
(e) catastrophic release from the 48.6 tonne storage acid settler vessel (full capacity, 48.6 tonne);
(f) release from a 50 mm effective diameter hole in the 48.6 tonne acid settler vessel;
(g) releases from certain sections of pipework (2 × full bore, 11.4 kg/s, 9.12 kg/s, 2.85 kg/s and 2.28 kg/s continuous release for 30 minutes).

All other releases from pipework, pumps and transfer couplings were not needed to be included.

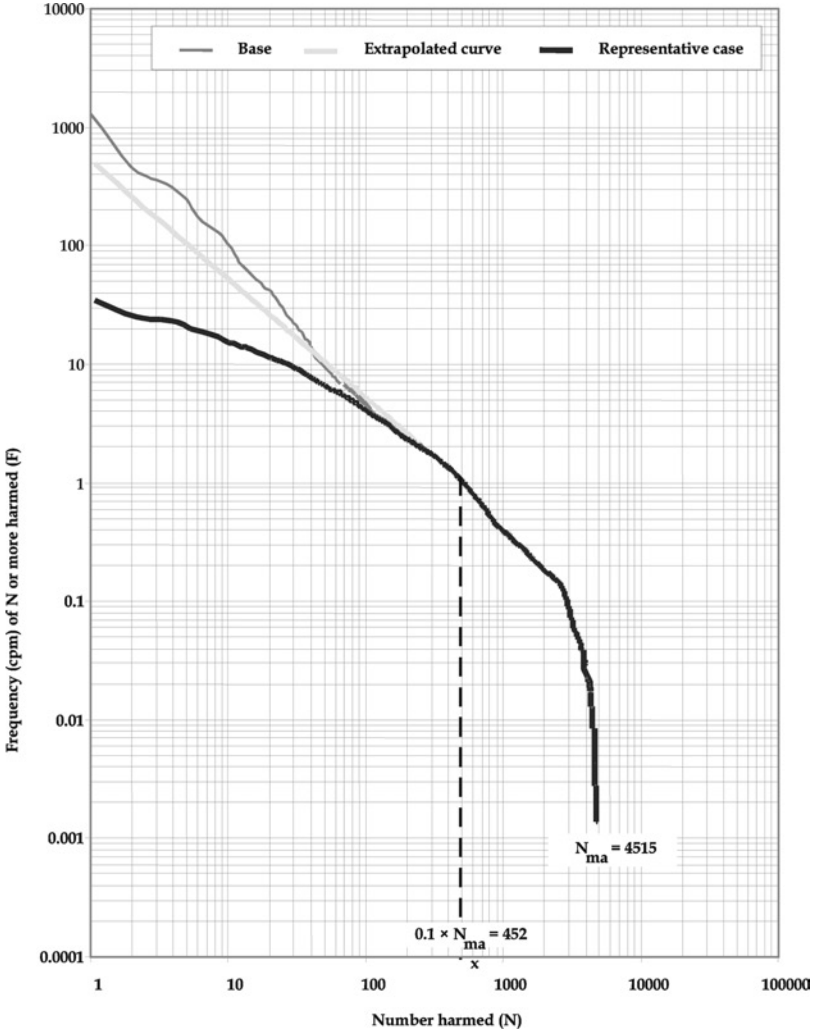

Figure 2. Chlorine installation: summary of societal risk curves

The societal risk curve for the representative case as illustrated in Figure 3 is similar to that of the base case for values of N in the range $0.1 \times N_{max}$ [N [N_{max}. Furthermore, the societal risk curve for the representative case is similar to that of the base case for values of N in the range 300 [N [$0.1 \times N_{max}$.

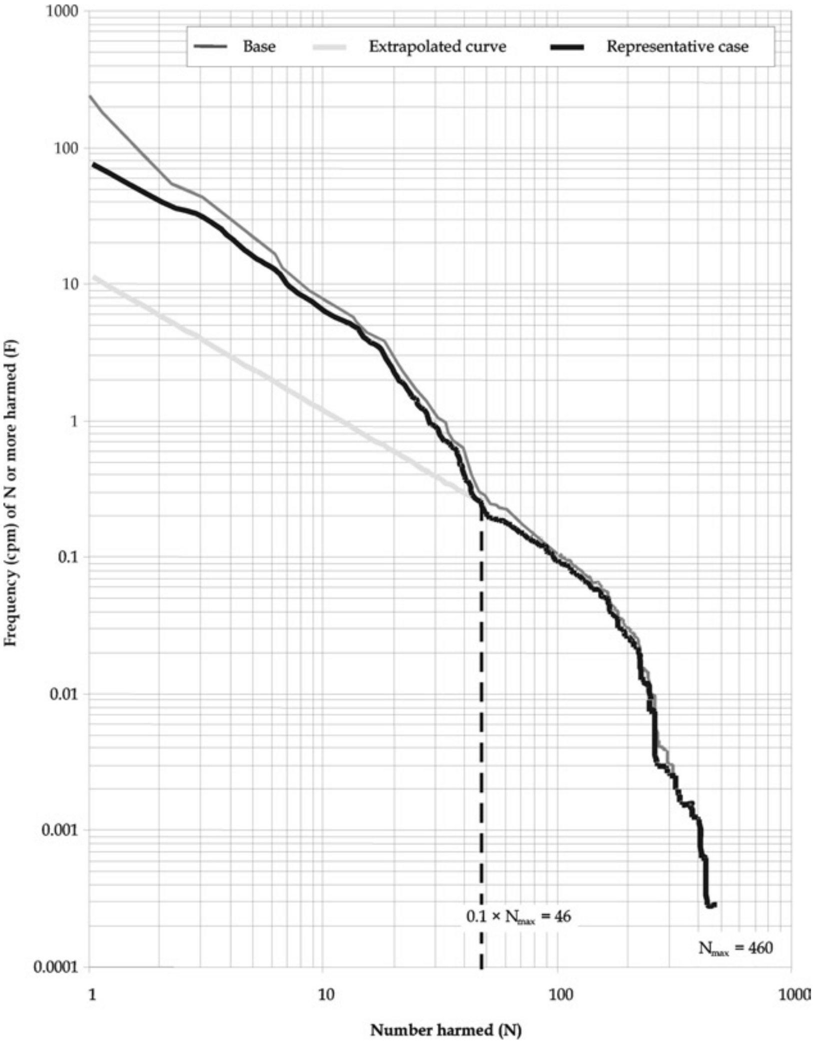

Figure 3. Hydrogen fluoride installation: summary of societal risk curves

The extrapolated societal risk curve (for values of N in the range N [0.1 × N_{max}) lies somewhat lower than that of the base case, and hence the extrapolated curve underestimates the societal risk in this region. However it is considered that this is a reasonable approximation to the base case.

CONCLUSIONS

Inspection and comparison of the representative cases with the corresponding base cases illustrates that the ‘right-hand’ part of the societal risk curve can be approximated by including fewer hazard sources and associated scenarios than typically included in the calculation of societal risks (i.e. the FN curve).

For the bulk chlorine installation the representative case only requires 5 scenarios and 1 hazard source rather than 51 scenarios and 7 hazard sources for the full FN base case. Similarly for the hydrogen fluoride installation only 12 scenarios and 5 hazard sources are required in the representative case, compared to 69 scenarios and 21 hazard sources in the base case.

Through extrapolation of the approximated ‘right-hand’ side of the FN curve, a reasonable approximation to the entire societal risk curve can be made (for installations of these types). The advantage of this is that far less installation data is required, and FN curve calculation requires less installation specific information and significantly less effort.

The QuickFN treatment has also been used for other types of installations including a chlorine drum installation, a liquefied flammable gas processing plant, and an LPG distribution depot. The details for these installations are not considered in this paper because of space restrictions. However, for the flammables installation, the results suggest that the number of scenarios and hazard sources considered cannot be significantly reduced while maintaining a close comparison to the societal risk curve of the base case. It is likely that this is due to the relatively small consequence harm envelopes compared to those for the toxics installations. As such, N_{max} is generally significantly lower than for the toxics installations. Hence an approximation to the societal risk curve for the base case for values of N in the range 0.1 × N [N [N_{max} requires inclusion of comparatively more hazard sources and scenarios.

Inspection and comparison of the societal risk curves for the different population sets illustrates that a reasonable approximation of the societal risk curves (by including fewer hazard sources and scenarios, for installations of these types) can be achieved by using a ‘low’ detail representation of the surrounding population (i.e. polygonised data).

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