NUMERICAL RISK ASSESSMENT AND LAND USE PLANNING

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The proposed siting of new chemical Hazardous Installations, modifications to existing Hazardous Installations, and proposals for development within the vicinity of these installations, are assessed by the Hazardous Installations Directorate (HID) of the Health & Safety Executive. Numerical risk assessment methodology is utilised to enable advice to be given to Local Planning Authorities.
The use of 'top down' Quantified Risk Assessment methodologies is well established in these circumstances. HID also uses simplified 'Risk Integral' techniques to enable decisions to be made on a consistent basis at low cost.
This paper describes the application of these numerical techniques with actual case studies which illustrate the methodologies and decision making criteria. The subsequent consideration and provision of risk reduction measures is also described with examples. The implications for the successful management of off-site risk are discussed.

Keywords: Hazardous installations, risk assessment, land use planning, numerical techniques

INTRODUCTION

Risks associated with major chemical accident hazards, though no different in many respects to all other health and safety risks, have the additional dimension of potentially resulting in a disaster, possibly involving members of the public. Though many aspects of societal concerns associated with major accidents are not amenable to analysis, the scale of the consequences and the associated likelihood are capable of numerical description and therefore provide a consistent though incomplete measure of risk.

Risk management is necessary both by industry and society to demonstrate that all reasonably practicable measures are taken to ensure the heath and safety of persons who may be affected, and the environment. This must include a decision making process which is appropriate, soundly based, open and transparent [1], so that all interested parties can participate and see that the objectives are achieved.

Successful management of these matters requires a systematic approach [2]:

Major Accident Prevention Policy (MAPP)
I
Organisation
I
Planning and implementation
I
Performance measurement
I
Review & audit

The Control of Major Accident Hazard Regulations 1999 (COMAH) implement the European Union (EU) Directive in the UK, and apply specifically to major chemical hazard sites. These requirements are in addition to the general requirements of the Health & Safety at Work etc Act 1974 and its associated Regulations, which include a requirement that employers are to conduct their undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in their employment who may be affected by work activities are not exposed to risks to their health and safety. Measures to reduce risk must be taken until the risk is broadly acceptable, or the cost, whether in money or effort, of further risk reduction, would be grossly disproportionate to the reduction in risk that would be achieved, in accordance with the principle of 'as low as reasonably practicable' (ALARP) [3]. Proposers of new hazardous installations need to show that adequate consideration has been given to the adoption of inherently safe technology.

RISK ASSESSMENT

Risk assessment is used to determine how the risks associated with an activity can be reduced to a level that is broadly acceptable. There are many possible methodologies which can be utilised [4]:

Qualitative risk assessment is the comprehensive identification and description of hazards from a specified activity, to people or the environment. The range of possible events may be represented by broad categories, with classification of the likelihood and consequences for comparison and the identification of priorities.

Semi-quantitative risk assessment is the systematic identification and analysis of hazards from a specified activity, and their representation by means of qualitative and quantitative descriptions of the frequency and extent of the consequences, to people or the environment. The assessment is informed by a representative selection of specific examples for comparison with standards.

Quantitative risk assessment is the application of methodology to produce a numerical representation of the frequency and extent of a specified level of exposure or harm, to specified people or the environment, from a specified activity. There is also a comparison of the results with specified criteria.

All assessments operate within a common framework:

Define scope
I
Perform hazard analysis
I
Perform risk estimation (with sensitivity and uncertainty analysis)
I
Compare with criteria
I
Consider of risk reduction measures
I
Report

DEFINITION OF SCOPE

- Risk from what? The system under scrutiny must be defined, including the circumstances in which it operates. Any relevant factors which are being excluded from consideration must be clearly stated.
- Risk to what? What are the objects of our concern?
- Risk of what? What are the measures of exposure and harm that we wish to assess?
- So what? Identification of the criteria against which to judge the outcome, including the basis for dealing with uncertainty.

HAZARD ANALYSIS

- Top down.

The possible hazardous events are identified in a general way and estimates of frequencies from knowledge of previous accidents and generic data sources are made. Dominating events are selected for more detailed analysis. The consequences and likelihood of the outcomes are described.

- Cause and effect.

Causes of possibly hazardous conditions are identified by means of checklists and analysis techniques, including reports of accidents from similar activities. The results are available during the design, commissioning, operation, maintenance and modification operations for an activity and appropriate means of prevention, control and mitigation established. Abnormal conditions are postulated and appropriate control systems specified.

- Comparison.

Relevant standards and best practice for the operations are identified and the recommendations adopted.

- Continuous.

Data is collected and audits are carried out to establish the actual safety performance of the operation, and appropriate remedial measures are identified.

RISK ESTIMATION

- Selection of a representative set of events.

This is not an exact or trivial process and requires judgement and experience. Also variations in the ambient conditions need to be included (day, night, summer, winter, wind-speed, atmospheric stability) as appropriate.

- Ranking of events by severity and likelihood eg. in a matrix.

This gives an initial indication of the relative importance of the causes and where most effort may be needed to reduce sensitivity and uncertainty in the final results. Screening methods, based on cautious estimates, may be used to eliminate non-contributing events from further analysis. The greater the uncertainty of the likelihood of an event, the more weight may be given to the consequences. Where the consequences are uncertain a 'worst case' basis may be appropriate.

- Calculation of the event frequencies and conditional consequence probabilities to give numerical estimates.

COMPARISON WITH CRITERIA

The estimated levels of risk are considered in relation to the tolerability criteria.

If the level of risk either for the installation as a whole, or for the aspects of the installation under consideration, is shown by professional judgement and comparison with known standards and good practice to be 'broadly acceptable' (ie individual risks are <1 cpm and societal risks are negligible) then a simple statement to this effect is sufficient.

Numerical results (risk contours, F-N curves etc) can be compared with the tolerability criteria identified at an early stage [3]. The main contributing causes of risk can be confirmed. Where uncertainty is high and large safety factors or a 'worst case' basis has been adopted, a decision can only be reached if the criteria are not exceeded.

SENSITIVITY ANALYSIS

- Would being more thorough be worthwhile?

Particularly where certain events dominate part of the risk spectrum additional analysis of those events could well be appropriate and give a much improved representation of the main contributing factors. In other cases it may be appropriate to look for additional ways that risks may be realised. For example, it is common not to include high wind speed conditions in dispersion studies due to their relatively low frequency. However where positively buoyant conditions occur at the source (eg fires and other hot releases, containing toxic substances), the inclusion of high wind speeds (eg 10 metres per second or more) in the consequence modelling may result in much larger ground level concentrations and overall risks in the near field [5]. What were the initial assumptions? Are they still appropriate?

UNCERTAINTY ANALYSIS

- What I know I don't know, and what I don't know I don't know.

Uncertainties occur in the data used to set frequencies and probabilities, in the consequence models, and in the risk assessment methodology [6], particularly where important aspects of a problem have not been identified during the hazard analysis.

Where risks are estimated on a 'cautious' basis and that is satisfactory, or the criteria are not exceeded, then further uncertainty analysis is not necessary. However, where options are being considered of a different nature, eg whether to transport hazardous goods by road, rail or pipeline, then the uncertainties can be very important and possibly make the results of a quantified risk assessment unsuitable for decision making. The initial result of the analysis may be to identify where the greatest uncertainties exist and thereby justify research to improve our understanding.

The assessment of uncertainty also involves uncertainty. In many cases a simple estimate of the uncertainties and the use of qualitative judgement is as good as can be expected.

RISK REDUCTION MEASURES

- What could be done to reduce the consequences and frequency?

Simply relying on compliance with established codes may not be sufficient. In the case of major hazard installations the analysis for severe faults needs to review the design basis and look beyond that which is 'reasonably forseeable'.

Elimination, prevention, control and mitigation all need consideration before such risks can be judged to be properly controlled. Does the cost exceed the benefit? Is there gross disproportion? The reduction in risk should be estimated for each possible option.

Cost-benefit analysis can be used for difficult cases where the frequencies are low but the consequences are high. In more straightforward cases 'lines of defence' analysis can be used to assess options. 'Affordability' is not a legitimate consideration. Numerical results cannot justify non-compliance with statutory duties nor risks which are greater than following known standards and best practice, but may justify deviations from standards where risks are thereby reduced.

REPORT

- Describing the process and outcomes in a suitable way for the recipient.

Good documentation of the whole assessment process is critical. An 'audit trail' should be established at the beginning of the process. It is important that the information necessary for the decisions to be taken is presented in such a way that the decision makers will have confidence in their decision. In many cases an executive summary of one or two pages is most appropriate, with the supporting documentation available for reference. Direct discussion between the assessors and the decision makers throughout the risk assessment process can prevent unnecessary time and effort being expended on unimportant aspects.

Early identification of problems and their consideration can be of great importance. Where necessary the scope of the assessment can be modified accordingly. The assessment may need to be referred to long after the persons concerned have moved on to other work.

LAND USE PLANNING

For the last 15 years HSE has used quantitative risk assessment to assess the 'residual' risk from hazardous chemical installations [7]. That is the risk that remains to persons offsite after the risks at the installation have been made as low as is reasonably practicable. The maximum quantities of hazardous substances that the sites are entitled to have present are used as the basis for the assessments. The usual product of the methodologies are three concentric contours on a map of the area showing defined levels of individual risk to a hypothetical house resident who spends all of their time in or in the vicinity of their dwelling. The level of harm specified is exposure to the dangerous toxic load (DTL) [8] or equivalent for thermal radiation or blast overpressure, or worse.

Exposure of persons to the DTL would cause:

severe distress to all
a substantial fraction of the population requiring medical attention
some requiring hospital treatment
some (about 1%) fatalities

In some cases, where the risk is from a clearly defined and dominating hazard, such as a bulk storage tank at a small liquified petroleum gas (LPG) distribution site which on jet flame impingement could fail catastrophically within about 15 minutes resulting in a boiling liquid expanding vapour explosion (BLEVE) and a consequent fireball, the contours may be established on the basis of hazard range alone.These contours form the basis of HSE's advice to local planning authorities (LPAs).

A site may voluntarily agree to reduce off-site risks. An example is given in case study 1.

OBJECTIVES

Hazardous Substance Authorities (HSAs), which are generally the same locally elected government bodies as the LPAs, are required to consult HSE about the siting of new hazardous installations and modifications to existing hazardous installations, and LPAs are required to consult HSE about applications for development in the vicinity of existing hazardous installations. The objective of consultations between LPAs and HSE is to keep incompatible developments apart, and to this end HSE advises against the granting of planning permission for a significant development proposal in the vicinity of a hazardous installation [8].

PLANNING APPLICATIONS

Planning applications for developments in the vicinity of hazardous installations are first considered using a four category and three zone policy, making use of the risk contours previously mentioned, forming the 'consultation distance'.

Development proposals are placed into 4 broad categories:

Industrial (factories, offices, warehouses of limited size)
Retail and leisure (shopping and leisure developments of limited size)
Residential (housing and hotels)
Institutional or sensitive (hospitals, schools, accommodation for the elderly etc)

The three zones are:

Inner (where the risk, of a hypothetical house resident of being exposed to the DTL or greater, exceeds 10 chances per million (cpm) per annum)
Middle (where the risk is between 10 and 1 cpm)
Outer (where the risk is between 1 and 0.3 cpm)

In the inner zone only industrial and other very small developments are not advised against.

In the outer zone only institutional or sensitive developments and very large examples of certain other developments are advised against.

In the middle zone and in other cases of where the above policy does not result in a final answer the development proposal is considered on its merits. The main factors that are considered are:

The numbers of persons at the development and their sensitivity
The intensity of the development
The level of risk, taking into account the pattern of use of the development

These factors are all included in a parameter known as the scaled risk integral (SRI) [9]. For example, a proposal for 30 houses on a 1.2 Ha site at a risk of 1 cpm would result in a SRI of approximately 2500, which is used as the decision boundary value for 'significant' risk.

For developments involving sensitive populations (children, elderly etc) the number of persons is first multiplied by 2. For developments involving working populations those numbers are first divided by 4.

PROPOSALS FOR NEW HAZARDOUS INSTALLATIONS

A new hazardous chemical installation requires 'consent' from the HSA [10]. The HSA has to consult HSE for advice on the level of risk to the existing community and allow HSE to specify any 'conditions' that should be imposed over and above compliance with statutory requirements. A proposal for a new hazardous installation (HI) is first assessed to determine whether there are possibly incompatible developments within the likely consultation distance. These are existing populations which would automatically receive advice against if they were to be proposed following the existence of the HI (eg housing in the 'inner' zone or where the SRI exceeds 35,000).

If this is not the case then the 'case societal risk' for the proposal is estimated using another parameter called the approximate risk integral (ARI) [11]. The risk integral (RI) is defined as the integral under the curve of the cumulative frequency (F) times the number of fatalities (N) that may be expected among the local community from the hazardous installation. This formulation includes a substantial allowance for numerical risk aversion which we consider appropriate in these circumstances [11]. (NB The SRI is equal to the RI divided by the area of the single development proposal.)

The ARI uses a simplifying assumption that the plot of cumulative frequency F against N has a slope of approximately -1 on a log-log scale. The ARI is calculated from an assessment of only a single event at the installation. That is the 'worst case' type of event in terms of consequences and frequency. If the value of ARI does not exceed 10,000, and there are no 'incompatible' existing developments in the vicinity, then no further consideration of risks are considered necessary.

GENERIC RISK ASSESSMENT

In addition to compliance with the Health & Safety at Work Act [12] all hazardous chemical sites that come within the scope of the COMAH Regulations [13] also require hazardous substance consent from the HSA [10]. In all applications the maximum quantity of substance must be specified. Also the manner in which the substance is to be kept (buried/mounded/above ground, plus temperature and pressure information) is specified along with the maximum vessel capacity.

If a site chooses to apply for (or 'claim' in the case of existing inventories at the time of introduction of the Regulations) hazardous substance 'consent', but wishes to retain flexibility concerning the quantities of specific substances that may be present, then they may apply for consent for a category of substance (eg. 'toxic', 'very toxic', 'flammable', 'reacts violently with water' etc) where those substances are not specifically named in the schedule to the regulations. In this case HSE carries out a very simple generic assessment based on a 'worst case' exemplar substance for that category, and combines this with cautious frequency and consequence values to produce a conservative assessment. An example is given in case study 2.

Where unconditional consent would not be acceptable, possible 'conditions' are discussed with the site until the estimate of risk complies with the previously stated criteria. An example is given in case study 3.

CONCLUSIONS

Good risk assessment principles are universal, but risk criteria need to reflect the practical, social and cultural context in which they are to be applied.

Risk assessments only need to be 'fit for purpose' and simple screening methods are useful to ensure that the most effort is applied to the most difficult problems.

A QRA must be both reasonable and practicable. If the cost of the proposed improvement is of the same order as the cost of carrying out the analysis then professional judgement, supported by appropriate information, is the best basis for a decision. If adequate data or physical modelling is not available then much of the analysis has to be based on judgement in any case. It is on these occasions that wishful thinking can ruin an otherwise sound approach.

Though consistency in the application of QRA to major chemical hazards can be achieved by the strict application of standardised methodology, the significance of the results may be questionable in absolute terms. However the methodologies are now well established and provide good insight into the relative merits of risk reducing options.

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Nothing in this paper should be interpreted as a statement of HSE policy.

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CASE STUDY 1: USE OF QRA TO DECIDE REASONABLY PRACTICABLE RISK REDUCTION MEASURES.

INTRODUCTION

This example is based on an sulphur trioxide/oleum production facility. The company decided to undertake a major refurbishment of the existing site at a cost of about £16M to reduce the risks to off-site populations as required by Section 3 of the HSW Act. This involved, among other things, relocation of the storage tanks, which in turn required a variation in the Company's hazardous substance consent to be granted by the LPA. HSE became involved when the Company and LPA sought advice.

RISK REDUCTION MEASURES (RRMS) PLANNED BY THE COMPANY

The Company had already designed a new plant to support its application, the purpose being to significantly reduce the risks from the manufacture, storage and tanker loading of sulphur trioxide and oleum.

The main measures proposed by the Company were:

I. To replace existing SO3 tanks (3 by 65 te) by new double skinned tanks located inside a refurbished building to provide a modern secondary containment building.
II. To undertake all tanker loading indoors.
III. To reduce the number of operations involving 65% oleum
IV. To reduce the inventory of 30% oleum from two 1500 te tanks (single skinned, outdoors) to one 500 te tank (double skinned, indoors).
V. To replace of the converter for producing SO3, heat exchangers, absorption towers, and associated equipment.

The Company employed consultants to assess the possible impact of the RRMs on its CD. Their QRA indicated that the contours defining the extremities of the inner, middle and outer zones would be reduced by about 40 to 50%.

HSE'S QRA TO SET A NEW CD AND CONSENT CONDITIONS

The Company decided that for operational flexibility it required three 100te tanks that would normally hold 65 te, but occasionally one may be full. In the event of an emergency the extra capacity would enable the contents of a leaking tank to be transferred to another tank, thereby mitigating the incident.

The HSE QRA confirmed the significant reduction in risk levels and highlighted that the extent of the outer zone was influenced by the number of SO3 tanker loadings and the extent of the outdoor pipe work between the new production unit and the storage area. As a result of discussions with HSE the company agreed to:

- increase the height of the internal bunding around vessels to prevent overtopping in the case of catastrophic vessel failure;
- implement the Consent conditions at 4, 5 and 6 below.

Releases resulting from the loading of oleum into tankers were not significant. Credit was given for double walled vessels; vessel failure rates (catastrophic and limited failures) were reduced by a factor of 10. Mitigation provided by the building was modelled as described by Porter et al (17).

The QRA was based on over 120 scenarios covering:

- Liquid SO3 releases indoors (vessels, pipework and tanker loading)
- Gaseous SO3 releases outside (Converter vessel and pipework)
- 20% and 30% Oleum releases indoors (vessel, pipework and tanker loading)
- Various failures of oleum absorption tower leading to release of 35% oleum outside
- Outside pipework and plant failures leading to releases of 35% oleum
- Outside pipework failures leading to releases of 27% oleum.

The QRA enabled risk contours to be drawn for the new arrangements. The approximate extents of the risk contours from the centre of the storage area before and after improvements are shown in Table 1 below.

The main conditions placed on the Express Consent application were:

I. SO3 and oleum to be stored in double-walled vessels.
II. No vessel to contain more than 100te
III. All vessels and loading operations to be located in a normally-closed building
IV. An automatic leak detection system to be installed in the building and interlocked with the outlet valves from the storage tanks so that they close ‘automatically’ in the event of a leak.
V. In the event of a leak, the leak detection system should close down the ventilation of the building, but suction to the scrubber should be maintained.
VI. An automatic leak detection system to be installed outside, which automatically triggers the shutdown of pumps on the 250 mm dia oleum pipework conveying oleum and SO3 between the manufacturing plant and the storage tanks.

The measures agreed between HSE and the Company lead to the risk contours being reduced by 60% to 80%. The risks to off-site populations are now considered to be more compatible with the off-site developments.

Risk contour	Before RRMs	After RRMs originally proposed	After RRMs agreed with HSE
10 cpm	500	300	100
1 cpm	1,100	600	300
0.3 cpm	1,600	800	650

Table 1 Approximate extents (m) of the risk contours from the centre of the storage area before and after risk reduction measures (RRMs).

CASE STUDY 2: VARIATIONS TO AN INITIAL GENERIC CONSENT CLAIM (EXAMPLE)

An initial claim was made by a site for 500 te (Qn = 500) of toxic liquids (controlled quantity 50 te, Qt = 50) and 40 te of very toxic liquids (controlled quantity 5te) in a single vessel area (Nv = 1).

The worst case substance that could be stored is considered to be methyl chloroformate.

The maximum vessel volume for toxic liquid was stated to be 40 m^3 (V = 40).

The installation is assessed on a 'worst case' basis.

The frequency of an event involving the maximum vessel volume is calculated from a formula:

$F = 10 \times (Qn/Qt)^{1/2}/Nv$ cpm ie $=10 \times (500/50)^{1/2} = 31.6$

The radius of the resulting pool of liquid is also calculated from a formula:

$R = 6.85 \times V^{0.44537}$ m ie = 35.4 m

The evaporation rates in D5 and F2 weather conditions are also parameterised:

$M_{D5} = 9.73 \times 10^{-3} \times R^{1.9296}$ kg/s $M_{F2} = 6.03 \times 10^{-3} \times R^{1.89}$ kg/s
ie $M_{D5} = 9.5$ kg/s and $M_{F2} = 5.1$ kg/s

A similar procedure is followed for the very toxic liquid.

These source terms and frequencies were then entered into a simple passive dispersion and risk calculation model and the following risk contours were produced (Figure 1).

The worst case of using methyl chloroformate as the exemplar for toxic liquid would be unnecessary if the site were to accept a variation to the consent to limit the toxicity of the substance to 0.5 mg/m^3 LC 50 (Rat) and a boiling point of no less than 75 degC.

In this case the exemplar substance can be changed to propionitrile with the following result (Figure 2).

CASE STUDY 3: RISK REDUCTION MEASURES IDENTIFIED AS A RESULT OF AN EXPRESS CONSENT APPLICATION

The company involved produces water treatment chemicals. It recently applied for express hazardous substance consent for 20 te of very toxic substances, and 500 te of toxic substances, but did not specify particular substances. (When companies do not specify the substances that they will store HSE uses a generic assessment methodology based on exemplars for risk assessment purposes.).

The site has two outdoor storage tanks (40 m3 and 25 m3) for toxic liquids. In addition there are storage areas for packaged toxic and very toxic substances held in a covered warehouse, in open warehouse areas, and outside storage areas. There are three production areas, one of which has 7 reactors processing toxic substances. Blending processes take place in all three production areas in vessels containing toxic and very toxic substances.

RISK ASSESSMENT

When the generic methodology was applied to define the LUP zones, the resulting risk contours shown in Figure 3 were presented to the company. These risk contours were based solely on information in the express consent application. The 10 cpm contour was dictated by the quantity of toxic solids (hazards from warehouse fire plumes) the other contours were dictated by the quantity of toxic and very toxic liquids, using methyl chloroformate as the surrogate i.e. the hazards presented by evaporation from a pool following a 40m3 spill in D5 and F2 weather.

It can be seen from Figure 3 that there are a large number of houses in the middle zone (1 to 10 cpm). There is also a school and possibly other sensitive populations in the outer zone (1 to 0.3 cpm). The societal risks are therefore significant and HSE would have advised the local authority not to grant the hazardous substance consent. Some risk reduction measures were necessary to reduce the impact of the site on the local population. These would need to become the conditions of consent given at the end of this appendix.

Using condition (ii), the generic risk assessment was repeated using less toxic liquids as exemplars ie methyl iodide and propionitrile. The latter reduced the extents of the 1 and 0.3 cpm contours so that few houses were in the middle zone and the school was beyond the outer zone. The analysis also showed that catastrophic failure of reactors was potentially more hazardous than storage vessel failure owing to the releases being at elevated temperature (200 deg C) so that the entire reactor contents become airborne following loss of containment. Limits for the maximum quantities of materials in reactors (largest 12 te) were set by the application of ARI methodology.. The consequences of a 12 te release of propionitrile were therefore assessed and used to estimate the ARI. The wind direction that would give the worst consequences was used, giving at least 250 fatalities (LD50). The failure frequency was taken as 16 cpm, based on four 12 te reactors each with an estimated failure frequency of 4 cpm. This gives an ARI of 3,700,000 which is significantly greater than the criterion value for acceptable societal risks ie 10,000.

It is not reasonably practicable to reduce the reactor failure frequency by a factor of 400 in order to meet the criterion so, inherently safer methods must be considered ie reduce stored quantities, use less toxic substances etc. Reverse ARI calculations were therefore conducted. These showed that 2 te of propionitrile per reactor (failure frequency 7 x 4 = 28 cpm) give an ARI of 6000. (Condition (iii))

These results were discussed with the company. They agreed to accept some conditions on their Consents application provided they could store larger quantities of two named substances. Reverse ARI calculations suggest reactor quantity limits of 12 and 5 te respectively for these substances. The company also agreed to limit the very toxic consent to the substance currently present and similar substances. [The substance is a viscous liquid with very low vapour pressure at ambient temperature (vapour pressure less than 1 Pa at 20^{o}C). It is classified as very toxic by inhalation because of tests undertaken with aerosols produced with the substance dissolved in water. On heating, decomposition begins before boiling. The company stores the substance in 200 l containers, and mixes it in blenders at ambient pressure. Provided that the substance is not pressurised, a significant off-site major hazard is not conceivable. (Condition (iv))

The site visit also enabled the warehouse RA to be updated. This and the changes agreed by the company results in the LUP zones shown in Fig 4 (LUP zones after the company agreed to adopt inherent safety measures).

HSE therefore advised the LPA that the express consent application, could be accepted provided that the following conditions are included in the consent:

i) The hazardous substances shall not be kept or used other than in accordance with the consent application particulars, nor outside the areas marked for storage of the substances on the plan which formed part of the application.

ii) No toxic substance shall be present on the site which has either a value for LC_{50} inhalation, rat, less than 0.5 mg l^{-1} $4hr^{-1}$ or a boiling point less than 75^{o}C at ambient pressure.

iii) No more than 2 t of toxic substances, along with up to 12 t of substance A or 5 t of substance B, shall be present in a reaction at above ambient pressure.

iv) No substance classified as very toxic shall be present on site other than the named substance. The named substance shall not be used in reactions or blending, above ambient pressure, being subject only to vessel recirculation pumping and self-standing pumping from moveable storage containers into a vessel.

GLOSSARY

ARI	Approximate risk integral
CD	Consultation distance
CPM	Chances per million per annum
COMAH	The Control of Major Accident Hazard Regulations 1999
DTL	Dangerous toxic load
HID	Hazardous installations directorate
HSA	Hazardous substance authority
LPA	Local planning authority
MAPP	Major accident prevention policy
QRA	Quantified risk assessment
RI	Risk integral
RRM	Risk reduction measure
SRI	Scaled risk integral

FIGURES

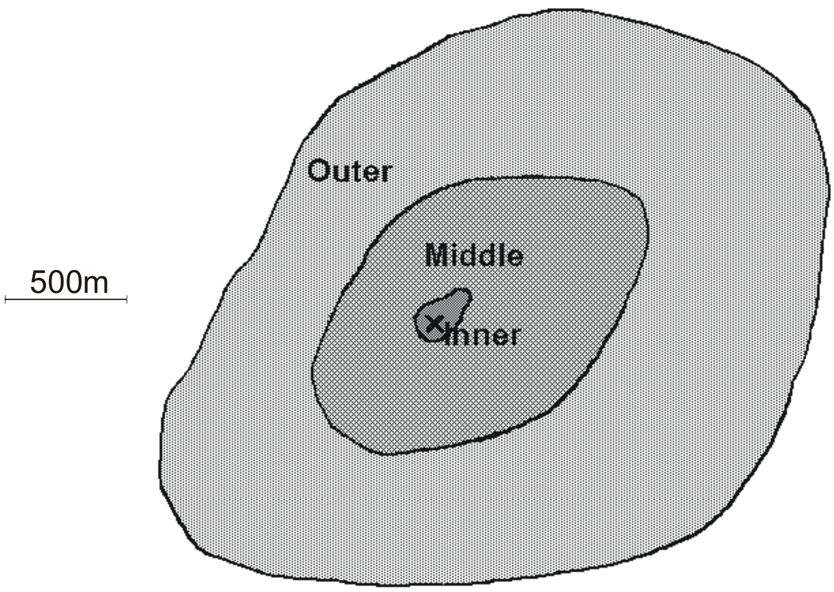

Figure 1: Land use planning zones: initial proposal

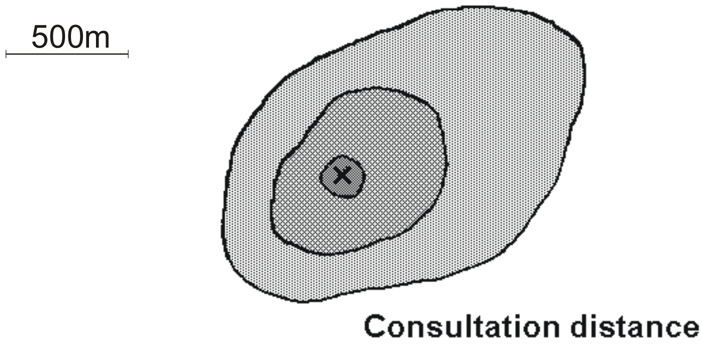

Figure 2: Land use planning zones: with conditions

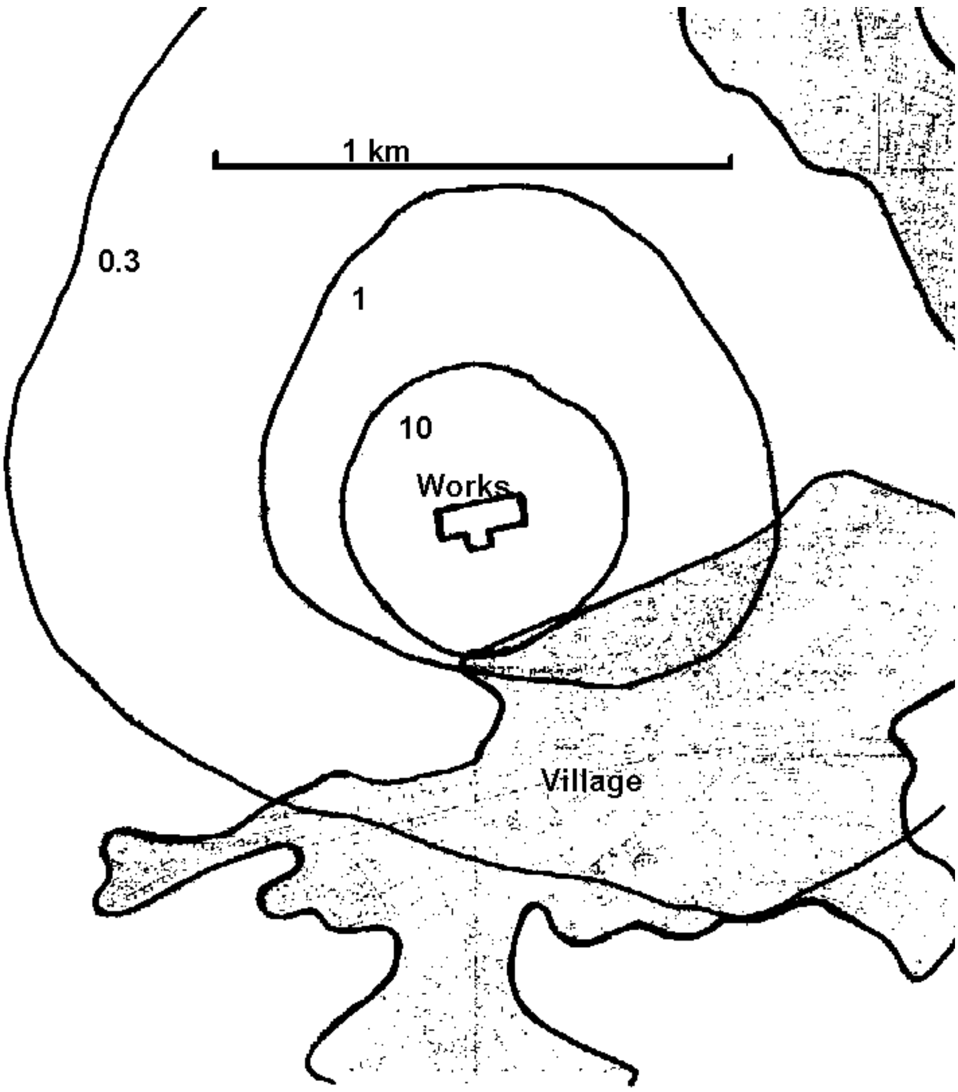

Figure 3: Land use planning zones: initial proposal

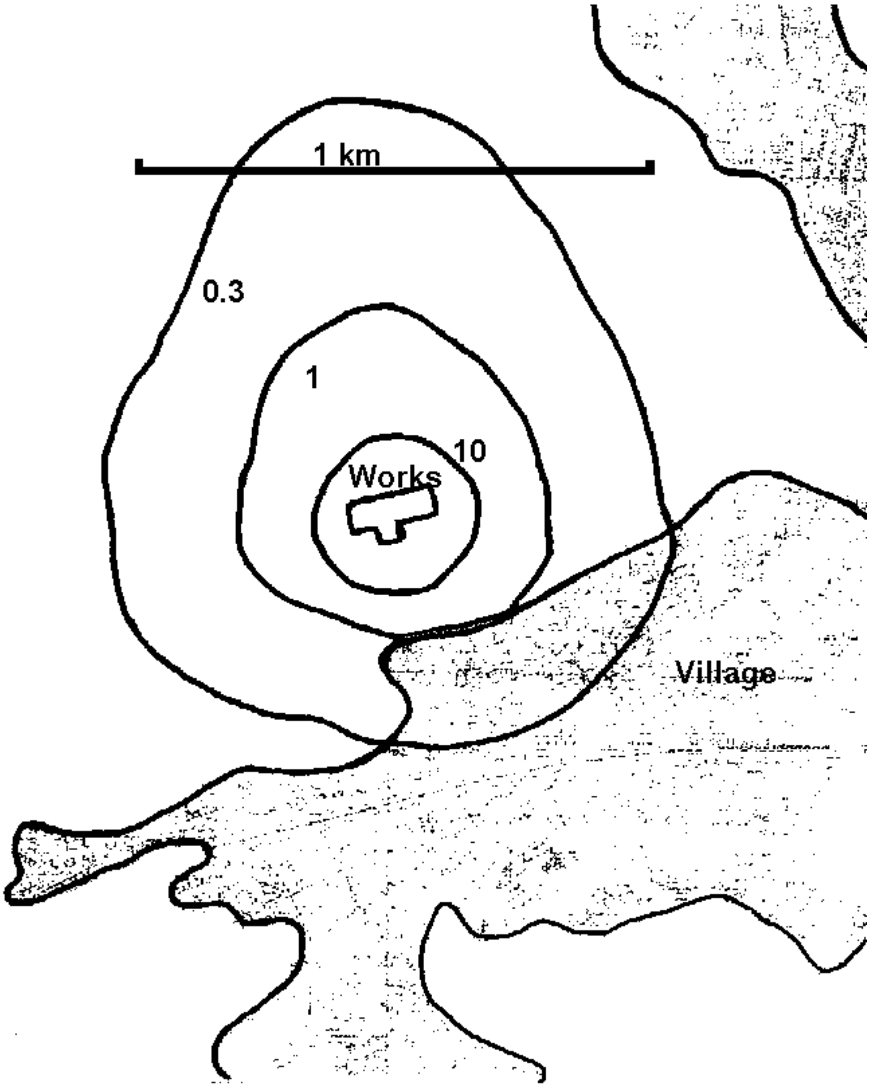

Figure 4: Land use planning zones: with conditions