A case study of land-use planning around pipelines

G. Spadoni[1], G. Antonioni[1], A. Barillari[2]

[1] University of Bologna, Department of Chemical, Mining and Environmental Engineering, Viale Risorgimento, n.2 – 40133 Bologna – ITALY

[2] Ferrara Municipality, Land-use Planning Service, Piazza del Municipio, 2 Ferrara - ITALY

In respect of art.12 of Seveso II Directive, the Italian regulation established criteria for land-use planning around major accidents establishments. In this paper its application, through a simplified procedure, is enlarged to pipelines, on behalf of Land-use Planning Service of Ferrara town which was interested in establishing criteria for assuring compatibility among an ammonia pipeline and residential areas and/or areas of public use. For sake of comparison, the accidental scenarios of the pipeline have been included in ARIPAR –GIS software and contour lines of individual risk have been calculated in order to show how territory planning could be alternatively achieved. Results are examined and compared and criteria, which could be inferred by the two outlined procedures, are discussed.

1. Introduction

The article 12 of the Seveso II Directive requires that the land-use planning policies pursue the objectives of preventing major accidents and limiting the consequences of such accidents in the vicinity of existing establishments by controlling developments or modifications of industrialised areas.

Italy, like other European Countries, defined the procedure for implementing such policies in a specific regulation (DM May 9th, 2001) which establishes criteria for assuring compatibility between residential areas, areas of public use, areas of particular natural sensitivity or interest and establishments. The main phases of the procedure are summarized in:

- identifying vulnerability categories of the territory: population in vulnerability centres like hospitals, schools, commercial centres,.., residential areas, areas of public use and industrial areas are classified in categories from A to F in descending order of vulnerability,
- evaluating damage areas of accidental scenarios: information and risk analyses performed by site managers are used and two or four distances to threshold values calculated for fires, fireballs, flash-fires, VCE and toxic atmospheric dispersions,
- establishing territorial and environmental compatibility: the judgement is given on the basis of probabilities (in a year) and damage distances of all the accidental events. For each couple (probability - distance to a threshold value)

of an accidental scenario the vulnerability categories in accordance with him are defined. If compatibility is not guaranteed, technological mitigation measures have to be evaluated in order to better protect population and environment.

This procedure is not required if the risk sources are pipelines transporting dangerous substances. Only an act dating from 1984 has to be respected that concerns the dangerous substance methane. As a consequence, when the land-use planning of a large territory must be done neither prescription nor suggestion is available to define which the right distance from a pipeline is.

Fig.1. Ammonia pipeline and Ferrara town territory

2. The case study

On behalf of Land-use Planning Service of Ferrara town, the pipeline transporting ammonia as a liquefied gas from Ferrara to Ravenna has been analysed, with particular reference to the part included in the Ferrara territory. The pipeline, whose layout is shown in Fig.1, has a length of about 15 km, starts from the Ferrara chemical establishment and crosses the town territory passing by inhabited areas (grey areas in the figure) and vulnerability centres (locations represented by numbers in the figure).

2.1 The risk analysis of pipeline

As far as the substance is concerned, the study has considered the toxicity property of ammonia, omitting consequences of its flammability due to its high LFL (Lower Flammable Limit) and to its small flammability range (15-28%).

To perform risk analysis study, the usual, and well known, procedure has been carried out and the three phases of identification of accidental events, evaluation of accident frequencies and calculation of consequences of scenarios have been performed. It is worth noting that the analysis of historical accidents are useful for both phases one and two, because detailed reports can be found and examined (EGIG, 1993) where accidents are described, technical reasons detailed and statistical analyses performed. These last statistical evaluations are based on the large number of accidents included in the data bank to which the report is referred and allow to distinguish among different typologies of breakages and to calculate the occurrence frequency of each one, once the analyst has classified the breakages in proper "rupture categories". As a short report of the available information, in Table 1 the three categories of breakage assumed in this study are summarised and the associated frequencies are reported.

Table 1. Accident frequencies in ev/(y · km) of an ammonia pipeline

Reference Study	*Category 1* (max. Diameter d = 20 mm)	*Category 2* (d = 40 mm)	*Category 3* (Catastrophic breakage)
Historical analysis	1.7×10^{-4}	2.3×10^{-5}	3.0×10^{-6}

Some remarks must be made. First, frequencies are given with reference to a fixed pipeline length of 1 km putting in evidence the nature of "linear risk source" of a generic pipeline. It results that the frequency of an accident to determine a reference damage in a fixed receptor (a point of the territory) depends on the length of the pipeline that is able to trigger that damage. Moreover, the value of the accident frequency of the first category is ten times greater than the value of the second category, which is ten times greater than that of the third category. The importance of the first category is surely dominant and only this category has been considered for applying the procedure derived from Italian Ministry Decree.

As far as accident consequences are concerned (the third phase of the risk analysis procedure), a numerical code (Yellow Book, 1997; TUTUM,1994) is required to simulate the accidents resulting from the feasible breakages, because the physical phenomena involved in an outflow of the liquefied gas ammonia are complex. The expansion from the high pressure inside the pipeline to atmospheric pressure causes a two-phase stream to come out and large and small droplets of liquid are included in the developing vapour phase; finally the aerosol flow disperses and the pool coming from large droplets evaporates. The physical-mathematical description takes also the flow dynamics into account, since flow rate of the emerging stream is reduced after the intervention of blockage valve. Owing to these phenomena, the concentration in a territory receptor cannot be constant during the release duration and a dose is the best variable to choose in order to define a threshold for human life. A lethal dose equal to 0.1% (LD0.1) has been assumed as "beginning of the lethality", i.e. a threshold introduced by Ministry Decree. The distances to the LD0.1 is obviously different in the

three accidental release categories and for each category also depends on the meteorological conditions, because wind velocity and atmospheric stability class influence the gas dispersion, whether a neutral or a heavy gas model is used. The two meteorological aggregations (stability class – wind velocity, with velocity in m/s) D-5 and F-2 have been considered adopting the suggestions of the guideline given by Italian Civil Protection Department for emergency planning actions in this way obtaining two dispersion scenarios.

With the outlined hypotheses the distances of 215 m and 770 m have been obtained respectively during D-5 and F-2 meteorological conditions with reference to release category n.1 (note that LD50 values are respectively 50 and 85 m).

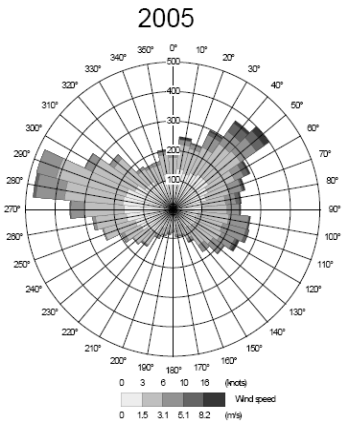

Fig. 2 Wind rose of the Ferrara territory (data from Regional Agency for Environment Protection)

The meteorological data of the territory were made available from Regional Agency and allowed to perform statistical analyses on annual distribution of wind intensity and origin direction: the wind rose of Fig.2 summarises the data used in evaluating probability of occurrence, during a year, for each meteorological aggregation of the study, once a specific release is considered. These values contribute to calculate final probabilities (in a year) of the two scenarios D-5 and F-2. Note that 36 values must be given for each as 36 are the sectors in which the wind rose is splitted.

3. The proposed compatibility procedure

Enlarging to pipelines the application of the procedure which the Decree asks for major hazard establishments is a hard task, owing to the linear nature of the risk source to be considered. The following simplified proposal started from the evaluation of the particular need of the Ferrara Land-Use Planning Service, which was interested, as a first aim, in establishing if the locations of vulnerability centres and built-up areas now located on the territory were respectful of the principles of the Decree.

The procedure here summarised is the first step to be done to perform this aim and afterwards can permit (and has actually permitted) to define rules for authorize new locations.

The steps are:

- identify all locations, where persons live, having distances from pipeline (measured on direction normal to pipeline) less or equal than those calculated for dispersions in classes D-5 and F-2 (215 and 770 m respectively). These locations could surely be subjected to a dangerous ammonia dose, in case of a release

- for all vulnerability centres or inhabitant areas identified,
    - calculate the length L of pipeline whose maximum distance do not overcome 770 m (215 m),
    - considering the stretch of the pipeline identified, evaluate which wind directions can hit individuals sited at that point,
    - sum the frequencies of the rose wind sectors identified and multiply this sum by the effective length the pipeline (about 10% of L for this case study).

Once multiplied by data in Tab.1, the result obtained is the probability (in a year) of the dispersion scenario D-5 or F-2 to determine in the point (area) on the territory a lethal dose greater than 0.1 %. Now the Decree can be applied establishing territorial and environmental compatibility, i.e. defining vulnerability categories accordant with these values.

Table 2. Vulnerability centres and compatibility of their locations

Point on the map	**Vulnerability centre**	**Probability to be involved in a release** (first release category - F-2)	**Local risk** (all release categories)	**Individual risk** (all release categories)
1	Church	1.3 10-7	9.8 10-08	6.9 10-09
2	Sport centre	1.9 10-7	4.8 10-08	1.6 10-08
3	Church	4.3 10-7	2.0 10-07	1.4 10-08
4 min. distance	Intermediate school	7.7 10-7	9.4 10-07	1.1 10-07
4 max. distance			8.9 10-08	1.1 10-08
5 min. distance	Sport centre	3.9 10-7	3.5 10-07	1.2 10-07
5 max. distance			1.9 10-07	6.3 10-08
6	Primary school	4.7 10-7	2.2 10-07	2.6 10-08
7	Intermediate school		8.9 10-08	1.1 10-08
8 min.distance	Sport centre	7.2 10-7	3.5 10-07	1.1 10-07
8 max. distance			2.6 10-08	8.4 10-09
9	Rest home	2.7 10-7	7.9 10-08	7.9 10-08
10	Centre for the elderly	7.2 10-7	4.0 10-08	2.0 10-08
11	Primary and intermediate school	8.6 10-8	3.7 10-08	4.5 10-09
13	Nursery school and kindergarten	2.1 10-7	2.6 10-08	3.1 10-09

4. Results

If attention is given to major-accident hazards which a pipeline can cause on a territory, the QARA methodology, well known for establishments, could be applied. This procedure was used in the case study and its results are here examined in order to put in evidence how land-use planning criteria could be verified adopting risk measures. For this purpose the ARIPAR-GIS code (Spadoni G., 2000) was used and local and individual risk measures evaluated. To avoid misunderstandings with other risk indices difference between the two cited measures is outlined: when local risk is evaluated a person is considered always present outdoor in a defined location, on the contrary the indoor protection and the presence probability of a person is taken into account in individual risk evaluation. This last measure would be used in defining land use planning criteria. Finally two procedures are available for comparing criteria.

4.1Preliminary remarks for complying Ministry Decree

Following the procedure outlined in paragraph. 3 each inhabited area or vulnerability centre can be examined on the basis of rules defined by Ministry Decree and territory compatible categories are established for each of them. The important consequence is the possibility to evaluate if the centre location agrees with law limitations. As above seen, the calculation of scenario probabilities is crucial to achieve results.
The probabilities obtained are given in Tab.2 with reference to the scenario called F-2.

4.2 A proposal for land-use planning with QARA

Iso-lines contours of local risk are presented in fig.3, with reference to the complete set of breakage categories as always done in typical QARA. Point values of local and individual risk are included in Tab.2 to know their exact values. Note that all centres would satisfy English planning criteria for establishments, which simply define threshold values of local risk to identify admissible territory areas.

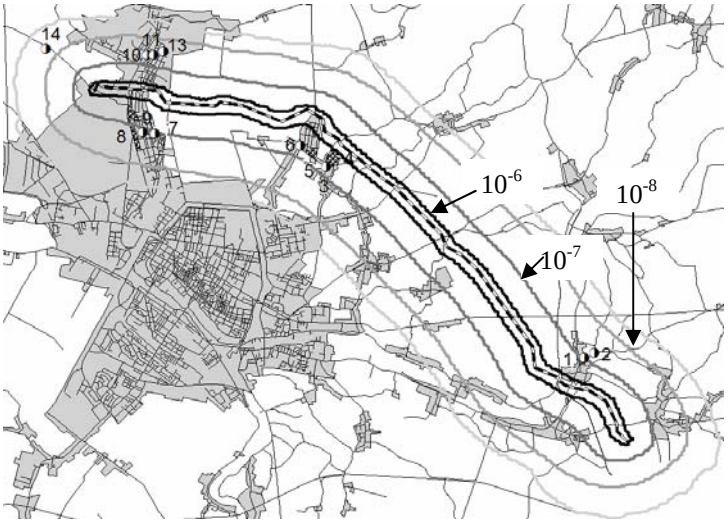

Fig.3 Iso-lines contours of local risk.

5. Conclusions

Land use planning procedures around pipelines are not established by European and national laws but major-accidents could occur in pipelines too if dangerous substances are transported. To judge if inhabitants live in low risk locations of a territory, a procedure has been proposed which is derived from that one requested for establishments by an Italian Ministry Decree. The procedure is simple enough and its results in a specific study (the Ferrara-Ravenna pipeline) show a good agreement with risk measures of QARA analysis. However, in spite of complex calculations requested by QARA, land-use planning criteria based on risk indexes should be simpler to apply.

References

DM May 9th, 2001, Italian GU June 6th, 2001 n.136.

EGIG, 1993, Gas pipelines incidents, report 1970/1992 – A report of the European Gas pipeline Incident data Group.

Van Den Bosh CJH, Weterings, RAPM. 1997, Methods for the calculation of physical effects (Yellow Book) The Hague (NL): Committee for the Prevention of Disasters.

TUTUM, 1994, Codice per la valutazione delle conseguenze. Regione Emilia-Romagna (in Italian).

Spadoni G, D. Egidi, S. Contini. 2000. Through ARIPAR-GIS the quantified area risk analysis supports land-use planning activities. Journal of Hazardous Materials, 71:423-436.