MEMbrain for Chemical Disasters Emergency Management

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1. Introduction

The nuclear disaster in Chernobyl in Ukraine, the toxic gas tragedy at Bophal in India, the toxic gas accident at Seveso in Italy, the unconfined gas cloud explosion in Flixborough in the UK and the crash of a road tanker with gas in San Carlos de la Rapita in Spain, have all shown the vulnerability of the modern society to industrial accidents.

In addition comes natuaral catastrophes like drought in African countries, hurricanes, earthquakes, forest fires in the USA, floods in China and Bangladesh,etc.

These examples illustrate that both industrial accidents and natural catastrophes happen all over the world, and represent a contious threat to world society.

The consequences may be of enormous scale. This has focused the world public opinion on industrial accidents aimed at avoiding them to happen. Stricter legislation and open international communication on problems have so far been the result of this. However, the potential that similar accidents should happen is still high. Even if a a lot of effort is put into reducing the probability that such accidents should happen, the modern society has to be prepared for both industrial and natural catastrophes in order to reduce the consequences and sufferings caused.

Information flow and access to reliable data, are the most critical aspects of efficient crises management. MEMbrain(Major Emergency Management) is an international EUREKA project aimed at developing a computerized decision support system for handling of environmental and other major crisis. It is based on international acknowledged, state-of-the-art technology.

2. The MEMbrain Concept

MEMbrain is a technology developed in an EUREKA project, EU 904. Companies and institutions from France, Finland, Denmark and Norway has participated and contributed to the project. The project was started in 1993, and the first application was delivered early 1997.

MEMbrain is a total emergency management concept which may comprise one or more of the following items:

- A risk assessment approach in order to define the functional requirements for the clients emergency management needs.
- A MEMbrain software system comprising of the necessary software modules fulfilling the clients needs for decision support in an emergency.
- Instrumentation, computer hardware and communication equipment necessary for equipping an emergency management senter.
- System installation and client user training and support.

The MEMbrain technology is modular and can meet different customers needs for different applications.

A set of software modules are available as stand alone software tools or integrated to a total integrated MEMbrain system, which can be tailor-made to the clients needs.

The MEMbrain technology is state-of-the-art technology for emergency management and is based on comercially available development tools. This assures that MEMbrain is a live system, always abreast with the newest technology in the hardware and software field. Figure 2.1 shows the MEMbrain system architecture.

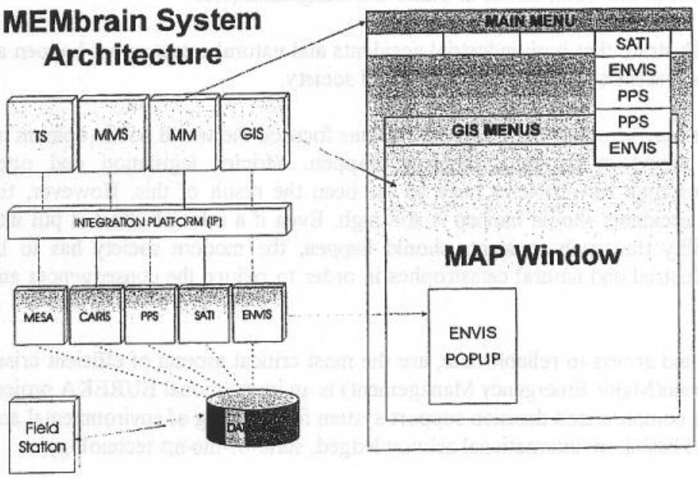

Figure 2.1. A sketch of the MEMbrain system architecture

3. MEMbrain Application for Nuclear Disasters

The first MEMbrain application is delivered to the Norwegian Radiation Protection Authority(NRPA) as a test application in the project. The system will be used as a decision support system for Norwegian nuclear emergency.

There are three data suppliers to NRPA:

- **The Norwegian Air Research Institute**
  Delivering radioactivity measurements from a radiation sensor network in Norway.
- **The Norwegian Meteorological Institute**
  Delivering weather forecast information and model results from simulation of large accidental releases of radioactive substances to the atmosphere from nuclear power plants or other sources.
- **OCEANOR**
  Delivering radioactive measurements in the sea from buoys located in the sea around Norway, and model results from simulations of dispersion of radioactivity substances in water.

The software decision system delivered to the NRPA is delivered with the following software modules:

- MM - Main Menu
- ENVIS - Environmental Information System
- SATI - Static Administrative and Technical Information System
- PPS - Public Protection System
- CARIS - Chemical and Radioactive Information System
- MMS - Message Management System
- GIS - Geographical Information System

The NRPA MEMbrain system has the following objectives:

- To present essential information of relevance to reduce the negative consequences in Norway of nuclear accidents.
- To form the basis for making the right decisions on countermeasures to reduce negative health effects and economical consequences.

The NRPA MEMbrain had its first real test during the world wide exercise on nuclear emergency in April 1997.

4. Potential Applications of MEMbrain

During the development period of MEMbrain, the project management of the project has been presenting the ideas of MEMbrain at different international technical conferences, and has been marketing the MEMbrain concept to different national authorities with the need for a crisis management system.

This has so far resulted in the following concrete projects where MEMbrain has been offered as a solution:

- Natural disaster management for China
- Disaster and preventive management for Shanghai/Pudong New Area
- Emergency management and response system for the Eastern Seaboard in Thailand
- Total emergency management for Ukraine
- Nuclear emergency management for North West Russia

There has been a good dialogue with authorities and emergency management experts in these countries, with the aim on defining the scope of work for these projects and finding sources for the financing of them.

5. The Generality of MEMbrain

The above mentioned projects comprise emergency management for different types of crises and accidents, like:

- eartquakes
- floods
- hurricanes
- fires
- chemical accidents
- nuclesr accidents
- oil spills

The application of MEMbrain so far has been for nuclear accidents. However, the generality of MEMbrain, makes it applicable for different types of accidents and natural catastrophes by implementing and adding models for the type of crisis or accident in question.

In the following is described the PPS module which handles the consequences of an accident or crisis, and the necessary development of this module for MEMbrain to handle chemical accidents.

6. The Public Protection Module PPS

PPS is an essential module in the MEMbrain system. The role of PPS is to assess the consequences, and to evaluate possible countermeasures, in case of an accident involving radioactive or toxic release to the environment. Figure 6.1 illustrates the role of PPS in a total MEMbrain application.

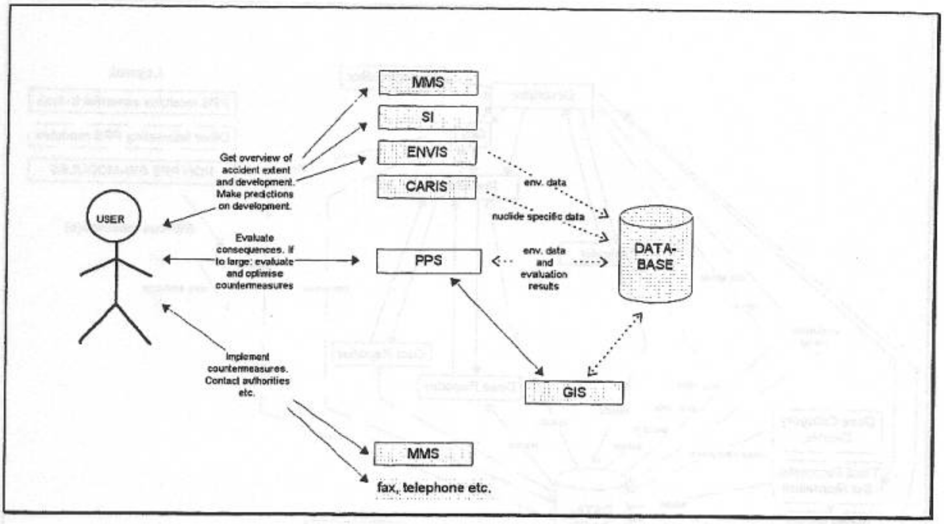

Figure 6.1. The role of PPS in a total MEMbrain application

The basis for PPS' evaluations is environmental data from predictions produced by other modules in the MEMbrain system, e.g. the ENVIS module. The user can prescribe protective actions and make assumptions about their efficiency. The results of the assessments and evaluations can be presented to the user as tables or as map overlays. In the following the PPS module interactions are described in connection with the major tasks a decision maker may want to perform before he decides on what to do.

The major concern of the decision maker are the consequences of an accident. In the radiological field this is usually expressed as doses to the population. The doses can come from inhalation of radiological nuclides, ingestion of contaminated foodstuff and external exposure from radioactive substances on ground or in the sky. In the early phase of an accident only doses from inhalation and external radiation will be of particular interest.

Secondly the decision maker want to find out what can be done to reduce the consequences, by applying different countermeasures, and evaluating the cost effectiveness of the different measures.

The main phases during this task is to set up an evaluation, do the calculations and present the results. The evaluation set-up is produced with the Descriptor and the Strategy Editor. The Evaluator calculates the results and the Presentor offers functionality to present the results on maps, tables or in graphs. The Reporter enables the user to produce dose reports and cost reports of results to file. Figure 6.2 illustrates the working processes in PPS.

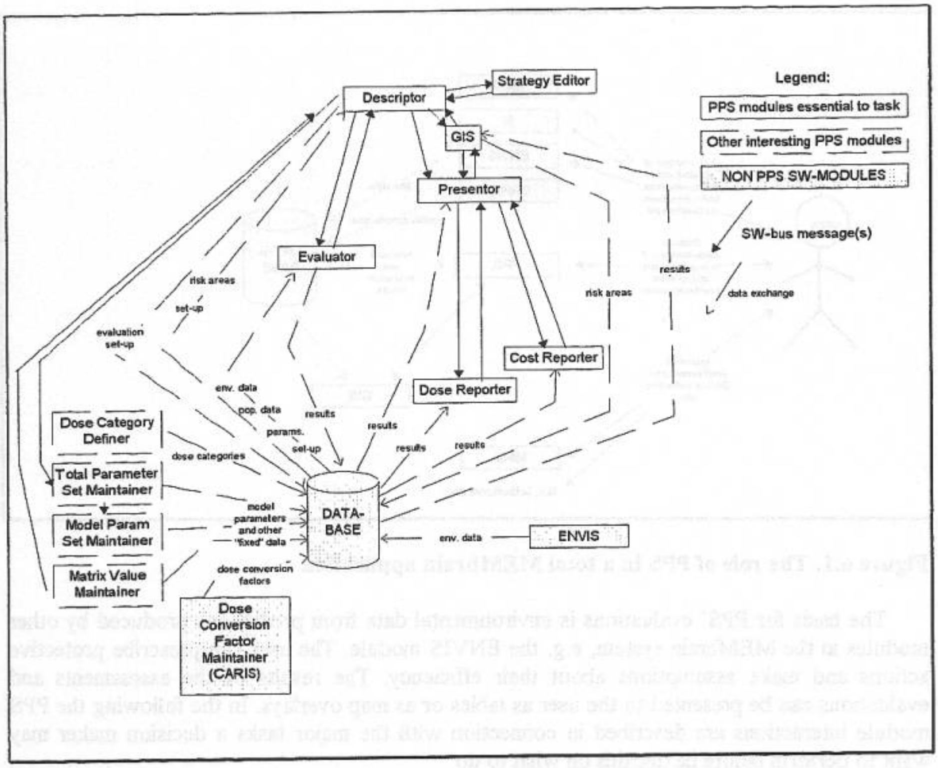

Figure 6.2. Illustration of the working processes in PPS

An evaluation set up includes which accident prediction to base the calculations on(e.g. produced by ENVIS), which area to consider, which dose categories that shall be calculated and possible countermeasures prescribed.

When an evaluation is to be performed, the set up is stored in the database by the Descriptor and a message is sent to Evaluator telling it to calculate the results. When the calculations are finished the results are stored in the database and the Evaluator sends a message to the calling module that it has finished the calculations.

When Descriptor receives the finishing message from Evaluator, it sends a message to Presentor telling it to present the newly calculated results. The Presentor may use the GIS module to present results on maps. From Presentor the user may start Dose Reporter or Cost Reporter to produce reports of a result.

When making decisions on what to do there is a lot of information which will be decisive for the strategy to select. This is information on population living in an area, resources necessary to implement a countermeasure, agricultural production in an area, alternative countermeasures, operational intervention level, etc. This information is fairly static in its nature and is therefore denoted as baseline information.

Some of the information has a geographical reference, like agricultural production, while other information is more general, like operational intervention levels.

Figure 6.3 shows a result from PPS presented in a map.

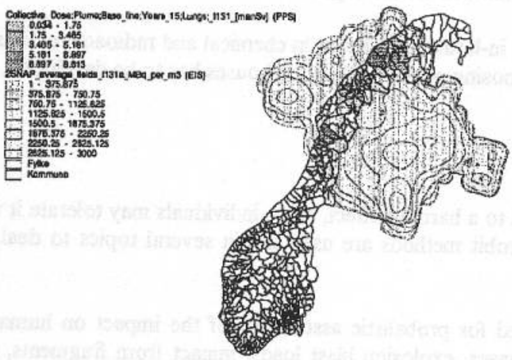

Figure 6.3. PPS result presented in a map

7. PPS for Chemical Disasters

The decision support problem in relation to accidental release of toxic chemicals is of a similar nature as corresponding problems for nuclear accidents. Most sub-modules in the nuclear application of PPS can therefore be retained in the chemical application.

As there is a need for calculation and assessment of release of toxic chemical enforced by the SEVESO directive, it will be given priority to this development.

The intention is that PPS shall be capable of handling accidents of different categories like fires, explosions, release of toxic or radioactive materials, earthquakes, flooding, storm, etc. Some sub-modules in the PPS are of generic nature, while others will be particularly developed for one of the above accidents. It is advantageous to choose methodologies which are as general as possible in the development. The system will be built up in such a way that sub-modules which are particularly developed for one accident type, easily can be substituted with sub-modules for other accidents.

Most of the sub-modules in the nuclear application are of generic nature. All sub-modules providing decision support with respect to rescue after major disasters are generic. Furthermore, selection of risk areas and corresponding strategies are required tasks in all accidents which develop sufficiently slowly to allow enough time for relieve operations. The behaviour models on notification, evacuation, seeking of refuge-in-house, etc. are also applicable for most slowly developing accidents.

The dose models, however, are particular for the nuclear application, and have to be substituted by relevant models for other accidents. In the nuclear application, a rough evacuation model is sufficient. However, this model may not be suitable for chemical hazards, and a more sophisticated model may have to be developed.

The protection offered by staying in-house is different in chemical and radioactive disasters. A dose model for toxic chemicals exposing persons staying in houses has to be developed.

7.1 Probit Methods

If a population becomes exposed to a harmful effect, some individuals may tolerate it while others may be seriously affected. Probit methods are used within several topics to deal with such problems.

Probit methods are already used for probalistic assessment of the impact on humans of thermal radiation, hot combustion gases, explosion blast loads, impact from fragments, toxic gases, etc. Hence, the methodology may be useful in the development of a generic PPS.

The general form of the Probit function is /ref. 1/:

$$Y = k_1 + k_2 \bullet \ln V \qquad (1)$$

Y: Probit which which can be directly converted to a percentage of the exposed population which sustains injury

k_1, k_2: Coefficients

V: A measure of the intensity of the effect which causes injury

In most populations there are some subjects that can tolerate a high exposure of a particular harmful effect. For this reason it is often found that the logarithm fits a normal distribution.

The coefficients k_1 and k_2 are calculated by fitting the above equation to the results of animal experiments or accidents or disasters with known outcome.

V is expressed as shown below for different types of accidental effects.

Radiation from fires: $V = \sum I_i^{(4/3)} \bullet t_i / 10^4$ (2)

Explosion: $V = p$ (3)

Toxicity of Chlorine, Ammonia: $V = \sum C_i^{2.75} \bullet t_i$ (4)

I = Thermal radiation (W/m^2)

p = Explosion peak overpressure (N/m^2)

C= Concentration of chemical in air (ppm)

t = Time interval

7.2 Requirements for PPS applied on release of toxic substances

A lot of toxicity data exists for toxic chemicals. The MEMbrain module CARIS/SAFECHEM contains most of them. The most relevant are:

- Threshold Limit Values (TLV's), which are limits for prolonged exposure during normal work.
- LD50, which is the dose for which 50% dies. The dose is absorbed orally or through the skin.
- LC50, which is the concentration in the air of a toxic chemical for which 50% dies. The exposure time is 4 hours, and the observation period of the exposed animals is 14 days.

Unfortunately, none of the above parameters are suitable for assessing the consequences of releases of toxic materials. What is needed is the coefficients k_1 and k_2 in the Probit equation, as well as the exponent in equation 4 (which is assessed at 2.75 for Chlorine and Ammonia /ref 1/). These figures have only been quantified for a few chemicals. Unless these values are available for a chemical, it will not be possible to quantify the consequences(i.e. number of fatalities) in PPS.

The following two options for solving above presented problem will be investigated:

- It can be attempted to assess the unknown coefficients for chemicals based on the LC50 data, TLV data and other available data, and also based on analogies to chemicals with known Probit coefficients. As the PPS consequence assessment anyhow involves considerable uncertainties, a very rough assessment may be acceptable.
- Available data in CARIS/SAFECHEM can be presented as decision support. Geographical areas with exposures above TLV or LC50 levels can be GIS presented, and the number of people within each area can be assessed. Areas to be evacuated can be (subjectively) selected based on the presented iso-lines. It will not be possible to compare and rank different protection strategies.

8. MEMbrain for Chemical Disasters Emergency Management

By developing the PPS for chemical accidents as described in the preceeding, and using appropriate dispersion models for tracking accidental release of chemicals, a MEMbrain system for chemical disasters emergency management should be available.

9. Conclusions

The MEMbrain system developed is of general architecture, which can fit different disaster situations. The delivered system to NRPA will give the project team a good feedback the coming year with the operation of MEMbrain for nuclear disasters as well as the applicability of MEMbrain as such.

The projects for which MEMbrain has been proposed as a solution, will be further elaborated in pilot projects in the coming year. Hopefully MEMbrain will be developed for these applications soon, making MEMbrain a universal tool for emergency management.

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