Available online at www.sciencedirect.com
ScienceDirect
Reliability Engineering and System Safety 92 (2007) 847–857
RELIABILITY ENGINEERING & SYSTEM SAFETY
www.elsevier.com/locate/ress

STRRAP system—A software for hazardous materials risk assessment and safe distances calculation

S.M. Godoy[a], A.S.M. Santa Cruz[a], N.J. Scenna[a,b,*]

[a]*GIAIQ—Grupo de Investigación en Informática Aplicada a la Ingeniería Química, Universidad Tecnológica Nacional—Facultad Regional Rosario, Zeballos 1341—S2000 BQA Rosario, Santa Fe, Argentina*

[b]*INGAR—Instituto de Desarrollo y Diseño (Fundación ARCIEN—CONICET), Avellaneda 3657—S3002 GJC Santa Fe, Argentina*

Received 30 August 2005; received in revised form 20 December 2005; accepted 21 February 2006
Available online 1 February 2007

Abstract

This work presents a powerful computational tool (Stochastic Toxic Release Risk Assessment Package, STRRAP) useful in risk assessment and emergency planning (safe distance calculation), which allows to handle the stochastic uncertainty of atmospheric parameters, critical for risk calculation when diffusion of hazardous gases or particulate matter occur as a consequence of an emission or accidental release. In fact, the random behaviour of wind intensity, wind direction, atmospheric stability and temperature, given a time horizon, (a season or a complete year), is taken into account considering also the day or night condition.

STRRAP can be used for releases or emissions from static sources (for example a stack or a fixed tank in a facility) or from transportation accidents (road, rail, maritime and pipeline transport) involving different scenarios.

After a stochastic simulation based on well-known diffusion models (dense and light gases, particulate matter) is carried out, the downwind pollutant concentrations are obtained, in order to compute safe distances and/or individual and societal risks.

Some study cases are analyzed to show STRRAP capabilities.

Keywords: Emergency planning; Safe distances; Transportation of dangerous substances; Consequence and vulnerability analysis; Risk assessment

1. Introduction

Road-accident rates in hazardous material transportation are of the same magnitude of releases due to fixed sources (process equipments, stacks, tank releases, etc.). Indeed, they have increased during the last decades (in fact, 95% of cases reported in the 20th Century occurred in the last 30 years) [1]. Consequently, it is necessary to improve the available tools and develop new ones to compute risk indexes and estimate safe distances for both cases (fixed and mobile sources), useful for emergency/contingency planning. For air diffusion of hazardous gases is important to consider the stochastic uncertainty of atmospheric parameters. In this work, an improved system (Stochastic Toxic Release Risk Assessment Package, STRRAP) which can handle uncertainties for both risk and safe distance calculation is presented.

Stochastic uncertainty arises from the natural variability of parameters related to the physical processes involved. For instance, the natural variability of the weather affects pollutant diffusion processes, and consequently risk calculation. Although additional data cannot reduce the stochastic uncertainty, they can provide information about its probability distribution [2,3].

So, an approach that takes into account the stochastic nature of meteorological parameters can be very helpful. In a recent work [2], a method for a risk assessment study case considering uncertainty was presented. It demonstrated that it is possible to achieve good approximated distributions over the whole impact area, using the Monte Carlo modeling approach (Fig. 1). In order to improve the system capabilities, particulate matter and Gaussian diffusion

*Corresponding author. Tel.: +54 342 4534451/5568; fax: +54 342 4553439.
E-mail address: nscenna@ceride.gov.ar (N.J. Scenna).

0951-8320/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ress.2006.02.012

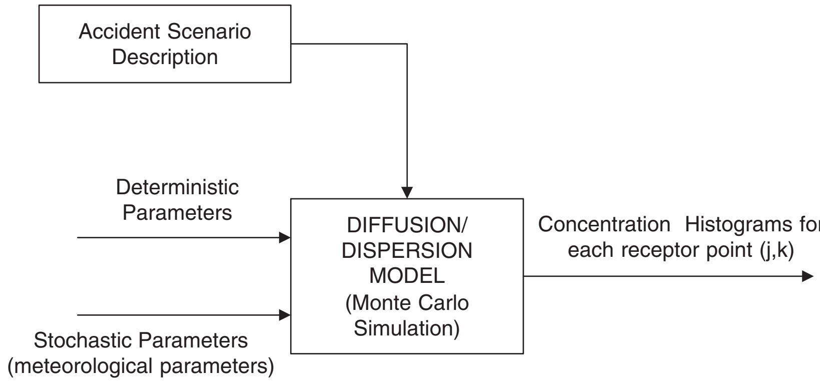

Fig. 1. Simplified scheme of the calculation strategy (Monte Carlo).

models were added to the calculation modules of the previous prototype. All these models are limited to air diffusion of toxic materials. Fire and explosions scenarios are not considered in this work.

The following sections explain the main aspects of the model and the software implementation. As it will be shown, STRAPP can model a toxic substance release as a consequence of transportation accidents or fixed emissions, either involving multiple fixed sources or only one.

2. STRRAP system

There are several well-known and very efficient atmospheric dispersion models if the adequate input data are available. STRRAP includes models for:

(1) Light and neutral gases (Gaussian model);
(2) Heavy gases;
(3) Particulate matter diffusion.

For heavy gases, DEGADIS model [4] was implemented. Its code was translated into FORTRAN 90 and modified so that it can consider the stochastic nature of the problem.

Also, all models are linked to each STRRAP module:

(1) The pre-processor;
(2) The processor;
(3) The post-processor.

Fig. 2 shows the system calculus modules interactions for a transport accident case.

The pre-processor module is in charge of the input file generation to the diffusion model. It reads the emission data included within a pattern file (substance properties, flow rates and other accident scenario parameters, the region under study, etc.) and then generates the random variable values. That is, it writes a file (*.inp extension) to be used by the calculus module. Since the time horizon (a season or the whole year) and the day or night condition is fixed, the values of the random variables (wind direction, wind velocity, temperature, humidity, and atmospheric stability) are determined. Then, the processor module (using a suitable model) computes the downwind pollutant concentration according to the conditions previously fixed by the pre-processor.

The post-processor module is in charge of storing and managing the results for all the trials in a database. Several subroutines or auxiliary programmes have been developed to display all the results in a graphical way, making the user's task easier.

Also, the post-processor can calculate risk values for a given area, safe distances, etc.

3. Risk calculation methodology for transportation accidents

Several indexes are possible to be defined to represent the risk analysis results. Common representations for individual risk are its contour plots, profiles and different average indexes, e.g. maximum individual risk, average individual risk, etc.

Societal risk includes quantification in terms of the number of affected people. Generally, it is represented as the frequency-number (F–N) curve, a plot of the complementary cumulative frequency versus a number of fatalities.

For risk definitions and risk estimation methodologies, see Refs. [3,5–8].

For transport accident releases there are five aspects to be considered in a quantitative risk analysis (QRA):

(a) Involvement of a dangerous vehicle in an accident.
(b) Breakage occurrence and characteristics (type, size, etc.).
(c) Release occurrence and characteristics.
(d) Calculation of the individual risk or societal risk due to each segment of the road in a given area.
(e) Calculation of risk distribution over the impact area.

Many works use a deterministic approach for each or some of the above-mentioned components [9–11].

Recent works have made important contributions to solve the risk assessment problem more precisely. Ref. [12] describes a risk assessment procedure which considers