MONTY: A Monte Carlo Method for Quantitative Risk Assessment

Stephen Ramsay[1]
Matthew Hilbert[2]
Boundary Layer Wind Tunnel Laboratory
University of Western Ontario
London, Ontario N6A 5B9

Abstract

This paper describes a Monte Carlo approach developed by the authors to address problems of quantitative risk assessment (QRA) in complex settings. The method has been implemented in the program MONTY which provides a flexible framework for investigating a wide range of industrial risk assessment problems (chemical plants, pipelines, transportation corridors etc). The method provides a predictive tool for estimating individual and societal risks of interest in plant design, emergency management and policy formulation. Analytical procedures have been developed to provide a basis for investigating the sensitivity of risk estimates to model and parameter uncertainties. Several cases studies have been conducted to compare the performance of the Monte Carlo approach with conventional QRA analysis. The results of a study involving flammable and explosive risks from a hexane/heptane distillation column are presented.

1. Introduction

In quantitative risk assessment (QRA) we are concerned with calculating the risk to people (in terms of injuries or deaths) or property (in terms of cost) resulting from industrial accidents.

Typically these problems involve the following steps: specifying the structure of the system to be analyzed (eg layout of a chemical plant); developing plausible scenarios for the cause of accident events (eg fault trees); estimating the statistics associated with the occurrence of events (eg magnitude/frequency relationships); calculating the physical effects arising from these events at a distance (eg dispersion modelling); and, calculating the effects of the event on exposed humans or structures (eg toxic dose modelling).

In principle the QRA problem is relatively straightforward and only requires that each part of the problem be adequately specified and the consequences of the various accident scenarios systematically evaluated. However, in practise this can be a formidable and often intractable task due to the complexity of the systems involved and the large numbers of possible cases that need to be considered.

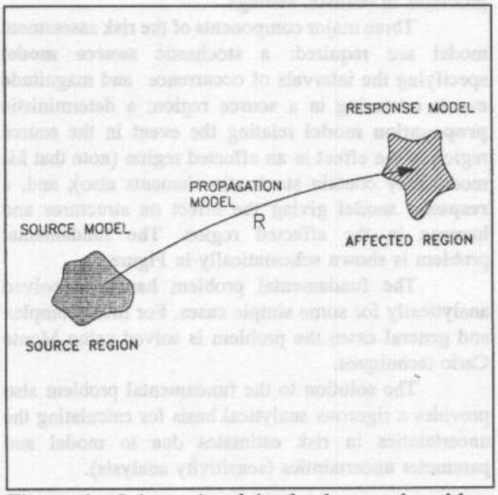

Figure 1 - Schematic of the fundamental problem in quantitative risk assessment.

[1] Research Director
[2] Research Associate

model resulting from an accidental release. These are taken form various sources. Many publications provide a wide range of possible consequence models for use in MONTY [see CCPS 1989].

The trials represent the basic simulation events in MONTY. Individual accident events are simulated for each source and class to provide risk estimate statistics.

3. Case Study

The case study considered here is taken from CCPS [1989] (Case Study 8.2 pp 443-477). The problem concerns the risks associated with the flammable materials in a C_6 distillation column used to separate hexane and heptane from a feed stream consisting of 58% (wt) hexane and 42% (wt) heptane (see Figure 3 for flow rates and line sizes). The overhead condenser, thermosyphon reboiler and accumulator are considered in this study.

The column operating pressure is 4 barg and the temperature range is from 130-160C from the top to the bottom of the column, respectively. The column bottoms and reboiler inventory is 6000 kg (roughly 5 min of holdup) and there is about 10,000 kg of liquid on the trays. The condenser is assumed to have no liquid holdup and the accumulator drum inventory is 12,000 kg (roughly 10 min holdup of feed rate). The material in the bottom of the column is approximately 90% heptane and 10% hexane. The relevant physical properties for these materials can be found in CCPS [1989].

The plant site layout is shown in Figure 4. To the east of the column, at a distance of 80 m, there is a residential area containing 200 people, distributed uniformly on 100 m by 100 m. The remaining area around the site consists of open fields.

The objective of the study is to estimate the risk to the residential community from the fractionation system from both the individual and societal risk perspectives.

The sources considered in this problem included: an instantaneous release (complete inventory loss) and a continuous release (11 kg/s). The statistics for the frequency of occurrence of events were taken from CCPS [1989].

The classes considered in this problem include: BLEVEs, jet fires, flash fires (instantaneous and

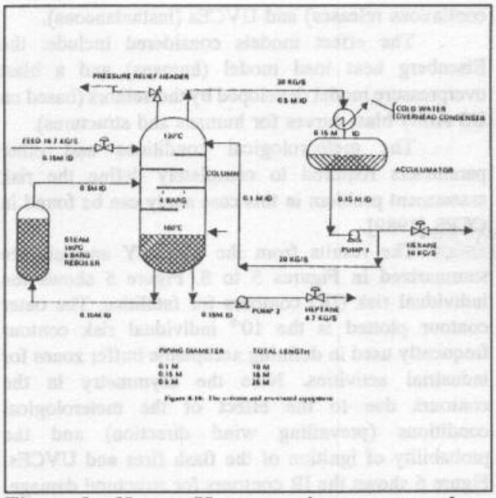

Figure 3 - Hexane/Heptane column case study

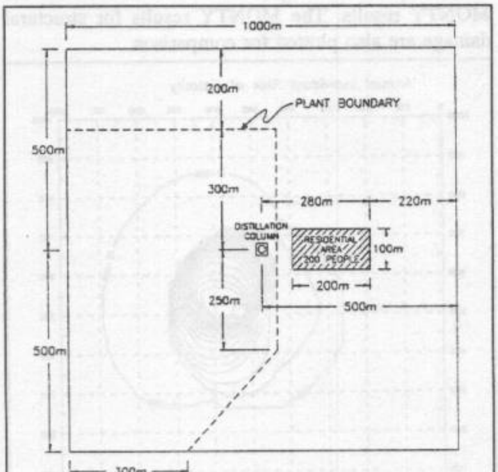

Figure 4 - Heptane/hexane distillation column example.

4. Summary

The summary of results presented here includes conclusions obtained from the more extensive study of the Monte Carlo approach as outlined in Hilbert [1994] and the investigation of the solution of the fundamental problem in QRA contained in Ramsay & Hilbert [1994b].

Based on the results obtained in these studies the following conclusions are emphasized:

1) The Monte Carlo approach to quantitative risk assessment implemented in the program MONTY provides a powerful tool for investigating a very general range of industrial risk assessment problems.

2) The analytical solution of the fundamental problem in QRA provides a rigorous mathematical basis for the Monte Carlo approach and an extensive analysis of the uncertainties in risk estimates due to model and parameter uncertainties.

3) The methodology developed in this study, considering the whole process of generation of an event, propagation from the source region to an affected region, and the response of structures and people, provides a powerful and effective tool to study chemical process risk in its broadest form.

4) The representation of the mean return periods is quite adequate of the prediction of risk at a point.

5) The final probability characterizing risk at a point is influenced by many parameters some of which are uncertain. For probabilities of exceedence not smaller than 0.01 the final distribution of extreme values of response is mainly influenced by the event generation process. But for smaller risks, the non-linear behaviour of the response given the intensity of excitation, affects considerably the final probability distribution of risk.

5) Risk at a single point does not indicate the potential damages from an event for an area.

6) Risk for an area must be defined in terms of a global quantity (i.e. total losses). No single parameter has been identified to represent this risk in simple terms. The entire probability distribution should be considered in this case.

6) The concept of a continuous damage function as developed in Ramsay & Hilbert [1994b] is a very fundamental tool to be used in risk analysis. It reflects important features of the damage-response interaction; therefore, it constitutes an important element in the study of losses.