BNL-62727
CONF-9511134--4

Trial Application of the Worker Safety Assessment Methodology*

Andrew R. Marchese[1] and Partha Neogy[2]

[1]U.S. Department of Energy
EH
GTN
Germantown, Maryland 20585

[2]Brookhaven National Laboratory
Department of Advanced Technology
Bldg. 130, P. O. Box 5000
Upton, New York 11973-5000

ABSTRACT

A Worker Safety Assessment Methodology has been developed to assess the risks to workers from radiological accidents at non-reactor nuclear facilities. The methodology utilizes Process Hazards Analysis, proposed risk goals, and Quantitative Risk Analysis. The first phase of a trial application of the methodology to a nuclear facility has been completed and is being reported.

1. INTRODUCTION

It has been generally recognized for some time that the primary recipients of risks from radiological accidents at non-reactor nuclear facilities are the facility workers. In order to assess these risks, the U.S. Department of Energy's (DOE) Office of Nuclear and Facility Safety developed a Worker Safety Assessment Methodology (WSAM) as described in a DOE report dated June 3, 1994. Subsequently, a trial application of the methodology to a DOE plutonium facility was initiated. The first phase of the trial application has been completed, and preliminary results are being reported in this paper.

2. METHODOLOGY

WSAM essentially augments the results of the Process Hazards Analysis (PrHA) element of the Process Safety Management (PSM) assessment, required for all DOE nuclear facilities, for those cases where PSM/PrHA results do not provide adequate assurance that DOE worker risks are acceptable. WSAM is a focused analysis of risks to workers from radiological accidents. It conserves resources by first screening and then analyzing in detail those selected accident scenarios which approach or exceed a preset threshold risk level. It achieves these results by utilizing three key elements: (1) the Process Hazards Analysis (PrHA) which identifies the various accident scenarios and provides semi-quantitative estimates of their frequencies and consequences, (2) proposed goals which provide metrics against which the risks of the accident scenarios can be measured, and (3) Quantitative Risk Analysis (QRA) which refines the risk estimates for selected scenarios that approach or exceed the threshold risk level.

The most significant of the proposed goals is a threshold risk level of 10^{-4} fatality per year. This is the average fatality risk from accidents in American industries, and provides the primary benchmark against which the accident scenario risks at the facility are compared. A maximum dose of 250 rem for all accident scenarios at all credible frequencies constitutes a second proposed goal, and guards against a non-negligible likelihood of prompt fatality. A risk level of 10^{-5} fatality per year (i.e., 10% of the average fatality risk from accidents in American industries) constitutes a third proposed goal - one to aspire to. Since WSAM deals with radiological risks, accident scenarios are represented on a risk matrix defined in terms of the scenario frequencies and maximum individual doses (Figure 1). The proposed goals are transferred on to the risk matrix by utilizing the appropriate latent fatal cancer risk coefficients applicable to workers ($4x10^{-4}$ per rem for doses below 20 rem, and $8x10^{-4}$ per rem at doses exceeding 20 rem).

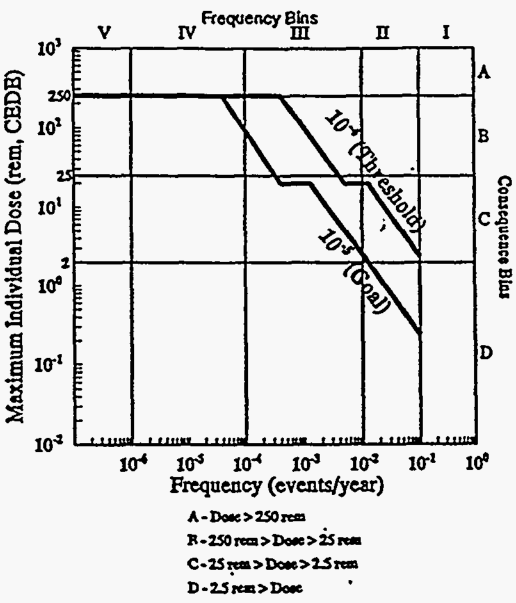

Figure 1 Risk matrix with proposed goals

*Work performed under the auspices of the U.S Department of Energy under Contract No. DEAC02-76CH00016.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

WSAM has been developed to enable its implementation within the Process Safety Management (PSM) framework being considered by DOE for all worker hazards. Process Hazards Analysis (PrHA) forms an important element of PSM as well as of WSAM. PrHA involves systematic procedures to identify the processes at a facility, select an assessment technique, and perform a systematic hazards analysis. PrHA is utilized in WSAM as a first step to provide semi-quantitative estimates of risks. In many cases, the semi-quantitative estimates are adequate to demonstrate that the risks are below proposed goals. In some cases, the risks estimated with PrHA may be sufficiently close to the threshold risk level to require more refined estimation involving quantitative analysis. Quantitative Risk Analysis (QRA) is performed by using standard techniques such as fault tree analysis for frequency quantification, and applying an accident analysis approach for consequence evaluation.

3. APPLICATION

One of the recommendations resulting from the development of the Worker Safety Assessment Methodology was that trial applications of the method should be performed in order to: (1) determine the feasibility of performing the assessment, (2) assess the expected resources needed for the assessment, and (3) evaluate whether the expected benefits from the assessment can be realized. Preliminary results from the first of the recommended trial applications are presented below.

The facility investigated utilizes a number of processes including plutonium metal production and fabrication, radioisotope heat source development, fabrication of uranium and plutonium based ceramic fuel, and recovery of plutonium and tritium. It incorporates a large number of glove boxes to carry out these processes while providing containment of airborne contaminants. Airborne contaminants are also contained within a four-zone ventilation system that maintains progressively lower pressures from uncontaminated areas to those with the potential for contamination, ensuring air flow from areas of lower contamination to those with higher contamination. The intake and exhaust of the ventilation system are provided with High Efficiency Particulate Air (HEPA) Filters to reduce release of particulate radioactivity to the environment. The facility is housed in a reinforced concrete building designed to withstand a 0.38g seismic event.

The PrHA team had identified and recorded 1435 scenarios having potential consequences to workers, the public and the environment. Each of these scenarios was reviewed as part of this study to determine if the risk is due to a radiological hazard, and if the risk recipient is a worker. Of the total number of scenarios, 533 were identified as posing radiological risks to workers. The PrHA had assigned frequency ranges and consequence categories A (loss of life), B (dose greater than maximum permissible body burden uptake), C (dose causing temporary work restriction), and D (dose causing minor or no injury) to each of the scenarios. The consequences categories in the PrHA represent effects differing by orders of magnitude as can be seen when expressed in dose ranges as illustrated in the table below.

Table 1 Relationship Between PrHA Consequence Categories, Maximum Possible Consequence, and Corresponding Dose Ranges

Consequence Category (PrHA)	Maximum Possible Consequence (PrHA)	Maximum Individual Dose Range (CEDE)
A	Loss of Life	> 250 rem
B	Dose > MPBB Uptake	250 rem > Dose > 25 rem
C	Dose Causing Temporary Work Restriction	25 rem > Dose > 2.5 rem
D	Minor or No Injury	< 2.5 rem

Given the likelihood and consequence categories, a risk matrix can be defined, and each scenario can be assigned to an element of the risk matrix. The risk matrix is labeled in terms of the frequencies of the events (per year) and maximum individual doses (CEDE rem). The proposed goals, which are defined in terms of the same units, can now be overlaid on the risk matrix to allow a direct comparison of the scenario risks with the proposed goals. This is illustrated in Figure 1, which shows the structure of the risk matrix with the proposed goals overlaid. The function of the proposed goals is to demarcate the risk matrix into regions of higher risk and dose (above the 10^{-4} fatality per year risk threshold and 250 rem dose cap), medium risk and dose (below the 10^{-4} per year risk threshold and 250 rem dose cap, but above the 10^{-5} fatality per year risk goal), and lower risk (below the 10^{-5} fatality per year risk goal). Frequency Category I (operating events) and Category V (events with frequency < 10^{-6} per year), although outside the scope of the present study, have been included in the risk matrix because the PrHA included these frequency ranges.

To compare the in-facility worker risks to the proposed goals, the accident frequencies and doses to the maximally exposed worker for each of the 533 scenarios were binned on the risk matrix (Figure 2). Of these, 171 scenarios were found to exceed either a fatality risk of 10^{-5} per year, or the 250 rem dose cap. There are two accident scenarios, both belonging to risk category BII and representing releases from glove boxes, that exceed a risk level of 10^{-4} fatality per year. There are 24 accident scenarios, belonging to risk category AIV and representing 21 criticality events, 2 releases from glove boxes, and 1 high intensity seismic event, which exceed the 250 rem dose cap, and some of which may exceed a risk level of 10^{-5} fatality per year. There are 20 accident scenarios in risk category BIII and 125 scenarios in risk category CII, most (if not all) of which exceed a risk level of 10^{-5} fatality per year, and a few of which may exceed a risk level of 10^{-4} fatality per year. Finally, there are 62 accident scenarios in risk category CIII some of which may exceed the risk level of 10^{-5} fatality per year. A similar process applied to the risks posed to the ex-facility workers shows that there are 3 scenarios in risk category CII that exceed the risk level of 10^{-5} fatality per year, and some of which may exceed the risk level of 10^{-4} fatality per year as well. There is 1 accident scenario in risk category AIV for which the 250 rem dose cap is exceeded; and there are 4 accident scenarios in risk category

CIII for which the risk level of 10^{-5} per year is exceeded. The much smaller number of scenarios applying to the ex-facility worker for which a risk level of 10^{-5} fatality per year is exceeded indicates that at a facility with a robust confinement structure and effluent filtration system, the in-facility worker is the primary risk recipient.

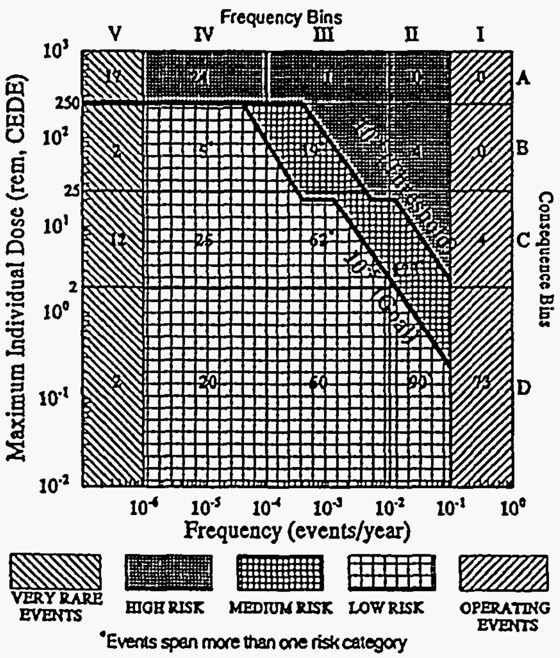

Figure 2 In-facility worker risk matrix

4. LIMITATIONS OF APPLICATION

In this phase of the study, only scoping quantitative risk estimates have been performed for a few selected scenarios. In a later phase, the scenarios with risk which may exceed or approach 10^{-4} fatality per year would be subjected to further detailed analysis to better quantify their frequencies, consequences, and the uncertainties in the frequencies and consequences.

The existing PrHA of the facility, partially motivated by the objective of providing the bases of a more detailed risk analysis, proved to be a valuable asset for evaluating worker risks and comparing them to proposed goals. The PrHA results, however, have limitations as well. They do not provide a sufficiently narrow range of risks to the workers; the scenario risks are not measured against objective criteria; and the risk discrimination provided may be insufficient to make informed decisions. These limitations can be removed by utilizing the results of the PrHA in a study like this, and extending it by performing QRA of the higher risk scenarios identified in this study. A follow-up QRA will have other benefits such as determining the importance of preventive and mitigative systems in reducing risk.

5. CONCLUSIONS

The present study shows that the WSAM provides a feasible methodology for assessing worker risks at DOE facilities. The cost of this phase of the present study was a modest fraction of the cost of performing the PrHA. A second phase involving QRA would be more resource intensive; however, QRA may be applied in a graded fashion to promote cost efficiency. The present study also indicates that WSAM has the potential to provide significant benefits in terms of facility risk characterization, and cost-effective prioritization of risk reduction measures.