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Environmental, and Emergency Planning Documents***

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Consistency in Accident Analyses in DOE Safety, Environmental, and Emergency Planning Documents

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Abstract

A consistency review of accident analyses in U.S. Department of Energy (DOE) safety, environmental, and emergency planning documents is presented. The range of and key differences in driving assumptions used in accident definition and frequency assessment, radiological source term generation, and atmospheric transport and fate modeling across recent environmental impact statements (EISs) and emergency planning documents and the effects of these differences on results are summarized. Considerable variation in both the assumptions and the underlying level of conservatism is shown to exist. Recommendations are made for source term generation and assumed meteorological conditions to reduce inconsistencies without being overly prescriptive. Recommendations also are made to improve consistency in assessing the frequencies of various generic accident sequences traditionally analyzed in EIS and emergency planning documents. All recommendations are shown to be consistent with currently applicable DOE guidance.

Introduction

Comparative reviews have been made of the approaches and driving assumptions used in accident analyses performed in support of recent U.S. Department of Energy (DOE) environmental impact statements (EISs) and site emergency planning documents.^{1,2} The degree to which applicable DOE guidance was followed was also assessed. These reviews showed that the differences in the approaches used by the teams preparing the EISs were often sufficiently significant to make comparisons among EISs evaluating essentially the same DOE actions difficult at best and impossible without careful review of the supporting analyses. In general, these supporting analyses, many of which were taken or adapted from safety analysis report studies, were found only in documentation referenced by, but not included in, the EISs, thus precluding convenient technical review. Although the overall approach to EIS accident analysis specified in the applicable DOE guidance³ was generally followed, different assumptions and technical bases used in the actual implementation of the approaches led to the cited differences in

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results. Essentially the same conclusions were reached for the comparative review of emergency planning studies.⁴⁻⁶

In this paper, the range of and key differences in the driving assumptions used in accident definition and frequency assessment, radiological source term generation, and atmospheric transport and fate modeling across recent EISs and emergency planning documents and the effects of these differences on results are summarized. Recommendations are made with respect to consequence and frequency modeling to reduce inconsistencies without being overly prescriptive. All recommendations are shown to be consistent with currently applicable DOE guidance.

We first discuss the objectives of environmental impact and emergency planning documents so as to identify key differences that preclude complete consistency in accident analyses across these documents. Differences in the key parameters are identified and their impacts discussed. The last section presents conclusions regarding the consistency of DOE analyses and makes recommendations to improve that consistency, both within documents and across document types.

Objectives of Accident Analysis in Environmental and Emergency Planning Documents

While achieving consistency in approach across DOE environmental and emergency planning documents is generally desirable, differences exist in the objectives of these two types of documents that preclude complete consistency. The primary purpose of accident analysis in environmental documents is to compare the human health risk impacts of accidents for the alternative actions under consideration. Differences in such human health risk impacts could provide a basis for preferring one alternative over others. In the emergency planning context, such alternatives are not relevant. One major purpose of accident analysis in emergency planning documents, such as hazards assessments, is to define the emergency planning zone (EPZ) within which response organizations should be prepared to initiate protective actions (e.g., sheltering, evacuation) to reduce or avoid human health impacts from radiological dose or chemical exposure. Another major purpose is to provide information that allows response organizations to make a graded response to an accident so that appropriate protective actions can be implemented when needed, but so that unnecessary protective actions can be avoided.

Because of the differences in the purposes of an environmental document and an emergency planning document, results that may be key for one may be unimportant for the other. Collective radioactive and chemical impacts are key results of an accident assessment in an environmental document because they are appropriate impacts for selecting among alternatives. On the other hand, since the objective of emergency planning is to avoid collective impacts through implementation of protective actions, calculation of collective impacts for a population not taking steps to avoid health impacts is not relevant. In environmental documents, estimating frequency of events is important for determining risks. In emergency planning, on the other hand, frequency is important only in the limited sense of determining if an event is reasonably

foreseeable (i.e., annual frequency of occurrence greater than or equal to 1×10^{-6}); if it is, then emergency planning should assume that it will occur and response organizations should be prepared to deal with it.

It is essential to establish an EPZ in an emergency planning hazards assessment. The boundary of the EPZ is determined on the basis of the area within which threshold radiological doses or chemical exposures (such as those causing the onset of early severe health effects) from the most severe reasonably foreseeable accidents are exceeded. On the basis of the size and location of the EPZ and the spectrum of reasonably foreseeable events, emergency planning personnel develop and prepare emergency plans and procedures and identify personnel and resources needed for an effective response. On the other hand, in environmental documents, the EPZ is not of particular interest except to the extent that the general public and on-site populations may suffer health impacts from accidents. In some environmental documents, such as programmatic environmental impact statements, the precise location of a facility at which an accident is postulated to occur is not identified; rather, consistent assumptions are made across alternatives (e.g., a number of programmatic EISs assume all facilities are located at the center of a given DOE site). However, in emergency planning, the precise location and size of the EPZ is important so that the population in the EPZ can be determined and the requirements, in personnel, facilities, and material, for effective responses can be identified.

Although accident analyses in environmental documents and in emergency planning documents have different ultimate uses, there should be consistency in many important areas. Both should identify and analyze a spectrum of reasonably foreseeable events. In general, both should use the same meteorological assumptions for the same site. When the EIS and the emergency planning hazards assessment address the same facility, the same accident scenarios should be used and the same release term assumptions should be made. The location of any appropriate receptors (worker and off-site public) should be the same for the same facility and DOE site. Use of information from a common safety analysis report, when appropriate, can help ensure consistency.

Comparisons of Accident Analysis Approaches and Assumptions

The comparisons in this section focus on the approaches used for specifying and then the assessing the frequencies of various generic accident sequences, generating source terms, and performing the concomitant atmospheric transport and exposure modeling.

Specification and Frequency Evaluation of Accidents

Both internal and external events were considered in each of the emergency planning studies reviewed. The internal events considered varied by document but overall included packaging breaches resulting from a variety of operational mishaps (e.g., forklift accident), benign equipment failures (e.g., packaging corrosion and breach), energetic equipment failures (e.g., overpressure failures), fires, and (in one case) containment breach by gunfire. The external

events also varied by document, but overall they included natural phenomena (e.g., severe weather conditions), as well as unplanned man-made initiators (e.g., aircraft and vehicle crashes and natural gas explosions) and acts of sabotage and terrorism. The characterization of frequencies for these events was based either on engineering judgment or on other studies, such as safety analysis reports (SARs), or was lacking altogether. In a number of cases, the various accident initiators and/or ensuing accident sequences were judgmentally grouped as leading to a common endpoint, such as a release exceeding the threshold quantity of chemicals in a predetermined set of release categories or release of a facility's entire inventory of hazardous materials for a given initiator.

The EISs reviewed relied heavily on existing SARs or related support documentation to help develop frequencies or at least assign frequency ranges or "bins" to accident initiators and/or sequences. Both generic and site-specific data were used to establish frequencies. The level of structured probabilistic analysis (e.g., event tree and/or fault tree quantification) used to establish frequencies appeared to vary considerably; the specifics were buried in the support documentation. Selected sequences (e.g., natural phenomena causing loss of facility containment) for a facility in one EIS that were assigned to one frequency bin were assigned to a different frequency bin for a second EIS because of the variety of underlying assumptions and degree of conservatism used. For example, events such as large aircraft crashes were considered in some EISs but were ruled as too improbable for analysis in other EISs for the same DOE site and comparably sized facilities. Because many of the actions proposed under the different alternatives for the site-specific EISs are continuations or variations of past operations, historic information was sometimes used to estimate the frequency of conditions leading to a release. For the programmatic EISs, accident frequencies were developed as a function of the accident scenario, which can vary due to the material type, form, amount, and process involved.

Source Term Estimation

A mix of conservative and seemingly nonconservative assumptions tended to be made in the determination of the source terms for the various documents. The material-at-risk (MAR) was defined through the screening process as described above. In some analyses, the entire inventory of hazardous materials was included in sequences where arguments could have been made to limit the quantity of material affected by the accident because of facility size and the lack of a justifiable propagation mechanism. In one case, a very conservative accident scenario assumed an eight-hour fire affecting the facility's entire inventory of hazardous materials. In other cases, severe fire sequences were sometimes restricted to relatively small fractions of the MAR with no clear rationale to support a lack of propagation to the rest of the MAR. In a number of documents, such source term parameters as damage fractions and leak path factors were not provided, thus making it impossible to assess of the postulated accident scenarios. Engineering judgment and a variety of reference documents were cited as the basis for selecting the airborne release rates, overall release times, and/or their equivalents.

It was generally assumed in the EISs that the primary exposure pathway for workers (except for criticality accidents) and the general public would be inhalation of aerosols in the respirable range of less than 10 μm aerodynamic equivalent diameter (AED) and vapor releases during potential accidents. A radiological atmospheric release source term in general may be treated as

the product of four terms: the quantity of material at risk (MAR); the damage fraction (DF) or fraction of MAR exposed to accident stresses capable of rendering the MAR airborne; the respirable airborne release fraction (RARF) or fraction of material subjected to accident stresses actually rendered airborne and respirable; and the leak path factor (LPF) or fraction of the respirable airborne inventory that escapes any containment or confinement barriers and reaches the ambient atmosphere.

Assumptions used to specify the MAR and DF for EIS facility accident studies varied widely. In some cases, the MAR and DF were implicitly combined, but assumptions for each were not delineated. The degree of detail in the RARF treatment also appeared to vary widely. In some cases, the RARF was implicitly combined with the MAR and DF, for example, by stating that 1% of the material was assumed to be released for potential inhalation. In these cases, supporting documentation indicating the particle size distribution of the MAR was not provided. In other cases, a careful assessment of the characteristics of the material under the relevant accident stresses appeared to have been performed, with the RARF being assigned on the basis of the recently published DOE report DOE-HDBK-3010-94⁷ or its predecessors. Insufficient documentation was supplied in the various EISs to establish whether a median, bounding, or weighted average was applied in the accident analysis for the RARF. Historically, the approach most commonly followed is to choose a bounding value for conservatism. The choice of applying a median or a bounding value can result in a variation of orders of magnitude in the source term. Leak path factor modeling in severe accident scenarios generally seemed to be avoided by conservatively assuming an LPF of unity, although explicit modeling does appear in some support documentation. However, even in the case of explicit LPF modeling, no credit was taken for building containment in some documents, presumably for conservatism purposes. In general, a single release point was used to represent several release points for a facility so as to simplify estimating atmospheric dispersion. Design features and institutional and organizational controls that can prevent or mitigate potential accidents were discussed in general terms in the EISs reviewed here but were not considered in any potential attenuation of the source term.

Atmospheric Transport and Exposure Modeling

A variety of generic and site-tailored atmospheric dispersion codes were used to estimate distances to various concentration levels of the radiological or chemical hazard of concern. The meteorological conditions assumed in the analyses varied. Depending on the document, “typical” (undefined in the safety documents reviewed but assumed here to refer to 50% meteorology), 95%, and 99.5% meteorological conditions were all used. Since a factor of 10 to 100 difference in predicted downwind concentration often results from assumptions of 50% and 99.5% meteorology, this inconsistency stands out.

Both generic and site-tailored codes were also used in atmospheric transport and dose calculations. Again, assigned meteorological conditions ranged from 99.5% probable to 50% probable. Since this assumption alone can cause differences from a factor of 10 to 100 in off-site population doses, the differences in the conservatism of published results are apparent. Individual receptors considered in EISs generally included the maximally exposed members of the uninvolved work force and the general public. Impacts to uninvolved workers were generally evaluated at two locations from the release point of the accident to account for workers outside

the emergency planning zone for a facility and thus exposed for a longer period. However, the distance of the uninvolved worker from the accident release point was generally not the same between different safety documents and could vary by an order of magnitude. The involved worker was generally considered, but underlying assumptions in treatment varied; for example, the volume in which a given release was concentrated and the time of worker exposure differed widely. In one EIS, the maximally exposed worker was assumed to be located in the center of a 1.5-meter hemisphere for the release, while another EIS assumed a 10-meter hemisphere for release purposes. A number of EISs, however, presented potential impacts to involved workers from postulated accidents in a qualitative fashion because of uncertainties in the application of Gaussian plume models to calculate consequences at or near the location of an accident. Various computer codes, site-tailored and generic, were used in the hazard assessments and EISs to calculate environmental transport and consequences for postulated radiological accidents.

Conclusions and Recommendations

The documents reviewed generally followed the cited DOE guidance except in the use of bounding calculations that were either explicitly calculated or used implicitly through reference to the SAR support. The variation in methods and assumptions, as noted above, generally makes comparisons of results impossible. In principle, facility accidents for similar DOE activities evaluated in complementary safety documents should have the same or directly comparable results, depending on the specific definitions of the alternatives. Currently, this generally is not the case, which points to the obvious need for increased standardization in selection of analysis methods and underlying assumptions. General guidance on how to bridge the gap between SAR information and the needs of an EIS or hazard assessment would be most useful. The challenge is to avoid reinventing the accident wheel when developing the data needed to satisfy the objectives of an EIS or hazard assessment.

The general approach used in the DOE's Draft Waste Management Programmatic Environmental Impact Statement (WM PEIS)⁸ helped to establish a more systematic look at accidents than observed in other EISs. An overview of the approach used to structure and implement the Draft WM PEIS accident analysis has been described by Mueller et al.² The use of recently published release fractions in safety analyses would help ensure consistency in EIS accident assessments. In addition, the probabilistic risk analysis approach taken in the Draft WM PEIS to develop functional event trees for systematic analyses of accident sequences would help reduce uncertainties, compared with the traditional bounding analyses used in safety analyses and EIS accident analyses.

A variety of modeling assumptions and computer codes were used in the sample of assessments discussed above. While the differences in computer models among the various documents led to wide variations in the predicted distances to various threshold concentrations and the proposed minimum EPZ radii, it is clear that the differences in proposed concentrations were also a strong function of the variation in assumptions used in the accident analysis modeling. This situation suggests that facilities similar in terms of the hazards actually present but located in different DOE sites may have considerably different EPZ boundaries. Economic considerations, for

example the desire to reduce the EPZ boundaries to simplify emergency planning requirements, could provide a incentive for DOE sites in more populated regions to reduce the level of conservatism in their supporting hazards assessments.

More detailed analysis guidance, even at the risk of being prescriptive, should be developed to improve the consistency among assessments. In particular, guidance as to what levels of frequency to consider in assessing accident sequences, as well as more guidance in determining the frequencies per se, would be useful. Because release rates are a strong function of both the physical characteristics of the material at risk and the accident stresses, the latest guidance⁷ should be used. Reviews of both radiological and chemical source term development methods and codes are ongoing within DOE. Selection of a common set of frequency-based meteorological conditions should also be prescribed by DOE, especially in light of the large variations in predicted consequences. Lastly, the analyses performed for SARs are often used to support EPZ boundary selection. Developing guidance on to how to best use the latest standards on safety analysis for EPZ determination should be considered.

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