UCRL-JC-129935
PREPRINT

Dose Refinement: ARAC's Role

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This paper was prepared for submittal to the
Environmental Protection Agency
Post-Emergency Response Issues Conference
Washington, DC
September 9-11, 1998

June 1, 1998

Lawrence Livermore National Laboratory

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1. INTRODUCTION

The Atmospheric Release Advisory Capability (ARAC), located at the Lawrence Livermore National Laboratory, since the late 1970's has been involved in assessing consequences from nuclear and other hazardous material releases into the atmosphere. ARAC's primary role has been emergency response. However, after the emergency phase, there is still a significant role for dispersion modeling. This work usually involves refining the source term and, hence, the dose to the populations affected as additional information becomes available in the form of source term estimates—release rates, mix of material, and release geometry—and any measurements from passage of the plume and deposition on the ground.

Many of the ARAC responses have been documented elsewhere.[1] Some of the more notable radiological releases that ARAC has participated in the post-emergency phase have been the 1979 Three Mile Island nuclear power plant (NPP) accident outside Harrisburg, PA, the 1986 Chernobyl NPP accident in the Ukraine, and the 1996 Japan Tokai nuclear processing plant explosion. ARAC has also done post-emergency phase analyses for the 1978 Russian satellite COSMOS 954 reentry and subsequent partial burn up of its on board nuclear reactor depositing radioactive materials on the ground in Canada, the 1986 uranium hexafluoride spill in Gore, OK, the 1993 Russian Tomsk-7 nuclear waste tank explosion, and lesser releases of mostly tritium. In addition, ARAC has performed a key role in the contingency planning for possible accidental releases during the launch of spacecraft with radioisotope thermoelectric generators (RTGs) on board (i.e. Galileo, Ulysses, Mars-Pathfinder, and Cassini), and routinely exercises with the Federal Radiological Monitoring and Assessment Center (FRMAC) in preparation for offsite consequences of radiological releases from NPPs and nuclear weapon accidents or incidents.

Several accident post-emergency phase assessments are discussed in this paper in order to illustrate ARAC's roll in dose refinement. A brief description of the tools (the models) then and now, is presented followed by a description of how these models have been applied during the post-emergency phase to various events.

2. THE ARAC MODELS

The ARAC wind flow model is a combination of two codes: MEDIC[2] interpolates meteorological observed winds to three-dimensional gridded space; MATHEW[2] mass adjusts the winds in the presence of terrain using atmospheric stability to affect this adjustment so that mass is conserved in the three-dimensional space. The dispersion model ADPIC[3] is a Lagrangian particle model with random displacement diffusion and has the flexibility for specifying various source characteristics with full decay and ingrowth of daughter products during transport and after ground deposition. In addition to these models, ARAC has a computer code that matches radionuclide air and ground deposition measurements in time and space with the model-generated air concentrations and ground deposition concentrations.

Over the past four years, ARAC has been developing new models to replace the older ones. ADAPT[4] is the interpolation and mass adjustment flow model and LODI[5] is the dispersion model. Since these models are under development, the present versions have only limited capability and are not yet part of the ARAC production environment. Major improvements in the new models are continuous terrain representation rather than the block terrain of the older models, and variable and graded resolution in both the horizontal and vertical dimensions. Other attributes in these models will be horizontally varying turbulence and boundary layer depths.

3. POST-ACCIDENT RESPONSES

A FRMAC would most likely be formed for offsite consequences from a significant radiological release within or impacting the US and its territories. The FRMAC works with the state, local government and tribal authorities to determine the consequences and to mitigate the consequences to the extent possible from a radiological release to the environment. ARAC works with the FRMAC both from the ARAC Center in Livermore and by deploying staff members to the field.

Based on both a real need and considerable experience, the ARAC program has developed a methodology to derive the amount of a radioactivity released by a matching procedure applied to model calculations and representative measurements. This is an iterative process of improving the source term estimate as more measurements are taken. The resulting refinement to the source term allows the dispersion model to better define the deposition boundaries and greatly adds to defining the airborne plume concentrations, which most likely will not be measured well during most accidental releases particularly during the earliest phase. ARAC may then answer with greater confidence who was exposed and at what dose. As a part of FRMAC exercises, ARAC routinely uses simulated measurements of ground deposition to re-scale the source term, and hence the computer generated air concentrations and ground deposition concentrations.

3.1 Chernobyl Accident

During the first few weeks following the 1986 Chernobyl accident, ARAC derived the first estimates of the total inventory released into the atmosphere using measurements that were then obtained from various European countries.[6] Calculations of projected air movement and radioactive air concentrations were matched with measurements from up to 20 sites throughout the Northern Hemisphere. Through an iterative process involving adjusting the source term geometry and release rates, ARAC was able to refine estimates of how the radioactivity released varied with time and how the radioactivity was initially distributed in the air. ARAC is presently working with Russian scientists (SPA Typhoon) to acquire additional meteorological data in the region surrounding the reactor in order to calculate a refined reconstruction of the dispersion. The refined plume may lead to improved dose reconstruction in the region. Since the Chernobyl accident, the available meteorological data sets, and improved ARAC models and tools permit better iterative plume and source term reconstructions.

3.2 General Chemical Accident

For several months after a 1993 major rail tank car spill of sulfur trioxide (oleum) in Richmond, California, ARAC participated in an intensive effort to assess the source release rates and total exposure to the population from the released sulfuric acid cloud.[7] Even though this event was not a radiological release, it did provide additional insight for plume reconstruction. Using just the standard reporting meteorological station data that were available through the World Meteorological Organization's global distribution system, the ARAC initial calculated plume did not follow the path that staff meteorologists believed it should have. The staff meteorologists had knowledge of non-reporting meteorological tower data in the vicinity of the plume. After rerunning the ARAC models with this additional data, the plume was judged to be in the right place. Later runs of a prognostic mesoscale forecast model[8] confirmed this flow pattern.

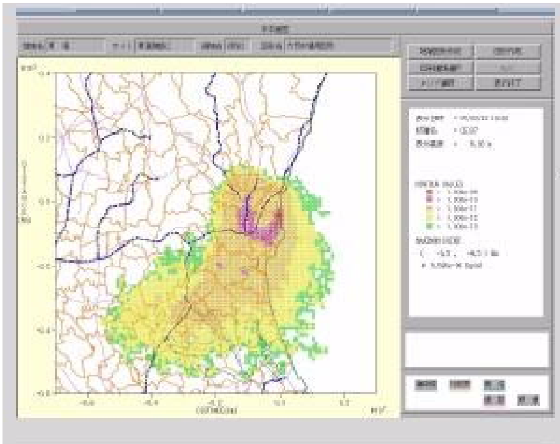
Over the next several months, the quantity of material released from the rail tank car was determined along with estimates of the release rates over a four-hour duration. ARAC and a private firm both recalculated the plume based on this new source term. Apart from one sampler that measured concentrations in the passing plume, the only source of information on exposure to the population to the cloud was the plume calculation. Litigation proceeded using plume calculations. This event serves as an example for what could occur for an unmonitored remote radiological release, particularly where the release is composed of mostly non-depositing noble gases and short lived radioactive iodines.

3.3 Tokai Accident

In March of 1997, PNC-Tokai corporation of Japan, located on the JAERI facility, experienced a fire and subsequent explosion in a fuels reprocessing facility. ARAC and JAERI were (and still are) collaborating on the development and evaluation of a nuclear accident assessment information Internet-based communication protocol, incorporating televideo, whiteboards and web pages.

During the Tokai accident and shortly thereafter, ARAC and JAERI were able to view each system's model assessment plots, discuss differences, locate measurements sites and values, discuss differences due to differences/deficiencies in meteorological data and then recompare and discuss results when comparable data were used in both systems. The dialogue with whiteboard interaction proved highly effective in communicating mutual understanding as well as unique insights. Shortly after assuring that both had the same meteorological data, JAERI received preliminary radiological measurement data and rapidly, using the graphical web pages on whiteboard, identified the locations and preliminary readings at three locations.

The shortfall of not having full live video was evident but not-detrimental. The results accomplished over a two-week period in a cooperative response to an actual event would have been impossible to achieve using conventional exchanges via phone, e-mail and telefax. The combination of the web pages and the teleconferences yielded a collaborative effort which could only have been otherwise achieved by actual face-to-face meetings. In fact, this prototype system even provides an advantage over the face-to-face exchange, as each participant is acting from their own institutional environments, where all local data and even colleagues are readily accessible, whereas travelers must reduce their tools and information to fit in a suitcase.



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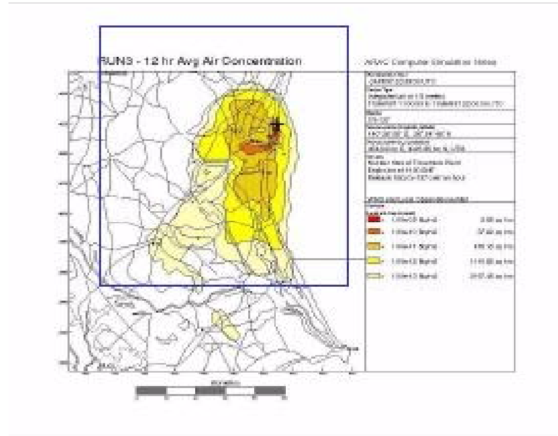

ARAC

Since the ARAC and SPEEDI transport and dispersion models provided similar results including estimates of the release magnitude within ±15% after the using same input data, both centers judged the interactive refinement process to be useful for the estimation of source term coupling with monitoring.

This work fits within the context of the Global Emergency Management Information Network Infrastructure (GEMINI) and is an example of the benefits of exploiting cyber technology for timely and enhanced accident assessment. We intend to offer this as a start toward an international “mutual aid” structure.

4. CONCLUSION

Examples of post-emergency phase assessments by ARAC for three real hazardous releases to the atmosphere were presented. The 20 years or more of ARAC experience in training for and responding to emergency releases of hazardous materials into the atmosphere has demonstrated the need for post-emergency assessment transport and dispersion model calculations for most major events until the exposure to the population has been fully determined. This is an iterative refinement process as source term estimates and air and surface concentrations measurements of the released material become available.

ACKNOWLEDGMENTS

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

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