Lawrence Livermore National Laboratory

Options for Providing Radiation Protection Shelter Quality Information to U.S. Local, State and Federal Government Agencies

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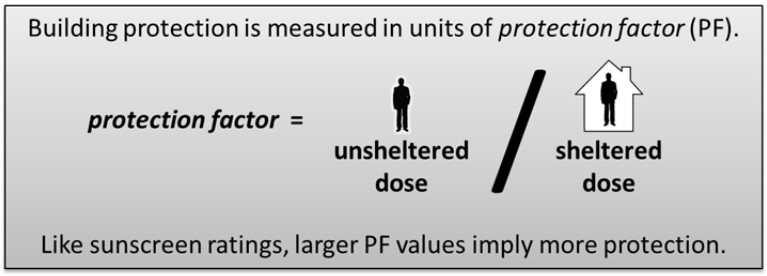
1. INTRODUCTION

This report describes available information on protection that can be provided by buildings from exposure to radioactive contamination in the environment, and options for how this information can be provided to government organizations across the United States. This information is potentially useful for planning how to protect the public in the event of an atmospheric release of radioactivity including, for example, from a Radiological Dispersal Device, an Improvised Nuclear Device detonation, or a Nuclear Power Plant accident. During these incidents, knowledge of the radiation protection provided by buildings is critical to predicting and assessing radiation dose to the population, and the associated health risk. These dose assessments inform emergency plans and decisions including, for example, identifying areas in which people should be sheltered in place, and determining when controlled population evacuations should be made.

The protection that different buildings provide their occupants can vary considerably from building to building, and at different locations within a given building. Previous work, for example, by Dillon et al. (2016), have summarized building protection by building type based on previously published studies. In the Dillon et al. (2016) study the focus was on the protection against radiation from outdoor fallout particles (external gamma radiation).



The protection buildings provide their occupants is often measured in units of *protection factor*. Protection factor is defined as the ratio of (a) the unsheltered, "open field" radiation dose to (b) the dose experienced within the building. For fallout radiation, unsheltered, "open field" exposure is the radiation exposure measured 1 m (approximately 3 ft) above an infinite flat plane uniformly contaminated with radioactive fallout. On occasion, building protection is reported in terms of *reduction factor* (also called *transmission factor*) which is the inverse of the protection factor. These factors are defined as follows:

$$Protection\ Factor = \frac{D_o}{D} = \frac{Unsheltered\ (Open\ Field)\ Dose}{Sheltered\ Dose}\ or\ \frac{Unsheltered\ (Open\ Field)\ Dose\ Rate}{Sheltered\ Dose\ Rate}$$

$$Reduction\ Factor = \frac{D}{D_o} = \frac{Sheltered\ Dose}{Unsheltered\ (Open\ Field)\ Dose}\ or\ \frac{Sheltered\ Dose\ Rate}{Unsheltered\ (Open\ Field)\ Dose\ Rate}$$

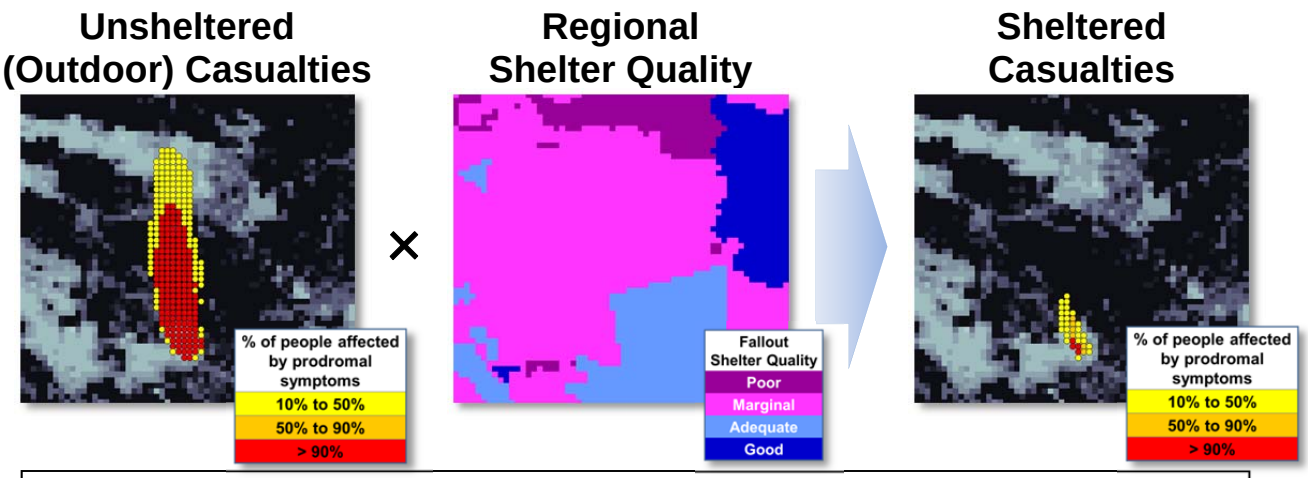
In the remainder of this report we describe available building protection information for different areas of the U.S. that could be used to better prepare government agencies for decision requirements of radiological emergencies. The focus of this report is on recent DHS and FEMA sponsored work to provide this type of information to state and local agency emergency planners and responders in the U.S., and recommendations for improving this information, and for facilitating the operational use of building protection data and tools by local, state and federal agencies.

2. POTENTIAL SOURCES OF U.S. BUILDING PROTECTION INFORMATION

In this section, we describe some previous work that can provide valuable sources of information on building protection across the United States.

2.1 DHS/FEMA, DOD REGIONAL SHELTER ANALYSIS METHODOLOGY AND DATABASE

Previous work by the Federal Emergency Management Agency and Department of Defense has developed a *Regional Shelter Analysis* (RSA) methodology and database (Dillon et al., 2015) that includes valuable information on building protection. The goal of the RSA was to provide a means of assessing the reduction in radiation exposure from nuclear fallout that is provided by buildings in different geographical areas. This RSA can be used to (a) characterize the quality of the fallout shelter in a given region to inform shelter improvement and evacuation planning, (b) support a choice of emergency response strategy, and (c) estimate the radiation exposure to sheltered civilian populations, when combined with outdoor radiation estimates, as illustrated in the figure below.

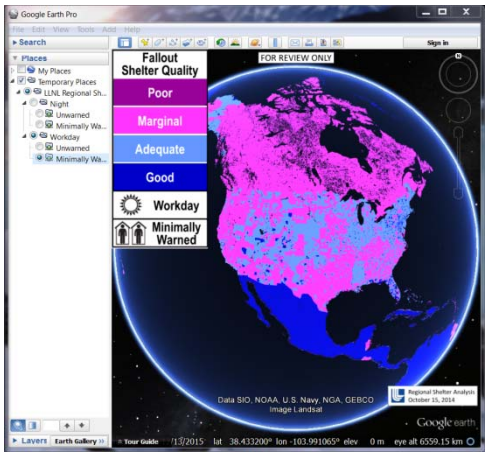


Example of a regional shelter analysis (center panel) and associated unsheltered (outdoor) and sheltered casualties due to fallout radiation (left and right panels, respectively).

The Regional Shelter Analysis capability currently exists in several complementary formats that assist both general and technical users in using and interacting with the shelter quality estimates. This includes shelter quality databases, visualization, and methods to calculate

fallout casualties from an externally provided outdoor fallout exposure plume.[1] These files are summarized here and described in more detail in the provided (a) "readme" distribution and (b) technical report. The report also describes the capability and key considerations.

Google Earth Visualization

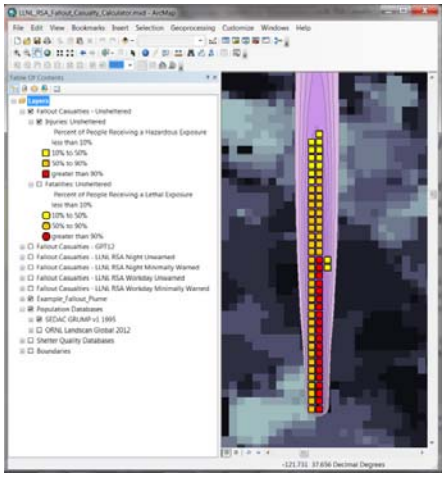


After loading the freely available Google Earth software program on their local computer,[2] users can view the regional shelter quality at any location, time of day (workday vs. night), and population posture (unwarned, also called no-response, vs. minimally warned, also called shelter-in-place).

Shelter Quality Datafiles

The global shelter quality database has been stored in several data formats including (a) human readable spreadsheets (comma separated ASCII text files) and (b) Esri compatible netCDF binary files. Additional spreadsheets list the shelter quality by country and US census tract.

Esri Analysis Tool



Advanced Esri[3] Geospatial Information System (GIS) analysts can use provided tools and databases to calculate the fallout casualties from an externally generated fallout plume.

[1] The LLNL re-distribution of the provided population and land use data is limited to US government organizations and contractors. The population and land use data are publicly available for download at www.ciesin.columbia.edu.

[2] Available at www.google.com/earth

[3] Esri is a widely used Geospatial Information System (GIS) software application (available at www.esri.com).

Casualty Calculation Spreadsheets

General users can use the provided spreadsheets to calculate fallout casualties for a user specified (a) country and/or US census tract, (b) population, and (c) outdoor fallout exposure.

2.2 DHS/FEMA SHELTER ANALYSIS FOR REGIONAL RAD/NUC PLANNING

LLNL has done related work to develop a prototype shelter quality analysis as part of their support for Federal Emergency Management Administration's (FEMA) Improvised Nuclear Device (IND) Program and the Improvised Nuclear Device City Planner Resource (iCPR). LLNL is developing the iCPR for FEMA Regional Planners to access IND effect information for Tier 1 and Tier 2 UASI cities. The shelter quality methodology utilizes components of FEMA's Hazus application, LLNL's Regional Shelter Analysis (RSA) Methodology building protection factors (Dillon et al., 2015), and an ESRI ArcGIS software application to map the shelter quality results. This shelter quality analysis has been designed for FEMA Regional Planners to assist them in developing their Radiological / Nuclear Plans.

The analysis utilizes data available in FEMA Hazus by extracting the Building Occupancy Type area distribution and population information at both the census block and tract levels. This data is then transformed using the methodology published by Hazus to convert the Building Occupancy Type to Building Construction Type. The Building Construction type is needed to determine a building's shelter protection quality. The building protection factors applied to the Building Construction Types are obtained from LLNL's RSA protection factor analysis. RSA utilizes a range of building protection factors ("Best", "2nd Best", "Median", "2nd Worst", and "Worst"). For FEMA analysis, the "Median", "Best", and "Worst" building protection factors have been used. One set of protection factors (e.g. "Best") is applied to the Hazus Building Construction Type and distributed within a census block / tract based on building area distribution. An area weighted average building protection factor is then calculated for each census block or tract. The calculated single protection factor for each census block or tract is then mapped in ESRI ArcGIS. The protection factors are color coded within certain PF ranges as seen in Figure 1.

Figure 1. Color coding of Protection Factor ranges.

Figure 2 shows an example of a "Best" building protection factor map for Philadelphia County. Similar maps can be produced for the "Median" and "Worst" protection factors. The building protection factor maps are provided to FEMA Regional Planners as pdf maps based on custom requests. LLNL is currently working with FEMA to determine the best presentation of this information for incorporation into the FEMA iCPR. Ultimately, the information will be available through the iCPR.

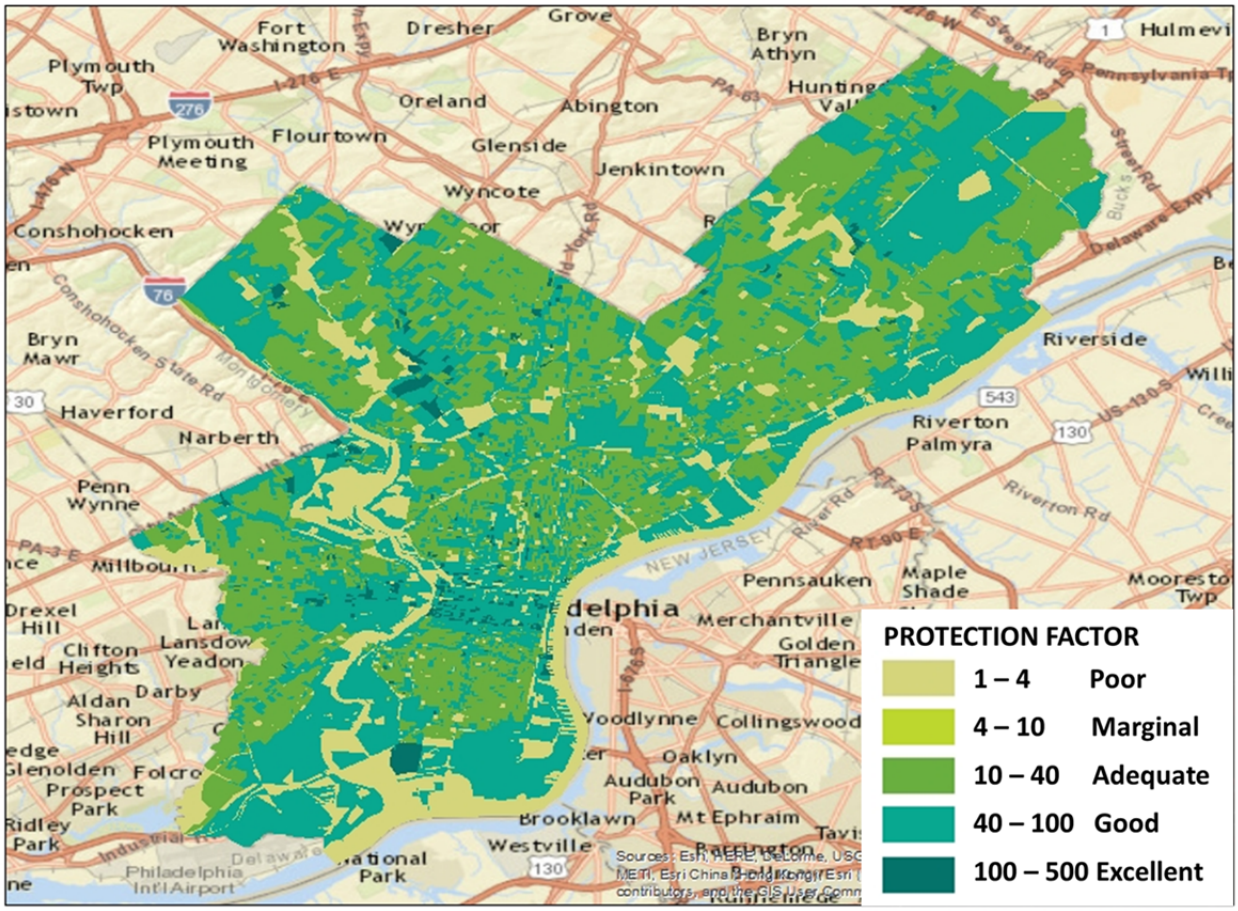


Figure 2. Protection Factors for Philadelphia County at census block level.

The challenge is to convey the meaning of the building protection information in a clear and understandable manner to the Regional Planners. The intent of the maps is to provide a general awareness of the general building protection for a geographic area. This information can then be used to help understand which shelter and evacuation actions can be planned for in different areas. As an example, if there are different areas with protection factors of "Excellent" and "Poor", a possible planning strategy could be to focus early evacuations in the areas with "Poor" level of protection.

3. RECOMMENDATIONS

The Regional Shelter Analysis database and tools are potentially useful to state and local agencies for emergency planning, as described above. To facilitate the broader understanding and use of these data and tools, we suggest the following:

- Provide improved distribution and display options for shelter quality information:
  - Provide real-time web-based serving of shelter quality maps for user-defined areas of interest. This approach can (a) provide maps without requiring users to manage the full dataset and (b) facilitate integration with other software tools, including web-based and mobile apps, such as CMweb and RadResponder. Surveying other relevant third-party software applications, in which users need access to shelter quality information, should be part of this effort.
  - Provide supporting files on a website for users to download. This option allows users to fully control and manage the data.
- Develop interpretation guides and training material to make the building protection information easier to understand and use.
- If feedback from users indicates a need, make the Esri-based analysis tools and supporting databases easier to use, with less expertise and training needed.
- If distribution to non-US government entities is desired, we recommend that all limited distribution information be removed, because LLNL does not have the right to redistribute population and land use data to non-US government entities.

In addition, we recommend several research and development activities to further improve the accuracy and detail of the Regional Shelter Analysis, including the following work:

- Identify the building properties required to assess the fallout protection within a given building,
- Update building categories (taxonomies) to more closely describe the different building properties of interest,
- Refine methods that incorporate detailed, individual building and population data, where it exists,
- Consider the potential for contamination inside shelters, if decontamination procedures are not followed by individuals entering buildings after the fallout arrival,

— Update the current building protection estimates with the new information,

— Consider actions people may take other than sheltering in the nearest building, e.g., traveling to a neighborhood shelter.

Furthermore, the current Regional Shelter Analysis capability is most applicable to situations in which the dominant injury pathway is exposure to gamma rays emitted from radioactive material (fallout) deposited on the ground and the building roof, and in which the buildings are intact and undamaged. Some other conditions that should also be evaluated are as follows:

— Building collapse and damage should be evaluated. For example, for a 10 KT surface explosion, the Moderate Damage Zone with significant building damage or collapse is expected to extend about a mile from ground zero. [4]

— For nuclear power plant accidents and radioactive dispersal device scenarios, other exposure pathways, including inhalation and immersion of airborne radioactive materials, as well as exposure to contaminated surfaces, including trees and nearby buildings should be further evaluated, as they may contribute significantly to the overall radiation exposure. Some of the same geospatial databases used for the Regional Shelter Analysis, as well as building leakiness databases[5], can be used for this.

Finally, future work should continue to investigate related capabilities that exist in the community in order to ensure that the overall package available to local planners and responders is integrated with other relevant capabilities.

[4] See www.remm.nlm.gov/PlanningGuidanceNuclearDetonation.pdf for more detail

[5] Chan, Wanyu R., William W. Nazaroff, Phillip N. Price, Michael D. Sohn, and Ashok J. Gadgil., Analyzing a database of residential air leakage in the United States, *Atmospheric Environment* 39 (2005): 3445-3455.

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