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Building Triage in Response to Wide-Area Bio-Releases: Concepts and Building Classification System

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National Institute of Standards and Technology • U.S. Department of Commerce

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ABSTRACT
In order to support effective responses to a wide-area release of an airborne biological, chemical or radiological agent in an urban area, a "building triage" approach is proposed for estimating the contamination levels within specific buildings that are likely to have been affected by the release. Current approaches to estimating building contamination do not typically account for differences in building design and operation that are known to impact airborne contaminant entry. The building triage concept is proposed as a means to account for these differences between buildings in estimating contamination levels. This report describes the triage concept in terms of the steps involved and the information required and produced at each step. Key efforts still needed to develop and evaluate this triage approach are then discussed, primarily the definition of a building classification system that will be used to identify key building features relevant to the level of contamination. In addition, generic building models need to be defined that will be used with the classification system, and an initial collection of buildings is described here. Future work that will follow the development of the classification system and the generic buildings is also described, specifically the development of calculation tools to estimate the contamination levels in specific buildings based on their particulate design, occupancy and operation characteristics. Ultimately, the usefulness and practicality of applying the building classification system, the generic building types and the calculation methods will need to be evaluated in demonstration exercises of wide-area releases and response.

Keywords: building design, building protection, chembio, response planning, ventilation, wide-area releases.

1. INTRODUCTION

The release of a biological, chemical or radiological agent in an urban area has been identified as a homeland security threat of particular concern (GAO 2008), and the Department of Homeland Security is pursuing a number of strategies to plan for and respond to such releases (DHS 2009). In the event of such a release, hundreds even thousands of buildings and building occupants could be affected, leading to large economic costs and other disruptions (Judd, Olson et al. 2009; Franco and Bouri 2010). In order to support response planning, including the development of plans for agent sampling and eventually building decontamination, a systematic approach is needed to identify which buildings are more or less likely to be contaminated and to what level. Such information would assist in allocating resources for sampling and decontamination, and for facilitating the clearance of buildings for reoccupancy. This approach, in which the design and operational characteristics of specific buildings are used to estimate contamination levels, is referred to here as "building triage." The goal of this approach is to obtain contamination estimates in a relatively short amount time and with must less effort than detailed calculation methods. This report constitutes a first step in the development of the triage approach, specifically an initial description of the concept itself, the development of an associated building classification system, and the definition of generic building models. The concepts and definitions presented here still need to be evaluated in terms of their practicality and the usefulness of the information produced. In addition, contamination estimation tools need to be developed and tested for application in the field.

2. TRIAGE CONCEPT

The objective of the "building triage" approach is, in the event of a wide-area airborne biological, chemical or radiological release, to provide a systematic method of identifying which buildings are more or less likely to be contaminated and to what level. In addition, the approach is intended to obtain these contamination estimates in a relatively short amount time and with must less effort than required by detailed calculation approaches. It is also anticipated that information can be provided on where the agent has ended up within the building, e.g., particle filters, surfaces of interior spaces, ductwork, lobbies, etc. Such a triage approach needs to be incorporated into broader response planning that generally includes the following steps: first response, characterization, decontamination, clearance and ultimately restoration. Note that the timing and management of these steps, which impact the role and timing of the triage process, are active areas of discussion and research.

Assuming such outdoor release event has occurred, the five steps in the triage process are currently envisioned as follows:

1. Analyze exterior dispersion to define the path of the agent plume.
2. Identify the buildings in the path of the plume.
3. Associate key building characteristics with each building identified.
4. Populate generic building models using key characteristics from each building.
5. Estimate agent entry into each building using validated calculation tools.

The dispersion analysis in Step #1 generates a profile of the outdoor agent concentration as a function of location and time. Many models exist that perform such analyses, with differences in the physical transport processes considered and the mathematical approaches employed (NRC 2003). Many of these models were originally developed for studying the transport of outdoor pollution, for example emissions from power plants, but more recently they have been employed in homeland security applications. Such models generate a plume of agent concentrations that impact the buildings of interest, with an example shown in Figure 1. In the context of building triage, it is assumed that the exterior dispersion analysis will be performed distinct from the triage effort and will serve as an input. The manner in which the information generated from the dispersion modeling will be provided to and used within building triage is yet to be determined.

Figure 1 Example of exterior plume from modeling analysis (NRC 2003; NCAR 2010)

The second step is to identify the buildings that are located in the path of the agent plume and that will be considered in the triage analysis. Given the uncertainties in exterior dispersion models, the buildings included should extend beyond the calculated plume to increase the likelihood of identifying all affected buildings. The degree to which it should be extended and how the model uncertainty will be considered for buildings that are located outside the plume will be determined based on interactions with the developers and users of these dispersion models. It is anticipated that the process of identifying buildings will benefit from methods that use urban maps to identify buildings and associate them with some limited building data. For example, the AWARE (Analyzer for Wide Area Restoration Effectiveness) software tool, developed by Sandia National Laboratory, uses a GIS-based (geographic information system) approach employing Google maps to identify buildings and generate a building database (Knowlton, Tucker et al. 2010). Building data from local tax assessor offices is another option that is being considered.

In Step #3 of the triage process, each of the identified buildings is associated with relevant building characteristics that will be used to estimate its degree of contamination. The next section of this report contains an initial building classification scheme that is intended to support this step by defining a list of the most relevant building parameters. In identifying these parameters, the amount of information required, the time needed for its collection and the availability of this information must be balanced with the accuracy of the estimates of agent entry into the building. More detailed information on the buildings will improve the accuracy of the estimates, but obtaining this information could be impractical for a large number of buildings. However, in some localities or for some higher risk buildings, these characteristics could be collected before an event occurs, which will expedite the process and presumably improve the contamination estimates.

In the next step, Step #4, each building is mapped to one of several generic buildings to generate a model of that specific building using the building characteristics from Step #3. It is not considered realistic to expect a unique building model to be developed of each identified building based on the time and resources required to do so. Therefore, the current approach is to define a set of generic buildings, and associated building models, that range in type, size, age and other key characteristics. As part of the triage process, each impacted building would be mapped to the appropriate generic building in this collection. This report describes an initial set of generic buildings.

In the last step of the triage process, Step #5, the weather conditions and building/system operating characteristics during the release will be used to estimate the outdoor air entry via infiltration and ventilation into each building. These calculations will use a modeling approach applied to the building-specific versions of the generic building models developed in Step #4. These infiltration and ventilation entry rates will be combined with the outdoor concentration profiles from Step #1 to estimate the amount of agent that enters the building as well as where the agent ends up in the building, i.e., system filters, interior surfaces, etc. The calculation approaches that will be used in Step #5 are still under development, but they will be based on standard mass balance theory as implemented in the CONTAM model (Walton and Dols 2005). In fact, the calculation tools may run CONTAM in the background while presenting the user with a simplified interface. However, the tools will be developed for speed and ease of use so they can provide reasonably accurate results in a timeframe consistent with the demands of the response process.

Several steps in the triage process still require further definition and development. As these efforts proceed, there may be some changes to the process as described above. However, the basic steps are not expected to change significantly.

3. BUILDING CLASSIFICATION

This section describes a preliminary system for classifying buildings that is being developed for use in the building triage process. This classification system would be used to obtain information on potentially affected buildings to support subsequent estimates of building contamination. The system was developed to capture building attributes that are likely to relate to the entry of an outdoor contaminant through both envelope infiltration and ventilation system air intake, and is divided into three categories. The first category, Basic Attributes, includes basic building descriptors that should be readily available and will support first-order estimates of contamination. The second category, System Attributes, includes information on building ventilation systems, which will require more effort to obtain, but which will support more accurate estimates. The last category, Advanced Building Attributes, includes more detailed building information to support even more refined estimates. In many cases, the attributes and their definitions employ variables and data ranges from the DOE Commercial Building Energy Consumption Survey (CBECS), which is conducted periodically to collect information on commercial building energy use (DOE 2003).

In defining the classification approach to be used in building triage, a balance will need to be established between the level of detail of building and system information and the accuracy of the contamination estimates. More information will increase the accuracy of the estimates. but the information requested must be accessible and not involve an excessive amount of effort to collect. The information used for building triage needs to be readily available to building owners and managers, or others involved in the process such as emergency planning teams and first responders. As the triage approach is developed further, two important questions will be considered: 1) how much information is needed to determine a sufficiently reliable estimate, and 2) how much building information can realistically be obtained by those involved in the process, given realistic constraints of time and resources. It is expected that field exercises and demonstrations will be employed to help answer these questions, including the quality of the contamination data produced for various levels of completeness of the building information.

3.1 Basic Attributes: These attributes are intended to identify the building and to provide enough data to support approximate calculations of contamination. These attributes were selected based on an expectation that they would be readily available to those employing the triage approach and for whom a first order estimate would be adequate.

1 Building identifier This entry is solely for the users of the approach and resulting tools to identify a specific building. No specific formatting requirements are anticipated.

2 Floor area Ideally the user will have access to a reliable value. If not, the user can select from among the CBECS floor area ranges listed in the leftmost column.

CBECS "floor area" ranges	**m^2**	**ft^2**
a	93 to 464	1,001 to 5,000
b	465 to 929	5,001 to 10,000
c	930 to 2322	10,001 to 25,000
d	2323 to 464	25,001 to 50,000
e	465 to 9290	50,001 to 100,000
f	9291 to 18580	100,001 to 200,000
g	18581 to 46450	200,001 to 500,000
h	> 46450	>500,000

3 Number of floors Total number of occupied levels of the building, including all basements and sub-basements. This value should be easily accessible to the user, but the CBECS ranges are provided below for reference. It is definitely preferable to provide the actual value as opposed to simply selecting one of the categories in the table, particularly for the taller buildings.

CBECS "number of floor" ranges	**# of floors**
a	1
b	2
c	3
d	4
e	5 to 9
f	10 or more

4 Number of occupants Ideally this value would be available to the user, but if no reliable value is known then the user can select from among the CBECS occupancy ranges. CBECS defines the "number of workers" as the number of people working in a building during the main shift on a typical workday, which excludes customers, students and other key occupants. For the purposes of the current effort, this value should include a best estimate of the number of occupants at full occupancy, without the CBECS exclusions.

CBECS "occupancy" ranges	**# of people**
a	< 5
b	5 to 9
c	10 to 19
d	20 to 49
e	50 to 99
f	100 to 249
g	> 250

5 Year constructed Per CBECS, this is the year in which the major part or largest portion of the building was constructed. The year constructed is generally useful information as it sometimes can be related to certain construction features. However, the existing data on commercial building airtightness does not currently support correlations with building age (Emmerich and Persily 2005). However, it is hoped that further database development may support the establishment of such correlations.

CBECS "year constructed" ranges	**Year constructed**
a	Before 1920
b	1920 to 1945
c	1946 to 1959
d	1960 to 1969
e	1970 to 1979
f	1980 to 1989
g	1990 to 1999
h	2000 to 2003

6 Building type The activity or function that occupies most of the building floorspace is referred to within the CBECS database as the Principal Building Activity or PBA. CBECS employs two variables to describe the Principal Building Activity: PBA8 includes 27 primary activity types, while PBAPLUS8 expands that list to 51 types. The numbers in parentheses after each building activity correspond to the PBA8 and PBAPLUS8 codes.

Building type	CBECS Principle Building Activities (PBA8/PBAPLUS8)
a	Education (14/28, 29)
b	Food Sales (6/14)
c	Food Service (15/ 32, 33)
d	Health Care
d1	Inpatient (16/35)
d2	Outpatient (8/18, 19)
e	Lodging (18/38, 39)
f	Mercantile
f1	Retail (Other Than Mall) (25/42)
f2	Enclosed and Strip Malls (23, 24/50, 51)
g	Office (2/2 through 7)
h	Public Assembly (13/21 through 26)
i	Public Order and Safety (7/16, 17)
j	Religious Worship (12/21)
k	Service (26/44 through 48)
l	Warehouse and Storage (5/9, 10)
m	Other (91/49)
n	Vacant (01/01)

7 Occupancy schedule The CBECS database contains the number of hours per week that a building is used, excluding hours when the building is occupied only by maintenance, security, or other support personnel. For buildings with a schedule that varies during the year, “Weekly Operating Hours” refer to the schedule most often followed. If operating hours vary throughout a building, the operating hours of the largest occupancy in the building (based on floorspace) determine the operating hours for the building.

CBECS “occupancy schedule” ranges	Weekly operating hours
a	<40
b	40 to 48
c	49 to 60
d	61 to 84
e	85 to 167
f	Open Continuously

An alternative approach, which may be more informative when considering the time of an outdoor release, is to select from among the following options. All of them can be answered yes/no and are not necessarily mutually exclusive.

Weekdays, basically 9 to 5 schedule: Yes/No
Also occupied during evenings: Yes/No
Occupied during weekends: Yes/No
Occupied 24/7: Yes/No

8 Ventilation approach The manner in which a building is ventilated is key to determining how much of an outdoor agent enters a building. Ventilation rates of an individual building can vary widely depending on weather conditions and system operation, easily by as much as an order of magnitude. In order to support an estimate of the ventilation rate during an event, it is important to have information on how the building is ventilated, either by envelope leakage (infiltration), with a mechanical system, with a natural or passive ventilation system, or some combination. The following table describes the basic options by which a building can be ventilated. The ventilation approaches are largely self-explanatory, but some comments are merited. Infiltration refers to uncontrolled leakage through unintentional openings (e.g. cracks) in the exterior envelope. Under type a, infiltration only, this leakage is driven by exterior weather conditions, i.e., wind and outdoor temperatures that differ from indoors. In type b, infiltration plus local exhaust, leakage is also induced by the pressures created by the operation of exhaust fans. Type g, natural ventilation (designed), refers to natural ventilation systems that are designed based on engineering analysis of the opening sizes and positions, the driving pressures due to weather and the airflow patterns within the building. They are distinguished from operable windows systems due to the likelihood that they will be more effective. Note that designed natural ventilation systems are relatively rare in U.S. commercial buildings.

"Ventilation approach"		**Comments**
a	Infiltration only	Ventilation only due to envelope leakage driven by weather and perhaps equipment (combustion) operation
b	Infiltration only and local exhaust	Same as "a," but with addition of local exhaust ventilation in kitchen areas, toilets, etc.
c	Infiltration and operable windows	Same as "a," but with operable windows
d	Infiltration, operable windows and local exhaust	
e	Mechanical system with outdoor air intake	Any type of mechanical ventilation system that brings outdoor air into the building through an identifiable intake location
f	Mechanical system with outdoor air intake, plus operable windows	Same as "e," but also with operable windows
g	Natural ventilation (designed)	Any type of natural ventilation system, i.e. consisting of intentional vents and driven by weather conditions, that is designed to achieve specific airflow patterns and even airflow rates; operable windows do not fall into this category

3.2 System Attributes: The following attributes include information on the building HVAC system that will support refined estimates of building contamination. Information on some of these will be harder to obtain than the Basic Attributes above, but they will support a more accurate contamination estimate. And while some of these may not necessarily be used in the first implementation of the triage approach, they are included for completeness.

<u>9 Operation schedule</u> Information about when the system operates is key to estimating how much of an outdoor release enters the building. The following entries are intended to collect that information:

- Whenever occupied: Yes/No
- Typical start/stop times
  - Weekdays: HH:MM/HH:MM
  - Weekends: HH:MM/HH:MM

<u>10 Outdoor air intake control</u> The manner in which the outdoor air intake rate is controlled is key to determining the amount of outdoor air ventilation, and therefore how much contaminant may have entered a building during an outdoor release. The options listed below are based on the building assessment protocol used in the EPA BASE (Building Assessment Survey and Evaluation) study (EPA 2003):

- 100% outdoor air: Yes/No
- Constant minimum outdoor air intake: Yes/No
- Economizer cycle: Yes/No

<u>11 Exhaust fans</u> Exhaust fans are common in commercial buildings, and their operation can have a major impact on building infiltration rates, and therefore contaminant entry.

- Existence of exhaust fans
  - Toilet: Yes/No
  - Commercial kitchen: Yes/No
  - Other systems: Yes/No
- For each exhaust system, the following information should be obtained:
  - Spaces from which the exhaust system draws air:
  - Control: Manual, Time clock, Interlocked with main ventilation systems
    - If time clock, when does it operate:
      - Whenever occupied: Yes/No
      - Typical start/stop times
        - Weekdays: HH:MM/HH:MM
        - Weekends: HH:MM/HH:MM
  - Airflow rate in L/s (cfm):
    - Source of airflow rate: Design value or Measured

12 Return air path The manner in which return air from the occupied space flows back to the air handler can impact building airflow dynamics.

- Return airflow path: Ducted or Plenum

13 Filtration The type of filtration and its condition impacts how much of an aerosol contaminant in the outdoor air actually enters the building. The options listed below are based on the building assessment protocol used in the EPA BASE study (EPA 2003):

Complete for each air handling system:

- Current filtration efficiency: MERV level
- Location: Outdoor air, mixed or return airstream
- Filter condition: 1, 2 or 3
  1 Filter frames in good physical condition, securely in position
  2 Filters somewhat old, some filters not securely in place
  3 Filters very old and deteriorating, some filters out of position, frames in very bad shape
- Filter fit into frames: 1, 2 or 3
  1 Filters fit very well into frames, minimal leakage around filters
  2 Filters fit marginally well into frames, some bypass around filters
  3 Filters fit poorly into frames, large amounts of bypass around filters

14 Shut-off mode This item describes whether the system has an automated shut off mode, which can quickly turn off the ventilation system. This information may not be used initially in the triage approach, but it is included here for completeness.

- Main air handlers: Yes/No
- Local exhaust systems: Yes/No

15 Purge cycle This item concerns whether the system has an operating mode to bring in 100 % outdoor air, which can be used to purge the building of an indoor contaminant. This information may not be used initially in the triage approach, but it is included here for completeness.

- Purge cycle: Yes/No

16 System Maintenance Ventilation system maintenance is key to the system performing consistently with its design intent. This information on maintenance may not be used initially in the triage approach is it included for completeness. The options listed below are based on the building assessment protocol used in the EPA BASE study (EPA 2003):

- Air handler inspection
  Regularly scheduled: Yes/No
  Frequency: Months or years between inspections
- Filter replacement
  Regularly scheduled: Yes/No
  Frequency: Months or years between replacement
- Condition of mechanical rooms: 1, 2 or 3
  1- Clean and no sign of water leakage
  2- Fairly dusty or some evidence of water on floor
  3- Very dirty or standing water on floor

3.3 Advanced Building Attributes: The following attributes include additional building information that may help refine the contamination estimates. They are beyond the information needed for a first order estimate and are likely to be harder to obtain for some buildings. Some of these may not necessarily be used in the first implementation of the triage approach but are included here for completeness.

17 Flooring The type of flooring impacts the amount of agent that deposits on the floors and the likelihood that it will be resuspended. It is currently not clear how to use this information to predict resuspension rates, but ongoing research may result in reliable methods for doing so.

- Most of the building (other than the lobby): Carpet, tile, wood, concrete
- Lobby: Carpet, tile, wood, concrete

18 Exterior wall construction The type of construction that describes the bulk of the exterior walls of the building, which can be used to estimate building leakage rates. The options listed below are based on the building assessment protocol used in the EPA BASE study (EPA 2003):

- Select one of the following
  Glass and metal curtain wall; Masonry; Precast concrete panels; Stone panels; Exterior insulation finish system; Siding on frame construction; Metal building system; Other

19 Shelter-in-place (SIP) facilities The existence of SIP spaces in a building can serve to reduce occupant exposure to exterior agent releases. While not necessarily critical to building triage, this information can be important in associated sample planning and risk assessment efforts.

- Does the building have SIP spaces: Yes/No
- Have the walls for the SIP spaces airtightened: Yes/No
- Are the SIP spaces positively pressurized with filtered air: Yes/No

20 Special use spaces The existence of spaces that may be isolated from the rest of the building can impact occupant exposure to exterior agent releases. While not necessarily critical to building triage, this information can be important in sample planning and risk assessment.

- Does the building have a lobby: Yes/No
  Is it ventilated by a separate system with supply and exhaust airflows? Yes/No
  Is it ventilated by a dedicated exhaust system? Yes/No
  Is it separated from the rest of the building by permanent partitions? Yes/No
- Does the building have a mailroom: Yes/No
  Is it ventilated by a separate system with supply and exhaust airflows? Yes/No
  Is it ventilated by a dedicated exhaust system? Yes/No
  Is it separated from the rest of the building by permanent partitions? Yes/No
- Does the building have a shipping/receiving area: Yes/No
  Is it ventilated by a separate system with supply and exhaust airflows? Yes/No
  Is it ventilated by a dedicated exhaust system? Yes/No
  Is it separated from the rest of the building by permanent partitions? Yes/No
- Does the building have a commercial kitchen area: Yes/No
  Is it ventilated by a separate system with supply and exhaust airflows? Yes/No
  Is it ventilated by a dedicated exhaust system? Yes/No
  Is it separated from the rest of the building by permanent partitions? Yes/No

21 Building response procedures Operational procedures for responding to agent releases have been discussed as a means of reducing the exposure of building occupants to these agents (NIOSH 2002; ASHRAE 2009). Examples include ventilation system shut down, or shutting outdoor air intake dampers and keeping the system on 100% recirculation. While not common in most buildings, the existence and use of such procedures is relevant to sample planning and risk assessment. Note that impact of these procedures requires knowledge or an assumption as to whether and when they were implemented during the release of interest.

- Does the building have a ventilation system response procedure in anticipation of an exterior release: Yes/No
  Are all the systems turned off? Yes/No
  Are the systems put on 100 % recirculation with no outdoor air intake? Yes/No
  Are all exterior doors kept shut with no occupant entry or exit? Yes/No
- Are building occupants moved to a shelter-in-place space in anticipation of an exterior release: Yes/No

4. GENERIC BUILDING TYPES

This section describes the generic building types that are currently being considered for use in the building triage process. A collection of commercial buildings has been defined based on 15 reference commercial buildings developed for the U.S. Department of Energy to analyze building energy consumption trends and opportunities to improve energy efficiency (Torcellini, Deru et al. 2008). Each building has a well-defined floor plan, with three versions for each building corresponding to three different ages, which in turn are associated with different levels of airtightness. The following table lists these buildings, along with the building ventilation type (discussed earlier) relevant to each, yielding 61 building/ventilation combinations. The three ages of each building results in a total of 183 commercial buildings.

	CBECS Principal Building Activity		**Building Ventilation Type**						
Name	PBA8	PBAPLUS8	a	b	c	d	e	f	g
Small Office	2	2-7	X	X	X	X	X	X	X
Medium Office	2	2-7					X	X	X
Large Office	2	2-7					X	X	X
Primary School	14	28					X	X	X
Secondary School	14	29					X	X	X
Stand-alone Retail	25	42					X	X	X
Strip Mall	23	50	X	X	X	X	X	X	X
Supermarket	6	14					X	X	X
Quick Service Restaurant	15	32					X	X	X
Full Service Restaurant	15	33					X	X	X
Small Hotel	18	39	X	X	X	X	X	X	X
Large Hotel	18	38					X	X	X
Hospital	13	35					X	X	X
Outpatient Health Care	8	18,19					X	X	X
Warehouse	5	9, 10	X	X	X	X	X	X	X

Building Ventilation Types

a Infiltration only
b Infiltration only and local exhaust
c Infiltration and operable windows
d Infiltration, windows and local exhaust
e Mechanical system with outdoor air intake
f Mechanical system with outdoor air, plus operable windows
g Natural ventilation (designed)

In addition to these commercial buildings, NIST has developed a set of 209 dwellings that represent the bulk of the U.S. housing stock (Persily, Musser et al. 2006). While the triage concept is initially being developed for commercial buildings, these dwellings constitute a separate collection of generic residential buildings. These dwellings are described in tables presented in Appendix A of this report.

5. NEXT STEPS IN TRIAGE DEVELOPMENT

In order to develop the triage approach to the point where it can be demonstrated and evaluated using actual release scenarios and buildings, a number of efforts are being pursued. A key first step is to assess the practicality of collecting the building characteristics described in this report and then to use the results of that assessment to define a working list of building characteristics. The preliminary list of characteristics described in this report will be reviewed with individuals and organizations involved in emergency response planning, sample planning and other relevant activities to assess the practicality of obtaining the information. If the data collection process is too onerous, it is less likely to be implemented by those involved in planning and response.

In addition to verifying the practicality of collecting the building information and refining the list of building characteristics, multizone airflow and contaminant transport models will be developed for the generic buildings descried earlier. These building models will be used to conduct contaminant transport analyses to determine the range of contamination variation for the different buildings and for the different values of the building characteristics. These simulations will be performed for a range of release scenarios, weather conditions and modes of ventilation system operation. The results will help identify those parameters that have the largest impacts on building contamination, and are therefore most important to characterize as part of the triage process. A key question that needs to be addressed in these simulations is how much information is needed for a sufficiently reliable estimate of building contamination. This question will be considered in conjunction with the issue of how much building information can realistically be obtained by those involved in the process. The simulation results will also serve to assess the accuracy of simpler contamination calculation methods that will be developed under this effort.

After the building characterization scheme has been defined, and as the contamination calculation methods are being evaluated, the triage concept will be applied in conjunction with wide-area release exercises and demonstration projects. These efforts involve the planning of responses to wide area releases of biological, chemical or radiological agents and an analysis of how response personnel and resources are deployed. An example of such a demonstration project is the recent work done under the IBRD (Interagency Biological Restoration Demonstration) program (Van Cuyk, Deshpande et al. 2010). The Wide Area Recovery & Resiliency Program (www.warrp.org), a new program to explore and demonstrate planning approaches to respond and manage a large scale chemical, biological or radiation release in the Denver urban area, is another opportunity to demonstrate the application of building triage. Such exercises will be useful to assess the practicality of collecting building information by response personnel, including the completeness of the information obtained and the time required for its collection.

Other items that need to be resolved include the manner in which the information generated from dispersion modeling will be used within the triage process. This issue includes the degree to which buildings beyond the calculated plume will be included in the analysis based on the estimated uncertainties in dispersion model predictions. These issues will be discussed with the developers of the dispersion models that are used in analyzing outdoor agent releases. Another outstanding issue is the use of data from urban maps or other existing resources to identify buildings within a plume area, as well as information about the buildings. This approach is being pursued by the developers of some plume models, and its applicability to building triage will be determined as part of the interactions with these teams. Finally, the manner in which the output of the triage analysis will be used for sample planning and other aspects of the response process needs to be considered as part of the overall process of response planning and execution.

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Appendix A: Collection of Generic Residential Buildings (Persily, Musser et al. 2006)

This appendix contains four tables that define the 209 generic dwellings, with one table for each housing type: detached (A1), attached (A2), manufactured home (A3) and apartment (A4).

Table A1. Detached Homes (83 total)

House Number	# of Floors	House Variable (key at end of table)				
		Floor area	Year Built	Foundation	Garage	Forced-air
DH-1	1	2	3	1	2	2
DH-2	1	1	2	3	2	2
DH-3	1	1	2	2	1	1
DH-4	1	1	2	2	2	2
DH-5	1	1	3	1	2	2
DH-6	2	1	1	3	2	2
DH-7	1	2	2	3	2	2
DH-8	1	1	2	1	2	2
DH-9	2	1	2	3	2	2
DH-10	2	2	3	3	2	2
DH-11	1	1	2	2	2	1
DH-12	2	3	3	3	2	2
DH-13	1	2	2	2	2	2
DH-14	2	2	1	3	2	2
DH-15	2	3	4	3	2	2
DH-16	1	1	2	2	1	2
DH-17	2	2	2	3	2	2
DH-18	2	1	1	3	1	2
DH-19	1	1	3	3	2	2
DH-20	2	2	1	3	2	1
DH-21	1	1	2	1	1	2
DH-22	2	3	3	1	2	2
DH-23	2	1	1	3	2	1
DH-24	2	2	3	1	2	2
DH-25	1	1	2	3	2	1
DH-26	1	1	2	1	1	1
DH-27	1	1	2	3	1	2
DH-28	2	3	4	1	2	2
DH-29	1	1	1	2	1	1
DH-30	1	2	3	2	2	2
DH-31	1	1	3	2	2	2
DH-32	1	1	4	1	2	2
DH-33	1	3	3	1	2	2
DH-34	1	1	3	1	1	2
DH-35	1	2	2	1	2	2
DH-36	2	2	4	1	2	2
DH-37	1	2	3	3	2	2
DH-38	1	1	3	2	1	2
DH-39	1	2	2	2	1	2
DH-40	2	2	3	2	2	2
DH-41	2	2	1	3	1	2
DH-42	1	1	3	2	1	1

House Number	# of Floors	House Variable (key at end of table)				
		Floor area	Year Built	Foundation	Garage	Forced-air
DH-43	2	2	2	3	2	1
DH-44	1	1	1	3	2	2
DH-45	2	2	3	4	2	1
DH-46	1	1	2	1	2	1
DH-47	1	1	3	2	2	1
DH-48	1	1	4	2	1	2
DH-49	1	1	2	3	1	1
DH-50	2	1	1	3	1	1
DH-51	2	3	3	2	2	2
DH-52	2	3	1	4	2	2
DH-53	1	2	3	1	1	2
DH-54	1	1	1	2	1	2
DH-55	1	1	4	2	2	2
DH-56	2	1	2	3	1	2
DH-57	1	2	2	2	2	1
DH-58	2	2	4	3	2	2
DH-59	2	3	2	3	2	1
DH-60	1	1	3	4	2	1
DH-61	1	1	1	4	1	2
DH-62	2	3	1	3	2	1
DH-63	2	1	2	4	2	1
DH-64	1	2	4	1	2	2
DH-65	1	1	1	4	1	1
DH-66	1	2	2	1	2	1
DH-67	1	1	1	2	2	2
DH-68	2	1	2	3	1	1
DH-69	2	3	3	4	2	1
DH-70	1	1	3	1	1	1
DH-71	2	1	3	1	2	2
DH-72	1	2	1	4	2	2
DH-73	2	1	3	4	2	2
DH-74	1	3	3	4	2	2
DH-75	3	2	3	1	2	2
DH-76	1	1	4	4	2	2
DH-77	3	2	3	4	2	2
DH-78	1	1	3	1	2	1
DH-79	1	2	3	2	1	2
DH-80	1	2	2	4	1	2
DH-81	2	2	1	4	1	1
DH-82	1	2	2	4	2	1
DH-83	1	1	3	3	1	2

# of floors: 1 = one story; 2 = two story
Floor area: 1 = less than 148.5 m^2 (1,599 ft^2); 2 = 148.6 m^2 to 222.9 m^2 (1,600 ft^2 to 2,399 ft^2); 3 = 223.0 m^2 (2,400 ft^2) or more
Year Built: 1 = before 1940; 2 = 1940-69; 3 = 1970-89; 4 = 1990 and newer
Foundation: 1 = concrete slab; 2 = crawl space; 3 = finished basement, 4 = unfinished basement
Garage: 1 = none; 2 = attached garage
Forced Air: 1 = other; 2 = central system present

TABLE A2. Modeling details – Attached Homes (53 total)

House Number	# of Floors	House Variable (key at end of table)				
		Floor area	Year Built	Foundation	Garage	Forced-air
AH-1	2	1	1	3	1	2
AH-2	2	1	3	1	1	2
AH-3	1	1	3	1	1	2
AH-4	1	1	3	1	2	2
AH-5	2	1	2	3	1	1
AH-6	2	1	3	1	2	2
AH-7	2	1	3	3	1	2
AH-8	1	1	2	1	1	1
AH-9	2	1	1	3	2	1
AH-10	2	1	1	3	1	1
AH-11	2	1	2	3	1	2
AH-12	1	1	4	1	2	2
AH-13	2	1	2	1	1	2
AH-14	1	1	2	1	1	2
AH-15	2	2	3	1	2	2
AH-16	2	1	1	2	1	1
AH-17	1	1	2	2	1	1
AH-18	2	1	3	1	1	1
AH-19	2	1	2	1	2	2
AH-20	2	1	1	4	2	2
AH-21	2	2	1	4	2	2
AH-22	2	1	3	1	2	1
AH-23	2	1	3	4	2	2
AH-24	2	2	1	3	1	1
AH-25	1	1	2	1	2	1
AH-26	2	1	4	1	1	2
AH-27	2	2	1	4	2	1
AH-28	2	2	3	3	1	2
AH-29	2	2	4	1	2	2
AH-30	1	1	3	2	2	1
AH-31	1	1	2	3	1	2
AH-32	1	1	2	4	2	2
AH-33	1	1	1	3	1	2
AH-34	2	3	3	3	1	2
AH-35	2	1	2	1	1	1
AH-36	1	1	2	1	2	2
AH-37	1	1	2	2	2	1
AH-38	1	1	1	4	2	1
AH-39	1	1	4	1	1	2
AH-40	2	1	1	1	1	1
AH-41	2	2	2	3	1	2
AH-42	2	1	2	4	2	2
AH-43	1	2	3	1	2	2
AH-44	1	1	3	2	1	1
AH-45	1	1	2	2	1	2
AH-46	2	1	2	2	1	2

House Number	# of Floors	House Variable (key at end of table)				
		Floor area	Year Built	Foundation	Garage	Forced-air
AH-47	1	1	3	4	2	2
AH-48	2	1	3	2	1	2
AH-49	1	1	1	2	2	1
AH-50	2	1	3	2	2	2
AH-51	2	1	3	3	1	1
AH-52	2	2	3	1	1	2
AH-53	1	1	4	2	1	2

# of floors: 1 = one story; 2 = two story
Floor area: 1 = less than 148.5 m^2 (1,599 ft^2); 2 = 148.6 m^2 to 222.9 m^2 (1,600 ft^2 to 2,399 ft^2); 3 = 223.0 m^2 (2,400 ft^2) or more
Year Built: 1 = before 1940; 2 = 1940-69; 3 = 1970-89; 4 = 1990 and newer
Foundation: 1 = concrete slab; 2 = crawl space; 3 = finished basement, 4 = unfinished basement
Garage: 1 = none; 2 = attached garage
Forced Air: 1 = other; 2 = central system present

TABLE A3. Modeling details – Manufactured Homes (4 total)

	House Variable (key at end of table)		
House Number	Floor area	Year Built	Forced-air
MH-1	1	3	2
MH-2	1	4	2
MH-3	1	3	1
MH-4	1	2	2

Floor area: 1 = less than 148.5 m^2 (1,599 ft^2); 2 = 148.6 m^2 (1,600 ft^2) or more
Year Built: 1 = before 1940; 2 = 1940-69; 3 = 1970-89; 4 = 1990 and newer
Forced Air: 1 = other; 2 = central system present

TABLE A4. Modeling details – Apartments (69 total)

	House Variable (key at end of table)				
Model Number	**# of Floors**	**# of Units**	**Floor area**	**Year Built**	**Forced-air**
APT-1	2	3	1	3	2
APT-2	3	3	1	3	2
APT-3	4	5	1	3	1
APT-4	2	1	1	1	1
APT-5	2	1	1	2	1
APT-6	2	2	1	3	2
APT-7	2	1	1	2	2
APT-8	2	2	2	3	2
APT-9	2	1	1	3	2
APT-10	2	3	1	3	1
APT-11	2	2	1	2	2
APT-12	3	5	1	3	1
APT-13	4	5	1	1	1
APT-14	2	1	2	3	2
APT-15	2	2	1	3	1
APT-16	1	1	1	2	1
APT-17	3	4	1	2	1
APT-18	3	1	1	1	1
APT-19	3	3	1	3	1
APT-20	2	3	1	2	2
APT-21	2	3	2	3	2
APT-22	2	1	1	3	1
APT-23	3	4	1	3	2
APT-24	5	5	1	2	1
APT-25	2	3	1	2	1
APT-26	3	3	1	2	1
APT-27	3	4	1	2	2
APT-28	2	1	2	1	1
APT-29	3	2	1	2	1
APT-30	4	5	1	2	1
APT-31	2	2	2	2	1
APT-32	2	1	1	1	2
APT-33	2	5	1	3	2
APT-34	3	4	1	1	1
APT-35	2	2	2	4	2
APT-36	4	5	1	3	2
APT-37	3	5	1	2	1
APT-38	2	4	1	3	2
APT-39	3	4	1	3	1
APT-40	2	2	1	2	1
APT-41	1	2	2	3	2
APT-42	3	2	1	1	1
APT-43	3	3	2	3	1
APT-44	3	3	1	1	1
APT-45	3	5	2	2	1
APT-46	3	1	1	2	1

	House Variable (key at end of table)				
Model Number	**# of Floors**	**# of Units**	**Floor area**	**Year Built**	**Forced-air**
APT-47	1	1	1	3	2
APT-48	3	5	1	1	1
APT-49	3	5	1	2	2
APT-50	3	4	2	3	2
APT-51	3	1	2	1	1
APT-52	4	5	1	2	2
APT-53	2	5	1	2	2
APT-54	2	4	1	3	1
APT-55	2	2	2	2	2
APT-56	2	4	1	2	1
APT-57	1	2	1	3	2
APT-58	2	3	2	2	1
APT-59	2	2	1	4	2
APT-60	3	2	1	4	2
APT-61	3	2	1	2	2
APT-62	2	2	1	4	1
APT-63	3	5	2	2	2
APT-64	2	3	1	4	2
APT-65	3	5	1	3	2
APT-66	3	3	2	1	2
APT-67	1	3	1	2	1
APT-68	3	2	1	3	1
APT-69	4	2	1	4	2

# of floors: 1 = 1 story; 2 = 2 story; 3 = 3 to 5 stories (modeled as 4); 4 = 6-15 stories (modeled as 10); 5 = 16+ stories (modeled as 10)
# of units: 1 = 2 to 4 (modeled as 4); 2 = 5 to 9 (modeled as 6); 3 = 10 to 19 (modeled as 16); 4 = 20 to 39 (modeled as 32); 5 = 40+ units in building (modeled as 20 units per floor)
Floor area: 1 = less than 92.8 m^2 (999 ft^2); 2 = 92.9 m^2 (1,000 ft^2) or more
Year Built: 1 = before 1940; 2 = 1940-69; 3 = 1970-89; 4 = 1990 and newer
Forced Air: 1 = other; 2 = central system present