Waste Estimation from a Wide-Area Radiological Incident: The Impact of Geography and Urban Footprint

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ABSTRACT

In the planning and preparedness stages for a response to a radiological incident, it is important to include waste management considerations when developing the decontamination/demolition/cleanup approach because waste management can be a driver for time and cost for return to normalcy. Waste management is also inextricably linked to the geography and urban footprint of the impacted area. The U.S. Environmental Protection Agency's (EPA's) Waste Estimation Support Tool (WEST) is a novel application based on the Federal Emergency Management Agency (FEMA) Hazus-MH software. WEST enables users to estimate the characteristics, amount, and residual radioactivity of waste generated from remediation and cleanup activities after a radiological incident, including incidents caused by radiological dispersal devices and improvised nuclear devices, as well as nuclear power plant accidents. These waste estimates are generated as a function of user-defined decontamination strategies and are specific to a geographic location. This paper will describe the recently released version 3 update to WEST, and how differences in geography and urban footprints can impact the waste that is generated.

INTRODUCTION

Recovery from a radiological incident, of all potential threats, could possibly be the most costly and time consuming [1]. Recovery can be largely a function of decontamination and waste management strategies, policies, timelines, available resources, and public sentiment. Historically, these factors have been decoupled from each other. Through a series of recent national-level exercises and planning activities, it has become apparent that to minimize the economic, environmental, and public health impacts of such an incident, these factors must be simultaneously considered using a "system-of-systems" approach, where decisions in one area (e.g., decontamination) profoundly affect decisions in another area (e.g., waste management). Decision makers must also account for the topological, geographic, and geometric properties of the impacted area as these considerations will largely influence the magnitude and characteristics of waste generated by decontamination activities. These considerations are especially true for urban areas where factors such as infrastructure density, construction materials, and abundance of vegetation vary greatly. Strictly speaking, there is no "one size fits all" solution when considering decontamination/demolition/cleanup approaches. Each approach is just as unique as the geographic location itself.

To help decision makers and planners better understand the impact that geography and urban footprints have on waste management considerations, the U.S. Environmental Protection Agency (EPA) Homeland Security Research Program (HSRP) developed the Waste Estimation Support Tool (WEST). WEST is a GIS-based decision support tool for estimating the characteristics, amount, and residual radioactivity of waste generated from remediation and cleanup activities after a wide-area radiological incident due to radiological dispersal devices, improvised nuclear devices, or nuclear power plant accidents [1, 2]. WEST incorporates a number of models and approaches, most notably, Esri's ArcGIS, FEMA's Hazus-MH software, and satellite image classification capabilities [3]. By leveraging these technologies in concert with a methodology for estimating the quantity of waste and debris that may result from a radiological incident, users can create customized decontamination strategies. This capability enables the end-user to evaluate different decontamination strategies and the impact on resulting waste generated for a given geographical locality.

Now in its seventh year of development, WEST has been applied in several radiologically themed federal exercises such as South Carolina's Southern Exposure Exercise, a FEMA Region 4 Improvised Nuclear Device (IND) exercise, the Department of Homeland Security (DHS) Wide Area Recovery and Resiliency Program (WARRP), the EPA's Liberty RadEx, and National Level Exercise 14 (2014). WEST version 3.0.1 was recently released and features improvements to the software usability, improved infrastructure resolution (i.e., decontamination technologies can now be assigned to specific building/occupancy types), and introduces a reporting and a GIS mapping feature. Current development efforts are focused on adding IND support, cost, time, and supplemental waste factors, and improvements to the back-end for faster processing and better memory management.

WEST OPERATION

WEST is a GIS-based decision support tool for estimating waste generated from remediation and cleanup activities following a radiological incident. Specifically, WEST compiles location-specific discrete (e.g., infrastructure) and continuous (i.e., surface media) information and uses this information to estimate the characteristics, amount, and residual radioactivity of waste, based on user-defined or pre-defined decontamination technologies. To collect this information, WEST uses two separate but interrelated core components: 1) WEST GIS, and 2) WEST Spreadsheet. Each of these two components serves a distinct purpose. The WEST GIS component consists of a custom GIS-based tool for estimating infrastructure surface media information specific to a geographic area. The stand-alone spreadsheet conducts a series of complex analyses based on a specified decontamination strategy using the derived GIS information. The methodology is further described in Figure 1.

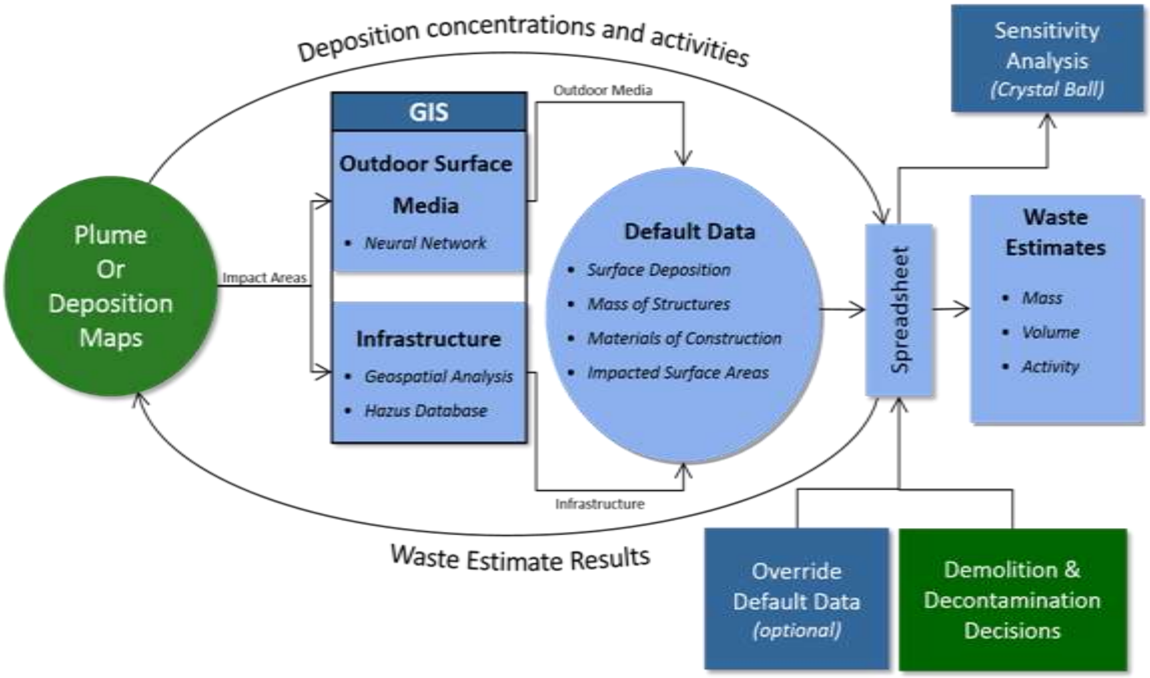

Figure 1. WEST Methodology

WEST GIS

WEST GIS is an adjunct piece of software to FEMA’s Hazus-MH software, a GIS-based software for predicting property loss due to an earthquake, wind, or flood event [3]. WEST GIS expands the functionality of Hazus by allowing users to collect geospatial information according to the boundaries of a plume (i.e., area of contamination). The area of contamination is defined by a user-provided plume divided into three polygons that represent three distinct levels of contamination. Using the plume as a guide, WEST GIS uses an ESRI ArcGIS-based Python script to conduct a geospatial analysis to quantify the underlying infrastructure and surface media. The script calculates the area of the plume and identifies census tracts that intersect the plume. The resulting census tracts are used to query the Hazus database for infrastructure information (i.e., building counts and building square footage) specific to the area of interest (AOI). In addition to the spatial information, the plug-in captures aerial imagery for estimating land cover, which is fed into a custom image classification tool used for identifying common outdoor surfaces (i.e., concrete, asphalt, soil/vegetation, and water) and the distribution of those surfaces within the AOI. The resulting data are then fed into the WEST Spreadsheet, which is described in more detail below.

WEST Spreadsheet

WEST uses a Visual Basic for Applications (VBA)-based Microsoft Excel spreadsheet that provides an interface for users to specify various required inputs, modify default parameters, and subsequently view the results of decontamination and demolition operations based on the outputs of the WEST GIS component. Upon opening the spreadsheet, the user is given the option of opening an existing scenario or creating a new one. When creating a new scenario, the user must establish three sets of parameters: 1) WEST GIS output, 2) time and activity specific to the radionuclide(s) assumed to be deposited within the plume, and 3) type of decontamination technology to be used on the various indoor and outdoor surfaces per user-defined building occupancy types in each deposition zone and fraction of buildings in any given zone to be demolished. These parameters can be intermingled and reused for comparing decontamination strategies on different geospatial data sets, running multiple decontamination strategies on a single geospatial data set, or examining decontamination approaches on different radionuclide release scenarios. Once the above parameters have been specified, WEST then generates an estimate containing the amount and radioactivity of contaminated waste. The waste estimates include waste generated by demolition, decontamination, or remediation activities conducted within the designated zones such as building materials, ground surface materials, and wastewater. These data can be exported for further scrutiny using sensitivity analysis software such as Crystal Ball to identify impacts of decisions on such output variables as amount/activity of waste, type of waste, or remediation costs.

Recent enhancements to WEST include a mapping and reporting function. The mapping function allows users to export results to Keyhole Markup Language (KML) formatted maps for use in ArcGIS or Google Earth. The reporting function generates a Microsoft Excel file that contains specific details, tables, and results based on scenario assumptions. The Excel file can be further customized depending the user's requirements.

COMPARE AND CONTRAST WASTE ESTIMATES

One of the advantages of using a tool such as WEST for planning purposes, is that several user-defined scenarios can be investigated so that a range of potential circumstances can be estimated, so that bounds can be placed on resource requirements based on a range of possible situations.

In addition to the overall decontamination approach, factors such as the city's size, age, design and architecture, construction materials, occupancy type distribution, and abundance of parks and vegetation may influence the volume and characteristics of the waste stream. The authors assume that these factors vary greatly by city, and thus a blanket decontamination approach will not suffice when remediating large urban areas. To test this hypothesis, the authors compared scenario results from Denver, CO, and Philadelphia, PA, for their differences in geography and population density. Denver can be described as topographically flat with hilly areas to the north, west and south. With a population of approximately 663,800 people and an area of 155 square miles, Denver has an estimated population density of 1,561 people per km^2 [4]. Philadelphia can be described as a generally flat, yet densely developed city. Philadelphia has an estimated population of 1,560,200 people with an area of 367 km^2 with an estimated population density of 4,492 people per km^2 [4].

For the purposes of this investigation, the authors used plumes based on modeling from the National Atmospheric Release Advisory Center (NARAC), which were generated for the Wide Area Recovery and Resiliency Program (WARRP) (Denver) and the Liberty RadEx National Level Exercise (Philadelphia). Both scenarios were developed to exercise resiliency (the ability to recover basic services) and to re-establish social and economic systems following a catastrophic chemical, biological, or radiological (CBR) event. These activities involved a large-scale hypothetical CBR incident as a result of a terrorist detonating a radiological dispersal device (RDD). The hypothetical RDD contained 2,300 curies of cesium-137 (as cesium chloride) and was dispersed over approximately 100 square kilometers via a 1,360 kilogram (kg) truck bomb. The defined levels of surface contamination used as input to WEST are as follows: zone 1 = 2000 microcuries per square meter (µCi/m^2), zone 2 = 200 µCi/m^2, and zone 3 = 20 µCi/m^2 as illustrated by different colors (e.g., zone 1 appears as dark orange). Figure 2 shows the boundaries (i.e., areas conforming to these levels of contamination) of WARRP (82.3 million m^2) and Liberty RadEx (19 million m^2), respectively. These plumes (i.e., polygons) were used to define the decontamination strategy for both cities.

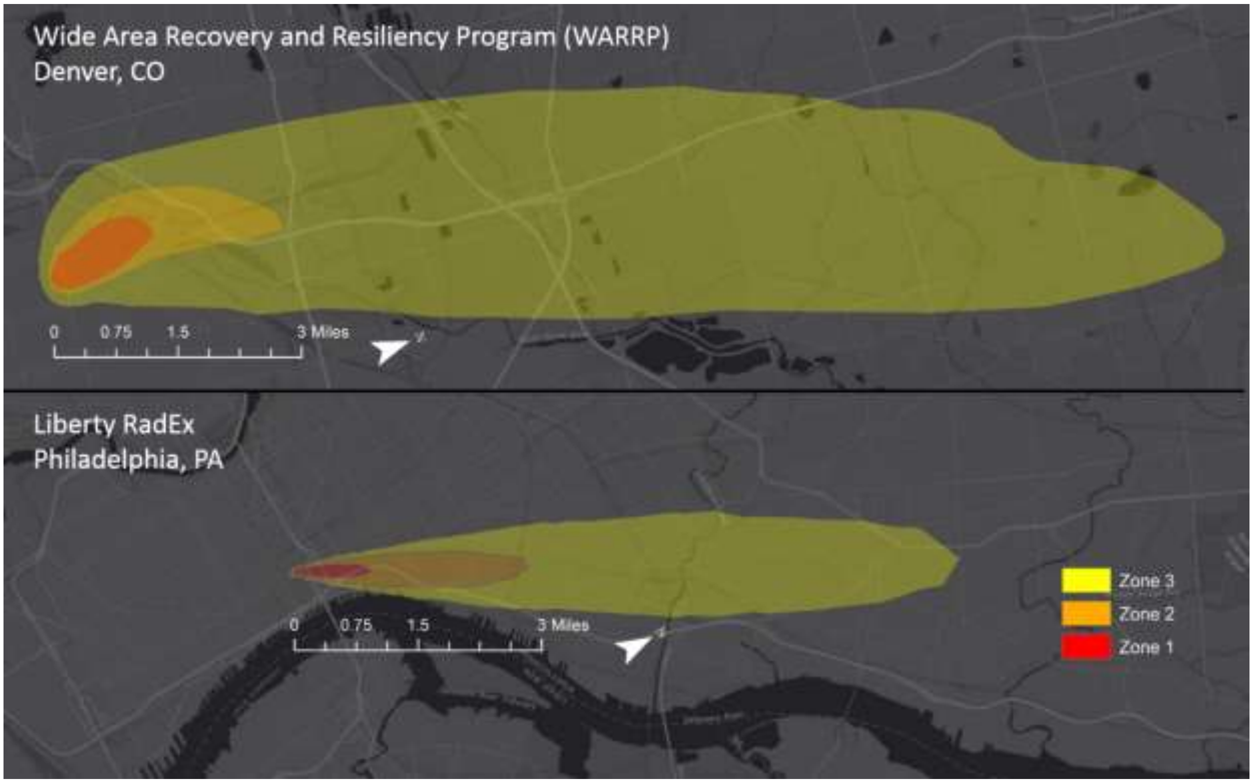

Figure 2. WARRP and Liberty RadEx Plume Shapefiles

Based on building data extracted from Hazus-MH for the affected areas in both cities, WEST aggregated various building occupancy classifications into ten general groupings. The distributions of general building types for each city in each contamination zone are shown in Table 1.

Table 1. Estimated Building Counts by General Occupancy Type

WEST Building Type	Denver			Philadelphia		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Agricultural	4	3	42	0	0	1
Multi Family	228	119	574	27	72	372
Medical	88	25	44	11	11	46
Entertainment	176	108	322	24	55	216
Parking	6	1	4	0	0	1
Educational	2	0	8	0	0	4
Emergency	4	1	4	3	5	6
Industrial	38	29	189	5	19	164
Single Family	122	1,205	31,382	222	5,356	37,139
Multi Use	108	117	1,195	36	131	799
TOTAL	**776**	**1,608**	**33,764**	**328**	**5,649**	**38,748**

Multifamily, medical, and entertainment buildings are more prevalent in zone 1 for Denver than for Philadelphia. Approximately the same numbers of those buildings are found in zone 2 for both cities; however, we see substantially more of those building types in zone 3 of Philadelphia versus Denver. In contrast, the number of single-family residences between the two cities as well as their distributions are notable. Table 2 lists the distribution of building types as percentages of building counts. We observe a denser concentration of single-family residences in Philadelphia versus Denver and single-family residences constitute the majority of the total structure types found in the affected area for Philadelphia (over 65% for zone 1 and over 90% for zones 2 and 3) whereas only approximately 16% of structures in zone 1 for Denver are single-family residential, and 75% for zone 2.

Table 2. Estimated Building Distribution Based on Building Count

WEST Building Type	Denver			Philadelphia		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Agricultural	0.5%	0.2%	0.1%	0%	0%	0.003%
Multi Family	29.4%	7.4%	1.7%	8.2%	1.3%	1.0%
Medical	11.3%	1.6%	0.1%	3.4%	0.2%	0.1%
Entertainment	22.7%	6.7%	1.0%	7.3%	1.0%	0.6%
Parking	0.8%	0.1%	0.01%	0%	0%	0.003%
Educational	0.3%	0%	0.02%	0%	0%	0.01%
Emergency	0.5%	0.1%	0.01%	0.9%	0.1%	0.02%
Industrial	4.9%	1.8%	0.6%	1.5%	0.3%	0.4%
Single Family	15.7%	74.9%	92.9%	67.7%	94.8%	95.8%
Multi Use	13.9%	7.3%	3.5%	11.0%	2.3%	2.1%

Decontamination Strategy

We selected and applied an "extensive decontamination" scenario for both cities, with the demolition and decontamination approach details as shown in Table 3. The prescribed demolition and decontamination strategies were applied to the buildings and surfaces in both cities to evaluate any impact of geography and urban footprint on the resulting waste amounts, assuming the exact same decontamination approach. WEST was designed to evaluate the impact of decontamination assumptions on the waste characteristics, but it can also allow comparison of a single decontamination approach applied to different geographic areas.

Table 3. "Extensive Decontamination" Approach Parameters

	Zone 1	Zone 2	Zone 3
Buildings	90 % demolition 10 % decontamination	0 % demolition 100 % decontamination	0 % demolition 100 % decontamination
Asphalt	2.5 cm removal – 50%	2.5 cm removal – 50 %	2.5 cm removal – 25 %
	Wash – 50 %	Wash – 50 %	Wash – 75 %
Concrete	2.5 cm removal – 50%	2.5 cm removal – 50 %	2.5 cm removal – 25 %
	Wash – 50 %	Wash – 50 %	Wash – 75 %
Soil	15 cm removal – 100 %	15 cm removal – 100 %	15 cm removal – 100 %
External Walls	Wash – 100 %	Wash – 100 %	Wash – 100 %
Roofs	Wash – 100 %	Wash – 100 %	Wash – 100 %
Interior Walls	Strippable Coating– 100 %	Washing – 50 % Strippable Coating – 50 %	Washing – 100 %
Floors	Material Removal – 100 %	Material Removal – 100 % Mop – 100 %	Mop – 100 %

The selection of demolition and decontamination parameters listed in Table 3 are in fact somewhat arbitrary, but do reflect a potentially reasonable approach to decontamination based on the general types of surfaces found in an urban and suburban environment, and not based on the structure type, use, or occupancy of the building (e.g., in an actual event, the decontamination approaches will likely vary based on the use and occupancy of a given structure, which could include considerations such as historical significance).

Waste Results

The WEST Spreadsheet estimated the amounts of waste generated using the decontamination strategy outlined above for both Denver and Philadelphia and the results are shown in the tables and figures that follow. Table 4 and Figure 3 show the estimated volumes of demolition waste generated for both cities, Table 5 and Figures 4 and 5 show the estimated decontamination waste, and Figure 6 illustrates the total amount of liquid waste that could be generated from both decontamination and demolition activities.

Table 4. Demolition Volumetric Waste Results, in Cubic Meters

	Zone 1		Zone 2		Zone 3	
	Denver	Philadelphia	Denver	Philadelphia	Denver	Philadelphia
Total Demolition Solid Waste	2.27E+05	3.17E+04	0	0	0	0
Total Demolition Liquid Waste	2.17E+05	2.29E+04	0	0	0	0

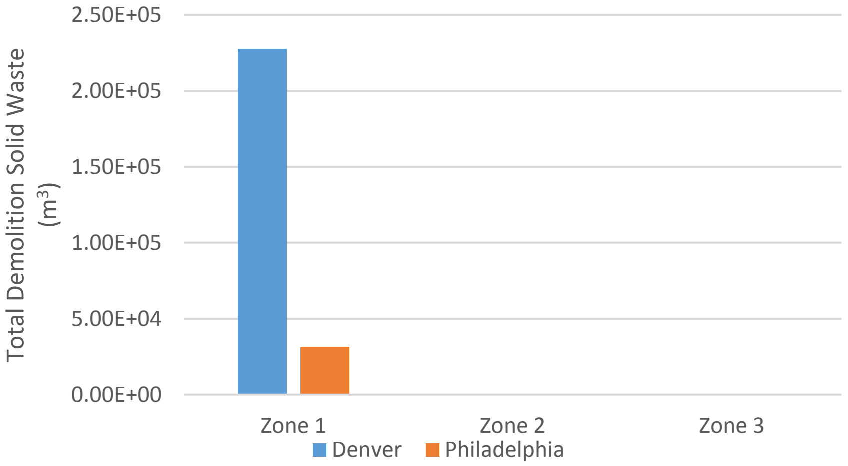

Figure 3. Demolition Solid Waste between Denver and Philadelphia

Table 5. Decontamination Volumetric Waste Results, in Cubic Meters

	Zone 1		Zone 2		Zone 3	
	Denver	**Philadelphia**	**Denver**	**Philadelphia**	**Denver**	**Philadelphia**
Total Decontamination Solid Waste	2.80E+04	6.83E+03	1.66E+05	9.43E+04	8.82E+06	6.01E+05
Coating Waste	3.12E+02	4.94E+01	1.34E+03	2.43E+03	0	0
Asphalt	3.92E+03	1.21E+03	2.07E+04	8.48E+03	5.28E+04	3.19E+04
Concrete	2.33E+03	3.88E+02	6.76E+03	3.03E+02	1.32E+04	1.06E+04
Soil	1.45E+04	4.41E+03	1.13E+05	5.63E+04	8.76E+06	5.59E+05
Interior Floor Materials	7.03E+03	7.73E+02	2.41E+04	2.68E+04	0	0
Total Decontamination Liquid Waste	3.38E+04	5.16E+03	2.85E+05	4.96E+05	3.27E+06	3.14E+06

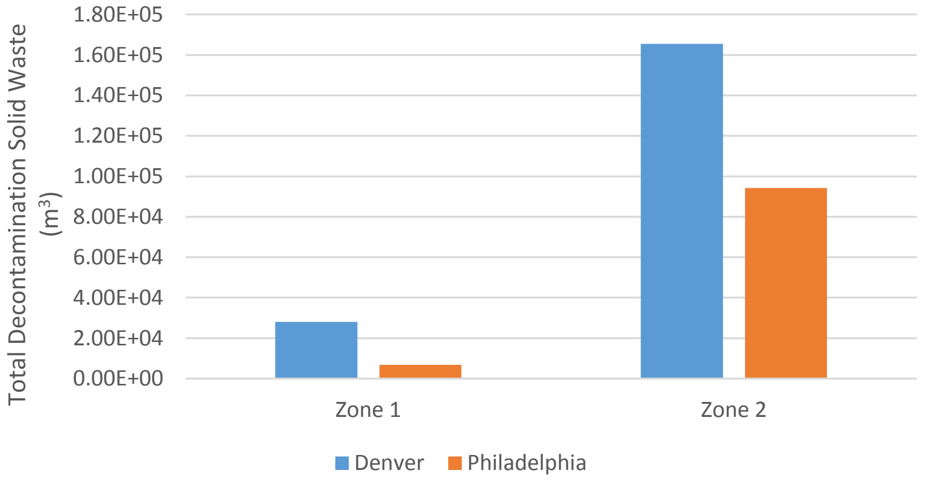

Figure 4. Decontamination Waste between Denver and Philadelphia, Zone 1 and Zone 2

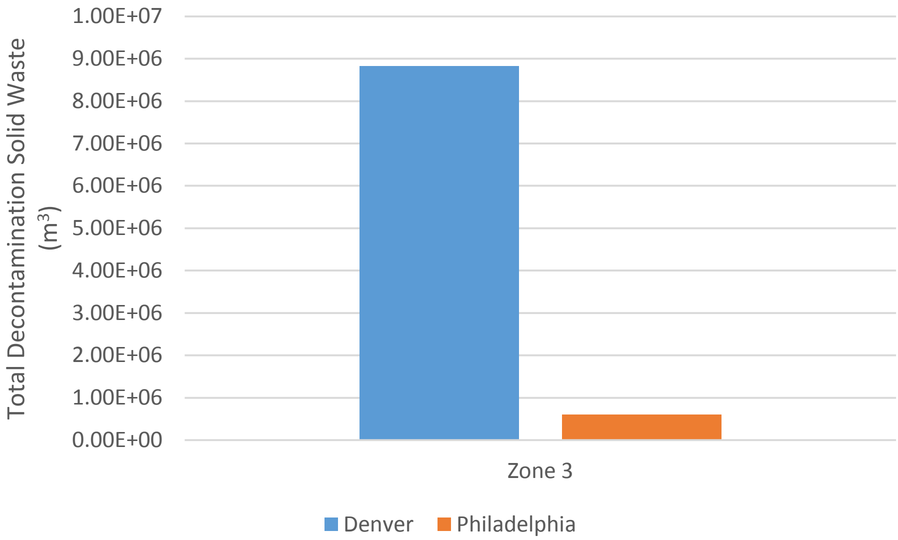

Figure 5. Decontamination Waste between Denver and Philadelphia, Zone 3

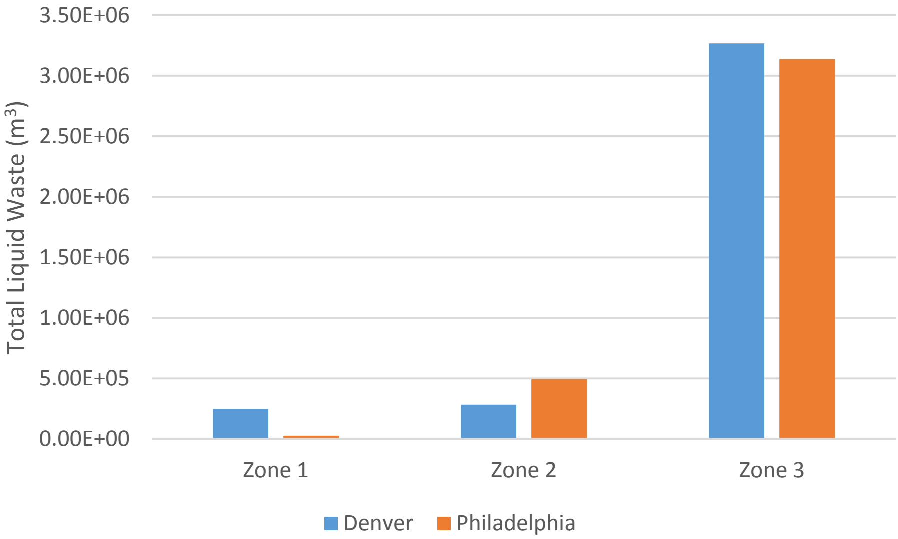

Figure 6. Liquid Waste between Denver and Philadelphia

Figure 7 below shows the percentage of solid waste, by volume that is comprised of excavated soil for both cities. Based on the total amount of solid waste generated, including building demolition, the overwhelming majority of waste generated in both cities is contaminated soil (over 96% for Denver and 84% for Philadelphia).

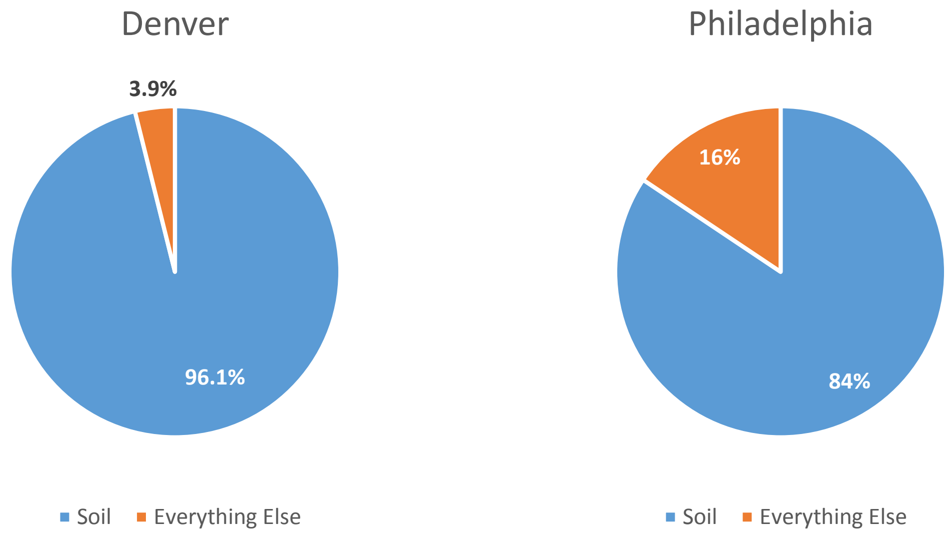

Figure 7. Distribution of Total Solid Waste between Denver and Philadelphia

If we consider the total solid and liquid waste generated between the two cities, excluding the soil volumes, we observe some differences in the waste distribution as shown in Table 6. Soil generated from cleanup activities is the largest component of waste, and liquid waste is the second largest waste component for both cities.

Table 6. Waste Volumetric Distribution Excluding Soil

Waste Material	Denver		Philadelphia	
	m^3	%	m^3	%
Strippable Coating Waste	1.66E+03	0.04%	2.48E+03	0.07%
Asphalt	7.73E+04	1.9%	4.16E+04	1.1%
Concrete	2.23E+04	0.5%	1.13E+04	0.3%
Interior Floor Materials	3.12E+04	0.7%	2.76E+04	0.7%
Total Demolition Solid Waste	2.27E+05	5.5%	3.17E+04	0.8%
Total Liquid Waste	3.80E+06	91.4%	3.66E+06	97.0%

After excluding the liquid waste fraction from the remaining waste stream, we observe the remaining waste distributions as shown in Figures 8 and 9.

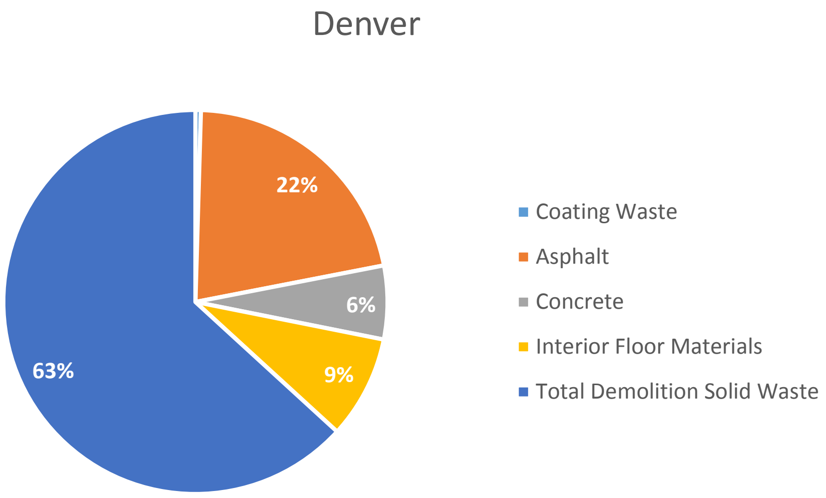

Figure 8. Distribution of Total Waste in Denver, Excluding Soil and Liquid Waste

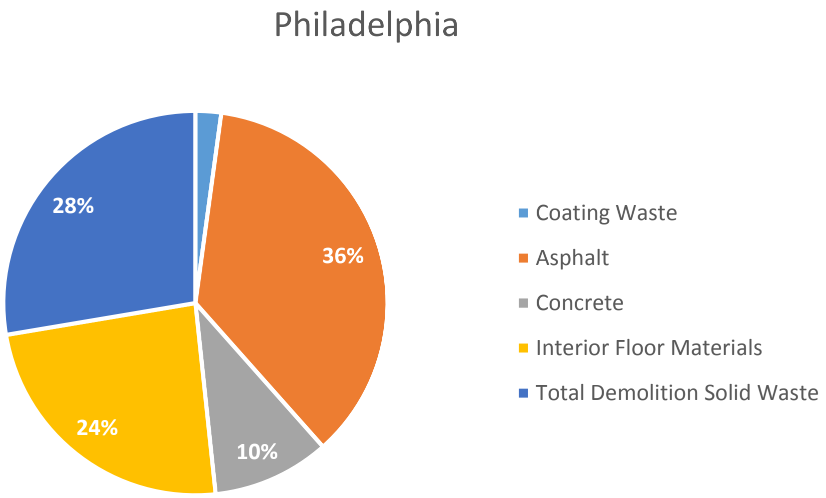

Figure 9. Distribution of Total Waste in Philadelphia, Excluding Soil and Liquid Waste

After determining that excavated soil and liquid waste are both very large constituents of the total waste stream, we compared the total waste volumes generated (including demolition waste) for both cities to the total ground surface areas and the total building surface areas. The ground surface areas, in square meters, include soil, concrete from streets and sidewalks, and street asphalt. The total building surface areas, also in square meters, include all of the estimated building surfaces from all buildings and represent the estimated sum of roofs, exterior walls, interior walls and ceilings, and interior floors.

Figures 10 through 15 show the total waste estimated from each zone in both cities (Figures 10, 12, and 14 for zones 1, 2, and 3, respectively) and the corresponding estimated ground and building surface areas (Figures 11, 13, and 15, respectively).

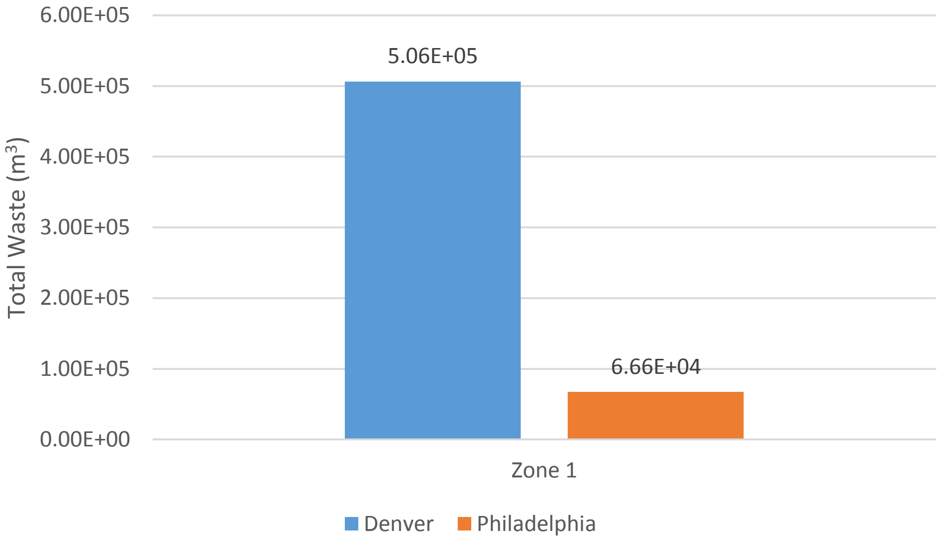

Figure 10. Total Estimated Waste (in m^3) for Zone 1

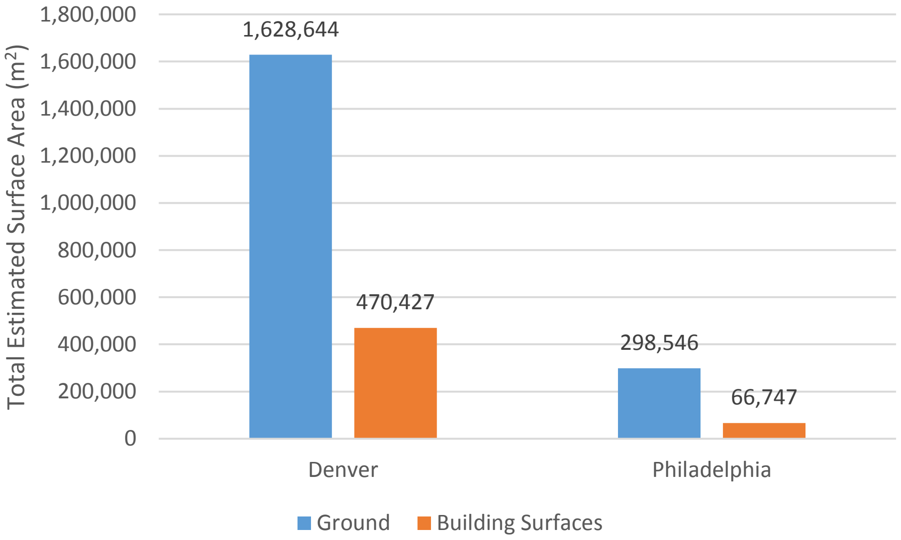

Figure 11. Total Estimated Ground and Building Surface Areas (in m^2) for Zone 1

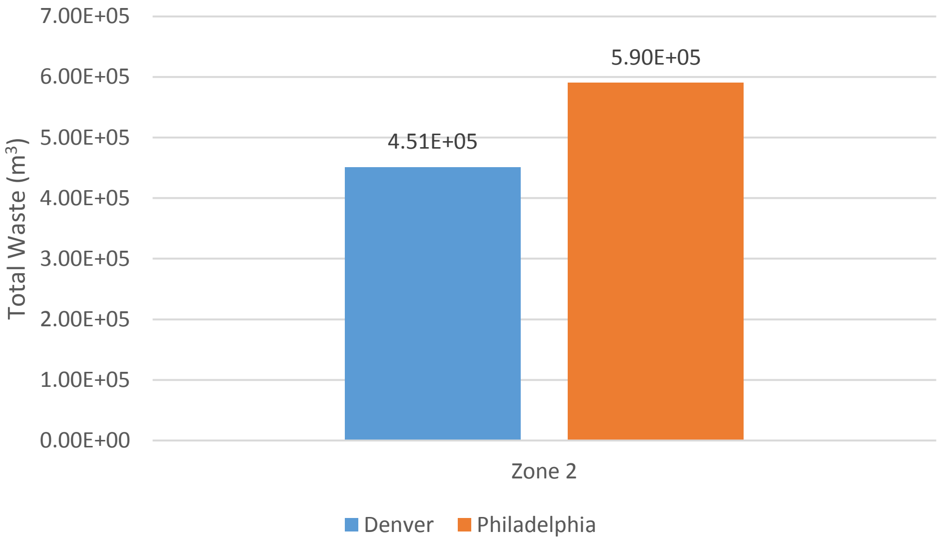

Figure 12. Total Estimated Waste (in m^3) for Zone 2

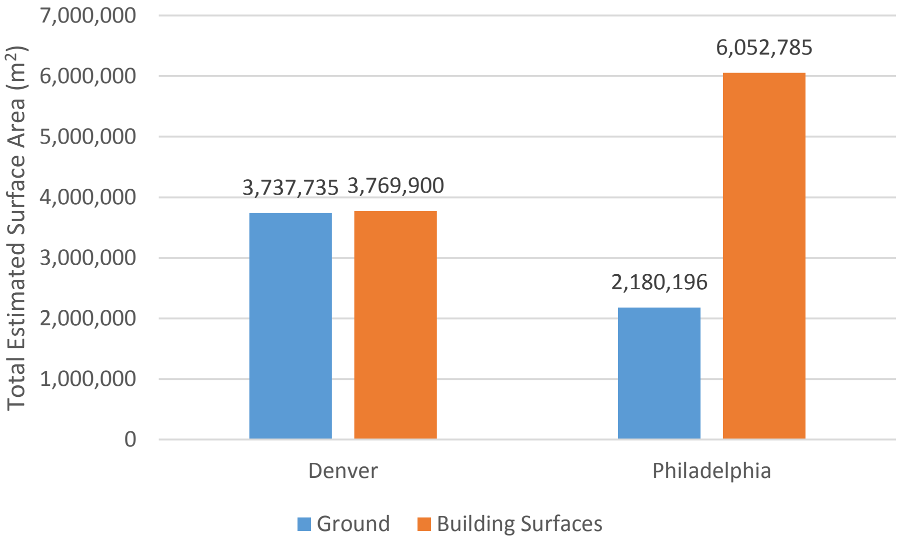

Figure 13. Total Estimated Ground and Building Surface Areas (in m^2) for Zone 2

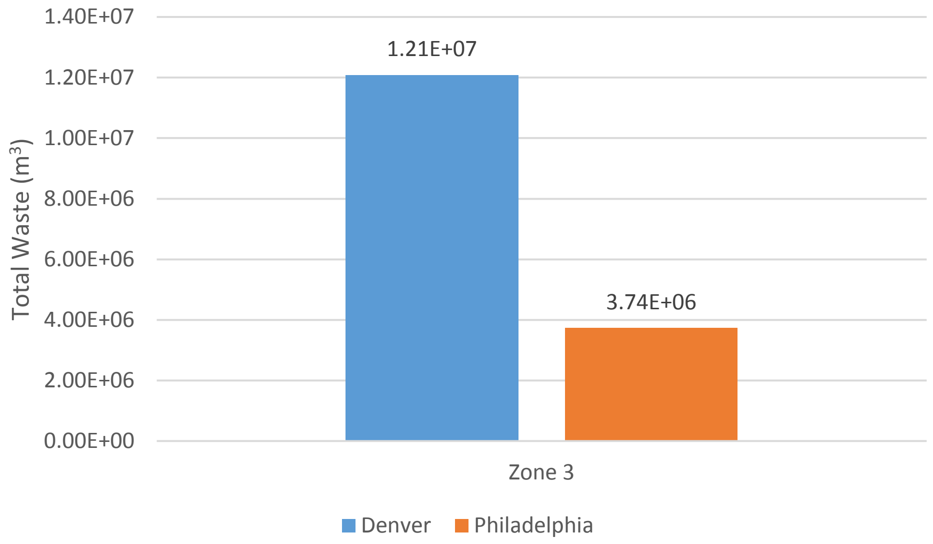

Figure 14. Total Estimated Waste (in m^3) for Zone 3

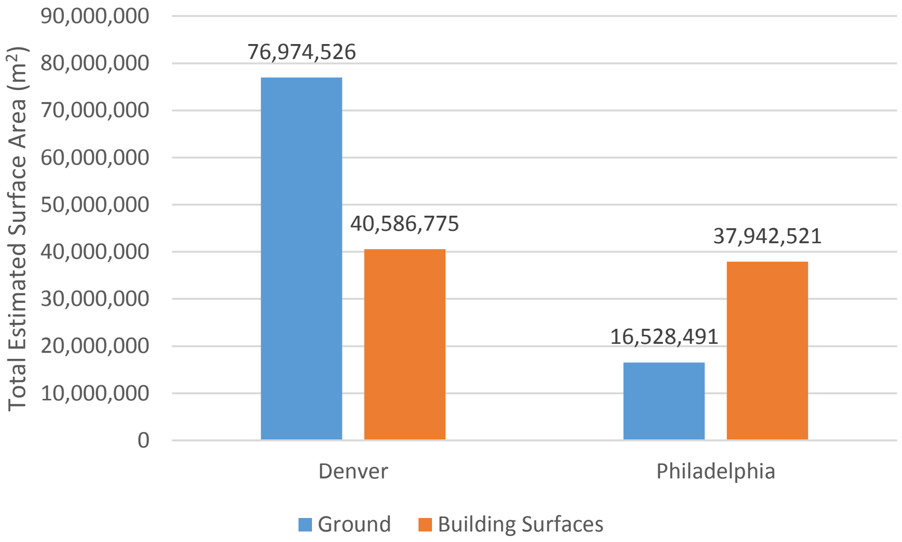

Figure 15. Total Estimated Ground and Building Surface Areas (in m^2) for Zone 3

For Zone 1, although we assume that 90% of the buildings are demolished in both cities and contribute to the total volumetric waste, the substantially higher ground surface area in Denver (and resulting soil excavation) appears to be driving the large difference in total waste between the two cities. In Zone 2, Denver has approximately equal areas of ground surfaces and building surfaces. Philadelphia, however, has almost three times as much building surface area as ground surface area and roughly double the building surface area, compared to Denver. The higher building surface area in Zone 2 for Philadelphia appears to be a primary contributor to the higher total waste volumes for that city. For Zone 3, we observe a situation similar to Zone 1. Denver has a substantially higher ground surface area in Zone 3 compared to Philadelphia, but the two cities have approximately equal building surface areas. None of the buildings in Zone 3 are assumed to be demolished, and we observe a substantially higher total waste amount in Zone 3 for Denver. As observed for Zone 1, the ground surfaces comprised of soil and the resulting excavated soil amounts appear to be the primary contributor to the higher estimated waste volumes for Zone 3 in Denver.

Lastly, because the total affected geographic areas are different between both cities (82.3 million square meters for Denver and 19 million square meters for Philadelphia), we evaluated the total estimated waste generation for each zone in both cities on a per-unit-area basis (Figure 16).

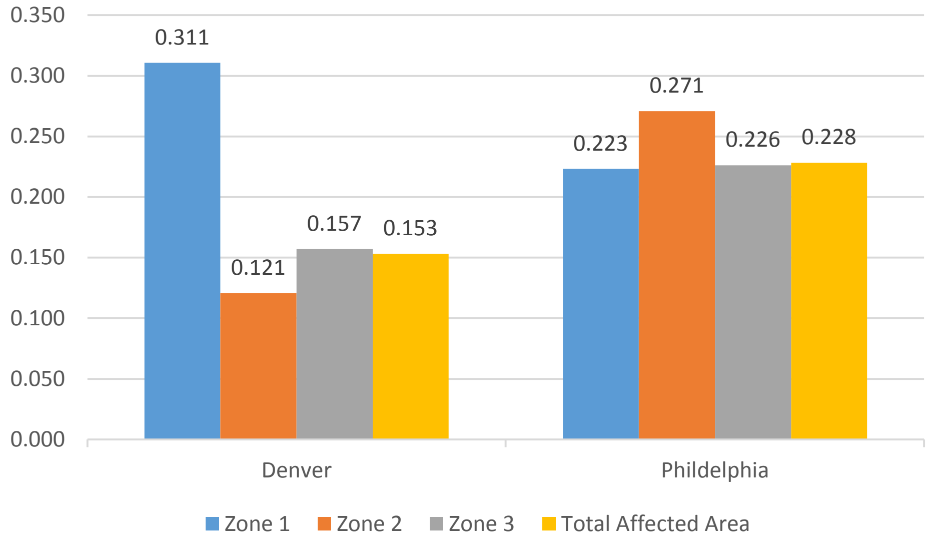

Figure 16. Total Waste Generated per Unit Affected Area (m^3/m^2)

The amount of estimated waste generated for Denver is 0.311 m^3 per m^2 in Zone 1 and drops to 0.121 m^3/m^2 and 0.157 m^3/m^2 for Zones 2 and 3, respectively. For Philadelphia, 0.223 m^3/m^2 and 0.226 m^3/m^2 are estimated for Zones 1 and 3, respectively, but a slightly higher amount is estimated for Zone 2 at 0.271 m^3/m^2. Overall waste estimates per unit affected area are 0.153 m^3/m^2 for Denver and 0.228 m^3/m^2 for Philadelphia.

FUTURE ENHANCEMENTS

Blast Scenario Support

INDs require a more complex analysis when compared to RDD incidents, as a result of the initial blast, which may significantly alter the urban landscape as well as producing a large amount of debris. To better account for this phenomenon, the waste estimate must be divided into two separate sections: 1) an estimate of the building debris resulting from the blast, and 2) an estimate of waste resulting from subsequent intermediate and long-term response/recovery operations including building demolition and decontamination. Efforts are currently underway to develop a blast module that can account for blast effects of improvised nuclear devices and nuclear weapons.

Cost and Time Factors

When recovering from a radiological incident, public sentiment and feasibility are largely a function of cost and time, as was directly evident in the Fukushima disaster [5]. If a specified decontamination strategy takes too long, businesses will close, and the city's inhabitants may permanently relocate. Furthermore, having the ability to estimate the cost and time factors associated with remediating a radiological incident is key to the foundation of waste management strategies. The ability to estimate the effects that cost and time of a specified decontamination approach have on recovery efforts would be invaluable.

Supplemental Waste Factors

Currently, waste estimates do not include discrete objects such as motor vehicles and trees because image segmentation and classification tools are either costly or ineffective at extracting these types of features from imagery. This capability requires a complex image segmentation process where objects of similar spectral characteristics and pixel proximity can be grouped and accounted for. The presence of these discrete objects is assumed to either influence the decontamination approach or the characteristics of the waste stream. For example, a recent analysis found that approximately 20-30% of New York City's surface area consisted of tree canopies. Estimation of quantities of contaminated biomass could significantly impact the quantity of potential waste that might be generated. Efforts are underway to develop an open source object detection tool for estimating discrete objectives for a given area of interest.

Processing and Memory Footprint Improvements

The WEST spreadsheet is currently built on Microsoft Excel. Excel has a number of memory limitations that, regardless of the memory capacity of the machine, may cause the WEST to require a prolonged period of time to run or to hang up, especially when running scenarios involving large densely packed urban areas. The EPA is currently conducting a feasibility study for alternative platforms that would allow improved processing and memory utilization.

CONCLUSIONS

Based on the results of the scenarios described above, the following observations and conclusions can be made:

- Decontamination of ground surfaces by excavation of soil contributes overwhelmingly to the total waste stream, regardless of the urban/suburban landscape. Additionally, for a downtown urban area where the majority of buildings may be demolished, large amounts of ground area requiring soil excavation may still contribute to the majority of the waste stream for that area.

- In addition to excavated soil, liquid waste generated during decontamination activities may constitute a large fraction of the overall waste generated. Liquid waste potentially requiring further treatment would result from decontamination activities including spraying and washing surfaces.
- For the two cities evaluated, the total waste estimated for Denver was three times more than for Philadelphia. Due to differences in the predicted atmospheric transport of the contaminants, the total affected area of Denver was about four times larger than Philadelphia, but the total amount of building surface area was approximately equal. The waste generation per unit of affected area was approximately 50% higher for Philadelphia. While the ground surface area and any resulting excavation is a large driver on the total waste amounts, the amount (or concentration) of building surface area in the affected area (relative to the ground surfaces) does vary by city and may correlate with the amount of waste generated per unit of affected area for a given decontamination approach.

It is important to include waste management considerations when developing the decontamination/ demolition/cleanup approach, because waste management can be a driver for time and cost. WEST allows users to better understand the impact of their decisions on generation of waste and enable them to make more informed decisions before, during, and following a radiological incident. But most importantly, the decisions are site specific, which is a key consideration for state and local planning authorities. Resource limitations and response bottlenecks specific to that locale can readily be identified.

DISCLAIMER

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REFERENCES

1. Boe, T., Lemieux, P., Schultheisz, D., Peake, T., Hayes, C. *Integrating Decontamination Strategies into a Waste Estimation Support Tool for Radiological Incidents*. In *Proceedings of the Waste Management Symposium*. 2015. Phoenix, AZ.
2. US EPA *Radiological Dispersal Device (RDD) Waste Estimation Support Tool Version 1.2*. 2012.
3. FEMA. *Hazus-MH Version 2.2*. 2015 [cited 2015; Available from: https://www.fema.gov/hazus, last accessed December, 2015.
4. US Census Bureau *American Fact Finder*. 2015 11/06/15]; Available from: http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml, last accessed December, 2015.
5. Fackler, M. *4 Years After Fukushima Nuclear Calamity, Japanese Divided on Whether to Return*. 2015 11/06/2015]; Available from: http://www.nytimes.com/2015/08/09/world/asia/japan-fukushima-nuclear-disaster-iitate-return-plan.html?, last accessed December, 2015.