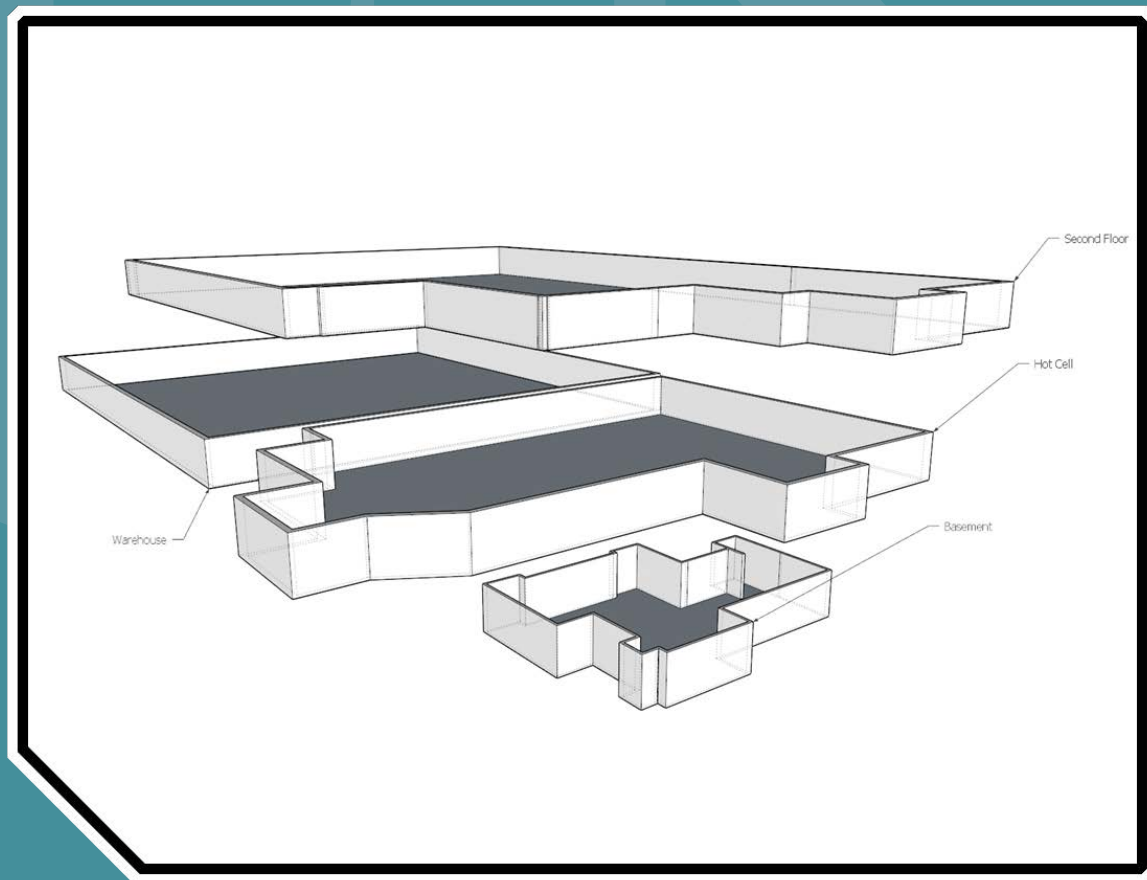


## Hot Spot Calculator to Optimize Radiological Cleanup Decisions



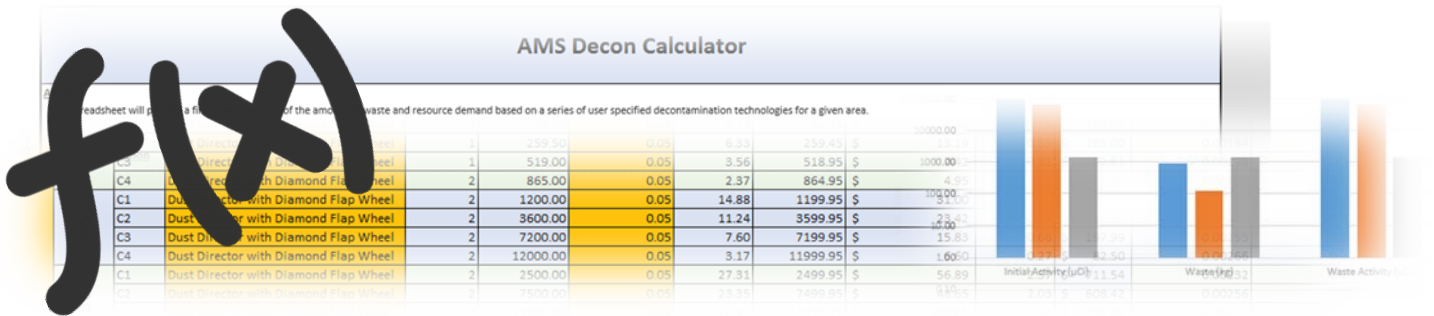
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Version

1

# HOT SPOT CALCULATOR: A SPREADSHEET TOOL FOR OPTIMIZING RADIOLOGICAL CLEANUP DECISIONS

U.S. Environmental Protection Agency



# HOTSPOT CALCULATOR User Guide

U.S. ENVIRONMENTAL PROTECTION AGENCY

# Hot Spot Calculator (HSC)

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U.S. Environmental Protection Agency  
Homeland Security Research Program  
Research Triangle Park, NC 27711

## **Disclaimer**

This tool was created by the U.S. Environmental Protection Agency through its Office of Research and Development's National Homeland Security Research Center (NHSRC). The contents of this workbook do not necessarily reflect the views of the Agency. The EPA has not validated these results against any real-world radiological contamination scenarios. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

## **Acknowledgements:**

Timothy Boe, Sang Don Lee, Paul Lemieux, Kathy Hall, Matthew Magnuson, Eugene Jablonowski, and Jim Mitchell

# Acronym /Abbreviation List

2D	2-Dimensional
3D	3-Dimensional
AMS	Advanced Medical Systems
HSC	Advanced Medical Systems Hot Spot Calculator
Co	Cobalt
EPA's	Environmental Protection Agency's
GB	gigabyte
GeGI	Germanium Gamma-Ray Imager
GHz	gigahertz
m	meter
NHSRC	National Homeland Security Research Center
PPE	Personnel Protective Equipment
RAM	random access memory

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# Introduction


*Easily deployable spreadsheet for rapidly evaluating decontamination options using the magnitude and extent of contamination derived from gamma-ray imaging*

The U.S. Environmental Protection Agency's (EPA's) Hot Spot Calculator (HSC) is a novel tool for evaluating mechanical decontamination technologies and the associated resource demand required to remediate areas of elevated radioactive contamination identified by gamma-ray imaging technology. The HSC was developed to help decision makers better understand potential options for decontamination and the consequences those options may have on remediation efforts (i.e., systems approach).

## ICON KEY

 Valuable information

 Optional

 Example

## How to Use This Manual

The purpose of this manual is to provide the necessary information to operate the HSC tool. Described in this manual are methods for installing, configuring, and operating HSC. Before operating HSC, it is highly recommended that users have previous experience in using Microsoft Excel®. The “icon key” to the left contains symbols intended to provide

support within a particular area. Look for these symbols throughout this guide for important information and additional guidance.



### Point(s) of Contact

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## Description

In July of 2015, Region 5 requested EPA's National Homeland Security Research Center's (NHSRC) support in determining cost effective decontamination options for remediating a radiologically contaminated facility in Cleveland, OH. The facility, otherwise known as the Advanced Medical Systems (AMS) site, manufactured Cobalt-60 (Co-60) sealed sources until production ceased in 1991. The manufacturing facility, which is located adjacent to a densely populated residential neighborhood, remains radioactive. Using a gamma-ray imaging device, a number of areas of elevated activity were identified at the facility by Region 5. Due to the potential cost of remediating the site in its entirety, NHSRC scientists were tasked with identifying cost effective decontamination options and to evaluate the impact of decontamination decisions on remediation efforts. From this need, the HSC tool was developed. The tool uses contamination level ( $\mu\text{Ci}$ ) and surface area information ( $\text{m}^2$ ), derived from gamma-ray imaging technology, to help guide decision makers in determining the most cost- and time-effective decontamination approach with respect to overall outcome of the remediation effort. Results are calculated based on two inputs: 1) decontamination technology and 2) targeted radioactivity. Using these two inputs, the tool estimates the number of applications (i.e., passes) of a given decontamination technology needed to achieve a specified activity. Decontamination cost, time, activity, and waste estimates are calculated as a function of decontamination technology and number of passes. Upon selecting the appropriate approach, the results are summarized in an easy to read format.

The tool was built on two different, yet complementary approaches: 1) transformation of 2-Dimensional (2D) gamma ray radiation field information onto a 3-Dimensional (3D) model for estimating surface area and surface contamination; and 2) an approach for estimating the impacts of decisions on remediation efforts (i.e., systems approach). These two approaches are discussed in further detail below.

### 3D Model

EPA Region 5 officials used a gamma-ray imager (GeGI®) to characterize the AMS facility [1]. This device can identify, localize, and quantify the distribution of gamma ray emitting materials by projecting a quantifiable gamma ray radiation field onto an optical image [1]. This technology offers a quick and easy method for quickly characterizing contaminated sites while simultaneously collecting spectral and spatial information. Figure 1 shows an example image captured by the GeGI unit.



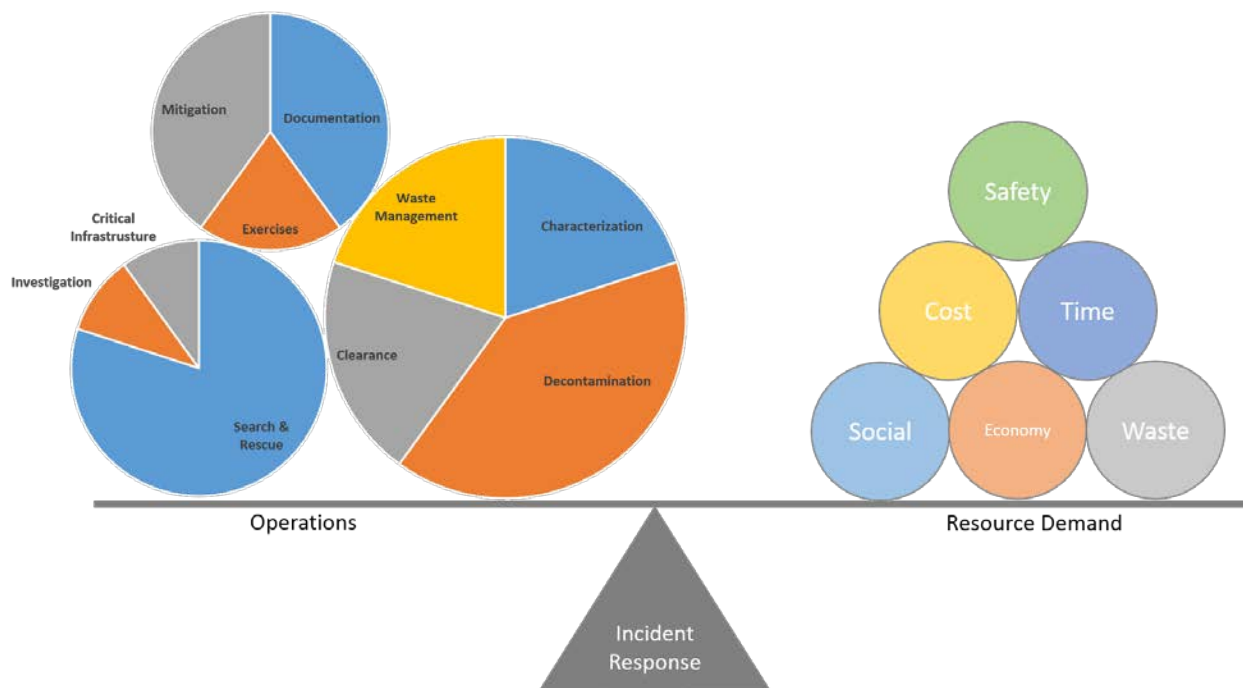


**Figure 1.** GeGI Image

One deficiency of the GeGI results was that it projected its radiation field onto a 2D image as shown in Figure 1. Because the images lacked depth, the area and orientation of the hot spot could not be fully determined. This was partially remediated by superimposing the gamma ray image onto a 3D surface, allowing the 3D model to reconstruct the orientation of the surfaces. By using this approach, the area and extent of contamination can be extrapolated and imported into the Hot Spot Calculator.

## Systems Approach

Historically, Chemical, Biological, Radiological, and Nuclear (CBRN) incident response decision support tools have solely focused on one particular problem or outcome, whether it is the identification of sampling locations for characterization purposes, cost of decontamination, or the management of waste. A majority of these tools ignore the impact a given decision (e.g., decontamination technology selection) may have on remediation efforts as a whole. The ability to measure or predict the impact decisions or operations may have en masse, would greatly enhance both decision making and remediation efforts. This concept of intricately tying together the various processes and stages of remediation, in order to create a more encompassing system, is known as the systems approach. As shown in Figure 2, as decisions are made, the resource demand may increase or decrease (typically the latter) in scale. With time, operationally driven decisions drive or tip the balance in favor of more resources. This typically causes remediation to become resource intensive in terms of cost and time (e.g., a particular decontamination method is costly, but is quicker). The systems approach seeks to balance the overall resource demand by leveraging the system as a whole and predicting the most optimal outcome, which in return provides greater insight and improves decision making. The HSC tool embodies this method by allowing the user to see how their decisions impact other operations (e.g., decontamination vs. waste management) with regards to resource demand (e.g., cost and time).



**Figure 2.** Systems Thinking Approach for CBRN Incidents

## Design

The HSC is composed entirely of a Microsoft Excel 2013 Workbook. The workbook is dynamic, in that it adjusts its calculations to accommodate user-defined variables and is adaptable and scalable in order to accommodate smaller or larger scenarios. The workbook consists of eight worksheets or tabs. These worksheets are arranged in a manner that logically steps the user through the processes necessary to calculate the resource demands associated with a selected decontamination technology. These steps are further described below.

**Home:** the Home worksheet is the first screen the user sees once the workbook is launched. It contains information about the tool, a text field to describe the active scenario, a results summary which contains information aggregated across the workbook, a disclaimer, and assumptions.

**Site Info:** the Site worksheet describes the location and extent of contamination for an area of elevated activity within a room or location on a remediation site. This sheet may be modified to accommodate smaller or larger scenarios.

**Decon Factors<sup>1</sup>:** the Decon Factors worksheet provides a list of decontamination technologies that can be prescribed within the Setup & Results sheet. The values in the Decon Factors sheet are collected from the EPA's technology evaluation reports [2]. The technology name and parameters may be changed

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<sup>1</sup> Decontamination technologies (beyond the five already available in the Decon Factors worksheet) should not be added unless you are an advanced user of this tool and Excel. For expert assistance, please contact the developer of this tool.

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**Miscellaneous Expenses:** the Miscellaneous Expenses worksheet captures costs not specifically associated with a decontamination technology and that are often hard to predict. This worksheet may be expanded to accommodate additional expenses associated with decontamination and waste management activities.

**Radionuclide Distribution:** this worksheet uses an equation to describe the relative distribution of a given radionuclide (Co-60 for AMS) in concrete<sup>2</sup>. Based on the distribution of the depth of the radionuclide, a removal efficacy/depth is estimated [3]. This sheet should not be modified. However the distribution values can be adjusted using the exploratory results from the initial decontamination work. For additional information please contact the developer of this tool.

**Radioactive Decay:** the Radioactive Decay worksheet can be used to estimate the activity level of the radioactive contaminant after a given period of time or how long it will take for a given initial activity of radioactive material to decay to a specified activity level. This worksheet may be updated based on a given isotope and half-life.

**Setup & Results:** the Setup & Results worksheet is used to prescribe a decontamination technology and specify a targeted activity per room, location, and zone. HSC will then calculate the number of applications/passes needed, specific to that decontamination technology's removal factor/depth, and other various resource demands. This worksheet may be expanded to accommodate additional rooms, locations, and zones.

**Charts:** the Charts worksheet aggregates the data in the Setup & Results and displays it in a chart format. This worksheet may be updated; however, experience with pivot charts may be useful.

Each worksheet within the workbook was designed to be printed and shared, with headers and footers that reflect the names of the overall workbook and the individual worksheets for documentation purposes.

## Expansion

Since HSC was built using Excel, the workbook may be modified to account for larger or smaller scenarios by simply dragging and expanding fields of interest. Chapter 3 will note whether or not a specified worksheet may be expanded and how.

## Assumptions

The HSC calculator is based on a number of assumptions derived through research results or professional judgement. The selection of decontamination parameters available in the "Setup & Results" tab are somewhat discretionary, but do reflect a potentially reasonable approach to decontamination. These estimates do not include time and cost demands associated with personnel training, travel, location transition, Personal Protective Equipment (PPE), or transportation. The penetration of radionuclides into the surfaces is based on results from which may not precisely reflect the surfaces in the AMS building [3]. Furthermore, the prescribed decontamination approach does not account for crevices, holes, or any other disturbance of the surface as this may have enhanced the penetration of the contaminant into the concrete.

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<sup>2</sup> For the immediate purposes of this tool, only radionuclide distribution information specific to concrete was considered. Future versions of the tool may include other surface types. Advanced users can reference the cited literature to specify exponential approximations that describe additional surface types.

## Installation & Setup

*Below you will find step-by-step instructions to download and install HSC*

**T**his chapter explains how to install and set up HSC. Before installation, confirm that your system meets or exceeds the recommended hardware and software requirements.

### Note

Upon launching the workbook, Excel may ask you to update links. It is recommended that you approve this request by pressing the “Update” button; otherwise some of the formulas may fail.

## Minimum System and Software Requirements

This section provides the minimum system requirements and required software for HSC. Meeting the minimum system requirements does not guarantee that HSC will operate as intended. Memory requirements are often dependent on the number of rows being used in the workbook. Excel 2013 is currently limited to 1,048,576 rows by 16,384 columns; however it is unlikely that this limitation will be met for the purposes of this workbook.

*Table 1. Minimum System and Software Requirements*

<i>Required Software</i>	Microsoft Office Excel 2013+
<i>Processor</i>	1 gigahertz (GHz) or faster x86- or x64-bit processor with SSE2 instruction set
<i>RAM</i>	1 gigabyte (GB) Random Access Memory (RAM) (32-bit); 2 gigabytes (GB) RAM (64-bit)
<i>Screen Resolution</i>	1024 x 768 pixels
<i>Operating System</i>	Windows 7-10
<i>Disk Space</i>	3.0 gigabytes (GB) available

## Quick Start User Guide

### *A quick start guide for using the HSC Tool*

This chapter provides the necessary steps to create a HSC scenario from beginning to end.

#### Note

The process of modeling gamma ray and 3D imagery will require the use of 3D modeling such as Sketchup or Blender.

## Combining Gamma Ray & 3D Blueprint Imagery

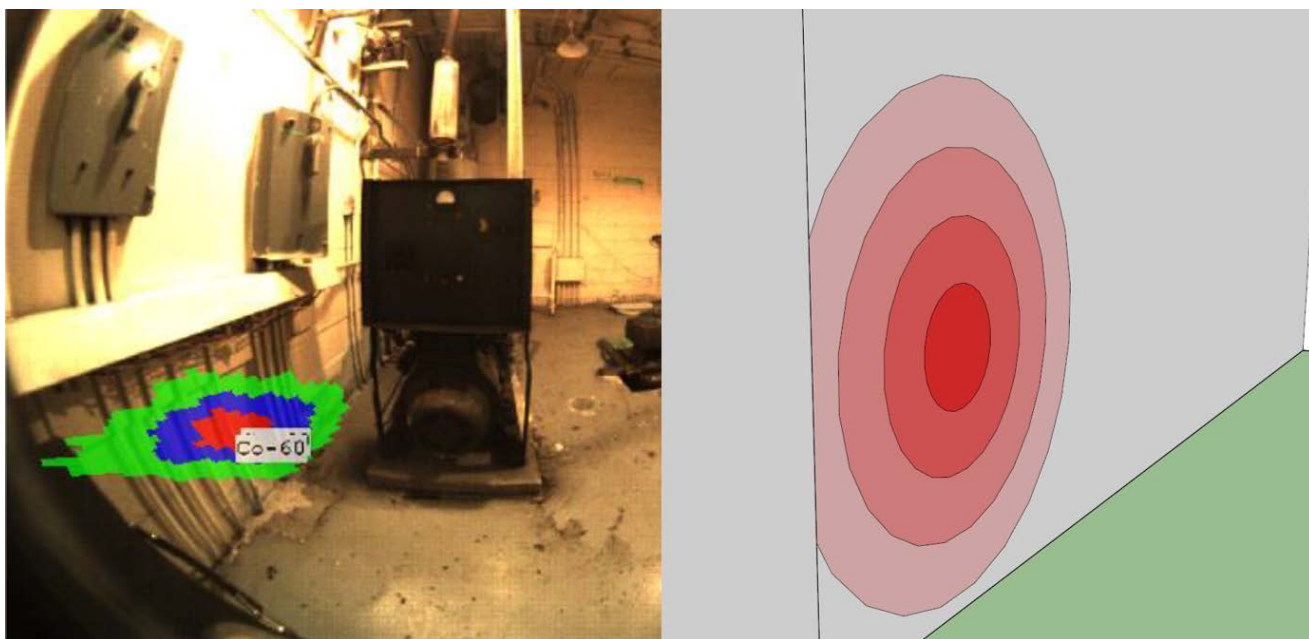
The HSC uses a novel method of projecting contamination information onto a 3D surface. This section will step the user through the process required for superimposing contamination information onto a 3D surface.



*Before proceeding, it is recommended that you have already documented the dimensions of the contaminated area and associated activity level using a gamma-ray imaging device.*

1. Information regarding contamination the type, level, and extent of contamination can be derived using a gamma-ray imaging device. The PHDS Co. Germanium Gamma-Ray Imager (GeGI) was referenced in the development of this tool. A complete and thorough characterization of the site should be conducted before using this tool.
2. Once the site has been characterized, the images taken by the imaging device can then be manually imported into a 3D modeling program of choice (e.g., SketchUp). The building footprint information will need to be imported into the 3D modeling software and the walls/floors extruded to the appropriate height. Using the images as a reference, draw the

contaminated area divided into 4 separate zones, onto the impacted surfaces. Figure 3 shows a gamma-ray image (derived from GeGI) (left) that was converted to a 3D image (right). One's judgement should be used when determining the orientation, size, and dimensions of a given hotspot.



**Figure 3.** Comparison of GeGI image converted to a 3D image

3. Using the 3D modeling software, extract the area of each zone in  $m^2$ . In Sketchup, this can be done by using the “**Select Tool**” and right clicking on a zone of interest and selecting “**Area**” and “**Selection**”.
4. This process will need to be completed for each location and area of contamination

## Home

The Home sheet is the first screen the user sees when the workbook is launched. It contains information about the tool, a text field to describe the active scenario, a results summary which contains information aggregated across the workbook, a disclaimer, and assumptions.

1. The purpose of the Home worksheet is to aggregate information pertaining to the scenario in an easy to read format.
2. The only portion of the Home worksheet that should be modified is the “Scenario Description”. The remaining sections reference information stored elsewhere in the workbook. Changes to the data or text can be made on the various workbook pages.

## Site Info

The Site worksheet describes the location and extent of contamination for an area of elevated activity within a room or location on a remediation site. This worksheet may be modified to accommodate smaller or larger scenarios.

1. The Site Info worksheet uses a distribution method to estimate the level of activity across a given contaminated area. The default percentages assigned to this table may be modified, but should not total over 100%.
2. The room descriptor, location, and zone designations are specific to the contaminated area or area of interest. They can be modified as necessary; however, it is highly recommended that rows be deleted or inserted per the guidance described here.
3. To expand the Setup and Results table, you must first add the area and activity field. To do this, select and right click the total row and select insert row, as shown in Figure 4. A new row will be added.

	A	B	C	D	E	F	G	H
64	Calibri	11		0.3716	m <sup>2</sup>	150	1000	μCi
65	B	I		0.2137	m <sup>2</sup>	300		μCi
66				0.0697	m <sup>2</sup>	500		μCi
67	Total			51.7		167810	167810	μCi
68								
69								
70								
71								
72								
73								
74								
75								
76								
77								
78								
79								
80								
81								
82								
83								
84								

**Figure 4.** Adding Rows in Worksheet

4. You may add additional rows (i.e., rooms, locations or zones) by repeating the above process. Once you have added the desired number of rows, you may now enter your area and activity

information. Note that the values shown in the “Area” column must be added and the total entered in the “Location Total” column.

5. The area and contamination information is retrieved by projecting the gamma ray imagery onto the 3D model, as described above. The activity is automatically calculated based on the distribution of contamination as defined in Step 1.
6. Note that any changes made to the site info sheet may impact calculations throughout the worksheet, including the results. An extensive review should be conducted to ensure formulas are operating as intended. This is especially important when expanding the site info sheet.

## Decon Factors

The Decon Factors worksheet provides a list of mechanical decontamination technologies that can later be prescribed within the "Setup & Results" sheet. The technology name and parameters may be changed; however, additional technologies (beyond the five slots) should not be added unless you are an advanced Excel user.

1. The Decon Factors worksheet contains specific information related to decontamination technologies. This information can be retrieved from literature or other sources.
2. The decontamination technology name and attributes highlighted in orange may be modified.
3. It is highly recommended that the units remain in their default value. You may add additional technologies; however, the list should not exceed five technologies as the workbook will not know where to reference this information later.
4. The reference for the default values is listed in Chapter Five of this report.

## Miscellaneous Expenses

The Miscellaneous Expenses worksheet captures costs not specifically associated with a decontamination technology. This worksheet may be expanded to accommodate additional expenses.

1. The default values and titles listed in the “Miscellaneous Expenses” worksheet can be modified to reflect site specific needs and information. Caution should be taken to ensure that the “Miscellaneous Expense Total” line is not removed since it is directly linked and referenced in the Home worksheet. New rows can be inserted or the user may drag and drop the line further up or down the worksheet. This will update the cell reference on the Home worksheet.



## Radionuclide Distribution

The Radionuclide Distribution worksheet uses an exponential approximation of the relative radionuclide distribution to estimate the distribution of a given radionuclide in concrete. Based on the distribution of the depth of the radionuclide, a removal efficacy/depth is estimated.

1. The cells highlighted in orange may be modified; however, this should only be done if you are familiar with this topic as modifying the exponential factor will impact the required removal depth per technology. The default factor was derived from NHSRC research on the fate and transport of radiocesium, radiostrontium and radiocobalt on urban building materials [3].
2. The Setup and Results worksheet uses a subset of this equation to estimate the number of passes needed based on a given decontamination technology.
3. A reference for the equation is listed in Chapter Five of this report

## Radioactive Decay

The Radioactive Decay worksheet can be used to estimate the activity level of radioactive contaminant left after a given period of time or how long it will take for a given initial activity of radioactive material to decay to a specified final activity level. This worksheet may be updated based on a given isotope and half-life.

1. The Radioactive Decay worksheet includes two functions; one to determine the remaining activity level after a specified decay period and the other to determine the time required to achieve a specified activity level. This worksheet is meant to function as a calculator/point of reference. The fields highlighted in orange can be modified; based on the isotope of interest. The inputs are used to calculate the time delay attribute located in the Home worksheet.

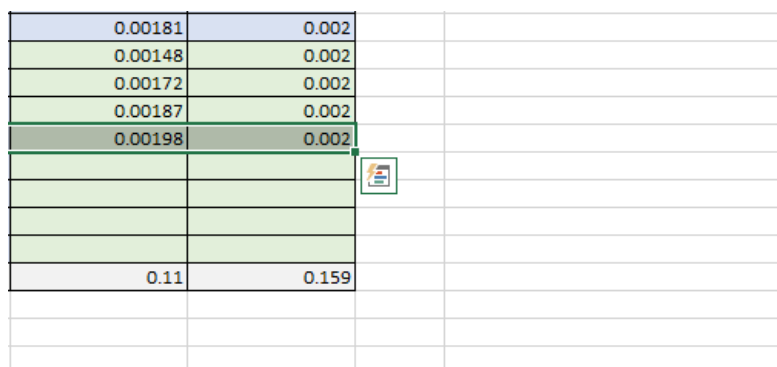
## Setup & Results

The Setup & Results worksheet is used to define the decontamination technology and targeted activity per room, location, and zone as well as the type of decontamination technology that will be applied. HSC will then calculate the number of applications/passes needed, specific to that decontamination technology's removal efficacy/depth, and other various resource demands. Aggregated results are displayed at the bottom of the table and in the "Home worksheet".

1. There are four modifiable areas in the Setup & Results worksheet: Room, Decon Technology, Targeted Activity, and the Additional Factors.
2. The Decon Technology column consists of a drop down menu where various types of decontamination technologies (defined in the Decon Factors worksheet) can be selected. Once

the appropriate decontamination technology is selected, Excel will calculate the number of applications/passes needed based on that technology's removal efficacy/depth and the contaminant's estimated vertical penetration (via the radionuclide distribution tab). Using this information, a required removal depth ( $\text{m}/\text{m}^2$ ) is estimated. The recommended removal efficacy/depth is then compared to the technology's removal efficacy/depth and is rounded up to a whole number. Based on this calculation, the number of applications/passes necessary to reach an established target activity is estimated.

3. The remaining variables such as waste, waste activity, waste disposal cost, etc. are calculated according to the number of applications/passes required per  $\text{m}^2$  of technology and amount of material decontaminated/removed per application/pass. The totals of these variables can be found at the bottom of the worksheet or on the Home worksheet.
4. To add more rows to represent rooms, locations, or zones, right click the total row and click "Insert". To auto populate the cells, select the contents of the top filled row and drag down – filling in the four rows. An example of this is shown in Figure 5.



0.00181	0.002
0.00148	0.002
0.00172	0.002
0.00187	0.002
0.00198	0.002
0.11	0.159

**Figure 5.** Expanding Rows in the Worksheet

5. The worksheet may still require some aesthetic modifications; however, the formulas should still be functional. This process can be repeated as many times as needed as long as the "Setup & Results" worksheet exactly reflects the areas described in the "Site Info" worksheet. The totals shown in the "Home worksheet" will automatically reflect the updated values.

## Charts

The Charts worksheet aggregates the data located in the Setup & Results worksheet and displays it in a chart format. Two different charts are created: 1) resource demands according to decontamination technology; and 2) resource demands according to location.

1. The resource demands according to decontamination technology chart is essentially a pivot chart. If any changes that are made to the “Setup & Results” worksheet (e.g., selecting a new decontamination technology) the chart will need to be refreshed. To refresh the pivot chart, right click on the chart and select “Refresh”. If major modifications are made to the “Setup & Results” worksheet, the pivot chart may need to be recreated.
2. The resource demand according to location is a simple table that aggregates information found in the “Setup & Results” worksheet. This table should automatically update; however, if any major modifications are made to the “Setup & Results” worksheet, the data range may need to be updated.



This concludes the HSC user guide. If you have any questions, please email the point of contact listed in Chapter 1.

## Troubleshooting

### *A troubleshooting guide*

**T**his chapter provides solutions to commonly found problems that users may encounter using the HSC tool. It is recommended that you confirm software and hardware compatibility (information found in Chapter 2 of this document) before continuing.

PROBLEM	CAUSE	REMEDY
Excel asks me to save even if I have not made any changes.	A few links may have been updated on startup without the user's knowledge. This is typical of Excel.	Unless you have made any updates to the workbook, it is not recommended that you save the document.
When I start the workbook, Microsoft Excel displays a warning asking me to update the links contained in the workbook.	The workbook contains links to other workbooks or files (called source files), and when the source files are changed, then the links in workbook may display information that is out of date and therefore needs to be updated.	Click the "Update" button
One of my cells reads as "#DIV/0"	You have likely deleted a variable that that cell is trying to use.	Review the worksheet for missing information or start over from scratch.

## Bibliography

### *A list of references*

1. PHDS, *Gamma-ray Imaging with GeGI at the Advanced Medical Systems Site: Data Analysis and Report*. 2015.
2. US EPA, *Evaluation of Five Technologies for the Mechanical Removal of Radiological Contamination from Concrete Surfaces*. 2011, U.S. Environmental Protection Agency, Washington, DC.
3. K. Maslova, I. Stepina, A. Konoplev, V. Popov, A. Gusarov, F. Pankratov, S.D. Lee, N. Il'icheva., *Fate and transport of radiocesium, radiostrontium and radiocobalt on urban building materials*. Journal of Environmental Radioactivity, 2013.

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