

## Material Compatibility for Historic Items Decontaminated with Gamma Irradiation



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# **Material Compatibility for Historic Items Decontaminated with Gamma Irradiation**

National Homeland Security Research Center  
Office of Research and Development  
U.S. Environmental Protection Agency  
Research Triangle Park, NC 27711

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## Disclaimer

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development's (ORD) National Homeland Security Research Center (NHSRC), funded and managed this investigation through contract EP-C-04-023 with ARCADIS U.S., Inc., Work Assignments (WA) 2-60, 5-60, 6-60 and WA 3-58, and contract EP-C-15-008 with Jacobs Technology Inc., WA 0-076. This report has been peer and administratively reviewed and has been approved for publication as an EPA document. It does not necessarily reflect the views of the Agency. No official endorsement should be inferred. EPA does not endorse the purchase or sale of any commercial products or services. Questions concerning this document or its application should be addressed to:

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## Acronyms and Abbreviations

<i>B.</i>	<i>Bacillus</i>
BI	biological indicator
CIE	International Commission on Illumination
$\Delta E^*$	color difference
D10	radiation dose required to reduce a viable population of a specific microorganism by 1 log
D <sub>65</sub>	standard illuminant defined by the International Commission on Illumination as representing average daylight
DQI	data quality indicator
EPA	U.S. Environmental Protection Agency
HEPA	high-efficiency particulate air
ID	identification
kGy	kilogray
NHSRC	National Homeland Security Research Center
NIST	National Institute of Standards and Technology
ORD	Office of Research and Development
RH	relative humidity
SAL	sterility assurance level
WA	work assignment

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## Executive Summary

This study was initiated by EPA's National Homeland Security Research Center (NHSRC) as part of a comprehensive research program to provide scientific expertise and evaluation of actual and potential decontamination technologies that can be used to restore and recover buildings and sensitive equipment subjected to a biological weapon attack. The project described in this report was conducted at EPA's Decontamination Technology Research Laboratory in Research Triangle Park, North Carolina, and was designed to provide direct information on the impact of gamma irradiation on sensitive high-value historical materials that can be viewed as surrogates for irreplaceable cultural objects that are commonly found in museums, galleries, and archives.

The study addressed the impact of gamma irradiation on several types of materials. Test materials included Category 1 (priority) materials that can be found in large quantities inside typical museum settings and Category 2 (secondary) materials that were surrogates for high-value historical objects that are less common in museum-type buildings. Priority materials tested in this study included historical oil paintings and painting surrogates; archival documents, books, and photographs; and other museum-quality items that are not easily removed from the site for off-site decontamination. Secondary materials were historical pastel paintings, wood/furniture, porcelain/bisque, fabrics, metal and alloy objects, and leather.

Decontamination of historical materials using gamma irradiation at 30 and 50 kilograys (kGy) was investigated to determine the short- and long-term effects on the test materials. Sample and reference coupons were prepared for each historical material type. Pre-gamma irradiation visual and technical assessments were performed on the sample and reference coupons to establish background values for the materials tested. Biological indicators were included in the samples as a check for the effectiveness of the gamma irradiation process. After irradiation, short-term visual and technical assessments were performed on the sample coupons to determine any effects from the irradiation process. After 5 months, visual and technical assessments of the coupons were performed to assess any long-term effects.

All Category 1 materials showed effects from gamma irradiation at both 30 and 50 kGy. All materials had some visual changes at the short-term 30 kGy gamma irradiation level except the oil painting test strip light hue and the archival photographs, both of which showed no impact. The long-term test samples showed continued effects except for the oil painting test strip dark hue and the archival books, which demonstrated no additional changes had occurred. Visual impacts were observed in the short-term 50 kGy samples except for the oil painting test strip dark hue and archival photographs, which showed no visual impact. All long-term 50 kGy samples showed visual impacts. All samples at both irradiation levels showed impacts in the technical assessment short-term data. Impacts for all samples increased for the long-term assessments for both the 30 and 50 kGy samples.

All Category 2 materials showed effects from gamma irradiation at both the 30 and 50 kGy. The 30 kGy short-term assessment samples showed visual changes except for the wood and metal samples, which showed no impacts. Visual impacts were observed on the long-term 30 kGy pastel painting, leather, and porcelain samples. The 30 kGy long-term wood, fabric, and metal samples had no visual changes. All 50 kGy short-term assessment samples showed visual impacts except for the fabric and metal samples. Only the wood, fabric and metal samples showed no long-term visual impact at the 50 kGy irradiation level. All samples at 30 and 50 kGy irradiation showed impacts in the technical assessment short-term data. The impacts increased for all long-term assessment samples at both the 30 and 50 kGy irradiation levels.

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BIs were placed with each of the materials that were irradiated. BIs for the 30 kGy gamma irradiation samples showed no growth for all samples with the exception of the *B. atrophaeus* BI in the historical documents sample, which showed growth. Three BIs for *B. atrophaeus* for the 50 kGy dose showed growth. The historical wood, light hue monochromatic pigment oil painting, and historical pastel painting sample BIs all showed growth. The remaining samples showed no growth. One BI for the leather samples showed growth for *B. pumilus*. The remaining sample BIs showed no growth. In the event that irradiation was being considered for inactivation of *B. anthracis* on valuable objects, environmental samples should be collected pre and post exposure to verify the item has been decontaminated.

## **1 Project Description and Objectives**

Under Homeland Security Presidential Directive 10, EPA is tasked with coordinating appropriate federal departments and agencies to develop comprehensive plans that “provide for seamless, coordinated Federal, state, local, and international responses to a biological attack.” As part of these plans, EPA in a coordinated effort with the Department of Homeland Security, is responsible for “developing strategies, guidelines, and plans for decontamination of persons, equipment, and facilities” to mitigate the risks of contamination following a biological agent release.

EPA’s NHSRC provides expertise and products that can be widely used to prevent, prepare for, and recover from public health and environmental emergencies arising from terrorist threats and incidents. The goal of the NHSRC decontamination research program is to provide expertise and guidance on the selection and implementation of decontamination methods and provide the scientific basis for a significant reduction in the time and cost of decontamination events.

The objective of this project was to investigate the impact of decontamination using gamma irradiation on selected historical materials. This report presents results of the material compatibility assessments approximately 3 weeks (short-term assessments) and 5 months after gamma irradiation (long-term assessments). These assessments include the impact on the aesthetic (visual) value of historical objects and instrumental spectrophotometric technical analyses for color changes in the materials.

### **1.1 Background**

This project continued research of the effects of decontamination methods for biological agents on materials identified as representative of types of irreplaceable objects or works of art found in museums and/or archive settings. In the previous research, surrogate materials were checked for compatibility with four decontamination methods: chlorine dioxide, hydrogen peroxide vapor, methyl bromide, and ethylene oxide gas. This project investigated the effects of gamma irradiation, which has also been shown to be an effective decontamination method for biological agents, on the surrogate test materials [1–3].

### **1.2 Project Objectives**

The goal of this project was to examine the effects of gamma irradiation on irreplaceable and/or high-value objects. Currently no experimental data are available that can predict the effects of gamma irradiation on these objects. Future guidance for the use of gamma irradiation as a decontamination method will depend on this information, and determining if gamma irradiation is compatible with these items will allow them to be safely and effectively decontaminated. This report presents data resulting from the following tasks:

- 
- Prepared sample and reference coupons for gamma irradiation.
  - Performed initial visual and technical assessments of sample and reference coupons to get sample baseline.
  - Prepared, packaged, and shipped coupons for gamma irradiation.
  - Performed short- and long-term visual and technical assessments and biological indicator (BI) evaluations after gamma irradiation.

## **2 Experimental Approach**

### **2.1 General Approach**

Decontamination of historical materials using gamma irradiation at 30 and 50 kilograys (kGy) was investigated to determine any short- or long-term effects on the test materials. Sample coupons and reference coupons (used to establish the baseline condition and as a comparison during the material compatibility assessment) were prepared for each historical material type. The reference coupons, which were never exposed to irradiation, underwent the same inspection scheme as the exposed coupons. This process allowed the visual or structural (as appropriate) impact of the irradiation process on the test materials to be assessed. All coupons were placed into a climate-controlled chamber for equilibration. The relative humidity (RH) and temperature were set to values recommended for museum-type settings, i.e.,  $70 \pm 4$  °F and  $45 \pm 5\%$  RH. The coupons remained in the chamber for a minimum of 7 days. After equilibration, pre-gamma irradiation visual and technical assessments were performed to establish background values for the materials. The sample coupons were packaged and sent off-site to a subcontracting laboratory for gamma irradiation. Biological indicators were included with each set of samples as a check of the effectiveness of the gamma irradiation process. After gamma irradiation, the samples were returned to the laboratory and placed in an environmental chamber along with the reference coupons for a minimum of 7 days for conditioning. After equilibration, short-term (approximately 3 weeks after gamma irradiation) visual and technical assessments of the sample coupons were performed. After the short-term assessments were completed, the sample and reference coupons were placed in the environmental chamber. After 5 months, the samples were removed from the chamber and long-term visual and technical assessments of the sample coupons were performed.

### **2.2 Test Materials**

#### **2.2.1 Material Types**

The materials that underwent gamma irradiation compatibility testing were representative of irreplaceable objects and works of art found in protected buildings and museums/galleries. These materials were selected to represent historical and irreplaceable items in terms of quality, surface characteristics, and structural integrity.

The materials tested were divided into two categories: Category 1 materials (also referred to here as priority materials) were high-value historical objects that are found in large quantities inside a typical museum setting and that often have large surface areas making them less suitable for off-site decontamination (e.g., oil paintings). Category 2 materials (or secondary materials) were high-value

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historical objects that are less common in museum-type buildings (e.g., leather or porcelain objects).  
Table 2-1 details the materials used in this study.

**Table 2-1. Test Materials**

Material	Sample Code	Description
<b>Category 1 Materials (Priority Materials)</b>		
Historical oil painting	OPS	Two paintings used for this sample. Painting 1: child painted between 1800 and 1899. Painting 2: floral composition painted in 1885.
Oil painting test strip light hue	OLT	Painted by trained professional in the color Alizarin crimson.
Oil painting test strip dark hue	ODT	Painted by trained professional in the color Van Dyke brown.
Archival documents	DS	Handwritten letters from 1860 to 1890 and handwritten letters from 1909 to 1957.
Archival books	BS	Historic books from the late 19th and early 20th centuries.
Archival photographs	PS	Vintage photographs from the 19th and 20th centuries.
<b>Category 2 Materials (Secondary Materials)</b>		
Pastel painting	PPS	Still life painting of fruit painted in 1905.
Leather	LS	Leather from the book cover of "Precious Thoughts" by John Ruskin, dated 1865, published by John Wiley and Sons of New York.
Wood	WS	1920s wooden coffee table.
Porcelain	PBS	Ten porcelain bread plates from Limoges Union Ceramique (UC) in France, produced in the 20th century from 1909 to 1938.
Fabric	FS	Two fabrics used for this sample. Fabric 1: silk table cloth, unknown age. Fabric 2: silk rope, unknown age.
Metal	MS	Brass serving tray dated 1928.

### 2.2.2 Coupon Preparation

Test coupons (5 cm x 5 cm) were prepared from the acquired historical materials by sawing, shearing, or cutting with a rotary cutter depending on material type. Each coupon had a small hole punched or drilled in a corner for attachment of an identification (ID) tag on a cotton string. Uniformity of test materials was maintained by obtaining a large enough quantity of material such that multiple test sample coupons could be made with presumably uniform characteristics (e.g., test coupons were cut from the interior rather than the edge of a large piece of material). This was not possible, however, for some test sets of vintage photographs due to their small size. In this instance, photographs taken at a similar time were used to complete the test set.

Each test set consisted of five test coupons and three reference coupons. When applicable, test sets were constructed in a way that allowed for assessment of a variety of materials (e.g., three types of books, including color prints; two types of historical paintings; three types of hand-written documents). After preparation, each set of test coupons was placed into a plastic container. The container was then placed into an environmental chamber for a minimum of 7 days for coupon conditioning, as described in section 2.2.4.

### 2.2.3 Coupon Labeling Scheme

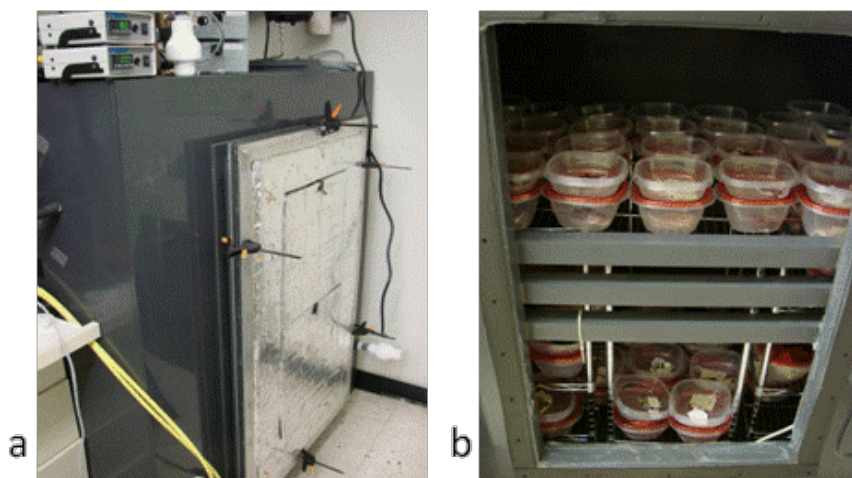
Each coupon was identified by a unique sample code that included its associated work assignment (project) number, material type, decontamination method, and process parameter information. Table 2-2 provides the sample coding used in this study.

**Table 2-2. Coupon Identification**

Coupon Identification: WA60 M SM DDkGy R or NS R		
Descriptor	Example Code	Description
WA60	WA60	Project identification
M (Material)	OLT/ODT	Oil painting test strip light hue/oil painting test strip dark hue
	OPS	Historical oil painting
	PPS	Historical pastel painting
	DS	Archival document
	BS	Historical book
	PS	Historical photograph
	FS	Historical fabric
	WS	Historical wood/furniture
	MS	Historical metal/metal alloy
	PBS	Historical porcelain/bisque
	LS	Historical leather
SM (sterilization method)	GI	Gamma irradiation
DDkGy (Dose)	50 kGy 30 kGy	50 kGy dose 30 kGy dose
NS (control coupon)	NS	For reference coupons, the SM-DDkGy descriptor will be replaced with NS (non-sterilized)
Replicate	R	A–E (test coupons and non-sterilized reference coupons)

## 2.2.4 Coupon Equilibration

Before conducting initial visual and technical assessments, all test and reference coupons were conditioned for a minimum of 7 days in an environmental chamber (Figure 2-1). The chamber was made of opaque PVC with a clear acrylic door, which was fastened with a bolted flange and covered with an opaque material to prevent light-catalyzed reactions from taking place during conditioning. The temperature and humidity in the chamber were kept at settings typical of a museum-type environment (i.e., approximately 70 °F and 45% RH). A Vaisala (Vantaa, Finland) temperature/RH sensor was used to monitor the environmental conditions within the chamber. RH was controlled by a feedback loop using LabVIEW software (National Instruments Corporation, Austin, TX, USA).



**Figure 2-1. Environmental chamber (a) and coupons stored in isolation chamber (b).**



### 2.2.5 Preparation of Coupons for Gamma Irradiation

Test-specific boxes were prepared for gamma irradiation after the test coupon initial visual and technical assessments. Each test box (Office Depot® brand white mailing boxes, 4 in. H x 9 1/4 in. W x 12 1/8 in. D; part no. 306689) had five test coupons suspended on cotton strings with ID tags. Coupons were hung so they did not touch the sample box or each other. Sample test boxes with coupons and tags are shown in Figure 2-2. Two types of BIs were placed inside the test box for checking sterilization effectiveness during the gamma irradiation process, as described in section 2.3.2. The boxes were then closed and sealed with carton sealing tape with paper backing (ProTapes Pro 184HD rubber high-tensile Kraft flat-back carton sealing tape with paper backing, 7 mils thick, 55 yd L x 2 in. W, ProTapes part no. Pro-184HD-2x55-DBR). Each test box was labeled with a permanent marker according to the coupon identification scheme given in Table 2-2. The label consisted of a description of the coupon material and a unique sample code that corresponded to the sampling matrix. All boxes were weighed individually and their weights recorded in the laboratory notebook, as well as on the chain of custody form submitted along with samples to the subcontracting laboratory. All 30 kGy gamma irradiation sample boxes were packaged together in one large box and all 50 kGy sample boxes were packaged together in a second box for shipping.

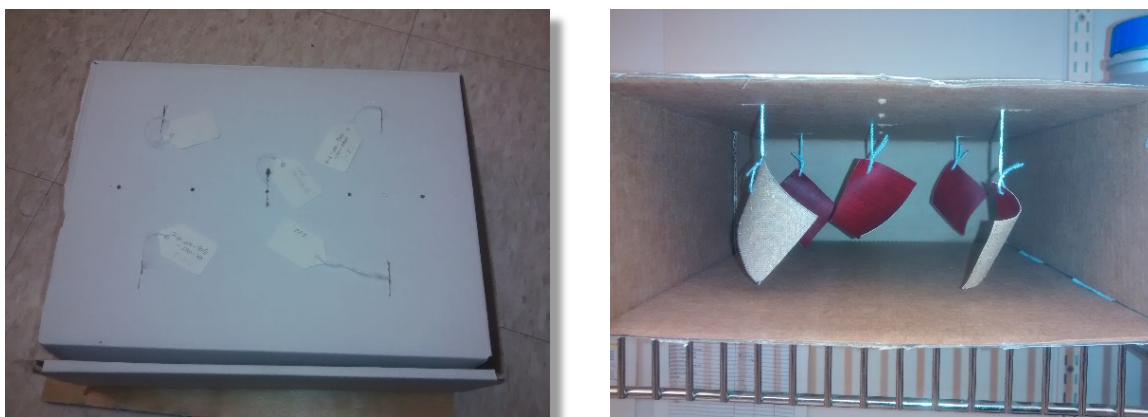


Figure 2-2. Test box with coupons.

## 2.3 Gamma Irradiation

The test material coupons were sent to Sterigenics International LLC (Oak Brook, IL, USA, <http://www.sterigenics.com>) for gamma irradiation. This facility performed the irradiations and verified delivery of the correct doses and sterilization effectiveness.

### 2.3.1 Dose Selection and Verification

Gamma radiation is a form of pure energy, similar in many ways to microwaves and X-rays, characterized by deep penetration and low dose rates. High-energy photons are emitted from an isotope source (usually Cobalt 60) producing ionization (electron disruptions) throughout a product. In living cells, these

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disruptions result in damage to the DNA and other cellular structures. These photon-induced changes at the molecular level cause the death of the organism or render the organism incapable of reproduction. While able to kill microorganisms effectively, gamma irradiation does not create residuals or have sufficient energy to impart radioactivity [4,5].

Two gamma irradiation doses (50 and 30 kGy) were selected for this study. Selection of the 50 kGy dose was based on the radiation dose that was used to kill 1 g of dry *Bacillus (B.) anthracis* spores in a threat envelope, with a sterility assurance equivalent to 14 logs of kill [6]. The second operational sterilization dose of 30 kGy was selected based on a theoretical radiosensitivity of dry *B. anthracis* spores and sterility assurance level (SAL). The radiosensitivity of microorganisms and spores is expressed in terms of its D10 value, which is the radiation dose required to reduce a viable population of a specific microorganism by 1 log. The D10 for dry spores from most *Bacillus* species range from approximately 2 to 3.3 kGy. A D10 value for *B. anthracis* spores of 3.3 kGy was used in this study [6]. The SAL is the probability of not more than one viable spore remaining in a set number of sterilized items. The SAL of  $1 \times 10^{-3}$  was selected for this study, which means that the probability is no more than one viable spore in a set of 1,000 irradiated items [6]. The lower dose also assumes that during actual decontamination, historical objects would be bagged and removed from a building contaminated with *B. anthracis* spores, with the level of contamination, or biological burden, initially reduced by use of a high-efficiency particulate air (HEPA) vacuum prior to bagging.

Radiochromic film dosimeters (Far West Technology, Goleta, CA, USA) were used to verify the dosage of radiation delivered to the coupons, i.e., quantification of absorbed radiation. The dosimeters were placed on the test boxes during irradiation. Sterility testing was then performed on the irradiated samples to determine if viable microorganisms were present (see section 2.3.2). This dose verification step determined whether or not a change in sterilization dose was needed. The inherent reliability of the gamma radiation process is outlined in detail in the standards document ANSI/AAMI/ISO 11137-1994 [7]. Additional information on dose kill curves can be found in a consolidated kill curve put together by the US Department of Defense [8].

### 2.3.2 Sterilization Effectiveness Checks

Biological indicators were used for sterility assurance purposes. Two types of BI spore strips (Mesa Labs, Inc., Lakewood, CO, USA) were used for this study:

- *Bacillus (B.) pumilus* – recommended by the manufacturer for validation of irradiation sterilization processes.
- *B. atrophaeus* – selected because *B. atrophaeus* is used as a surrogate for *B. anthracis* in many NHSRC decontamination research projects.

Both BIs have a minimum population (bioburden) of 1,000,000 ( $1 \times 10^6$ ) spores. After exposure to the sterilant, the strips were incubated at 30–35 °C, using the population assay procedure provided by the manufacturer (Appendix A). Sterilization efficacy was determined by growth/no-growth of the biological agent on the BI spore strips that underwent the gamma irradiation treatment (as compared to amount of biological agent recovered from positive control BI spore strips, i.e., not exposed to the gamma irradiation procedure). If the D10 for *B. anthracis* spores is 3.3 kGy/log reduction and the bioburden is  $1 \times 10^6$ , then sterilization would require  $3.3 \text{ kGy/log} \times 6 = 19.8 \text{ kGy}$  to reduce the spore count by 6 logs, i.e., from  $1 \times 10^6$  to  $1 \times 10^0$ . After applying a SAL of  $1 \times 10^{-3}$ , i.e., not more than one item out of 1,000 irradiated items

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would have a single viable spore, then the radiation dose should be  $3.3 \text{ kGy/log} \times 9 = \sim 30 \text{ kGy}$  to reduce the spore count by 6 logs on 1,000 items..

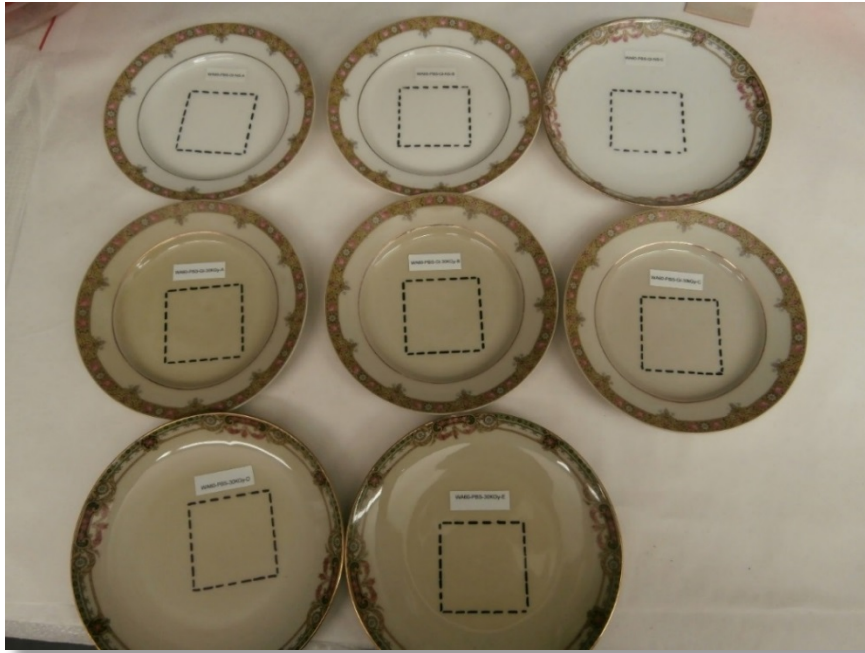
## **2.4 Assessment of Gamma Irradiation Effects**

### **2.4.1 Visual Inspection**

Gamma irradiation visual impacts were expressed as the sum of the numerical values describing the extent of noticeable physical changes in the tested materials. Seven physical characteristics were checked for each test material coupon:

- Changes in color
- Changes in contrast
- Fading of the material
- Cracking or chipping
- Brittleness and thinning
- Legibility
- Odors

A numerical value was assigned to each of the seven categories. The values ranged from 0, which indicated no observable change), through 0.5 – indicating a very low change, 1 – a low change, 2 – moderate change, and 3 which described a high level of change. For six data sets when the analyst indicted an ultra-low (but perceptible) level of change sub-0.5 values (0.1 or 0.2) were used. The values for the seven categories were summed together to get a cumulative impact score for the sample. The five sample cumulative impact scores were then averaged to determine the average cumulative impact score for the sample set. In addition to the use of numerical descriptors indicating a level of change in appearance of the test coupon material, the analysts was also using narrative descriptions to note more distinctive or unique problems with material condition. The coupon-specific narrative descriptions of changes were noted along with an associated numerical descriptor in the respective short- and long-term visual assessment check lists (Appendix B). The combined use of numerical and narrative descriptors most faithfully explains analyst observation of visual changes in the post-exposure condition of historical materials and historical material surrogates. All investigated materials were photodocumented, which was a suitable tool for gross visual changes (an example of severe photodocumentation visual impacts is shown in Figure 2-3). However, photography did not capture subtle changes (e.g., glossiness) in material appearance very well. These changes were documented using narrative descriptors.



**Figure 2-3. Example of severe visual impacts.**

#### **2.4.2 Technical Inspection**

Technical assessments were performed on the test materials by spectrophotometric analysis. A spectrophotometer (CM-2500c, Konica Minolta Sensing, Japan) was used to measure the color change of the coupons. Instrument parameters were set as follows:

- Illuminant 1: D<sub>65</sub>
- Illuminant 2: A
- Observer angle: 2°
- Color spacing: L\*a\*b\*, E\*

D<sub>65</sub> simulates daylight (color temperature of 6504K including ultraviolet light), and A simulates an incandescent lamp (color temperature of 2856K). The observer angle of 2° is from the International Commission on Illumination (CIE). CIE originally defined the standard observer angle in 1931 using a 2° field of view. L\*a\*b\* color spacing includes all colors perceivable to the human eye. L\* is the lightness of the sample, a\* is the red-green component, and b\* is the yellow-blue component of the sample. E\* is the total color difference between the initial reading and the sample reading. For data analysis, the color difference ( $\Delta E^*$ ) tolerance was set at 1.0, assuming that a  $\Delta E^*$  of 1.0 is the smallest color difference that the human eye can see (i.e., any  $\Delta E^*$  less than 1.0 is imperceptible and any  $\Delta E^*$  greater than 1.0 is noticeable). It might be considered a “best case scenario” of the human eye perception of color differences.

An initial reading was taken with the spectrophotometer of each sample coupon. The surface of the coupon was read in a 4 cm x 4 cm grid pattern, moving 1 cm for each reading for a total of 16 readings. The 16 readings were averaged to get a composite reading for the coupon surface. After the coupons were irradiated, the short-term samples were measured using the same spectrophotometer settings and

sampling procedure used for the initial sample readings. The initial sample readings were used to calculate any color changes in the coupon surfaces. This process was repeated after 5 months to determine any long-term effects of gamma irradiation.

Table 2-3 lists colorimetric data used for technical assessments of post-exposure material changes due to irradiation.

**Table 2-3. Colorimetric Data Used For Spectrophotometric Technical Assessments [9]**

Data	Description
Color difference $\Delta E^*_{ab}$ (D65)	The difference between two colors can be calculated using an equation developed by the International Commission on Illumination (CIE) in 1976 called $\Delta E_{ab}$ . This equation calculates the linear (Euclidian) distance between two points in the $L^*a^*b^*$ three-dimensional space. D65 is a code that identifies a light source; D 65 is a standard Illuminant; average daylight (including ultraviolet wavelength region) with a correlated color temperature of 6504 K; used for measuring specimens that will be illuminated by daylight including ultraviolet radiation.
$L^*$ (D65)	The absolute value of lightness in the $L^*a^*b^*$ color space
$a^*$ (D65)	The absolute value of a chromaticity coordinate in the $L^*a^*b^*$ color space
$b^*$ (D65)	The absolute value of b chromaticity coordinate in the $L^*a^*b^*$ color space
$d L^*$ (D65)	The change of lightness in the $L^*a^*b^*$ color space (brighter/darker)
$d a^*$ (D65)	The change of the chromaticity coordinate $a^*$ in the $L^*a^*b^*$ color space (+ $a^*$ is the red direction, - $a^*$ is the green direction)
$d b^*$ (D65)	The change of the chromaticity coordinate $a^*$ in the $L^*a^*b^*$ color space (+ $b^*$ is the yellow direction, and - $b^*$ is the blue direction)
Lightness evaluation (D65)	The parameter that describes the subjective brightness perception of a color for humans along a lightness–darkness axis (color amplitude) – defines the difference between bright colors and dark colors
Saturation evaluation (D65)	The saturation of a color is determined by a combination of light intensity and how much it is distributed across the spectrum of different wavelengths
Hue evaluation (D65)	Hue is the degree to which a stimulus can be described as similar to or different from stimuli that are described as red, green, blue, and yellow (the unique hues)
Metameric index (D65)	Parameter that describes a phenomenon in which two colors appear the same under one light source but different under another. In this study, secondary illumination was a standard Illuminant A, i.e., incandescent light with a correlated color temperature of 2856 K; used for measuring specimens that will be illuminated by incandescent lamps

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## 3 Results and Discussion

Results of this investigation for both short- and long-term effects of gamma irradiation on the historical materials are discussed in this section. Visual and technical assessment results at two gamma radiation doses (30 and 50 kGy) are described for each historical material in Categories 1 and 2. Following the short-term assessments (~ 3 weeks post-sterilization), all test samples were stored in an environmental chamber, and long-term assessments were performed 5 months later. Visual impact data sheets for category 1 and 2 materials are in Appendix B. Technical assessment data sheets for category 1 and 2 materials are in Appendix C. The procedures for visual and technical assessments are given in Section 2.4.1 and 2.4.2 respectively.

### 3.1 Category 1 Material Visual and Technical Inspections

#### 3.1.1 Historical Oil Paintings

##### 3.1.1.1 Visual Inspection

Visual impacts were assessed of 30 kGy and 50 kGy gamma irradiation of historical oil paintings. Visual inspection of this material type at 30 kGy irradiation resulted in both short-term and long-term cumulative impact scores of 0.6. The total cumulative impact score for the 30 kGy samples was 1.2, which shows a low level of change in the tested material. For the 50 kGy samples, the short-term cumulative impact score was 0.1 and the long-term cumulative impact score was 0.7. The total cumulative impact score for the 50 kGy samples is 0.8. This shows low impact on the tested material. This data are summarized in Table 3-1.

**Table 3-1. Visual Impact Data from Historical Oil Paintings**

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical oil paintings	0.6	0.6	1.2	0.1	0.7	0.8

##### 3.1.1.2 Technical Inspection

Technical assessments of historical oil paintings were also made after 30 kGy and 50 kGy gamma irradiation. The 30 kGy short-term assessment samples showed a slight average color change after irradiation of 0.980. The long-term assessment color change for the 30 kGy samples increased to 4.582. The 50 kGy short-term samples showed a color change average of 1.804. For the long-term samples, the color change average increased to 3.986. These data are illustrated in Figure 3-1.

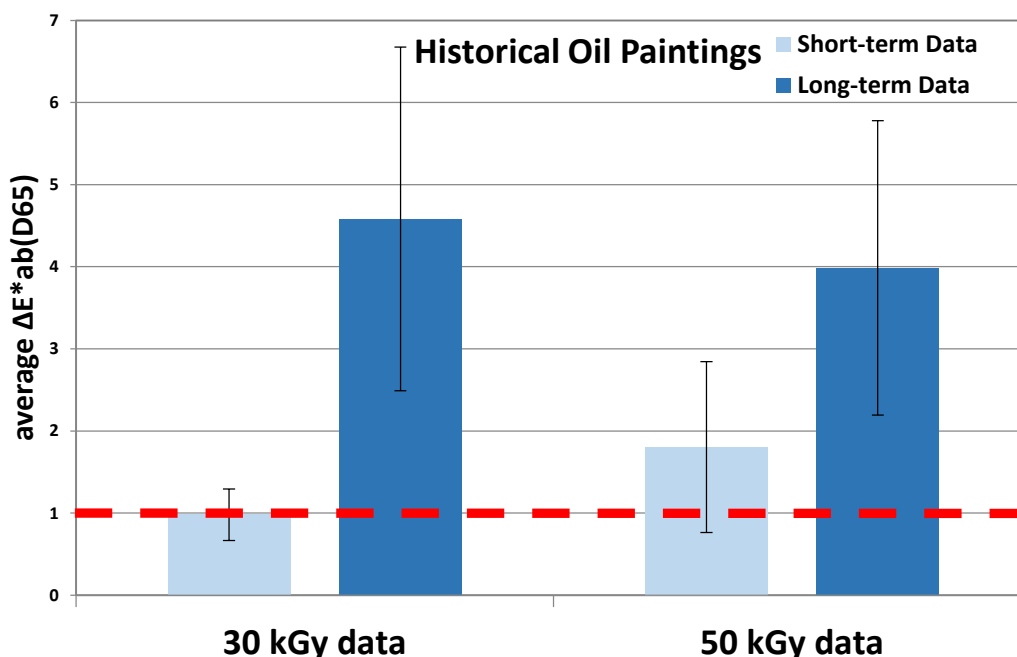


Figure 3-1. Technical impact data from historical oil paintings. Red dashed line indicates the smallest color difference that the human eye can perceive,  $dE^*ab=1$ .

### 3.1.2 Light Hue Monochromatic Pigment Oil Paintings

#### 3.1.2.1 Visual Inspection

Visual impacts were assessed from both 30 and 50 kGy gamma irradiation of these test samples. The 30 kGy samples had a short-term cumulative impact score of 0 and a long-term cumulative impact score of 0.4. The total cumulative impact score for the 30 kGy samples was 0.4, which showed a low level of impact on the tested material. The 50 kGy sample short-term cumulative impact score was 0.18, and the long-term cumulative impact score was 0.6. The total cumulative impact score for the 50 kGy samples was 0.78, showing a low impact on the tested material. These data are summarized in Table 3-2.

Table 3-2. Visual Impact Data from Light Hue Monochromatic Pigment Oil Paintings

Material	Visual Changes 30 kGy			Visual Changes 50 kGy		
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	Total Cumulative Impact	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	Total Cumulative Impact
Light hue monochromatic pigment oil painting	0	0.4	0.4	0.18	0.6	0.78



### 3.1.2.2 Technical Inspection

Technical assessments were made of the light hue monochromatic pigment oil paintings after 30 and 50 kGy gamma irradiation. The 30 kGy short-term assessment samples had an average color change after irradiation of 1.344. The long-term assessment had an average increase to 5.488. The 50 kGy short-term assessment samples showed more of a color change than the 30 kGy samples, with an average of 3.246. The long-term assessment sample average color change increased to 4.206. These data are illustrated in Figure 3-2.

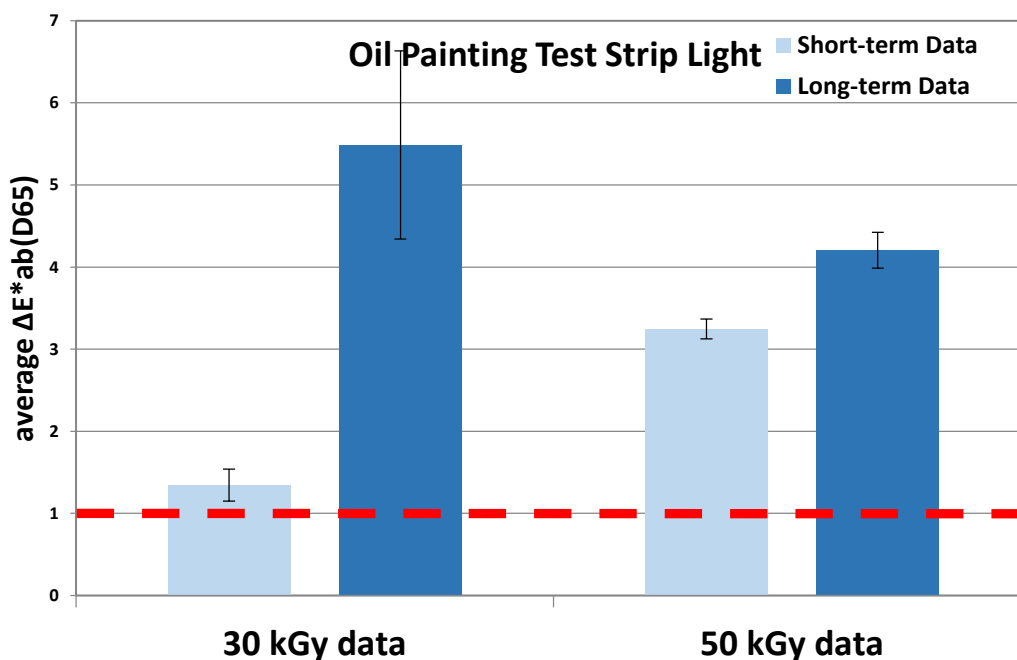


Figure 3-2. Technical inspection data from light hue monochromatic pigment oil paintings. Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*ab=1$ .

### 3.1.3 Dark Hue Monochromatic Pigment Oil Paintings

#### 3.1.3.1 Visual Inspection

Visual impacts from 30 and 50 kGy gamma irradiation were assessed on this set of test samples. The 30 kGy samples had a short-term cumulative impact score of 1, and the long-term cumulative impact score was 0. The total cumulative impact score for the 30 kGy samples was 1, which shows a low level of impact on the tested material. The 50 kGy samples had a short-term cumulative impact score of 0 and a long-term cumulative impact score of 0.2. The total cumulative impact score for the 50 kGy samples is 0.2, again showing a low impact on the tested material. These data are summarized in Table 3-3.



**Table 3-3. Visual Impact Data from Dark Hue Monochromatic Pigment Oil Paintings**

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Dark hue monochromatic pigment oil painting	1	0	1	0	0.2	0.2

### 3.1.3.2 Technical Inspection

Technical assessments were made of the impact of 30 and 50 kGy gamma irradiation on light hue monochromatic pigment oil paintings. The 30 kGy short-term assessment samples showed an average color change after irradiation of 1.590. After the long-term assessment, the average color change for the 30 kGy samples increased to 3.520. The 50 kGy short-term assessment samples showed a color change average of 1.562. The long-term assessment average color change increased to 3.134. These data are illustrated in Figure 3-3.

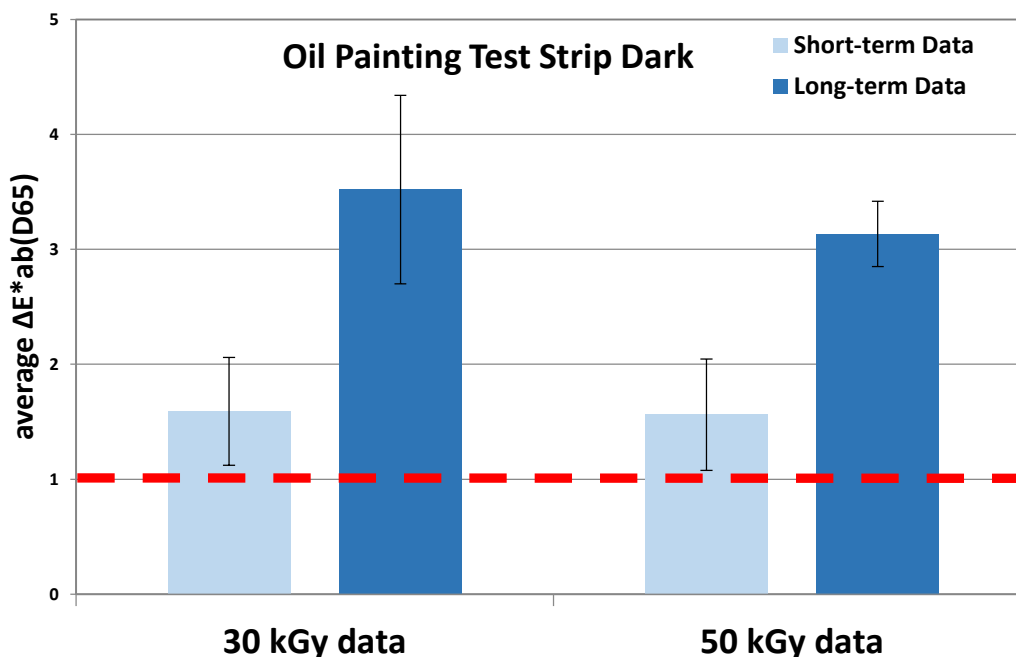


Figure 3-3. Technical impact data from dark hue monochromatic pigment oil paintings. Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*ab=1$ .

### 3.1.4 Historical Documents

#### 3.1.4.1 Visual Inspection

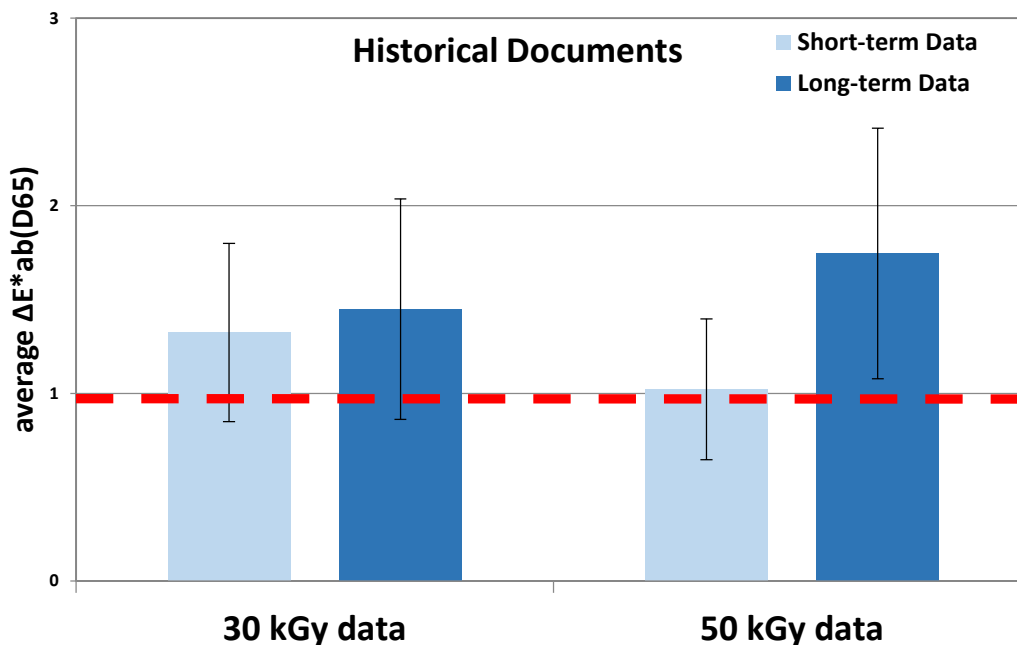
Visual impacts on historical document test samples were assessed after 30 and 50 kGy gamma irradiation. The 30 kGy samples had a short-term cumulative impact score of 0.82 and a long-term cumulative impact score of 0.5. The total impact score for the 30 kGy samples was 1.32, showing a low to moderate impact on the documents. The 50 kGy sample short-term cumulative impact score was 0.18 and the long-term cumulative impact score was 0.5. The total cumulative impact score for the 50 kGy samples of 0.68 shows a low impact on the tested material. These data are summarized in Table 3-4.

**Table 3-4. Visual Impact Data from Historical Documents**

Material	Visual Changes 30 kGy			Visual Changes 50 kGy		
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	Total Cumulative Impact	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	Total Cumulative Impact
Historical documents	0.82	0.5	1.32	0.18	0.5	0.68

### 3.1.4.2 Technical Inspection

Technical assessments were made of the historical documents after 30 kGy and 50 kGy gamma irradiation. The 30 kGy samples showed an average short-term color change after irradiation of 1.324. The long-term assessment showed the average color change for the 30 kGy samples increased to 1.448. The 50 kGy samples showed less of a color change than the 30 kGy samples in the short-term assessment with an average of 1.022. After the long-term assessment, the average color change increased to 1.746. These data are illustrated in Figure 3-4.



**Figure 3-4. Technical inspection data from historical documents.** Red dashed line indicates the smallest color difference that the human eye can perceive,  $dE^*ab=1$ .

### 3.1.5 Historical Books

#### 3.1.5.1 Visual Inspection

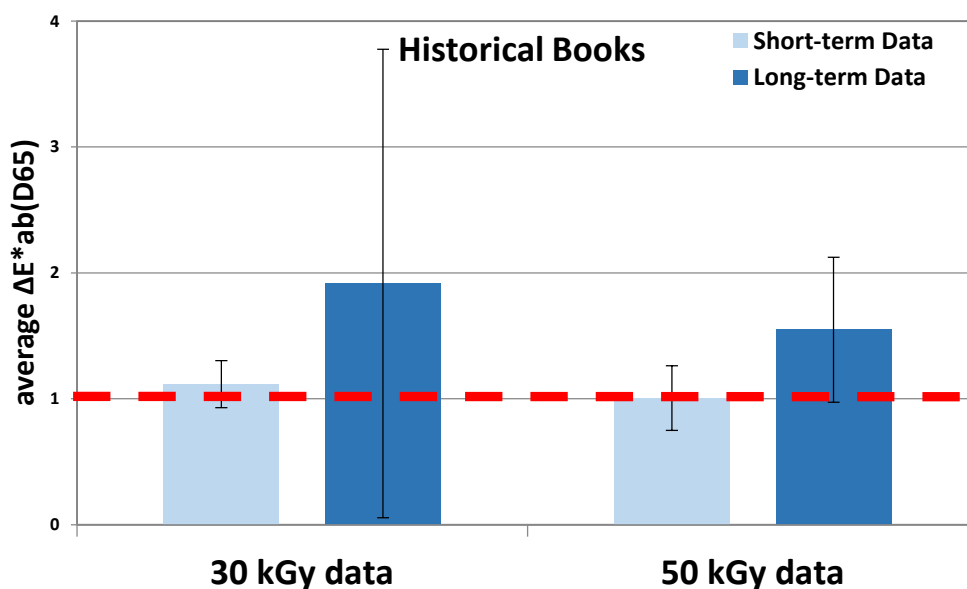
Visual impacts on historical books were assessed from gamma irradiation at both 30 and 50 kGy. The 30 kGy samples showed a short-term cumulative impact score of 0.52 and a long-term cumulative impact score of 0. The total cumulative impact score for the 30 kGy samples was 0.52, which shows a low level of impact on this test material. The 50 kGy sample short-term cumulative impact score was 0.14 and the long-term cumulative impact score was 0.1. The total cumulative impact score for the 50 kGy samples was 0.24, also showing a low impact on the tested material. These data are summarized in Table 3-5.

**Table 3-5. Visual Impact Data from Historical Books**

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical books	0.52	0	0.52	0.14	0.1	0.24

#### 3.1.5.2 Technical Inspection

Technical assessments were also made of the impact of 30 kGy and 50 kGy gamma irradiation on historical books. The 30 kGy samples showed an average color change after the short-term assessment of 1.116. For the long-term assessment, the average color change for the 30 kGy samples increased to 1.916. The 50 kGy samples showed less of a color change than the 30 kGy samples after the short-term assessment, with an average of 1.006. After 5 months, the average color change increased to 1.548. These data are illustrated in Figure 3-5.



**Figure 3-5. Technical inspection data from historical books.** Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*_{ab}=1$

### 3.1.6 Historical Photographs

#### 3.1.6.1 Visual Inspection

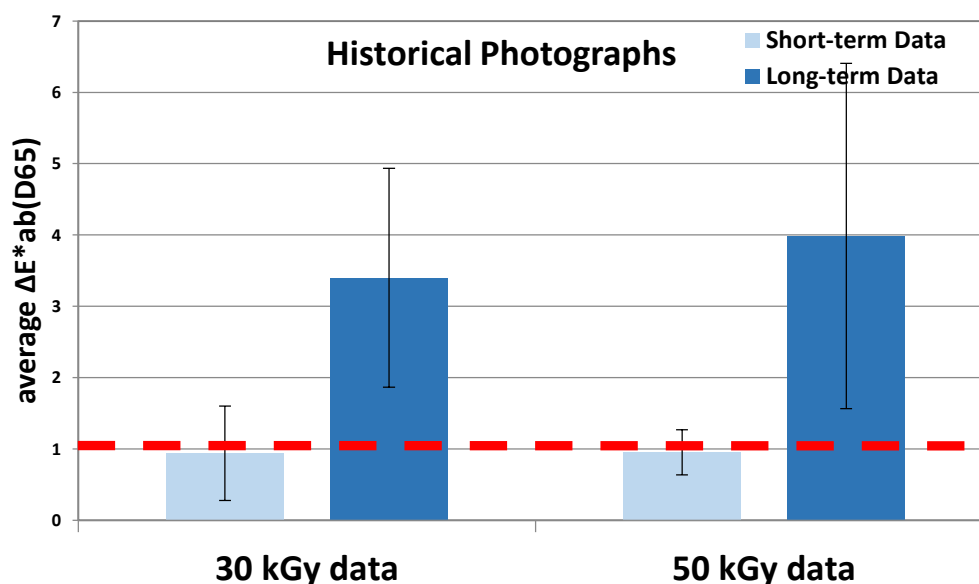
Visual impacts were observed from gamma irradiation at 30 and 50 kGy on test samples for the long-term assessment only. The 30 kGy samples showed a short-term cumulative impact score of 0 and a long-term cumulative impact score of 0.1. The total impact score for the 30 kGy samples was 0.1, which showed a low level of impact on the historical photograph test material. The 50 kGy sample short-term cumulative impact score was 0, and the long-term cumulative impact score was 0.3. The total cumulative impact score for the 50 kGy samples was 0.3, again showing a low impact. These data are shown in Table 3-6.

**Table 3-6. Visual Impact Data from Historical Photographs**

Material	Visual Changes 30 kGy			Visual Changes 50 kGy		
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	Total Cumulative Impact	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	Total Cumulative Impact
Historical photographs	0	0.1	0.1	0	0.3	0.3

#### 3.1.6.2 Technical Inspection

Technical assessments were made of the historical photograph test samples after 30 kGy and 50 kGy gamma irradiation. The 30 kGy samples showed an average color change after irradiation of 0.940. The long-term assessment showed the average color change for the 30 kGy samples increased to 3.400. The 50 kGy samples showed more of a color change than the 30 kGy samples after the short-term assessment with an average of 0.954. After 5 months, the average color change increased to 3.986. These data are illustrated in Figure 3-6.



**Figure 3-6. Technical inspection data from historical photographs.** Red dashed line indicates the smallest color difference that the human eye can perceive,  $dE^*ab=1$ .

## 3.2 Category 2 Material Visual and Technical Inspections

### 3.2.1 Historical Pastel Paintings

#### 3.2.1.1 Visual Inspection

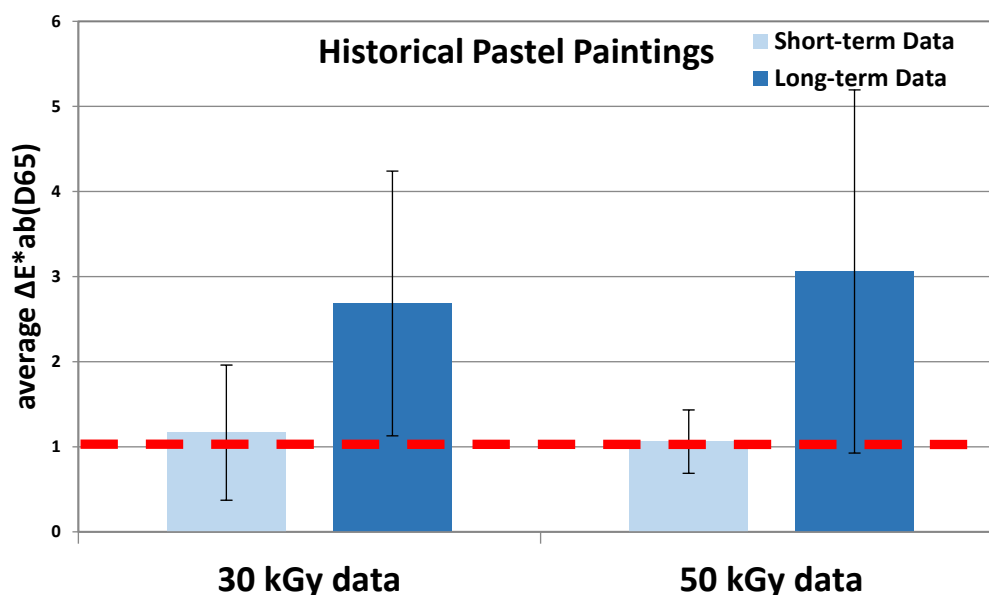
Visual impacts from gamma irradiation on historical pastel paintings were assessed at both the 30 and 50 kGy irradiation levels. The 30 kGy samples showed a short-term cumulative impact score of 1 and a long-term cumulative impact score of 0.3. The total impact score for the 30 kGy samples was 1.3. This showed a low level to moderate impact on the pastel paintings. The 50 kGy sample short-term cumulative impact score was 0.2, and the long-term cumulative impact score was 0.2. The total cumulative impact score for the 50 kGy samples was 0.4, showing a low impact on the tested material. These data are summarized in Table 3-7.

**Table 3-7. Visual Impact Data from Historical Pastel Paintings**

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical pastel paintings	1	0.3	1.3	0.2	0.2	0.4

#### 3.2.1.2 Technical Inspection

Technical assessments were made of historical pastel paintings at 30 kGy and 50 kGy gamma irradiation. The 30 kGy short-term samples showed an average color change after irradiation of 1.166. The 30 kGy long-term assessment samples showed that the average color change increased to 2.684. The 50 kGy short-term samples showed an average color change of 1.060, and the 50 kGy long-term assessment samples showed an average color change of 3.060. These data are illustrated in Figure 3-7.



**Figure 3-7. Technical impact data from historical pastel paintings.** Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*ab=1$ .

### 3.2.2 Historical Leather Items

#### 3.2.2.1 Visual Inspection

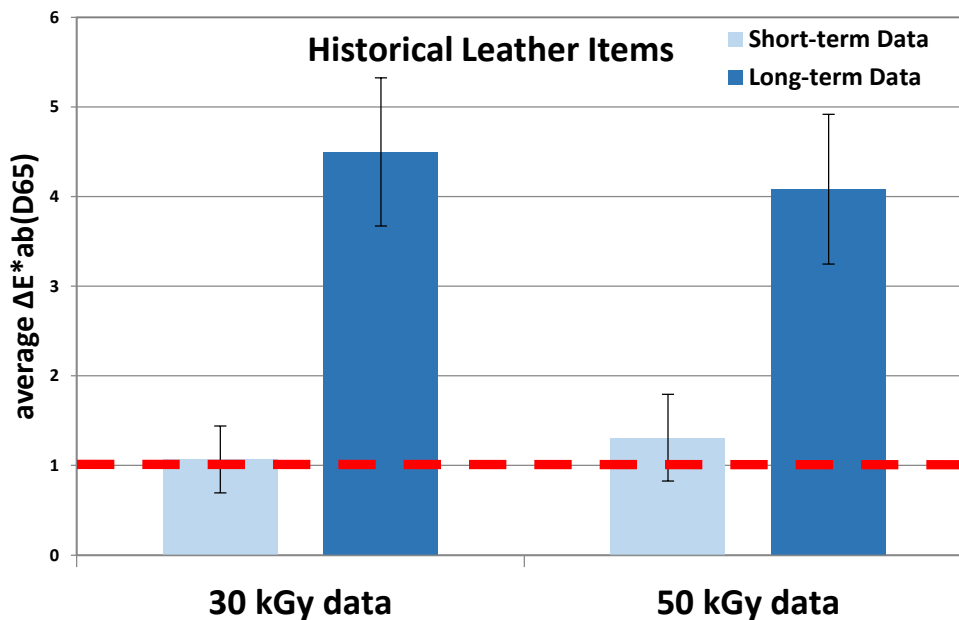
Visual impacts of 30 and 50 kGy gamma irradiation were assessed on historical leather test samples. The 30 kGy samples showed a short-term cumulative impact score of 0.8 and a long-term cumulative impact score of 0.1. The total impact score for the 30 kGy samples was 0.9, which shows a low level of impact on this type of material. The 50 kGy sample short-term cumulative impact score was 0.34, and the long-term cumulative impact score was 0.2. The total cumulative impact score for the 50 kGy samples of 0.54 showed a low impact on the tested material. These data are summarized in Table 3-8.

**Table 3-8. Visual Impact Data from Historical Leather Items**

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical leather	0.8	0.1	0.9	0.34	0.2	0.54

#### 3.2.2.2 Technical Inspection

Technical assessments were made of historical leather samples at 30 kGy and 50 kGy gamma irradiation. The 30 kGy short-term samples showed an average color change after irradiation of 1.068. The long-term assessment color change increased to 4.498. The 50 kGy short-term color assessment showed an average of 1.310, and the 50 kGy long-term assessment showed a color change of 4.082. These data are illustrated in Figure 3-8.



**Figure 3-8. Technical impact data from historical leather items.** Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*ab=1$ .

### 3.2.3 Historical Wood Items

#### 3.2.3.1 Visual Inspection

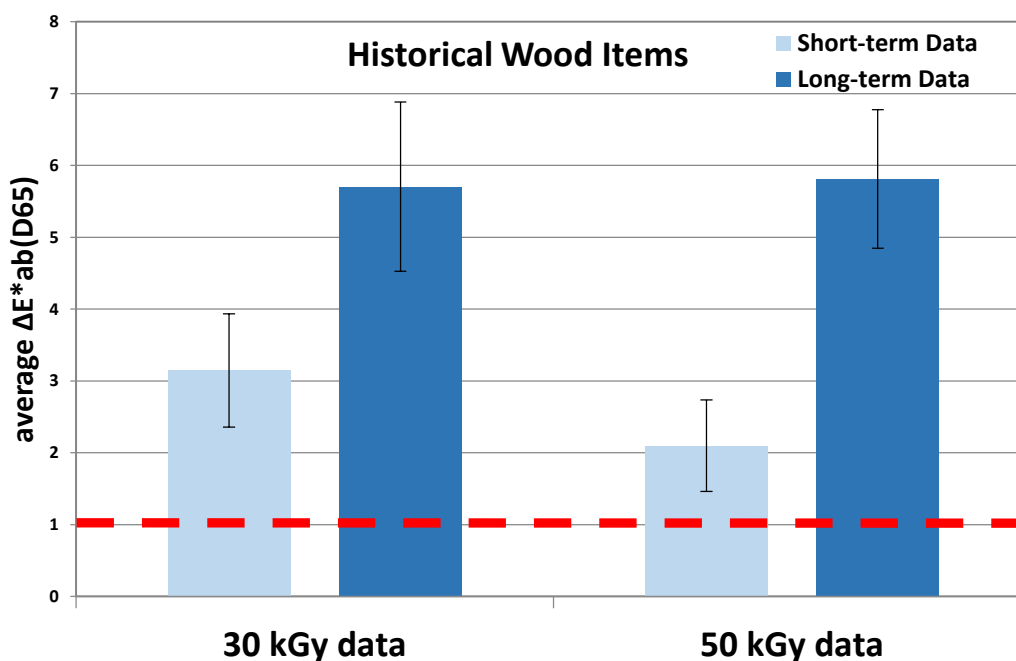
Visual impacts from gamma irradiation were observed only in the 50 kGy short-term test samples for historical wood. The 50 kGy samples showed a short-term cumulative impact score of 0.2. All other samples showed no visual impacts. These data are summarized in Table 3-9.

**Table 3-9. Visual Impact Data from Historical Wood Items**

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical wood	0	0	0	0.2	0	0.2

#### 3.2.3.2 Technical Inspection

Technical assessments were made of historical wood items after 30 kGy and 50 kGy gamma irradiation. The 30 kGy short-term samples showed an average color change of 3.146. The long-term samples showed an average color change increase to 5.704. The 50 kGy short-term samples showed less of a color change than the 30 kGy samples after irradiation, with an average of 1.804. For the long-term samples, the average color change increased to 5.810. These data are illustrated in Figure 3-9.



**Figure 3-9. Technical impact data from historical wood items.** Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*ab=1$ .

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### 3.2.4 Historical Porcelain Items

#### 3.2.4.1 Visual Inspection

Visual impacts from gamma irradiation of historical porcelain items were observed at both the 30 and 50 kGy irradiation levels. The 30 kGy samples showed a short-term cumulative impact score of 3 and a long-term cumulative impact score of 8.4. The total impact score for the 30 kGy samples was 11. This shows a high level of impact on the tested porcelain material. The 50 kGy sample short-term cumulative impact score was 4.4, and the long-term cumulative impact score was 7.8. The total cumulative impact score for the 50 kGy samples of 12.2, again shows a significant impact on the tested material. These data are summarized in Table 3-10.

**Table 3-10. Visual Impact Data from Historical Porcelain Items**

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical porcelain	3	8.4	11.4	4.4	7.8	12.2

#### 3.2.4.2 Technical Inspection

Technical assessments were made of historical porcelain items at 30 kGy and 50 kGy gamma irradiation. The 30 kGy short-term samples showed a large average color change after irradiation of 21.668. The 30 kGy long-term sample average color change decreased slightly to 19.178. The 50 kGy short-term samples showed an average color change of 21.920. For the 50 kGy long-term samples, the average color change slightly decreased to 18.736. These data are illustrated in Figure 3-10.



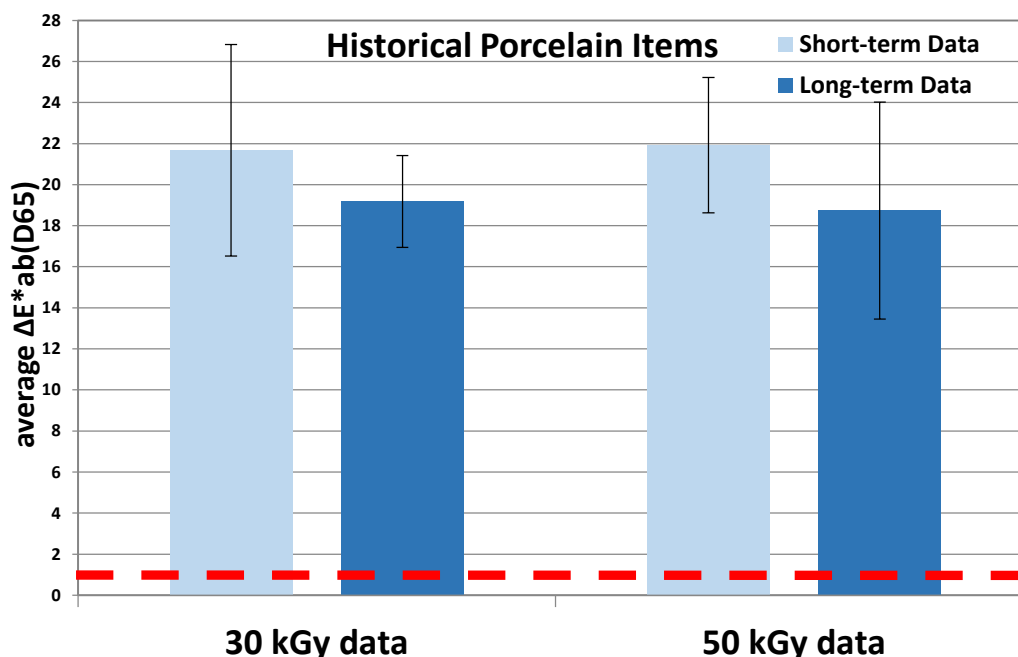


Figure 3-10. Technical impact data from historical porcelain items. Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*ab=1$ .

### 3.2.5 Historical Fabric Items

#### 3.2.5.1 Visual Inspection

Visual impacts from gamma irradiation of the historical fabric test samples were seen only at the short-term 30 kGy irradiation level. The impact score for the short-term 30 kGy samples was 0.7. All other tests showed no visual impacts. These data are summarized in Table 3-11.

Table 3-11. Visual Impact Data from Historical Fabric Items

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical fabric	0.7	0	0.7	0	0	0

#### 3.2.5.2 Technical Inspection

Technical assessments were made of historical fabric samples at 30 kGy and 50 kGy gamma irradiation. The 30 kGy short-term samples showed an average color change of 2.062. The long-term assessment showed an average color change of 4.246. The short-term assessment 50 kGy samples showed an average color change of 1.726. For the long-term 50 kGy assessment samples, average color change increased to 2.694. These data are illustrated in Figure 3-11.

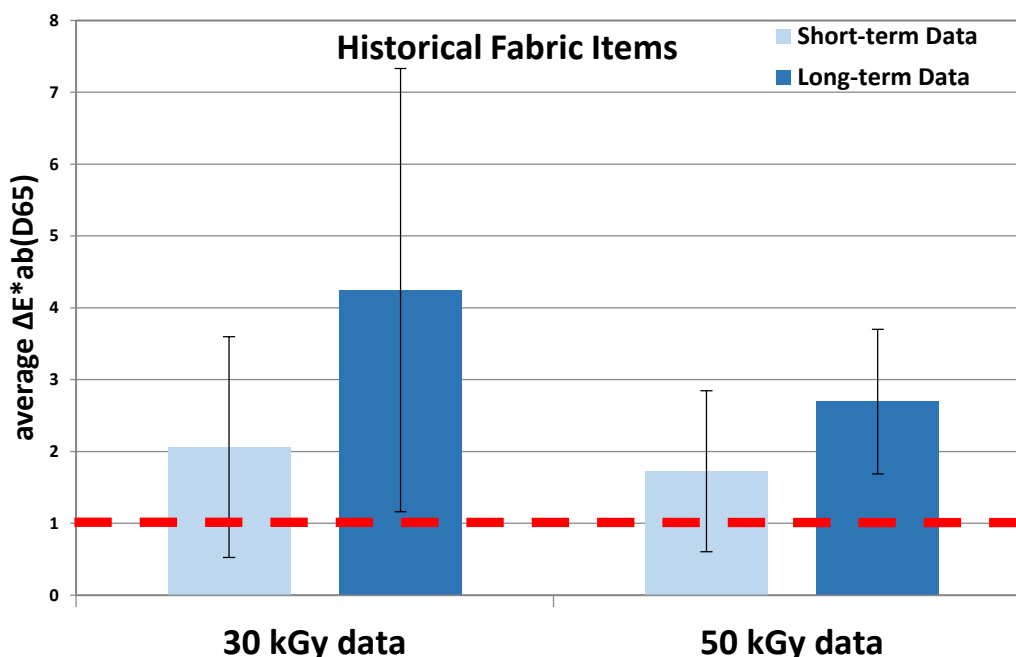


Figure 3-11. Technical impact data from historical fabric items. Red dashed line indicates the smallest color difference that the human eye can perceive,  $dE^*ab=1$ .

### 3.2.6 Historical Metal Items

#### 3.2.6.1 Visual Inspection

No visual impacts were observed from gamma irradiation of the historical metal samples at both the 30 and 50 kGy irradiation levels. These data are summarized in Table 3-12.

Table 3-12. Visual Impact Data from Historical Metal Items

Material	Visual Changes 30 kGy		Total Cumulative Impact	Visual Changes 50 kGy		Total Cumulative Impact
	Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score		Short-Term Cumulative Impact Score	Long-Term Cumulative Impact Score	
Historical metal	0	0	0	0	0	0

#### 3.2.6.2 Technical Inspection

Technical assessments were made of historical metal surrogates at 30 kGy and 50 kGy gamma irradiation. The 30 kGy short-term samples showed an average color change after irradiation of 1.334, and the long-term assessment showed an average color change of 3.602. The 50 kGy short-term samples showed an average color change of 1.768, and the long-term assessment showed a color change of 3.956. These data are illustrated in Figure 3-12.

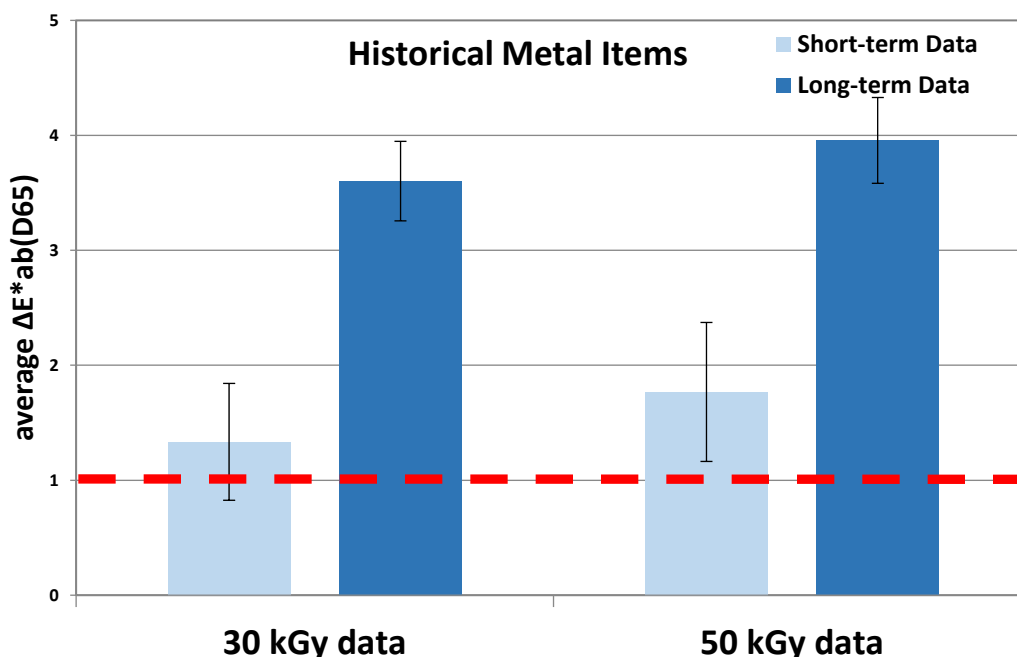


Figure 3-12. Technical impact data from historical metal items. Red dashed line indicates the smallest color difference that the human eye can perceive,  $\Delta E^*ab=1$ .

### 3.3 Dosage and Sterilization Verification

#### 3.3.1 Dosage Verification Data

Each irradiation level was checked with dosimeters to verify the gamma irradiation dosage. The acceptance criteria for the dosimeter data was  $\pm 20\%$  of target value. The 30 kGy samples received a measured dosage of 33.3 kGy. The 50 kGy samples received a measured dosage of 53.3 kGy. The certificates for irradiation are provided in Appendix D.

#### 3.3.2 Sterilization Verification Data

BIs for the 30 kGy gamma irradiation samples showed no growth for all samples with the exception of the *B. atrophaeus* BI in the historical documents sample, which showed growth. All positive controls showed growth and all negative controls showed no growth for all samples. The sample sheet for the 30 kGy data is given in Appendix E.

Three BIs for *B. atrophaeus* for the 50 kGy dose showed growth. The historical wood, light hue monochromatic pigment oil painting, and historical pastel painting sample BIs all showed growth. The remaining samples showed no growth. All positive controls showed growth and all negative controls showed no growth.

One BI for the leather samples showed growth for *B. pumilus*. The remaining sample BIs showed no growth. All positive controls showed growth and all negative controls showed no growth. The 50 kGy data can be found in Appendix E.

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The BIs used in this project were analyzed following irradiation by placing the BI in growth media and examining for growth or no growth. This is a qualitative measurement and would only take one spore to turn the growth media turbid resulting in a positive designation. The 30 and 50 kGy doses were chosen based on previous research. In the event that irradiation was being considered for inactivation of *B. anthracis* on valuable objects, environmental samples should be collected pre and post exposure to verify the item has been decontaminated.

## 4 Quality Assurance

The objective of this study was to assess the impact of decontamination with gamma irradiation on museum-quality materials at conditions known to be effective against biological threats. The data quality indicators (DQIs) address this impact using visual and technical inspections to assess the potential damage and loss in value. The following measurements were deemed critical to accomplishing part or all of the project objectives (see Table 4-1):

- Gamma irradiation dose
- Material inspections (visual and technical assessments)

The following non-critical measurements were also required to ensure the quality of project data:

- Temperature and %RH values for the environmental chamber used for conditioning and storage of coupons
- Mass of sample boxes sent to gamma irradiation facility
- Sterility assurance checks using BIs

In addition to the spectrophotometer used for the technical assessments, standard laboratory equipment such as balances and RH/temperature probes were routinely monitored for proper performance. Calibration of instruments was done at the frequency shown in Table 4-2. Any deficiencies were noted, and the instrument was adjusted to meet calibration tolerances and recalibrated within 24 hours. If tolerances were not met after recalibration, additional corrective action was taken that possibly included recalibration or replacement of the equipment.

Standard commercial spore strips (i.e., BIs) were analyzed for growth/no growth to verify sporicidal efficacy. All BIs were maintained in their sterile Tyvek/Mylar envelopes and placed into the sample boxes before they were sent to be gamma-irradiated. After the samples returned from gamma-radiation the BIs were analyzed for growth/no growth.

**Table 4-1. Data Quality Indicators for Critical Measurements**

Measurement Parameter	Analysis Method	Accuracy	Precision/Repeatability	Completeness %
Gamma irradiation dose	Dosimeter	±20% of target value	NA	100%
Visual assessments	Visual assessment checklist	NA	Individual human eye perception threshold/ performed by same analyst	100%
Technical assessments	Spectrophotometry	0.25 $\Delta E^*ab^a$ , D65 <sup>b</sup>	$\Delta E^*ab$ , D65 within 0.05 standard deviation	100%
<sup>a</sup> $\Delta E^*ab$ : color difference measured with standard illuminant D65; averaged for 12 British Ceramic Research Association series II color tiles compared to values measured with master body at 23 °C. <sup>b</sup> White calibration plate measured 30 times at 10-second intervals after white calibration is performed.				

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**Table 4-2. Test Equipment Calibration Schedule**

Equipment	Calibration	Frequency
Spectrophotometer	Calibrated using white calibration plate CM-A153	Prior to each test
Vaisala probe (RH, temperature)	Calibrated using salt solution wells (RH) and by comparison to NIST-traceable thermocouple (temperature) via standard laboratory procedures	Yearly
Balance	Calibrated using NIST-traceable standards	Yearly
<sup>a</sup> NIST: National Institute of Standards and Technology		

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## 5 Conclusions

### 5.1 Category 1 Materials (Priority Materials)

All category 1 materials showed effects from gamma irradiation at both 30 and 50 kGy. Visual assessments for the historical oil paintings and historical documents showed an increased impact from the short-term assessments to the long-term assessments. The light hue monochromatic pigment oil painting samples showed no visual impact in the short-term 30 kGy assessment, but changes were observed in the long-term assessment. The 50 kGy data showed an impact in the short-term assessment, which increased in the long-term assessment. The dark hue monochromatic pigment oil painting samples showed an impact on the 30 kGy short-term samples, but no impact on the long-term samples. The 50 kGy samples showed no short-term impacts, but a slight impact after the long-term assessments. The results for historical paintings were similar – samples exposed to 30 kGy and 50 kGy were minimally to moderately affected short term, but shown significant impacts long-term. The historical books showed both short- and long-term changes. The historical photographs showed no short-term impact at both 30 and 50 kGy, but long-term effects were observed.

The technical assessments showed short- and long-term impacts for all category 1 samples. An increased color change was noted for all samples from the short-term assessment to the long-term assessment. The short-term 50 kGy samples showed a greater impact than the 30 kGy samples except for the historical documents and the historical books. The historical document short-term 30 kGy samples showed a greater impact than the 50 kGy samples. On the other hand, the long-term 50 kGy historical document samples showed a greater impact than the 30 kGy samples. The historical book 30 kGy samples showed more impact than the 50 kGy samples in both the short- and long-term assessments.

### 5.2 Category 2 Materials (Secondary Materials)

The visual assessment showed some impact for all samples except the metal samples, which showed no changes. The fabric samples only showed a visual impact for the 30 kGy short-term samples. The wood samples showed a visual impact for the short-term 50 kGy samples only. The remaining samples, pastel painting, leather, and porcelain showed impacts for both 30 and 50 kGy in the short- and long-term assessments.

The technical assessments showed impacts for all short- and long-term samples. An increase was observed for all samples from the short-term assessment to the long-term assessment except for the historic porcelain, which showed a slight decrease from the short-term to the long-term assessment. The pastel paintings, wood, and fabric all showed a higher short-term impact for 30 kGy than the 50 kGy samples. The long-term assessment impacts for wood samples showed the 50 kGy samples had a greater impact than the 30 kGy samples. The long-term 30 kGy samples for the fabric showed a greater impact than the 50 kGy samples. The analysis of historical pastel paintings and leather samples showed very minimal short-term impact at both 30 and 50 kGy, but long-term effects were observed. The porcelain matrix was material most dramatically affected by gamma-irradiation with average short- and long-term impacts over 15 to 20 times higher than the human eye perception threshold. The cumulative impacts of gamma-irradiation were predominantly driven by changes in color, hue and saturation: lighter but less saturated colors were mostly observed, the predominant post-exposure change in hue was yellowing (Appendix C). - see Tables 3-1 through 3-4 for details).

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These experimental results provide an insight into which materials are most at risk for damage from the use of irradiation. Some of the materials experienced degradation following irradiation. In some instances, additional degradation occurred as a function of time. A different decontamination approach should be used for these items that are impacted by irradiation.

### 5.3 Biological Indicator Results

BIs were placed with each of the materials that were irradiated. BIs for the 30 kGy gamma irradiation samples showed no growth for all samples with the exception of the *B. atrophaeus* BI in the historical documents sample, which showed growth.

Three BIs for *B. atrophaeus* for the 50 kGy dose showed growth. The historical wood, light hue monochromatic pigment oil painting, and historical pastel painting sample BIs all showed growth. The remaining samples showed no growth.

One BI for the leather samples showed growth for *B. pumilus*. The remaining sample BIs showed no growth.

The BIs used in this project were analyzed following irradiation by placing the BI in growth media and examining for growth or no growth. This is a qualitative measurement and would only take one spore to turn the growth media turbid resulting in a positive designation. The 30 and 50 kGy doses were chosen based on previous research. In the event that irradiation was being considered for inactivation of *B. anthracis* on valuable objects, environmental samples should be collected pre and post exposure to verify the item has been decontaminated.



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## 6 References

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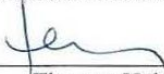
## Appendix A: Biological Indicator Certificates of Analysis



### CERTIFICATE OF ANALYSIS MESA BIOLOGICAL INDICATORS

*Bacillus atrophaeus* Spore Strips - Recommended for use in evaluating Dry Heat or Ethylene Oxide gas sterilization processes.

This document certifies that the biological indicators for this lot meet Mesa Labs' quality control specifications, AAMI/ISO 11138:2006 parts 1 & 2 and suggested performance parameters published in the current United States Pharmacopeia.

  
Thomas Halpenny  
Quality Assurance Specialist  
Mesa Labs

Manufacture: **07JAN2015**

Release: **27JAN2015**

Performance Data for Lot # **11632111** Batch **321GB** Expiration Date **01/2017**

Organism: ***Bacillus atrophaeus*** ATCC<sup>(R)</sup> No. 9372

Nominal Population	<b><math>3.8 \times 10^6</math></b>	CFU* /1.5" x 0.25" strip
D <sub>EtO</sub> Value**	<b>3.6</b>	minutes (600 mg EtO/L, 54°C, 60% RH- This accuracy shall not exceed +/- 0.5)
D <sub>160</sub> Value**	<b>1.1</b>	minutes (Dry Heat, 160°C- This accuracy shall not exceed +/- 0.2)
Z-value***	<b>33.8</b>	°C; approximate

\* Colony Forming Units

\*\* Determined on primary spore crop using paper strips in glassine envelopes, Spearman-Kärber method. The D-value is reproducible only under the exact conditions under which it was determined. The user would not necessarily obtain the same results. Therefore, the user would need to determine the suitability for its particular use.

\*\*\* See reverse side.

Resistance Characteristics: (Based on US Pharmacopeia Calculations)

AGENT	CONDITIONS	SURVIVES	KILLED
Ethylene Oxide	54 ± 1°C, 600 ± 30 mg/L, 60 ± 10% RH	<b>16.5</b> min.	<b>38.1</b> min.
Dry Heat	160 ± 2°C	<b>5.0</b> min.	<b>11.6</b> min.

**Purity:** No evidence of contaminants using standard plate count techniques.

**Incubation:** 7 days in soybean-casein digest broth at a temperature of 30 - 35°C

**Storage:** 15 - 27°C (60 - 80°F), 30 - 70% RH, away from sterilizing agents, direct sunlight and all other forms of UV light. (Do Not Refrigerate).

**Disposal:** Do not use after expiration date. Sterilize all cultures before discarding.

ATCC is a Registered Trademark of the American Type Culture Collection

09/21/12

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**Our Quality System is Registered to ISO 13485 Standards**



## CERTIFICATE OF ANALYSIS

### MESA BIOLOGICAL INDICATORS

*Bacillus pumilus* Spore Strips - Recommended for use in evaluating gamma radiation sterilization processes.

This document certifies that the biological indicators for this lot meets Mesa Labs' quality control specifications, and suggested parameters published in the current United States Pharmacopeia.

Thomas Halpenny  
Quality Assurance Specialist  
Mesa Labs

Manufacture: **03OCT2014**

Release: **08OCT2014**

Performance Data for Lot # **716707**      Batch **70P**      Expiration Date **10/2016**

Organism: ***Bacillus pumilus***      ATCC<sup>(R)</sup> No. 27142

Nominal Population       **$1.9 \times 10^6$**       CFU\* /1.5" x 0.25" strip

D<sub>Mrad</sub> Value\*\* **0.12**      Mrads      (1 Mrad = 10 kGry)

Pour plate dilutions indicate less than 3% *Bacillus subtilis*

\* Colony Forming Units

\*\* Determined at time of manufacture, using Linear Regression method. The D-value is reproducible only under the exact conditions under which it was determined. The user would not necessarily obtain the same results. Therefore, the user would need to determine the suitability for its particular use.

Purity: No evidence of contaminants using standard plate count techniques.

Incubation: 7 days in soybean-casein digest broth at a temperature of 30 - 35°C.

Storage: 60 - 80°F (15 - 27°C), 30 - 70% RH, away from sterilizing agents, direct sunlight, and all other forms of UV light. (Do Not Refrigerate).

Disposal: Do not use after expiration date. Sterilize all cultures before discarding.

ATCC is a Registered Trademark of the American Type Culture Collection.  
09/24/12

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## Appendix B: Visual Impact Data Sheets

### B-1: Short-Term Data

#### Check List for the Basic Visual Assessments Historical Oil Painting 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:5/29/2015, by: Josh Nardin)									
Historical Oil Painting 1	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-A	0	0	0	0.5	0.5 top layer thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A:1									
Historical Oil Painting 2	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-B	0	0	0	0	0.5 corner thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0.5									
Historical Oil Painting 3	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-C	0.5 darker	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0.5									
Historical Oil Painting 4	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-D	0	0	0.5 lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0.5									
Historical Oil Painting 5	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 2.5									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Oil Painting 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:6/3/20015, by: Josh Nardin)									
Historical Oil Painting 1	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Oil Painting 2	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-B	0	0	0.5 lighter red coloration	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0.5									
Historical Oil Painting 3	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Historical Oil Painting 4	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Oil Painting 5	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0.5									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

**Check List for the Basic Visual Assessments Light Hue Monochromatic Pigment Oil Painting 30 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:5/29/2015, by: Josh Nardin)									
Light Hue Monochromatic Pigment Oil Painting 1	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Light Hue Monochromatic Pigment Oil Painting 2	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Light Hue Monochromatic Pigment Oil Painting 3	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Light Hue Monochromatic Pigment Oil Painting 4	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Light Hue Monochromatic Pigment Oil Painting 5	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

**Check List for the Basic Visual Assessments Light Hue Monochromatic Pigment Oil Painting 50 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
<b>1<sup>st</sup> visual assessment after sterilization (performed: 6/4/2015, by: Josh Nardin)</b>									
Light Hue Monochromatic Pigment Oil Painting 1	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-A	0	0	0.2 slightly darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: <b>0.2</b>									
Light Hue Monochromatic Pigment Oil Painting 2	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-B	0	0	0.5 slightly darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: <b>0.5</b>									
Light Hue Monochromatic Pigment Oil Painting 3	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: <b>0</b>									
Light Hue Monochromatic Pigment Oil Painting 4	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: <b>0</b>									
Light Hue Monochromatic Pigment Oil Painting 5	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-E	0	0	0.2 slightly darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: <b>0.2</b>									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): <b>0.9</b>									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, <0.5: ultra-low but perceptible change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

**Check List for the Basic Visual Assessments Light Dark Monochromatic Pigment Oil Painting 30 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
<b>1<sup>st</sup> visual assessment after sterilization (performed: 6/3/2015, by: Josh Nardin)</b>									
Dark Hue Monochromatic Pigment Oil Painting 1	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Dark Hue Monochromatic Pigment Oil Painting 2	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-B	1 more brown	0	1 lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 2									
Dark Hue Monochromatic Pigment Oil Painting 3	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-C	1 more brown	0	1 lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 2									
Dark Hue Monochromatic Pigment Oil Painting 4	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Dark Hue Monochromatic Pigment Oil Painting 5	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-E	0.5 slightly browner	0	0.5 slightly lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 1									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 5									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*



**Check List for the Basic Visual Assessments Light Dark Monochromatic Pigment Oil Painting 50 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:6/3/2015, by: Josh Nardin)									
Dark Hue Monochromatic Pigment Oil Painting 1	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Dark Hue Monochromatic Pigment Oil Painting 2	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Dark Hue Monochromatic Pigment Oil Painting 3	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Dark Hue Monochromatic Pigment Oil Painting 4	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Dark Hue Monochromatic Pigment Oil Painting 5	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1 –Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Documents 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 5/29/2015, by: Josh Nardin)									
Historical Document 1	30 kGy 5/18/2015	WA60-DS-GI-30kGy-A	0	0	0.1 slightly lighter backing	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0.1									
Historical Document 2	30 kGy 5/18/2015	WA60-DS-GI-30kGy-B	1 less yellow more gray	0	1 backing duller	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 2									
Historical Document 3	30 kGy 5/18/2015	WA60-DS-GI-30kGy-C	0	0	1 backing and script slightly lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C:1									
Historical Document 4	30 kGy 5/18/2015	WA60-DS-GI-30kGy-D	1 more brown	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D:1									
Historical Document 5	30 kGy 5/18/2015	WA60-DS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 4.1									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1 –Low level of change, 0.5 –Very low level of change, <0.5 –ultra-low but perceptible change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Documents 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 5/29/2015, by: Josh Nardin)									
Historical Document 1	50 kGy 5/17/2015	WA60-DS-GI-50kGy-A	0	0	0.2 backing slightly darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0.2									
Historical Document 2	50 kGy 5/17/2015	WA60-DS-GI-50kGy-B	0	0	0.5 lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0.5									
Historical Document 3	50 kGy 5/17/2015	WA60-DS-GI-50kGy-C	0	0	0.2 backing darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0.2									
Historical Document 4	50 kGy 5/17/2015	WA60-DS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Document 5	50 kGy 5/17/2015	WA60-DS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0.0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0.9									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1 –Low level of change, 0.5 –Very low level of change, <0.5 –ultra-low but perceptible change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Books 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 6/03/2015 , by: Josh Nardin)									
Historical Book 1	30 kGy 5/18/2015	WA60-BS-GI-30kGy-A	0	0	0.2 barely darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: <b>0.2</b>									
Historical Book 2	30 kGy 5/18/2015	WA60-BS-GI-30kGy-B	0.5 yellowier backing	0	0.5 brighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: <b>1</b>									
Historical Book 3	30 kGy 5/18/2015	WA60-BS-GI-30kGy-C	0.5 more yellow	0	0.5 brighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: <b>1</b>									
Historical Book 4	30 kGy 5/18/2015	WA60-BS-GI-30kGy-D	0	0	0.2 slightly duller	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: <b>0.2</b>									
Historical Book 5	30 kGy 5/18/2015	WA60-BS-GI-30kGy-E	0	0	0.2 brighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: <b>0.2</b>									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): <b>2.6</b>									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1 –Low level of change, 0.5 –Very low level of change, <0.5 –ultra-low but perceptible change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Books 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 6/03/2015, by: Josh Nardin)									
Historical Book 1	50 kGy 5/17/2015	WA60-BS-GI-50kGy-A	0.5 slightly darker brown	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0.5									
Historical Book 2	50 kGy 5/17/2015	WA60-BS-GI-50kGy-B	0	0	0.1 less yellow	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0.1									
Historical Book 3	50 kGy 5/17/2015	WA60-BS-GI-50kGy-C	0	0	0.1 slightly lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0.1									
Historical Book 4	50 kGy 5/17/2015	WA60-BS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Book 5	50 kGy 5/17/2015	WA60-BS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0.7									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1 –Low level of change, 0.5 –Very low level of change, <0.5 –ultra-low but perceptible change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Photographs 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 5/29/2015, by: Josh Nardin)									
Historical Photograph 1	30 kGy 5/18/2015	WA60-PS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Photograph 2	30 kGy 5/18/2015	WA60-PS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Photograph 3	30 kGy 5/18/2015	WA60-PS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Historical Photograph 4	30 kGy 5/18/2015	WA60-PS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Photograph 5	30 kGy 5/18/2015	WA60-PS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

**Check List for the Basic Visual Assessments Historical Photographs 50 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 6/3/2015, by: Josh Nardin)									
Historical Photograph 1	50 kGy 5/17/2015	WA60-PS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Photograph 2	50 kGy 5/17/2015	WA60-PS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Photograph 3	50 kGy 5/17/2015	WA60-PS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Historical Photograph 4	50 kGy 5/17/2015	WA60-PS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Photograph 5	50 kGy 5/17/2015	WA60-PS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Pastel Paintings 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:5/29/2015, by: Josh Nardin)									
Historical Pastel Painting 1	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-A	0	0	0.5	0	1.5 Top layer thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A:2									
Historical Pastel Painting 2	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-B	0	0	0	0	1.5 Top layer thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B:1.5									
Historical Pastel Painting 3	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-C	0	0	0	0	0.5	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C:0.5									
Historical Pastel Painting 4	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D:0									
Historical Pastel Painting 5	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-E	0	0	0	0	0.5	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E:0.5									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 4.5									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition



### Check List for the Basic Visual Assessments Historical Pastel Paintings 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
<b>1<sup>st</sup> visual assessment after sterilization (performed:6/3/2015, by: Josh Nardin)</b>									
Historical Pastel Painting 1	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-A	0	0	0.2	0	0.2 Thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: <b>0.4</b>									
Historical Pastel Painting 2	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-B	0	0	0	0	0.2 Thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: <b>0.2</b>									
Historical Pastel Painting 3	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-C	0	0	0	0	0.2	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: <b>0.2</b>									
Historical Pastel Painting 4	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: <b>0</b>									
Historical Pastel Painting 5	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-E	0	0	0	0	0.2 Thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: <b>0.2</b>									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): <b>1</b>									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1 –Low level of change, 0.5 –Very low level of change, <0.5 –ultra-low but perceptible change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Leather Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:5/29/2015, by: Josh Nardin)									
Historical Leather 1	30 kGy 5/18/2015	WA60-LS-GI-30kGy-A	1 lighter yellow	0	0.5 lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A:1.5									
Historical Leather 2	30 kGy 5/18/2015	WA60-LS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Leather 3	30 kGy 5/18/2015	WA60-LS-GI-30kGy-C	0.5 yellower	0	0.5 lighter	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C:1									
Historical Leather 4	30 kGy 5/18/2015	WA60-LS-GI-30kGy-D	0	0	0.5 lighter back	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0.5									
Historical Leather 5	30 kGy 5/18/2015	WA60-LS-GI-30kGy-E	0.5 lighter	0	0.5 lighter front	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E:1									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 4									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Leather Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 6/3/2015, by: Josh Nardin)									
Historical Leather 1	50 kGy 5/17/2015	WA60-LS-GI-50kGy-A	0	0	0	0	0.5 thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0.5									
Historical Leather 2	50 kGy 5/17/2015	WA60-LS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Leather 3	50 kGy 5/17/2015	WA60-LS-GI-50kGy-C	0.2 darker patches	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0.2									
Historical Leather 4	50 kGy 5/17/2015	WA60-LS-GI-50kGy-D	0	0	0	0	0.5 thinning	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0.5									
Historical Leather 5	50 kGy 5/17/2015	WA60-LS-GI-50kGy-E	0.5 strip of more orange color	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0.5									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 1.7									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1 –Low level of change, 0.5 –Very low level of change, <0.5 –ultra-low but perceptible change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Wood Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 5/29/2015, by: Josh Nardin)									
Historical Wood 1	30 kGy 5/18/2015	WA60-WS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Wood 2	30 kGy 5/18/2015	WA60-WS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Wood 3	30 kGy 5/18/2015	WA60-WS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Historical Wood 4	30 kGy 5/18/2015	WA60-WS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Wood 5	30 kGy 5/18/2015	WA60-WS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Wood Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 6/4/15, by: Josh Nardin)									
Historical Wood 1	50 kGy 5/17/2015	WA60-WS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Wood 2	50 kGy 5/17/2015	WA60-WS-GI-50kGy-B	0.5 shine	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0.5									
Historical Wood 3	50 kGy 5/17/2015	WA60-WS-GI-50kGy-C	0.5 shine	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0.5									
Historical Wood 4	50 kGy 5/17/2015	WA60-WS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Wood 5	50 kGy 5/17/2015	WA60-WS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 1									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Porcelain Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed: 5/29/2015, by: Josh Nardin)									
Historical Porcelain 1	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-A	3 turned greenish	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 3									
Historical Porcelain 2	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-B	3	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 3									
Historical Porcelain 3	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-C	3	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 3									
Historical Porcelain 4	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-D	3	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 3									
Historical Porcelain 5	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-E	3	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 3									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 15									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Porcelain Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
<b>1<sup>st</sup> visual assessment after sterilization (performed:6/4/2015, by: Josh Nardin)</b>									
Historical Porcelain 1	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-A	2 yellow/green	0	2 darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: <b>4</b>									
Historical Porcelain 2	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-B	2.5 yellow/green	0	2 darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: <b>4.5</b>									
Historical Porcelain 3	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-C	3 yellow/green	0	2.5 darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: <b>5.5</b>									
Historical Porcelain 4	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-D	2 yellow/green	0	1 darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: <b>3</b>									
Historical Porcelain 5	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-E	3 yellow/green	0	2 darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: <b>5</b>									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): <b>22</b>									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Fabric Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
<b>1<sup>st</sup> visual assessment after sterilization (performed:5/29/2015, by: Josh Nardin)</b>									
Historical Fabric 1	30 kGy 5/18/2015	WA60-FS-GI-30kGy-A	1 more purple	0	1 darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: <b>2</b>									
Historical Fabric 2	30 kGy 5/18/2015	WA60-FS-GI-30kGy-B	0.5 more purple	0	0.5 slightly darker	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: <b>1</b>									
Historical Fabric 3	30 kGy 5/18/2015	WA60-FS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: <b>0</b>									
Historical Fabric 4	30 kGy 5/18/2015	WA60-FS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: <b>0</b>									
Historical Fabric 5	30 kGy 5/18/2015	WA60-FS-GI-30kGy-E	0.5 slightly deeper gold	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: <b>0.5</b>									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): <b>3.5</b>									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*



### Check List for the Basic Visual Assessments Historical Fabric Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:6/3/2015, by: Josh Nardin)									
Historical Fabric 1	50 kGy 5/17/2015	WA60-FS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Fabric 2	50 kGy 5/17/2015	WA60-FS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Fabric 3	50 kGy 5/17/2015	WA60-FS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Historical Fabric 4	50 kGy 5/17/2015	WA60-FS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Fabric 5	50 kGy 5/17/2015	WA60-FS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

### Check List for the Basic Visual Assessments Historical Metal Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:5/29/2015, by: Josh Nardin)									
Historical Metal 1	30 kGy 5/18/2015	WA60-MS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Metal 2	30 kGy 5/18/2015	WA60-MS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Metal 3	30 kGy 5/18/2015	WA60-MS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Historical Metal 4	30 kGy 5/18/2015	WA60-MS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Metal 5	30 kGy 5/18/2015	WA60-MS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition

### Check List for the Basic Visual Assessments Historical Metal Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
1 <sup>st</sup> visual assessment after sterilization (performed:6/3/2015, by: Josh Nardin)									
Historical Metal 1	50 kGy 5/17/2015	WA60-MS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample A: 0									
Historical Metal 2	50 kGy 5/17/2015	WA60-MS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample B: 0									
Historical Metal 3	50 kGy 5/17/2015	WA60-MS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample C: 0									
Historical Metal 4	50 kGy 5/17/2015	WA60-MS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample D: 0									
Historical Metal 5	50 kGy 5/17/2015	WA60-MS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 1 <sup>st</sup> assessment sample E: 0									
Cumulative impact for 1 <sup>st</sup> assessment (n=5): 0									

*\*Grading system/descriptors for 1<sup>st</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to the baseline (pre-exposure) condition*

## Long-Term Data

### Check List for the Basic Visual Assessments Historical Oil Painting 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/5/2015, by: Josh Nardin)									
Historical Oil Painting 1	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-A	0	0	0	1	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A:1									
Historical Oil Painting 2	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-B	0	0	0	1	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B:1									
Historical Oil Painting 3	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-C	1	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C:1									
Historical Oil Painting 4	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Oil Painting 5	30 kGy 5/18/2015	WA60-OPS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 3									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment :5.5									

\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition

### Check List for the Basic Visual Assessments Historical Oil Painting 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed: 11/5/2015, by: Josh Nardin)									
Historical Oil Painting 1	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-A	1	0	0	0.5	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 1.5									
Historical Oil Painting 2	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-B	1 darker	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B:1									
Historical Oil Painting 3	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-C	0.5 lighter	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0.5									
Historical Oil Painting 4	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Oil Painting 5	50 kGy 5/17/2015	WA60-OPS-GI-50kGy-E	0.5 darker	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E:0.5									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 3.5									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment : 4									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

**Check List for the Basic Visual Assessments Historical Light Hue Monochromatic Pigment Oil  
Painting 30 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:10/28/2015, by :Josh Nardin)									
Light Hue Monochromatic Pigment Oil Painting 1	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-A	0.5	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A:1									
Light Hue Monochromatic Pigment Oil Painting 2	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Light Hue Monochromatic Pigment Oil Painting 3	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-C	0.5	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C:1									
Light Hue Monochromatic Pigment Oil Painting 4	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Light Hue Monochromatic Pigment Oil Painting 5	30 kGy 5/18/2015	WA60-OLT-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 2									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 2</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

**Check List for the Basic Visual Assessments Historical Light Hue Monochromatic Pigment Oil Painting 50 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:10/28/2015, by: Josh Nardin)									
Light Hue Monochromatic Pigment Oil Painting 1	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Light Hue Monochromatic Pigment Oil Painting 2	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-B	1 darker	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B:1									
Light Hue Monochromatic Pigment Oil Painting 3	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-C	0.5	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C:1									
Light Hue Monochromatic Pigment Oil Painting 4	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-D	0	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0.5									
Light Hue Monochromatic Pigment Oil Painting 5	50 kGy 5/17/2015	WA60-OLT-GI-50kGy-E	0	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0.5									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 3									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 3.9</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

**Check List for the Basic Visual Assessments Historical Dark Hue Monochromatic Pigment Oil Painting 30 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin)									
Dark Hue Monochromatic Pigment Oil Painting 1	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Dark Hue Monochromatic Pigment Oil Painting 2	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Dark Hue Monochromatic Pigment Oil Painting 3	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Dark Hue Monochromatic Pigment Oil Painting 4	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Dark Hue Monochromatic Pigment Oil Painting 5	30 kGy 5/18/2015	WA60-ODT-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 5</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*



**Check List for the Basic Visual Assessments Historical Dark Hue Monochromatic Pigment Oil Painting 50 kGy**

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin)									
Dark Hue Monochromatic Pigment Oil Painting 1	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Dark Hue Monochromatic Pigment Oil Painting 2	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-B	0	0	0	0	0.5	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0.5									
Dark Hue Monochromatic Pigment Oil Painting 3	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Dark Hue Monochromatic Pigment Oil Painting 4	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Dark Hue Monochromatic Pigment Oil Painting 5	50 kGy 5/17/2015	WA60-ODT-GI-50kGy-E	0	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0.5									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 1									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment :1</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Documents 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin)									
Historical Document 1	30 kGy 5/18/2015	WA60-DS-GI-30kGy-A	1	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A:1.5									
Historical Document 2	30 kGy 5/18/2015	WA60-DS-GI-30kGy-B	1	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B:1									
Historical Document 3	30 kGy 5/18/2015	WA60-DS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Document 4	30 kGy 5/18/2015	WA60-DS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Document 5	30 kGy 5/18/2015	WA60-DS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 2.5									

Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment : 6.6
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\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition

### Check List for the Basic Visual Assessments Historical Documents 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
<b>2<sup>nd</sup> visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin</b>									
Historical Document 1	50 kGy 5/17/2015	WA60-DS-GI-50kGy-A	1 lighter	0	0.5 font faded	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: <b>1.5</b>									
Historical Document 2	50 kGy 5/17/2015	WA60-DS-GI-50kGy-B	1	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: <b>1</b>									
Historical Document 3	50 kGy 5/17/2015	WA60-DS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: <b>0</b>									
Historical Document 4	50 kGy 5/17/2015	WA60-DS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: <b>0</b>									
Historical Document 5	50 kGy 5/17/2015	WA60-DS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: <b>0</b>									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): <b>2.5</b>									

Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment : <b>3.4</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Books 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/3/2015, by: Josh Nardin)									
Historical Book 1	30 kGy 5/18/2015	WA60-BS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Book 2	30 kGy 5/18/2015	WA60-BS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Book 3	30 kGy 5/18/2015	WA60-BS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Book 4	30 kGy 5/18/2015	WA60-BS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Book 5	30 kGy 5/18/2015	WA60-BS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment :2.6									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Books 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/3/2015, by: Josh Nardin)									
Historical Book 1	50 kGy 5/17/2015	WA60-BS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Book 2	50 kGy 5/17/2015	WA60-BS-GI-50kGy-B	0.5 darker	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0.5									
Historical Book 3	50 kGy 5/17/2015	WA60-BS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Book 4	50 kGy 5/17/2015	WA60-BS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Book 5	50 kGy 5/17/2015	WA60-BS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0.5									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 1.2</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Photographs 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin)									
Historical Photograph 1	30 kGy 5/18/2015	WA60-PS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Photograph 2	30 kGy 5/18/2015	WA60-PS-GI-30kGy-B	0	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0.5									
Historical Photograph 3	30 kGy 5/18/2015	WA60-PS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Photograph 4	30 kGy 5/18/2015	WA60-PS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Photograph 5	30 kGy 5/18/2015	WA60-PS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0.5									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment :0.5									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Photographs 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin)									
Historical Photograph 1	50 kGy 5/17/2015	WA60-PS-GI-50kGy-A	0	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0.5									
Historical Photograph 2	50 kGy 5/17/2015	WA60-PS-GI-50kGy-B	0	0	1 lighter	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B:1									
Historical Photograph 3	50 kGy 5/17/2015	WA60-PS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Photograph 4	50 kGy 5/17/2015	WA60-PS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Photograph 5	50 kGy 5/17/2015	WA60-PS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 1.5									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment :1.5</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Pastel Painting 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin)									
Historical Pastel Painting 1	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-A	0	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0.5									
Historical Pastel Painting 2	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Pastel Painting 3	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-C	1	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 1									
Historical Pastel Painting 4	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Pastel Painting 5	30 kGy 5/18/2015	WA60-PPS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 1.5									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 6</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*



### Check List for the Basic Visual Assessments Historical Pastel Painting 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2nd visual assessment after sterilization (performed:11/4/2015, by: Josh Nardin)									
Historical Pastel Painting 1	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-A	0	0	0.5	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0.5									
Historical Pastel Painting 2	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Pastel Painting 3	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-C	0	0	0.5 some fading	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0.5									
Historical Pastel Painting 4	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Pastel Painting 5	50 kGy 5/17/2015	WA60-PPS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 1									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 2</b>
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\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition

### Check List for the Basic Visual Assessments Historical Leather Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed: 11/2/2015, by: Josh Nardin)									
Historical Leather 1	30 kGy 5/18/2015	WA60-LS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Leather 2	30 kGy 5/18/2015	WA60-LS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Leather 3	30 kGy 5/18/2015	WA60-LS-GI-30kGy-C	0.5 lighter	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0.5									
Historical Leather 4	30 kGy 5/18/2015	WA60-LS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Leather 5	30 kGy 5/18/2015	WA60-LS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0.5									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 4.5</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Leather Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/2/2015, by: Josh Nardin)									
Historical Leather 1	50 kGy 5/17/2015	WA60-LS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Leather 2	50 kGy 5/17/2015	WA60-LS-GI-50kGy-B	0.5 lighter	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0.5									
Historical Leather 3	50 kGy 5/17/2015	WA60-LS-GI-50kGy-C	0.5 lighter	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0.5									
Historical Leather 4	50 kGy 5/17/2015	WA60-LS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Leather 5	50 kGy 5/17/2015	WA60-LS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 1									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 2.7</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Wood Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed: 11/2/2015, by: Josh Nardin)									
Historical Wood 1	30 kGy 5/18/2015	WA60-WS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Wood 2	30 kGy 5/18/2015	WA60-WS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Wood 3	30 kGy 5/18/2015	WA60-WS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Wood 4	30 kGy 5/18/2015	WA60-WS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Wood 5	30 kGy 5/18/2015	WA60-WS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment : 0									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Wood Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed: 11/2/2015, by: Josh Nardin)									
Historical Wood 1	50 kGy 5/17/2015	WA60-WS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Wood 2	50 kGy 5/17/2015	WA60-WS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Wood 3	50 kGy 5/17/2015	WA60-WS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Wood 4	50 kGy 5/17/2015	WA60-WS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Wood 5	50 kGy 5/17/2015	WA60-WS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment : 1									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Porcelain Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2nd visual assessment after sterilization (performed:11/3/15, by: Josh Nardin)									
Historical Porcelain 1	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-A	3	3	3	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A:9									
Historical Porcelain 2	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-B	3	3	3	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B:9									
Historical Porcelain 3	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-C	2	2	2	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C:6									
Historical Porcelain 4	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-D	3	3	3	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D:9									
Historical Porcelain 5	30 kGy 5/18/2015	WA60-PBS-GI-30kGy-E	3	3	3	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E:9									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 42									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment :57									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Porcelain Items 50 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/3/2015, by: Josh Nardin)									
Historical Porcelain 1	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-A	2	2	2	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A:6									
Historical Porcelain 2	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-B	3	3	3	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B:9									
Historical Porcelain 3	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-C	3	3	3	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C:9									
Historical Porcelain 4	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-D	2	2	2	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D:6									
Historical Porcelain 5	50 kGy 5/17/2015	WA60-PBS-GI-50kGy-E	3	3	3	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E:9									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 39									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment :61									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Fabric Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/5/2015, by: Josh Nardin)									
Historical Fabric 1	30 kGy 5/18/2015	WA60-FS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Fabric 2	30 kGy 5/18/2015	WA60-FS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Fabric 3	30 kGy 5/18/2015	WA60-FS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Fabric 4	30 kGy 5/18/2015	WA60-FS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Fabric 5	30 kGy 5/18/2015	WA60-FS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 3.5</b>
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*



### Check List for the Basic Visual Assessments Historical Fabric Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed:11/5/2015, by: Josh Nardin)									
Historical Fabric 1	50 kGy 5/17/2015	WA60-FS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Fabric 2	50 kGy 5/17/2015	WA60-FS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Fabric 3	50 kGy 5/17/2015	WA60-FS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Fabric 4	50 kGy 5/17/2015	WA60-FS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Fabric 5	50 kGy 5/17/2015	WA60-FS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0									

<b>Cumulative impact for 1<sup>st</sup> and 2<sup>nd</sup> assessment : 0</b>
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*\*High level of additional changes for 2<sup>nd</sup> assessment (3), Moderate level of additional changes for 2<sup>nd</sup> assessment (2), Low level of additional changes for 2<sup>nd</sup> assessment (1), Very low level of additional changes for 2<sup>nd</sup> assessment (0.5), No additional changes for 2<sup>nd</sup> assessment (0)*

### Check List for the Basic Visual Assessments Historical Metal Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
<b>2<sup>nd</sup> visual assessment after sterilization (performed: 11/4/2015, by: Josh Nardin)</b>									
Historical Metal 1	30 kGy 5/18/2015	WA60-MS-GI-30kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: <b>0</b>									
Historical Metal 2	30 kGy 5/18/2015	WA60-MS-GI-30kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: <b>0</b>									
Historical Metal 3	30 kGy 5/18/2015	WA60-MS-GI-30kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: <b>0</b>									
Historical Metal 4	30 kGy 5/18/2015	WA60-MS-GI-30kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: <b>0</b>									
Historical Metal 5	30 kGy 5/18/2015	WA60-MS-GI-30kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: <b>0</b>									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): <b>0</b>									
Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment : <b>0</b>									

*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

### Check List for the Basic Visual Assessments Historical Metal Items 30 kGy

Matrix	Test Date and Condition	Sample Code /Photodocumentation Code	Noticeable Change in the Physical Characteristics of Material Observed*						
			Color	Contrast	Fading	Cracking /Chipping	Brittleness /Thinning	Legibility	Odors
2 <sup>nd</sup> visual assessment after sterilization (performed: 11/4/2015, by: Josh Nardin)									
Historical Metal 1	50 kGy 5/17/2015	WA60-MS-GI-50kGy-A	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample A: 0									
Historical Metal 2	50 kGy 5/17/2015	WA60-MS-GI-50kGy-B	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample B: 0									
Historical Metal 3	50 kGy 5/17/2015	WA60-MS-GI-50kGy-C	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample C: 0									
Historical Metal 4	50 kGy 5/17/2015	WA60-MS-GI-50kGy-D	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample D: 0									
Historical Metal 5	50 kGy 5/17/2015	WA60-MS-GI-50kGy-E	0	0	0	0	0	0	0
Cumulative impact for 2 <sup>nd</sup> assessment sample E: 0									
Cumulative impact for 2 <sup>nd</sup> assessment (n=5): 0									

Cumulative impact for 1 <sup>st</sup> and 2 <sup>nd</sup> assessment : 0
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*\*Grading system/descriptors for 2<sup>nd</sup> visual assessment: 3 –high level of change, 2 –moderate level of change, 1–Low level of change, 0.5–Very low level of change, 0 –No change; relative change as compared to 1<sup>st</sup> visual assessment (short term post-exposure) condition*

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## **Appendix C: Short-Term and Long-term Technical Assessment Data**

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-BS-GI-30kGy-A	1.33	44.53	7.6	14.95	-1.02	0.82	-0.19	1.02 darker	0.19 more saturated	0.82 redder	0.82 redder	0.19 less yellow	0.29
WA60-BS-GI-30kGy-B	1.06	80.61	-0.13	11.68	0.98	-0.24	-0.33	0.98 lighter	0.33 less saturated	0.24 yellower	0.24 less red	0.33 less yellow	0.1
WA60-BS-GI-30kGy-C	0.9	82.58	1.25	16.82	0.45	-0.21	0.75	0.45 lighter	0.73 more saturated	0.27 yellower	0.21 less red	0.75 yellower	0.18
WA60-BS-GI-30kGy-D	1.29	80.72	0.41	13.91	1.13	-0.37	-0.5	1.13 lighter	0.52 less saturated	0.35 yellower	0.37 less red	0.50 less yellow	0.16
WA60-BS-GI-30kGy-E	1	72.47	2.13	18.62	0.9	0.08	-0.42	0.90 lighter	0.41 less saturated	0.13 redder	0.08 redder	0.42 less yellow	0.11
WA60-BS-GI-50kGy-A	1.21	52.46	8.38	21.32	1.01	0	0.66	1.01 lighter	0.62 more saturated	0.24 yellower	0.00 redder	0.66 yellower	0.1
WA60-BS-GI-50kGy-B	0.81	80.54	-0.17	11.56	0.56	-0.32	-0.48	0.56 lighter	0.48 less saturated	0.32 yellower	0.32 less red	0.48 less yellow	0.14
WA60-BS-GI-50kGy-C	0.68	82.9	1.28	15.91	0.61	-0.28	-0.11	0.61 lighter	0.13 less saturated	0.27 yellower	0.28 less red	0.11 less yellow	0.09
WA60-BS-GI-50kGy-D	1.05	80.95	0.04	13	0.89	-0.42	-0.36	0.89 lighter	0.37 less saturated	0.41 yellower	0.42 less red	0.36 less yellow	0.14
WA60-BS-GI-50kGy-E	1.28	70.96	-3.03	28.25	-0.09	-1.12	-0.61	0.09 darker	0.51 less saturated	1.17 greener	1.12 greener	0.61 less yellow	0.3

### 30 and 50 kGy Short-Term Assessment Historical Book Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-DS-GI-30kGy-A	0.77	77.89	-2.32	4.57	0.57	0.19	0.48	0.57 lighter	0.33 more saturated	0.40 yellower	0.19 less green	0.48 yellower	0.15
WA60-DS-GI-30kGy-B	2.06	81.52	0.21	15.91	-0.95	0.11	-1.82	0.95 darker	1.82 less saturated	0.13 redder	0.11 redder	1.82 less yellow	0.34
WA60-DS-GI-30kGy-C	1.31	85.35	-0.62	15.07	1.01	-0.73	-0.39	1.01 lighter	0.38 less saturated	0.74 yellower	0.73 less red	0.39 less yellow	0.23
WA60-DS-GI-30kGy-D	1.1	80.16	0.8	15.93	0.88	-0.39	-0.53	0.88 lighter	0.56 less saturated	0.35 yellower	0.39 less red	0.53 less yellow	0.16
WA60-DS-GI-30kGy-E	1.38	70.5	1.45	14.19	1.19	-0.53	-0.46	1.19 lighter	0.52 less saturated	0.47 yellower	0.53 less red	0.46 less yellow	0.18
WA60-DS-GI-50kGy-A	1.36	78.41	-2.16	5.11	1.05	0.18	0.84	1.05 lighter	0.68 more saturated	0.53 yellower	0.18 less green	0.84 yellower	0.25
WA60-DS-GI-50kGy-B	1.24	83.99	0.39	16.76	0.72	-0.05	-1	0.72 lighter	1.00 less saturated	0.03 yellower	0.05 less red	1.00 less yellow	0.18
WA60-DS-GI-50kGy-C	1.24	85.02	-0.63	15.4	0.84	-0.83	-0.37	0.84 lighter	0.36 less saturated	0.84 yellower	0.83 less red	0.37 less yellow	0.26
WA60-DS-GI-50kGy-D	0.47	74.42	3.31	20.3	-0.13	-0.13	0.43	0.13 darker	0.40 more saturated	0.20 yellower	0.13 less red	0.43 yellower	0.12
WA60-DS-GI-50kGy-E	0.8	70.28	1.53	14.1	0.75	-0.26	0.13	0.75 lighter	0.10 more saturated	0.27 yellower	0.26 less red	0.13 yellower	0.1

### 30 and 50 kGy Short-Term Assessment Historical Document Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-PS-GI-50kGy-A	0.19	72.39	0.77	17.31	0.14	-0.05	-0.12	0.14 lighter	0.12 less saturated	0.04 yellower	0.05 less red	0.12 less yellow	0.02
WA60-PS-GI-50kGy-B	1.48	64.4	0.09	6	-0.77	-0.66	-1.08	0.77 darker	1.12 less saturated	0.59 yellower	0.66 less red	1.08 less yellow	0.32
WA60-PS-GI-50kGy-C	1.26	74.21	-0.34	12.06	0.96	-0.31	-0.75	0.96 lighter	0.74 less saturated	0.32 greener	0.31 greener	0.75 less yellow	0.18
WA60-PS-GI-50kGy-D	1.51	50.28	0.23	5.77	1.49	-0.2	0.15	1.49 lighter	0.14 more saturated	0.21 yellower	0.20 less red	0.15 yellower	0.09
WA60-PS-GI-50kGy-E	0.26	45.61	-0.01	6.52	0.06	0.04	-0.25	0.06 lighter	0.25 less saturated	0.04 yellower	0.04 less green	0.25 less yellow	0.03
WA60-PS-GI-30kGy-A	0.85	70.6	0.68	17.62	-0.85	-0.03	0.04	0.85 darker	0.04 more saturated	0.03 yellower	0.03 less red	0.04 yellower	0
WA60-PS-GI-30kGy-B	1.06	49.69	-0.25	4.94	-0.75	-0.17	-0.73	0.75 darker	0.73 less saturated	0.19 greener	0.17 greener	0.73 less yellow	0.21
WA60-PS-GI-30kGy-C	1.42	64.21	0.69	14.81	-1.3	-0.39	-0.43	1.30 darker	0.45 less saturated	0.37 yellower	0.39 less red	0.43 less yellow	0.15
WA60-PS-GI-30kGy-D	0.56	46.88	0.26	5.28	0.48	-0.17	0.23	0.48 lighter	0.21 more saturated	0.19 yellower	0.17 less red	0.23 yellower	0.07
WA60-PS-GI-30kGy-E	0.88	57.05	-0.2	9.69	0.6	-0.09	-0.64	0.60 lighter	0.64 less saturated	0.10 greener	0.09 greener	0.64 less yellow	0.13

### 30 and 50 kGy Short-Term Assessment Historical Photo Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-OLT-GI-30kGy-A	1.38	34.39	39.51	14.42	0.96	-0.94	0.3	0.96 lighter	0.78 less saturated	0.60 yellower	0.94 less red	0.30 yellower	0.31
WA60-OLT-GI-30kGy-B	1.41	32.2	35.8	12.37	1.2	-0.35	0.65	1.20 lighter	0.12 less saturated	0.73 yellower	0.35 less red	0.65 yellower	0.22
WA60-OLT-GI-30kGy-C	1.34	33.06	35.99	12.65	1.17	0.03	0.66	1.17 lighter	0.24 more saturated	0.61 yellower	0.03 redder	0.66 yellower	0.22
WA60-OLT-GI-30kGy-D	1.56	33.61	38.46	13.98	0.95	0.45	1.16	0.95 lighter	0.81 more saturated	0.94 yellower	0.45 redder	1.16 yellower	0.12
WA60-OLT-GI-30kGy-E	1.03	33.52	38.16	13.77	0.64	-0.33	0.74	0.64 lighter	0.07 less saturated	0.80 yellower	0.33 less red	0.74 yellower	0.11
WA60-OLT-GI-50kGy-A	3.25	32.61	35.97	12.93	0.79	-3.02	-0.9	0.79 lighter	3.15 less saturated	0.17 yellower	3.02 less red	0.90 less yellow	0.87
WA60-OLT-GI-50kGy-B	3.37	30.36	29.44	9.59	0.63	-3.24	-0.71	0.63 lighter	3.30 less saturated	0.31 yellower	3.24 less red	0.71 less yellow	0.92
WA60-OLT-GI-50kGy-C	3.36	34.11	37.09	13.41	-0.23	-3.2	-1	0.23 darker	3.35 less saturated	0.14 yellower	3.20 less red	1.00 less yellow	0.9
WA60-OLT-GI-50kGy-D	3.14	33.76	35.52	12.83	0.13	-3.06	-0.69	0.13 lighter	3.12 less saturated	0.38 yellower	3.06 less red	0.69 less yellow	0.86
WA60-OLT-GI-50kGy-E	3.11	32.62	35.02	12.32	0.17	-3.04	-0.67	0.17 lighter	3.09 less saturated	0.36 yellower	3.04 less red	0.67 less yellow	0.85

### 30 and 50 kGy Short-Term Assessment Oil Painting Light Hue Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-ODT-GI-30kGy-A	1.35	30.46	3.17	4.44	1.27	-0.35	-0.28	1.27 lighter	0.44 less saturated	0.12 yellower	0.35 less red	0.28 less yellow	0.14
WA60-ODT-GI-30kGy-B	2.31	30.03	3.15	4.1	2.27	-0.31	0.25	2.27 lighter	0.00 less saturated	0.40 yellower	0.31 less red	0.25 yellower	0.07
WA60-ODT-GI-30kGy-C	1.51	28.45	2.46	3.15	-0.47	-1.08	-0.95	0.47 darker	1.42 less saturated	0.23 yellower	1.08 less red	0.95 less yellow	0.45
WA60-ODT-GI-30kGy-D	1.72	26.92	1.79	1.86	1.24	-1.13	0.38	1.24 lighter	0.69 less saturated	0.97 yellower	1.13 less red	0.38 yellower	0.27
WA60-ODT-GI-30kGy-E	1.06	29.83	3.19	4.21	0.44	-0.78	0.58	0.44 lighter	0.09 less saturated	0.96 yellower	0.78 less red	0.58 yellower	0.19
WA60-ODT-GI-50kGy-A	1.85	27.75	2.12	2.2	1.72	-0.17	0.65	1.72 lighter	0.29 more saturated	0.60 yellower	0.17 less red	0.65 yellower	0.19
WA60-ODT-GI-50kGy-B	1.69	28.17	2.26	2.31	1.64	-0.18	0.36	1.64 lighter	0.10 more saturated	0.39 yellower	0.18 less red	0.36 yellower	0.09
WA60-ODT-GI-50kGy-C	2.03	27.8	2.38	2.99	1.76	0	1.02	1.76 lighter	0.73 more saturated	0.71 yellower	0.00 less red	1.02 yellower	0.29
WA60-ODT-GI-50kGy-D	1.46	29.28	2.81	3.26	1.38	-0.36	0.33	1.38 lighter	0.01 less saturated	0.49 yellower	0.36 less red	0.33 yellower	0.1
WA60-ODT-GI-50kGy-E	0.78	28.04	2.24	3.01	0.08	-0.67	-0.39	0.08 lighter	0.72 less saturated	0.28 yellower	0.67 less red	0.39 less yellow	0.24

### 30 and 50 kGy Short-Term Assessment Oil painting Dark Hue Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-OPS-GI-30kGy-A	1.41	51.11	-0.75	8.4	0.98	-0.85	0.55	0.98 lighter	0.58 more saturated	0.83 yellower	0.85 less red	0.55 yellower	0.18
WA60-OPS-GI-30kGy-B	0.7	34.35	8.55	11.54	0.64	-0.21	0.18	0.64 lighter	0.02 more saturated	0.28 yellower	0.21 less red	0.18 yellower	0.04
WA60-OPS-GI-30kGy-C	0.69	29.35	1.8	2.01	0.66	0.01	0.2	0.66 lighter	0.15 more saturated	0.13 yellower	0.01 redder	0.20 yellower	0.05
WA60-OPS-GI-30kGy-D	0.91	50.07	8.97	30.16	0.85	-0.31	0.15	0.85 lighter	0.05 more saturated	0.34 yellower	0.31 less red	0.15 yellower	0.1
WA60-OPS-GI-30kGy-E	1.19	56.68	-3.54	16.26	-1.19	-0.08	0.11	1.19 darker	0.13 more saturated	0.06 greener	0.08 greener	0.11 yellower	0.11
WA60-OPS-GI-50kGy-A	2.01	48.03	5.57	0.27	0.99	1.08	-1.37	0.99 lighter	0.79 more saturated	1.56 redder	1.08 redder	1.37 less yellow	0.3
WA60-OPS-GI-50kGy-B	3.26	41.87	13.11	25.34	1.97	1.29	2.26	1.97 lighter	2.60 more saturated	0.12 redder	1.29 redder	2.26 yellower	0.4
WA60-OPS-GI-50kGy-C	0.36	26.69	1.93	1.97	-0.22	-0.25	-0.14	0.22 darker	0.28 less saturated	0.07 yellower	0.25 less red	0.14 less yellow	0.09
WA60-OPS-GI-50kGy-D	1.85	50.27	9.01	31.21	1.32	-0.32	1.24	1.32 lighter	1.10 more saturated	0.67 yellower	0.32 less red	1.24 yellower	0.22
WA60-OPS-GI-50kGy-E	1.54	54.22	-0.91	16.03	0.23	0.41	1.47	0.23 lighter	1.43 more saturated	0.52 yellower	0.41 less green	1.47 yellower	0.26

### 30 and 50 kGy Short-Term Assessment Historical Oil Painting Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-WS-GI-30kGy-A	4.04	27.89	15.23	12.65	3.27	-1.67	1.69	3.27 lighter	0.34 less saturated	2.35 yellower	1.67 less red	1.69 yellower	0.48
WA60-WS-GI-30kGy-B	3.91	25.6	15.6	10.66	-0.69	-1.65	-3.48	0.69 darker	3.41 less saturated	1.79 redder	1.65 less red	3.48 less yellow	0.54
WA60-WS-GI-30kGy-C	2.41	26.14	14.32	10.62	1.71	-1.55	-0.71	1.71 lighter	1.67 less saturated	0.34 yellower	1.55 less red	0.71 less yellow	0.42
WA60-WS-GI-30kGy-D	2.43	27.42	15.67	11.45	1.39	-1.85	-0.73	1.39 lighter	1.93 less saturated	0.48 yellower	1.85 less red	0.73 less yellow	0.51
WA60-WS-GI-30kGy-E	2.94	26.35	14.92	10.91	1.97	-1.7	-1.37	1.97 lighter	2.18 less saturated	0.10 redder	1.70 less red	1.37 less yellow	0.48
WA60-WS-GI-50kGy-A	2.11	26.49	16.87	12.69	1.55	-1.13	-0.87	1.55 lighter	1.42 less saturated	0.02 redder	1.13 less red	0.87 less yellow	0.32
WA60-WS-GI-50kGy-B	3.09	27.63	17.83	13.52	2.37	-1.23	-1.55	2.37 lighter	1.92 less saturated	0.47 redder	1.23 less red	1.55 less yellow	0.35
WA60-WS-GI-50kGy-C	1.57	26.34	16.53	12.22	1.35	-0.77	-0.22	1.35 lighter	0.75 less saturated	0.27 yellower	0.77 less red	0.22 less yellow	0.23
WA60-WS-GI-50kGy-D	1.51	27.06	19.22	14.98	0.94	-0.81	-0.85	0.94 lighter	1.16 less saturated	0.17 redder	0.81 less red	0.85 less yellow	0.23
WA60-WS-GI-50kGy-E	2.21	26.26	13.48	9.99	1.34	-1.45	-1	1.34 lighter	1.76 less saturated	0.05 yellower	1.45 less red	1.00 less yellow	0.39

### 30 and 50 kGy Short-Term Assessment Historical Wood Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-LS-GI-30kGy-A	1.42	40.09	16	26.36	-0.33	-0.65	-1.21	0.33 darker	1.37 less saturated	0.07 redder	0.65 less red	1.21 less yellow	0.19
WA60-LS-GI-30kGy-B	0.64	40.29	17.03	24.04	-0.51	0.02	-0.37	0.51 darker	0.29 less saturated	0.23 redder	0.02 redder	0.37 less yellow	0.07
WA60-LS-GI-30kGy-C	0.9	41.66	16.02	27.69	-0.65	-0.05	-0.62	0.65 darker	0.56 less saturated	0.27 redder	0.05 less red	0.62 less yellow	0.08
WA60-LS-GI-30kGy-D	1.5	40.21	17.92	25.67	-0.71	-0.33	-1.28	0.71 darker	1.24 less saturated	0.46 redder	0.33 less red	1.28 less yellow	0.14
WA60-LS-GI-30kGy-E	0.88	49.49	12.44	18.47	-0.23	-0.68	-0.5	0.23 darker	0.80 less saturated	0.28 yellower	0.68 less red	0.50 less yellow	0.2
WA60-LS-GI-50kGy-A	1.61	40.74	17.14	25.65	-0.58	-0.78	-1.29	0.58 darker	1.51 less saturated	0.07 redder	0.78 less red	1.29 less yellow	0.24
WA60-LS-GI-50kGy-B	1.84	42.92	15.35	27.61	-0.36	-1.06	-1.46	0.36 darker	1.79 less saturated	0.21 yellower	1.06 less red	1.46 less yellow	0.3
WA60-LS-GI-50kGy-C	0.79	39.61	15.82	25.39	-0.5	-0.23	-0.57	0.50 darker	0.60 less saturated	0.10 redder	0.23 less red	0.57 less yellow	0.09
WA60-LS-GI-50kGy-D	1.51	40.09	17.24	23.99	-0.56	-0.83	-1.12	0.56 darker	1.40 less saturated	0.02 yellower	0.83 less red	1.12 less yellow	0.25
WA60-LS-GI-50kGy-E	0.8	47.97	13.53	20.04	-0.5	-0.56	-0.27	0.50 darker	0.53 less saturated	0.31 yellower	0.56 less red	0.27 less yellow	0.16

### 30 and 50 kGy Short-Term Assessment Historical Leather Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-MS-GI-30kGy-A	1.13	37.79	1.97	14.58	1.01	0.18	0.46	1.01 lighter	0.48 more saturated	0.12 redder	0.18 redder	0.46 yellower	0.12
WA60-MS-GI-30kGy-B	0.9	34.6	1.71	13.83	0.88	0.2	0.03	0.88 lighter	0.05 more saturated	0.20 redder	0.20 redder	0.03 yellower	0.06
WA60-MS-GI-30kGy-C	1.9	37	2.72	14.81	1.74	0.2	0.74	1.74 lighter	0.77 more saturated	0.06 redder	0.20 redder	0.74 yellower	0.16
WA60-MS-GI-30kGy-D	0.88	36.43	1.93	13.87	0.87	0.12	0	0.87 lighter	0.01 more saturated	0.12 redder	0.12 redder	0.00 less yellow	0.04
WA60-MS-GI-30kGy-E	1.86	38.28	1.98	14.96	1.82	0.13	0.34	1.82 lighter	0.35 more saturated	0.08 redder	0.13 redder	0.34 yellower	0.1
WA60-MS-GI-50kGy-A	1.21	36.71	3.18	14.09	1.18	0.05	0.3	1.18 lighter	0.30 more saturated	0.01 yellower	0.05 redder	0.30 yellower	0.07
WA60-MS-GI-50kGy-B	2.78	36.11	2.13	14.17	2.68	0.2	0.71	2.68 lighter	0.73 more saturated	0.09 redder	0.20 redder	0.71 yellower	0.17
WA60-MS-GI-50kGy-C	1.43	35.99	2.06	14.57	1.29	0.03	0.62	1.29 lighter	0.62 more saturated	0.06 yellower	0.03 redder	0.62 yellower	0.14
WA60-MS-GI-50kGy-D	1.76	35.98	2.17	14.42	1.34	-0.02	1.14	1.34 lighter	1.12 more saturated	0.20 yellower	0.02 less red	1.14 yellower	0.24
WA60-MS-GI-50kGy-E	1.66	35.31	2.68	14.48	1.46	0.47	0.63	1.46 lighter	0.70 more saturated	0.36 redder	0.47 redder	0.63 yellower	0.18

### 30 and 50 kGy Short-Term Assessment Historical Metal Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-PBS-GI-50kGy-A	16	72.96	-3.83	13.63	-11.11	-1.63	11.4	11.11 darker	11.03 more saturated	3.32 yellower	1.63 greener	11.40 yellower	3.39
WA60-PBS-GI-50kGy-B	21.67	68.45	-4.04	16.82	-15.33	-1.83	15.21	15.33 darker	14.56 more saturated	4.75 yellower	1.83 greener	15.21 yellower	4.37
WA60-PBS-GI-50kGy-C	24.82	67.72	-4.04	18.73	-17.52	-1.81	17.49	17.52 darker	16.61 more saturated	5.78 yellower	1.81 greener	17.49 yellower	4.92
WA60-PBS-GI-50kGy-D	17.4	71.16	-4.27	14.81	-11.7	-1.95	12.73	11.70 darker	12.30 more saturated	3.81 yellower	1.95 greener	12.73 yellower	3.71
WA60-PBS-GI-50kGy-E	28.45	65.62	-5.39	22.46	-17.64	-3.11	22.1	17.64 darker	20.79 more saturated	8.12 yellower	3.11 greener	22.10 yellower	6.01
WA60-PBS-GI-30kGy-A	23.89	68.23	-4.57	18.81	-15.43	-2.31	18.09	15.43 darker	16.97 more saturated	6.66 yellower	2.31 greener	18.09 yellower	5.14
WA60-PBS-GI-30kGy-B	22.72	68.04	-4.09	14.01	-18.42	-1.75	13.18	18.42 darker	12.12 more saturated	5.48 yellower	1.75 greener	13.18 yellower	4.03
WA60-PBS-GI-30kGy-C	16.22	68.67	-3.04	9.27	-14.04	-0.74	8.1	14.04 darker	7.17 more saturated	3.83 yellower	0.74 greener	8.10 yellower	2.67
WA60-PBS-GI-30kGy-D	22.36	71.12	-5.16	18.88	-13.96	-2.98	17.21	13.96 darker	16.83 more saturated	4.69 yellower	2.98 greener	17.21 yellower	4.88
WA60-PBS-GI-30kGy-E	24.41	69.43	-5.37	20.39	-15.2	-3.18	18.83	15.20 darker	18.40 more saturated	5.13 yellower	3.18 greener	18.83 yellower	5.25

### 30 and 50 kGy Short-Term Assessment Historical Porcelain Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-FS-GI-30kGy-A	2.92	35.37	26.53	-30.06	1.22	-1.9	1.85	1.22 lighter	2.65 less saturated	0.20 bluer	1.90 less red	1.85 less blue	0.42
WA60-FS-GI-30kGy-B	4.32	35.34	25.35	-29.06	0.17	2.26	-3.67	0.17 lighter	4.25 more saturated	0.75 bluer	2.26 redder	3.67 bluer	1.42
WA60-FS-GI-30kGy-C	0.96	65.93	-17.18	-4.77	0.76	0.59	-0.01	0.76 lighter	0.57 less saturated	0.16 bluer	0.59 less green	0.01 bluer	0.15
WA60-FS-GI-30kGy-D	1.47	67.49	-16.78	-4.14	1.07	0.83	0.55	1.07 lighter	0.94 less saturated	0.33 greener	0.83 less green	0.55 less blue	0.32
WA60-FS-GI-30kGy-E	0.64	80.31	1.87	14.11	-0.09	0.58	-0.26	0.09 darker	0.20 less saturated	0.60 redder	0.58 redder	0.26 less yellow	0.14
WA60-FS-GI-50kGy-A	3.25	34.79	26.74	-30.37	0.3	1.74	-2.73	0.30 lighter	3.20 more saturated	0.53 bluer	1.74 redder	2.73 bluer	1.06
WA60-FS-GI-50kGy-B	2.59	36.74	21.68	-24.35	1.67	-1.21	1.57	1.67 lighter	1.98 less saturated	0.13 redder	1.21 less red	1.57 less blue	0.44
WA60-FS-GI-50kGy-C	0.98	66.71	-16.74	-3.68	0.76	0.55	0.29	0.76 lighter	0.60 less saturated	0.17 greener	0.55 less green	0.29 less blue	0.2
WA60-FS-GI-50kGy-D	1.07	67.81	-17.7	-4.99	0.94	0.48	0.16	0.94 lighter	0.51 less saturated	0.02 greener	0.48 less green	0.16 less blue	0.15
WA60-FS-GI-50kGy-E	0.74	80.26	1.89	14.69	0.4	0.48	0.4	0.40 lighter	0.45 more saturated	0.43 redder	0.48 redder	0.40 yellower	0.17

### 30 and 50 kGy Short-Term Assessment Historical Fabric Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-PPS-GI-30kGy-A	0.8	71.09	-3.37	12.05	0.44	0.61	-0.29	0.44 lighter	0.45 less saturated	0.50 yellower	0.61 less green	0.29 less yellow	0.14
WA60-PPS-GI-30kGy-B	1.84	52.75	9.01	11.34	1.09	-1.44	0.34	1.09 lighter	0.69 less saturated	1.31 yellower	1.44 less red	0.34 yellower	0.36
WA60-PPS-GI-30kGy-C	0.52	76.97	-1.66	11.4	0.46	-0.12	-0.21	0.46 lighter	0.19 less saturated	0.14 greener	0.12 greener	0.21 less yellow	0.06
WA60-PPS-GI-30kGy-D	2.19	56.76	0.2	0.71	2.17	-0.21	0.23	2.17 lighter	0.10 more saturated	0.29 yellower	0.21 less red	0.23 yellower	0.05
WA60-PPS-GI-30kGy-E	0.48	77.3	-0.67	13.6	-0.33	-0.02	-0.35	0.33 darker	0.35 less saturated	0.04 greener	0.02 greener	0.35 less yellow	0.04
WA60-PPS-GI-50kGy-A	1.36	71.84	-1.14	13.63	0.59	-0.63	1.05	0.59 lighter	1.08 more saturated	0.57 greener	0.63 greener	1.05 yellower	0.29
WA60-PPS-GI-50kGy-B	1.32	53.21	4.28	9.47	1.27	-0.34	0.14	1.27 lighter	0.02 less saturated	0.36 yellower	0.34 less red	0.14 yellower	0.08
WA60-PPS-GI-50kGy-C	0.47	77.08	-3.39	6.22	-0.46	-0.03	-0.12	0.46 darker	0.09 less saturated	0.09 greener	0.03 greener	0.12 less yellow	0.03
WA60-PPS-GI-50kGy-D	1.23	67.89	-0.2	2.7	1.23	0.09	0.06	1.23 lighter	0.06 more saturated	0.10 yellower	0.09 less green	0.06 yellower	0.03
WA60-PPS-GI-50kGy-E	0.92	78.05	-0.25	11.14	0.81	0.1	-0.42	0.81 lighter	0.43 less saturated	0.09 yellower	0.10 less green	0.42 less yellow	0.08

### 30 and 50 kGy Short-Term Assessment Historical Pastel Painting Technical Data



Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-BS-GI-30kGy-A	5.15	46.95	10.98	17.77	1.39	4.21	2.63	1.39 lighter	4.30 more saturated	2.47 redder	4.21 redder	2.63 yellower	1.04
WA60-BS-GI-30kGy-B	0.83	79.99	0.14	12.75	0.36	0.03	0.75	0.36 lighter	0.75 more saturated	0.02 redder	0.03 redder	0.75 yellower	0.22
WA60-BS-GI-30kGy-C	0.63	81.82	1.35	16.61	-0.31	-0.11	0.54	0.31 darker	0.53 more saturated	0.15 yellower	0.11 less red	0.54 yellower	0.11
WA60-BS-GI-30kGy-D	1.19	80.40	1.09	15.22	0.81	0.32	0.81	0.81 lighter	0.83 more saturated	0.26 redder	0.32 redder	0.81 yellower	0.25
WA60-BS-GI-30kGy-E	1.78	71.20	3.79	19.20	-0.37	1.73	0.16	0.37 darker	0.42 more saturated	1.69 redder	1.73 redder	0.16 yellower	0.42
WA60-BS-GI-50kGy-A	1.99	51.66	8.19	22.63	0.22	-0.19	1.97	0.22 lighter	1.77 more saturated	0.88 yellower	0.19 less red	1.97 yellower	0.33
WA60-BS-GI-50kGy-B	0.79	79.93	0.17	12.84	-0.05	0.02	0.79	0.05 darker	0.79 more saturated	0.01 redder	0.02 redder	0.79 yellower	0.22
WA60-BS-GI-50kGy-C	1.19	82.82	1.52	17.09	0.52	-0.04	1.07	0.52 lighter	1.06 more saturated	0.14 yellower	0.04 less red	1.07 yellower	0.22
WA60-BS-GI-50kGy-D	1.57	79.81	0.70	14.89	-0.25	0.25	1.53	0.25 darker	1.54 more saturated	0.19 redder	0.25 redder	1.53 yellower	0.41
WA60-BS-GI-50kGy-E	2.20	70.70	-3.88	29.78	-0.35	-1.97	0.92	0.35 darker	1.11 more saturated	1.87 greener	1.97 greener	0.92 yellower	0.65

### 30 and 50 kGy Long-Term Assessment Historical Book Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-DS-GI-30kGy-A	1.88	75.68	-2.62	5.00	-1.64	-0.12	0.91	1.64 darker	0.85 more saturated	0.35 yellower	0.12 greener	0.91 yellower	0.24
WA60-DS-GI-30kGy-B	0.89	82.12	0.92	17.70	-0.35	0.82	-0.04	0.35 darker	0.01 less saturated	0.82 redder	0.82 redder	0.04 less yellow	0.17
WA60-DS-GI-30kGy-C	2.25	86.42	0.34	16.29	2.08	0.22	0.83	2.08 lighter	0.83 more saturated	0.21 redder	0.22 redder	0.83 yellower	0.24
WA60-DS-GI-30kGy-D	1.03	78.66	1.34	17.28	-0.62	0.15	0.82	0.62 darker	0.82 more saturated	0.09 redder	0.15 redder	0.82 yellower	0.27
WA60-DS-GI-30kGy-E	1.19	68.19	1.88	15.04	-1.12	-0.10	0.39	1.12 darker	0.37 more saturated	0.14 yellower	0.10 less red	0.39 yellower	0.14
WA60-DS-GI-50kGy-A	2.39	77.40	-2.24	6.66	0.04	0.10	2.38	0.04 lighter	2.15 more saturated	1.04 yellower	0.10 less green	2.38 yellower	0.66
WA60-DS-GI-50kGy-B	1.46	83.94	1.31	18.72	0.68	0.87	0.95	0.68 lighter	0.99 more saturated	0.82 redder	0.87 redder	0.95 yellower	0.34
WA60-DS-GI-50kGy-C	2.41	85.07	0.43	18.00	0.89	0.23	2.23	0.89 lighter	2.23 more saturated	0.19 redder	0.23 redder	2.23 yellower	0.62
WA60-DS-GI-50kGy-D	1.64	73.94	3.87	21.33	-0.61	0.43	1.46	0.61 darker	1.51 more saturated	0.17 redder	0.43 redder	1.46 yellower	0.38
WA60-DS-GI-50kGy-E	0.83	68.86	1.67	14.43	-0.67	-0.12	0.47	0.67 darker	0.45 more saturated	0.18 yellower	0.12 less red	0.47 yellower	0.18

### 30 and 50 kGy Long-Term Assessment Historical Document Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-PS-GI-50kGy-A	5.42	66.26	0.88	19.15	-5.19	0.18	1.57	5.19 darker	1.58 more saturated	0.11 redder	0.18 redder	1.57 yellower	0.25
WA60-PS-GI-50kGy-B	4.44	46.05	-0.38	5.11	-4.39	-0.30	-0.57	4.39 darker	0.56 less saturated	0.33 greener	0.30 greener	0.57 less yellow	0.21
WA60-PS-GI-50kGy-C	2.96	68.10	0.58	16.58	2.59	-0.51	1.34	2.59 lighter	1.31 more saturated	0.57 yellower	0.51 less red	1.34 yellower	0.37
WA60-PS-GI-50kGy-D	1.53	47.49	0.13	6.08	1.09	-0.30	1.03	1.09 lighter	1.01 more saturated	0.36 yellower	0.30 less red	1.03 yellower	0.27
WA60-PS-GI-50kGy-E	2.65	54.11	-0.53	11.50	-2.34	-0.42	1.16	2.34 darker	1.18 more saturated	0.38 greener	0.42 greener	1.16 yellower	0.25
WA60-PS-GI-30kGy-A	5.65	66.83	0.99	19.03	-5.41	0.17	1.60	5.41 darker	1.60 more saturated	0.09 redder	0.17 redder	1.60 yellower	0.27
WA60-PS-GI-30kGy-B	5.83	59.40	0.16	6.49	-5.77	-0.59	-0.58	5.77 darker	0.62 less saturated	0.55 yellower	0.59 less red	0.58 less yellow	0.25
WA60-PS-GI-30kGy-C	0.84	74.06	-0.20	12.78	0.82	-0.17	-0.03	0.82 lighter	0.03 less saturated	0.17 greener	0.17 greener	0.03 less yellow	0.08
WA60-PS-GI-30kGy-D	1.90	47.17	0.10	6.55	-1.62	-0.33	0.93	1.62 darker	0.92 more saturated	0.37 yellower	0.33 less red	0.93 yellower	0.24
WA60-PS-GI-30kGy-E	5.71	50.41	-0.61	9.73	4.86	-0.56	2.95	4.86 lighter	2.97 more saturated	0.45 greener	0.56 greener	2.95 yellower	0.77

### 30 and 50 kGy Long-Term Assessment Historical Photograph Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-OLT-GI-30kGy-A	3.65	30.60	42.05	15.79	-2.82	1.61	1.67	2.82 darker	2.08 more saturated	1.02 yellower	1.61 redder	1.67 yellower	0.50
WA60-OLT-GI-30kGy-B	5.17	28.21	39.48	14.51	-2.79	3.34	2.79	2.79 darker	4.07 more saturated	1.55 yellower	3.34 redder	2.79 yellower	1.00
WA60-OLT-GI-30kGy-C	6.01	29.39	40.47	15.07	-2.51	4.52	3.08	2.51 darker	5.28 more saturated	1.40 yellower	4.52 redder	3.08 yellower	1.30
WA60-OLT-GI-30kGy-D	6.59	29.70	42.63	16.47	-2.97	4.63	3.64	2.97 darker	5.59 more saturated	1.84 yellower	4.63 redder	3.64 yellower	1.52
WA60-OLT-GI-30kGy-E	6.02	29.65	42.40	16.26	-3.23	3.92	3.23	3.23 darker	4.78 more saturated	1.70 yellower	3.92 redder	3.23 yellower	1.26
WA60-OLT-GI-50kGy-A	4.08	28.65	41.17	15.20	-3.16	2.17	1.38	3.16 darker	2.51 more saturated	0.56 yellower	2.17 redder	1.38 yellower	0.89
WA60-OLT-GI-50kGy-B	4.05	26.61	34.81	11.76	-3.12	2.13	1.47	3.12 darker	2.48 more saturated	0.73 yellower	2.13 redder	1.47 yellower	0.68
WA60-OLT-GI-50kGy-C	4.03	30.96	42.14	15.60	-3.38	1.85	1.18	3.38 darker	2.14 more saturated	0.48 yellower	1.85 redder	1.18 yellower	0.79
WA60-OLT-GI-50kGy-D	4.52	29.94	40.49	15.31	-3.69	1.91	1.78	3.69 darker	2.41 more saturated	1.02 yellower	1.91 redder	1.78 yellower	0.83
WA60-OLT-GI-50kGy-E	4.35	29.26	40.44	14.76	-3.19	2.38	1.77	3.19 darker	2.84 more saturated	0.87 yellower	2.38 redder	1.77 yellower	0.88

### 30 and 50 kGy Long-Term Assessment Oil Painting Light Hue Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-ODT-GI-30kGy-A	3.19	26.01	3.20	4.89	-3.17	-0.32	0.17	3.17 darker	0.05 less saturated	0.36 yellower	0.32 less red	0.17 yellower	0.12
WA60-ODT-GI-30kGy-B	2.22	25.75	3.26	4.77	-2.00	-0.19	0.93	2.00 darker	0.61 more saturated	0.73 yellower	0.19 less red	0.93 yellower	0.18
WA60-ODT-GI-30kGy-C	4.12	24.90	2.74	4.50	-4.02	-0.79	0.41	4.02 darker	0.14 less saturated	0.88 yellower	0.79 less red	0.41 yellower	0.23
WA60-ODT-GI-30kGy-D	4.01	21.98	1.53	2.10	-3.70	-1.39	0.63	3.70 darker	0.67 less saturated	1.37 yellower	1.39 less red	0.63 yellower	0.38
WA60-ODT-GI-30kGy-E	4.06	25.58	3.29	4.85	-3.81	-0.67	1.22	3.81 darker	0.49 more saturated	1.30 yellower	0.67 less red	1.22 yellower	0.28
WA60-ODT-GI-50kGy-A	3.24	22.89	1.90	2.23	-3.15	-0.39	0.68	3.15 darker	0.16 more saturated	0.77 yellower	0.39 less red	0.68 yellower	0.19
WA60-ODT-GI-50kGy-B	3.07	23.53	1.99	2.40	-3.00	-0.46	0.45	3.00 darker	0.01 less saturated	0.64 yellower	0.46 less red	0.45 yellower	0.16
WA60-ODT-GI-50kGy-C	3.43	22.76	2.00	2.90	-3.28	-0.39	0.92	3.28 darker	0.42 more saturated	0.91 yellower	0.39 less red	0.92 yellower	0.22
WA60-ODT-GI-50kGy-D	2.68	25.48	2.91	4.04	-2.42	-0.26	1.11	2.42 darker	0.66 more saturated	0.93 yellower	0.26 less red	1.11 yellower	0.25
WA60-ODT-GI-50kGy-E	3.25	24.89	2.67	4.46	-3.06	-0.24	1.06	3.06 darker	0.72 more saturated	0.81 yellower	0.24 less red	1.06 yellower	0.22

### 30 and 50 kGy Long-Term Assessment Oil Painting Dark Hue Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-OPS-GI-30kGy-A	4.24	46.54	-1.84	9.03	-3.59	-1.94	1.18	3.59 darker	1.36 more saturated	1.81 yellower	1.94 less red	1.18 yellower	0.42
WA60-OPS-GI-30kGy-B	8.05	33.80	11.33	18.99	0.10	2.57	7.63	0.10 lighter	7.77 more saturated	2.12 yellower	2.57 redder	7.63 yellower	1.02
WA60-OPS-GI-30kGy-C	4.49	24.21	1.56	2.00	-4.48	-0.23	0.18	4.48 darker	0.02 less saturated	0.30 yellower	0.23 less red	0.18 yellower	0.09
WA60-OPS-GI-30kGy-D	3.69	46.91	9.82	32.84	-2.31	0.54	2.82	2.31 darker	2.86 more saturated	0.30 yellower	0.54 redder	2.82 yellower	0.15
WA60-OPS-GI-30kGy-E	2.44	55.69	-3.87	17.17	-2.17	-0.41	1.02	2.17 darker	1.09 more saturated	0.19 greener	0.41 greener	1.02 yellower	0.31
WA60-OPS-GI-50kGy-A	2.26	45.87	6.31	0.97	-1.17	1.81	-0.68	1.17 darker	1.59 more saturated	1.10 redder	1.81 redder	0.68 less yellow	0.37
WA60-OPS-GI-50kGy-B	6.94	39.45	13.09	29.89	-0.45	1.27	6.81	0.45 darker	6.70 more saturated	1.76 yellower	1.27 redder	6.81 yellower	0.42
WA60-OPS-GI-50kGy-C	3.89	23.30	2.91	3.37	-3.61	0.72	1.25	3.61 darker	1.41 more saturated	0.33 yellower	0.72 redder	1.25 yellower	0.34
WA60-OPS-GI-50kGy-D	3.92	46.99	9.55	33.35	-1.96	0.21	3.39	1.96 darker	3.31 more saturated	0.77 yellower	0.21 redder	3.39 yellower	0.27
WA60-OPS-GI-50kGy-E	2.92	52.59	-1.18	17.12	-1.40	0.14	2.55	1.40 darker	2.53 more saturated	0.34 yellower	0.14 less green	2.55 yellower	0.41

### 30 and 50 kGy Long-Term Assessment Historical Oil Painting Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-WS-GI-30kGy-A	7.15	23.64	19.50	17.54	-0.98	2.59	6.58	0.98 darker	6.08 more saturated	3.62 yellower	2.59 redder	6.58 yellower	0.74
WA60-WS-GI-30kGy-B	6.70	20.52	20.20	15.84	-5.78	2.95	1.70	5.78 darker	3.36 more saturated	0.52 redder	2.95 redder	1.70 yellower	0.77
WA60-WS-GI-30kGy-C	5.39	21.38	18.29	15.05	-3.06	2.42	3.72	3.06 darker	4.19 more saturated	1.47 yellower	2.42 redder	3.72 yellower	0.62
WA60-WS-GI-30kGy-D	4.86	23.53	19.73	15.71	-2.51	2.21	3.53	2.51 darker	3.88 more saturated	1.51 yellower	2.21 redder	3.53 yellower	0.58
WA60-WS-GI-30kGy-E	4.42	21.97	18.65	15.37	-2.41	2.02	3.09	2.41 darker	3.50 more saturated	1.19 yellower	2.02 redder	3.09 yellower	0.51
WA60-WS-GI-50kGy-A	6.33	21.78	21.18	18.02	-3.16	3.19	4.46	3.16 darker	5.28 more saturated	1.48 yellower	3.19 redder	4.46 yellower	0.81
WA60-WS-GI-50kGy-B	4.29	23.33	21.18	18.25	-1.93	2.13	3.18	1.93 darker	3.67 more saturated	1.09 yellower	2.13 redder	3.18 yellower	0.53
WA60-WS-GI-50kGy-C	6.14	21.39	19.81	16.73	-3.61	2.51	4.28	3.61 darker	4.62 more saturated	1.83 yellower	2.51 redder	4.28 yellower	0.64
WA60-WS-GI-50kGy-D	6.78	22.40	22.69	20.84	-3.72	2.67	5.01	3.72 darker	5.28 more saturated	2.07 yellower	2.67 redder	5.01 yellower	0.70
WA60-WS-GI-50kGy-E	5.51	21.10	16.82	14.48	-3.82	1.89	3.49	3.82 darker	3.65 more saturated	1.54 yellower	1.89 redder	3.49 yellower	0.48

### 30 and 50 kGy Long-Term Assessment Historical Wood Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-LS-GI-30kGy-A	4.64	38.04	17.51	31.45	-2.39	0.86	3.88	2.39 darker	3.79 more saturated	1.20 yellower	0.86 redder	3.88 yellower	0.18
WA60-LS-GI-30kGy-B	5.06	37.46	18.34	27.97	-3.35	1.33	3.56	3.35 darker	3.69 more saturated	0.89 yellower	1.33 redder	3.56 yellower	0.31
WA60-LS-GI-30kGy-C	4.98	39.43	17.17	32.22	-2.88	1.10	3.91	2.88 darker	3.96 more saturated	0.92 yellower	1.10 redder	3.91 yellower	0.20
WA60-LS-GI-30kGy-D	4.76	37.57	19.55	30.08	-3.34	1.30	3.13	3.34 darker	3.33 more saturated	0.64 yellower	1.30 redder	3.13 yellower	0.28
WA60-LS-GI-30kGy-E	3.05	47.15	13.28	20.60	-2.58	0.17	1.62	2.58 darker	1.44 more saturated	0.76 yellower	0.17 redder	1.62 yellower	0.12
WA60-LS-GI-50kGy-A	4.72	37.71	18.70	29.88	-3.60	0.77	2.95	3.60 darker	2.89 more saturated	0.95 yellower	0.77 redder	2.95 yellower	0.16
WA60-LS-GI-50kGy-B	3.81	40.37	16.73	31.50	-2.91	0.32	2.43	2.91 darker	2.28 more saturated	0.88 yellower	0.32 redder	2.43 yellower	0.12
WA60-LS-GI-50kGy-C	4.78	37.45	17.06	29.79	-2.66	1.01	3.84	2.66 darker	3.82 more saturated	1.09 yellower	1.01 redder	3.84 yellower	0.21
WA60-LS-GI-50kGy-D	4.34	37.70	18.73	28.23	-2.95	0.66	3.12	2.95 darker	2.94 more saturated	1.24 yellower	0.66 redder	3.12 yellower	0.15
WA60-LS-GI-50kGy-E	2.76	46.21	14.25	21.87	-2.27	0.17	1.57	2.27 darker	1.39 more saturated	0.74 yellower	0.17 redder	1.57 yellower	0.09

### 30 and 50 kGy Long-Term Assessment Historical Leather Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-MS-GI-30kGy-A	3.60	35.60	1.90	17.52	-1.17	0.11	3.40	1.17 darker	3.39 more saturated	0.29 yellower	0.11 redder	3.40 yellower	0.52
WA60-MS-GI-30kGy-B	4.10	31.54	1.67	17.27	-2.18	0.16	3.47	2.18 darker	3.47 more saturated	0.19 yellower	0.16 redder	3.47 yellower	0.48
WA60-MS-GI-30kGy-C	3.65	33.93	2.87	17.45	-1.33	0.35	3.38	1.33 darker	3.39 more saturated	0.23 yellower	0.35 redder	3.38 yellower	0.48
WA60-MS-GI-30kGy-D	3.13	35.07	2.27	16.93	-0.49	0.47	3.05	0.49 darker	3.09 more saturated	0.06 redder	0.47 redder	3.05 yellower	0.45
WA60-MS-GI-30kGy-E	3.53	35.20	1.79	17.92	-1.26	-0.06	3.30	1.26 darker	3.27 more saturated	0.43 yellower	0.06 less red	3.30 yellower	0.52
WA60-MS-GI-50kGy-A	3.38	33.47	2.97	16.45	-2.07	-0.16	2.66	2.07 darker	2.58 more saturated	0.69 yellower	0.16 less red	2.66 yellower	0.39
WA60-MS-GI-50kGy-B	3.90	30.13	1.98	15.56	-3.29	0.05	2.10	3.29 darker	2.09 more saturated	0.23 yellower	0.05 redder	2.10 yellower	0.30
WA60-MS-GI-50kGy-C	3.97	32.80	2.00	17.43	-1.90	-0.03	3.48	1.90 darker	3.45 more saturated	0.47 yellower	0.03 less red	3.48 yellower	0.52
WA60-MS-GI-50kGy-D	4.39	32.61	1.87	17.15	-2.03	-0.32	3.88	2.03 darker	3.80 more saturated	0.84 yellower	0.32 less red	3.88 yellower	0.62
WA60-MS-GI-50kGy-E	4.14	31.38	2.06	17.17	-2.48	-0.15	3.32	2.48 darker	3.27 more saturated	0.60 yellower	0.15 less red	3.32 yellower	0.50

### 30 and 50 kGy Long-Term Assessment Historical Metal Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-PBS-GI-50kGy-A	20.70	69.95	-5.27	15.93	-13.71	-3.00	15.21	13.71 darker	14.40 more saturated	5.75 yellower	3.00 greener	15.21 yellower	4.58
WA60-PBS-GI-50kGy-B	20.26	69.81	-4.65	12.15	-16.65	-2.31	11.31	16.65 darker	10.53 more saturated	4.75 yellower	2.31 greener	11.31 yellower	3.58
WA60-PBS-GI-50kGy-C	15.46	69.11	-3.53	8.43	-13.60	-1.22	7.25	13.60 darker	6.55 more saturated	3.34 yellower	1.22 greener	7.25 yellower	2.41
WA60-PBS-GI-50kGy-D	18.69	73.28	-5.55	15.77	-11.80	-3.37	14.11	11.80 darker	13.98 more saturated	3.88 yellower	3.37 greener	14.11 yellower	4.25
WA60-PBS-GI-50kGy-E	20.78	70.64	-5.73	16.50	-13.99	-3.54	14.95	13.99 darker	14.79 more saturated	4.18 yellower	3.54 greener	14.95 yellower	4.48
WA60-PBS-GI-30kGy-A	12.76	74.70	-4.16	10.67	-9.37	-1.96	8.44	9.37 darker	8.32 more saturated	2.42 yellower	1.96 greener	8.44 yellower	2.68
WA60-PBS-GI-30kGy-B	18.35	70.36	-4.56	13.91	-13.42	-2.35	12.30	13.42 darker	11.90 more saturated	3.89 yellower	2.35 greener	12.30 yellower	3.74
WA60-PBS-GI-30kGy-C	23.34	68.05	-4.81	16.82	-17.19	-2.58	15.58	17.19 darker	14.94 more saturated	5.11 yellower	2.58 greener	15.58 yellower	4.57
WA60-PBS-GI-30kGy-D	14.45	72.37	-4.55	11.77	-10.48	-2.23	9.69	10.48 darker	9.51 more saturated	2.92 yellower	2.23 greener	9.69 yellower	2.98
WA60-PBS-GI-30kGy-E	24.78	67.52	-6.11	19.11	-15.74	-3.83	18.75	15.74 darker	17.75 more saturated	7.14 yellower	3.83 greener	18.75 yellower	5.44

### 30 and 50 kGy Long-Term Assessment Historical Porcelain Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-FS-GI-30kGy-A	4.12	32.62	26.72	-28.50	-1.53	-1.72	3.41	1.53 darker	3.68 less saturated	1.03 redder	1.72 less red	3.41 less blue	2.08
WA60-FS-GI-30kGy-B	9.59	32.97	29.24	-32.41	-2.20	6.16	-7.02	2.20 darker	9.34 more saturated	0.15 bluer	6.16 redder	7.02 bluer	1.52
WA60-FS-GI-30kGy-C	2.10	66.75	-19.13	-4.55	1.58	-1.37	0.21	1.58 lighter	1.27 more saturated	0.54 greener	1.37 greener	0.21 less blue	0.36
WA60-FS-GI-30kGy-D	2.41	68.40	-18.56	-3.72	1.98	-0.95	0.98	1.98 lighter	0.71 more saturated	1.17 greener	0.95 greener	0.98 less blue	0.51
WA60-FS-GI-30kGy-E	3.01	82.40	2.55	16.23	2.01	1.25	1.85	2.01 lighter	1.99 more saturated	1.02 redder	1.25 redder	1.85 yellower	0.61
WA60-FS-GI-50kGy-A	3.44	33.38	27.49	-29.74	-1.10	2.48	-2.10	1.10 darker	3.23 more saturated	0.41 redder	2.48 redder	2.10 bluer	0.36
WA60-FS-GI-50kGy-B	2.03	34.75	24.65	-26.88	-0.32	1.76	-0.96	0.32 darker	1.89 more saturated	0.66 redder	1.76 redder	0.96 bluer	0.83
WA60-FS-GI-50kGy-C	2.23	67.37	-18.94	-3.50	1.43	-1.65	0.47	1.43 lighter	1.52 more saturated	0.80 greener	1.65 greener	0.47 less blue	0.46
WA60-FS-GI-50kGy-D	1.71	67.77	-19.11	-4.03	0.89	-0.93	1.13	0.89 lighter	0.63 more saturated	1.31 greener	0.93 greener	1.13 less blue	0.56
WA60-FS-GI-50kGy-E	4.06	83.04	2.67	16.48	3.18	1.26	2.18	3.18 lighter	2.33 more saturated	0.96 redder	1.26 redder	2.18 yellower	0.67

### 30 and 50 kGy Long-Term Assessment Historical Fabric Surrogate Technical Data

Data Name	dE*ab(D65)	L*(D65)	a*(D65)	b*(D65)	dL*(D65)	da*(D65)	db*(D65)	Lightness(D65)	Saturation(D65)	Hue(D65)	a* Evaluation(D65)	b* Evaluation(D65)	MI(D65, A)
WA60-PPS-GI-30kGy-A	1.30	70.47	-3.89	11.05	-0.17	0.08	-1.28	0.17 darker	1.24 less saturated	0.34 greener	0.08 less green	1.28 less yellow	0.30
WA60-PPS-GI-30kGy-B	5.12	47.36	7.80	10.09	-4.29	-2.64	-0.91	4.29 darker	2.42 less saturated	1.41 yellower	2.64 less red	0.91 less yellow	0.73
WA60-PPS-GI-30kGy-C	1.46	75.34	-2.42	11.60	-1.16	-0.88	-0.01	1.16 darker	0.14 more saturated	0.87 greener	0.88 greener	0.01 less yellow	0.24
WA60-PPS-GI-30kGy-D	3.17	57.65	0.06	1.23	3.06	-0.36	0.75	3.06 lighter	0.59 more saturated	0.58 yellower	0.36 less red	0.75 yellower	0.21
WA60-PPS-GI-30kGy-E	2.37	75.30	-0.71	14.40	-2.33	-0.06	0.45	2.33 darker	0.45 more saturated	0.04 greener	0.06 greener	0.45 yellower	0.11
WA60-PPS-GI-50kGy-A	1.56	72.15	-1.51	13.38	0.91	-1.00	0.79	0.91 lighter	0.87 more saturated	0.93 greener	1.00 greener	0.79 yellower	0.32
WA60-PPS-GI-50kGy-B	4.90	54.32	7.15	12.77	2.38	2.54	3.45	2.38 lighter	4.23 more saturated	0.63 redder	2.54 redder	3.45 yellower	0.99
WA60-PPS-GI-50kGy-C	0.30	77.30	-3.37	6.53	-0.24	0.00	0.19	0.24 darker	0.17 more saturated	0.08 yellower	0.00 greener	0.19 yellower	0.06
WA60-PPS-GI-50kGy-D	5.28	61.46	-0.52	1.81	-5.21	-0.23	-0.82	5.21 darker	0.76 less saturated	0.38 greener	0.23 greener	0.82 less yellow	0.20
WA60-PPS-GI-50kGy-E	3.26	74.11	-0.20	12.48	-3.13	0.15	0.92	3.13 darker	0.91 more saturated	0.17 yellower	0.15 less green	0.92 yellower	0.24

### 30 and 50 kGy Long-Term Assessment Historical Pastel Painting Surrogate Technical Data

## Appendix D: Certificates for Irradiation

R5530460		Sterigistics		Date - 05/18/15	
RIS0003		Bill of Material Print		Time - 14:27:18 GMT	
As of Date: 05/18/15		Long Address Number		Page - 1 of 1	
Customer Name: Arcadis U.S., Inc. - Highlands Ranch, CO.		P-B-S-USARCA01			
Customer Number: 244116					

Parent Item	116_M14_0488	Parent Description	I/T A5
Branch/Plant	116	Requested UOM	TT
		Description Line 2	HI: TA4 LO: 0C4

Level	Component Item	Component Description	Branch/Plant	Description Line 2	Quantity Per	Ext Qty	UM	Oper Seq No	Dimensions	H - W - D	Density	Weight
1	ARC_DOC_SAMPLES	DOC SAMPLES	116	Document Sample 30 kGy	1	1,000	EA					

Product Code:	General Industrial Other	Tote Notes:	DT: 16.0 (1385)
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### Dose Distribution Map Certification

Last Major Irradiator Qualification: 07/18/2014  
Date (mm/dd/yyyy)

Page 1 of 1

Processing Flow: A5

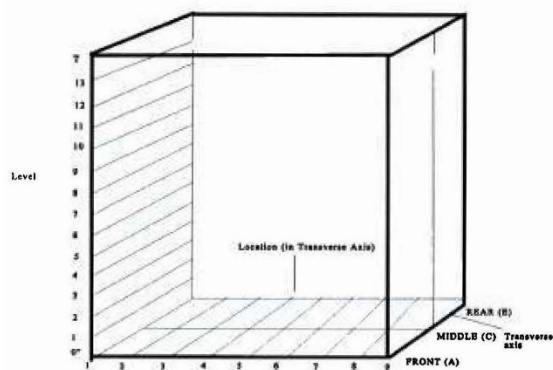
DoseMap Id: 116\_M14\_0488

Pkg Per Tote: 1

WO#: 1511838

Irradiation Date: 14 MAY 15 13:04:00

Location:	Tote 1
0A4	18.4
0C4	16.7
0C5	16.7
0C9	16.8
6A5	19.3
7A5	19.6
TA4	21.5



Sterigenics certifies that the dosages listed above are representative readings of each position and accuracy of the dosimetry system utilized. Based on the statistical equivalency of the values, the high and low locations to be monitored on future runs will be as follows:

**High:** TA4

**Low:** 0C4

Certified By: [Signature]

Date: 5/18/15 10:22

Verified By: [Signature]

Date: 5/18/15

Date/Time Format: MM/DD/YY XX.XX

Document N°: HA-F-019

Revision N°: 1

User must verify the revision number of printed or downloaded document against the effective version.

Confidential Information

Page 1 of 1



# HAW RIVER PALLET DEFAULT

Date Printed : 5/13/2015  
Last Saved : 5/12/2015

	<p>GMA (Notched) 48x40x5</p> <table border="1"> <thead> <tr> <th>Package (OD)</th> <th>UnitLoad (Pallet Inc)</th> </tr> </thead> <tbody> <tr> <td>Ln: 16.000 in</td> <td>48 in</td> </tr> <tr> <td>Wd: 16.000 in</td> <td>40 in</td> </tr> <tr> <td>Ht: 48.750 in</td> <td>54 in</td> </tr> <tr> <td>Wt: 12.000 lb</td> <td>77 lb</td> </tr> <tr> <td>Package:</td> <td>1</td> </tr> <tr> <td>Cubic Efficiency:</td> <td>10.00 %</td> </tr> <tr> <td>Cases per layer:</td> <td>1</td> </tr> <tr> <td>Layers/load:</td> <td>1</td> </tr> <tr> <td>Dns (g/cc):0.0266</td> <td>0.0266</td> </tr> </tbody> </table>	Package (OD)	UnitLoad (Pallet Inc)	Ln: 16.000 in	48 in	Wd: 16.000 in	40 in	Ht: 48.750 in	54 in	Wt: 12.000 lb	77 lb	Package:	1	Cubic Efficiency:	10.00 %	Cases per layer:	1	Layers/load:	1	Dns (g/cc):0.0266	0.0266
	Package (OD)	UnitLoad (Pallet Inc)																			
Ln: 16.000 in	48 in																				
Wd: 16.000 in	40 in																				
Ht: 48.750 in	54 in																				
Wt: 12.000 lb	77 lb																				
Package:	1																				
Cubic Efficiency:	10.00 %																				
Cases per layer:	1																				
Layers/load:	1																				
Dns (g/cc):0.0266	0.0266																				

Customer Name: ARCADIS  
Dose Map #: M14-0488

Cell(s): A  
Flow: A5

Notes: 3-PALLET RISE HEIGHT PRODUCT FILL 2" FROM TOP OF CTN. 3.50" IN FROM THE SIDE USE TAPE TO STABILIZE LOAD.

Sterigenics - 03:36 pm (TOPS Pro Version 6.02)

*Eric Hester* 18 May 15

Eric Hester

R5530460  
RIS9063

As of Date: 05/18/15  
Customer Name: Arcadis U.S., Inc. - Highlands Ranch, CO.  
Customer Number: 244116

Sterigenics  
Bill of Material Print  
Long Address Number P-B-S-USARCA01

Date - 05/18/15  
Time - 12:52:50 GMT  
Page - 1 of 1

Parent Item 116\_M14\_0489  
Branch/Plant 116 Type M  
Parent Description I/T A5  
Requested UOM TT  
Description Line 2 HI: TA4 LO: 0C4

Level	Component Item	Component Description	Branch/Plant	Description Line 2	Quantity Per	Ext Qty	UM	Seq No	Oper	Dimensions H - W - D	Density	Weight
1	ARC_DOC_SAMPLES_50	DOC SAMPLES 50	116	Document Samples 50 kGy	1	1.000	EA					

Product Code: General Industrial Other





### Dose Distribution Map Certification

Last Major Irradiator Qualification: 07/18/2014  
Date (mm/dd/yyyy)

Page 1 of 1

Processing Flow: A5

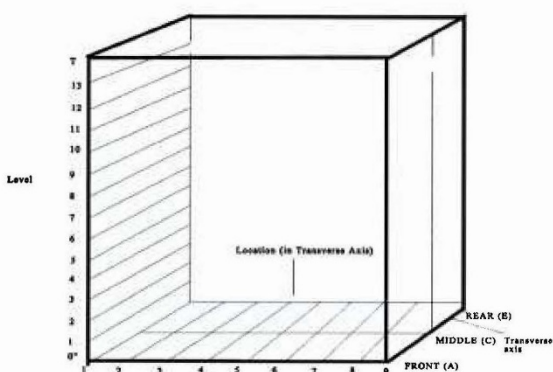
DoseMap Id: 116\_M14\_0489

Pkg Per Tote: 1

WO#: 1511840

Irradiation Date: 14 MAY 15 14:02:00

Location:	Tote 1
0A4	26.9
0C4	24.0
0C5	24.4
0C9	24.2
6A5	28.2
7A5	28.6
TA4	31.0



Sterigenics certifies that the dosages listed above are representative readings of each position and accuracy of the dosimetry system utilized. Based on the statistical equivalency of the values, the high and low locations to be monitored on future runs will be as follows:

High: TA4

Low: 0C4

Certified By: [Signature]  
Verified By: [Signature]

Date: 5/18/15 8:39  
Date: 18 May 15

Date/Time Format: MM/DD/YY XX.XX

Document N°: HA-F-019

Revision N°: 1

User must verify the revision number of printed or downloaded document against the effective version.

Confidential Information

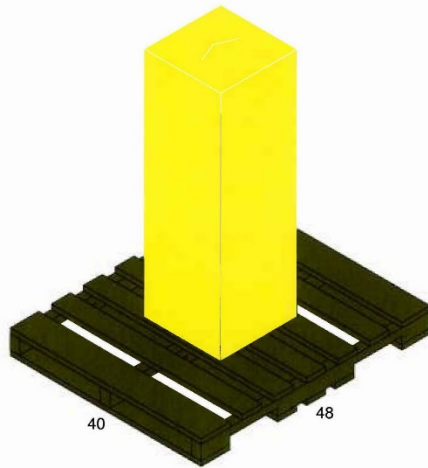
Page 1 of 1



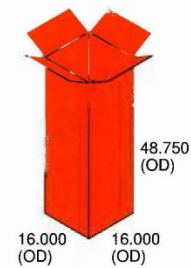


# HAW RIVER PALLET DEFAULT

Date Printed : 5/13/2015  
Last Saved : 5/12/2015



GMA (Notched) 48x40x5		
	Package (OD)	UnitLoad (Pallet Inc)
Ln:	16.000 in	48 in
Wd:	16.000 in	40 in
Ht:	48.750 in	54 in
Wt:	12.000 lb	77 lb
Package:		1
Cubic Efficiency:		10.00 %
Cases per layer:		1
Layers/load:		1
Dns (g/cc):	0.0266	0.0266



Customer Name: ARCADIS  
Dose Map #: M14-0489

Cell(s): A  
Flow: A5

..

Notes: 3-PALLET RISE HEIGHT PRODUCT FILL 2" FROM TOP OF CTN. 3.50" IN FROM THE SIDE USE TAPE TO STABILIZE LOAD.

Sterigenics - 03:38 pm (TOPS Pro Version 6.02)

*Eric Hester* 18 May 15

Eric Hester



## Certificate of Processing

STERIGENICS 1148 Porter Ave. Haw River NC 27258  
TEL 336 578-5876 FAX 336 578-5859 www.sterigenics.com

R55480102

05/18/2015 12:57:05 GMT  
Page 1 of 1

Customer Name: Arcadis U.S., Inc.- Highlands Ranch, CO. Processing Facility: Haw River Work Order # 1511840  
P.O.# D15-045 Sales Order # 1317006  
50.0-No Max ARC, Gamma Treatment Received Date/Time: 05/13/2015 14:12:00 GMT

SO Line #	Qty	UOM	Customer Item Number	Customer Item Description	Customer Lot Number	Customer Load Number
101.000	1	EA	DOC SAMPLES 50	Document Samples 50 kGy	NA	NA
	1	EA	Total			

### Quality Test Summary

Op#	Quality Test Description	Minimum Spec	Maximum Spec	Result	Pass/Fail	-----Signed By ----- User	Date /Time
450.00	Minimum Dose	50.0 kGy	300.0 kGy	53.3 KGY	Pass	BBUNTIN BRAD BUNTIN	05/17/2015 11:04:15 GMT
		Reason Code Test					

Sterigenics certifies that the materials listed above (as described by the Manufacturer) received the indicated doses within the precision and accuracy of the dosimetry system employed.

Electronically Signed By: STEFANI ALLRED  
Reason: Work Order Completions

Date: 05/18/2015 12:56:09 GMT



## Certificate of Processing

STERIGENICS 1148 Porter Ave. Haw River NC 27258  
TEL 336 578-5876 FAX 336 578-5859 www.sterigenics.com

R55480102

05/19/2015 13:33:05 GMT  
Page 1 of 1

Customer Name: Arcadis U.S., Inc.- Highlands Ranch, CO. Processing Facility: Haw River Work Order # 1511838  
P.O.# D15-045 Sales Order # 1317003  
30.0- No Max ARC, Gamma Treatment Received Date/Time: 05/13/2015 14:12:00 GMT

SO Line #	Qty	UOM	Customer Item Number	Customer Item Description	Customer Lot Number	Customer Load Number
101.000	1	EA	DOC SAMPLES	Document Sample 30 kGy	NA	NA
	1	EA	Total			

### Quality Test Summary

Op#	Quality Test Description	Minimum Spec	Maximum Spec	Result	Pass/Fail	-----Signed By ----- User	Date /Time
450.00	Minimum Dose	30.0 kGy	300.0 kGy	33.3 KGY	Pass	THARVEY Timothy Harvey	05/18/2015 09:52:45 GMT
		Reason Code Test					

Sterigenics certifies that the materials listed above (as described by the Manufacturer) received the indicated doses within the precision and accuracy of the dosimetry system employed.

Electronically Signed By: STEFANI ALLRED  
Reason: Work Order Completions

Date: 05/18/2015 14:31:19 GMT



## Appendix E: Sterilization Verification Data



**4915 Prospectus Drive  
Durham, NC 27713  
(919) 541-3662  
FAX (919) 544-5690  
Page 1**

<b>Report to:</b>  <b>Barbara Wyrzykowska-Ceradini</b>	<b>Bill to:</b> Not Applicable <hr/> <hr/> <hr/>
--	--

### Chain of Custody Record

PROJECT NUMBER RN990276.0060		PO# Not Applicable		<b>No. of Containers</b>	<b>Analysis Required</b>	LABORATORY: Onsite Microbiology Laboratory c/o Nicole Griffin Gatchalian	
PROJECT NAME Material Compatibility of Gamma Irradiation						LAB ADDRESS EPA / RTP NC	
COLLECTED BY (SIGNATURE) Barbara Wyrzykowska-Ceradini						REPORT FORMAT (CIRCLE ALL REQUIRED) ELECTRONIC/VERBAL/FAX/HARD COPY	
FIELD SAMPLE ID	RUSH FACTOR	SAMPLE Matrix	DATE/TIME			REMARKS	LAB ID NO. (for lab use only)
✓ WA 6-60 BI-B.atrophaeus DS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Documents test set BI1, irradiated at 30kGy	
✓ WA 6-60 BI-B.atrophaeus WS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Wood test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus ODT-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Oil dark surrogate test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus OLT-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Oil light surrogate test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus FS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Fabric test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus MS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Metal test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus PBS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Porcelain test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus BS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Books test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus PS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Photographs test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus OPS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Oil historical test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus LS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Leather test set BI1, irradiated at 30 kGy	
✓ WA 6-60 BI-B.atrophaeus PPS-30 kGy	1 week TAT	BI test strip ATCC # 9372	5/26/14	1	Qualitative	Pastel test set BI1, irradiated at 30 kGy	



WA 6-60 BI- <i>B.pumilus</i> DS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Documents test set BI2, irradiated at 30kGy	
WA 6-60 BI- <i>B.pumilus</i> WS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Wood test set BI2, irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> ODT-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Oil dark surrogate test set BI2, irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> OLT-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Oil light surrogate test set BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> FS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Fabric test set BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> MS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Metal test set BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> PBS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Porcelain test set BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> BS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Books test ste BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> PS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Photographs test set BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> OPS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Oil historical test set BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> LS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Leather test set BI2, Irradiated at 30 kGy	
WA 6-60 BI- <i>B.pumilus</i> PPS-30 kGy	1 week TAT	BI test strip ATCC # 27142	5/26/14	1	Qualitative	Pastel test set BI2, Irradiated at 30 kGy	
<b>REMARKS</b> BIs ( <i>B.atrophaeus</i> test strip Log 6 and <i>B.pumilus</i> test strip log 6) for WA 6-60 samples, irradiated at 30 kGy Do not refrigerate.							
<b>RELINQUISH</b> <b>ED BY:</b> BUC 5/27/2015			<b>DATE</b>		<b>TIME</b> 16:46	<b>RECEIVED</b> BY: Jngg	<b>DATE</b> 5/27/15 <b>TIME</b> 16:46



4999

Test Information

EPA Project No.	6-60
Technicians Name	Nicole Griffin Gatchalian
Recorders Name	Nicole Griffin Gatchalian
PI	Shannon Serre
Test Date	5/26/2015
BIs into TSB	5/27/2015
Test No.	BIs for WA 6-60 irradiated at 30 kGy
BI Lot Number/Expiration Date	<i>B. atrophaeus</i> Lot 1163211 Exp 1/17
BI Lot Number/Expiration Date	<i>B. pumilus</i> Lot 716707 Exp 10/16

Results

Date	6/4/2015	6/5/2015	6/5/2015
	Tube Result	Plate Result	Final Result
<b>Sample ID</b>			
WA 6-60 BI- <i>B. atrophaeus</i> DS-30-kGy	G	G	G
WA 6-60 BI- <i>B. atrophaeus</i> WS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> ODT-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> OLT-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> FS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> MS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> PBS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> BS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> PS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> OPS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> LS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> PPS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> DS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> WS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> ODT-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> OLT-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> FS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> MS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> PBS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> BS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> PS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> OPS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> LS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. pumilus</i> PPS-30-kGy	Z	Z	Z
WA 6-60 BI- <i>B. atrophaeus</i> positive 1	G	G	G
WA 6-60 BI- <i>B. atrophaeus</i> positive 2	G	G	G
WA 6-60 BI- <i>B. atrophaeus</i> positive 3	G	G	G
WA 6-60 BI- <i>B. pumilus</i> positive 1	G	G	G
WA 6-60 BI- <i>B. pumilus</i> positive 2	G	G	G
WA 6-60 BI- <i>B. pumilus</i> positive 3	G	G	G
TSB Neg 1	Z	Z	Z
TSB Neg 2	Z	Z	Z
TSB Neg 3	Z	Z	Z
TSA Neg 1	Z	Z	Z
TSA Neg 2	Z	Z	Z
TSA Neg 3	Z	Z	Z
Initials of analyst	NGG	NGG	NGG

Key:

G = growth

N = no growth



**4915 Prospectus Drive**  
**Durham, NC 27713**  
**(919) 541-3662**  
**FAX (919) 544-5690**  
 Page 1

Report to:  Barbara Wyrzykowska-Ceradini	Bill to: Not Applicable _____ _____ _____
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### Chain of Custody Record

PROJECT NUMBER RN990276.0060		PO# Not Applicable		No. of Containers	Analysis Required	LABORATORY: Onsite Microbiology Laboratory c/o Nicole Griffin Gatchalian	
PROJECT NAME Material Compatibility of Gamma Irradiation						LAB ADDRESS EPA / RTP NC	
COLLECTED BY (SIGNATURE) Barbara Wyrzykowska-Ceradini						REPORT FORMAT (CIRCLE ALL REQUIRED) ELECTRONIC/VERBAL/FAX/HARD COPY	
FIELD SAMPLE ID	RUSH FACTOR	SAMPLE Matrix	DATE/ TIME			REMARKS	LAB ID NO. (for lab use only)
WA 6-60 BI-B. <i>atrophaeus</i> DS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Documents test set B11, irradiated at 30kGy	
WA 6-60 BI-B. <i>atrophaeus</i> WS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Wood test set B11, irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> ODT-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Oil dark surrogate test set B11, irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> OLT-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Oil light surrogate test set B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> FS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Fabric test set B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> MS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Metal test set B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> PBS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Porcelain test set B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> BS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Books test ste B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> PS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Photographs test set B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> OPS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Oil historical test set B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> LS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Leather test set B11, Irradiated at 50 kGy	
WA 6-60 BI-B. <i>atrophaeus</i> PPS-50 kGy	1 week TAT	BI test strip ATCC # 9372	5/28/15	1	Qualitative	Pastel test set B11, Irradiated at 50 kGy	

*B. atrophaeus* lot 11632111 Exp 1/17



WA 6-60 BI- <i>B.pumilus</i> DS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Documents test set BI2, irradiated at 30kGy	
WA 6-60 BI- <i>B.pumilus</i> WS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Wood test set BI2, irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> ODT-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Oil dark surrogate test set BI2, irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> OLT-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Oil light surrogate test set BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> FS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Fabric test set BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> MS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Metal test set BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> PBS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Porcelain test set BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> BS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Books test ste BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> PS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Photographs test set BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> OPS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Oil historical test set BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> LS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Leather test set BI2, Irradiated at 50 kGy	
WA 6-60 BI- <i>B.pumilus</i> PPS-50 kGy	1 week TAT	BI test strip ATCC # 27142	5/28/15	1	Qualitative	Pastel test set BI2, Irradiated at 50 kGy	
<b>REMARKS</b> BIs ( <i>B.atrophaeus</i> test strip Log 6 and <i>B.pumilus</i> test strip log 6) for WA 6-60 samples, irradiated at 50 kGy Do not refrigerate.		<b>RELINQUISH ED BY:</b> BHC	<b>DATE</b> 5/28/2015	<b>TIME</b> 16:00 16 344	<b>RECEIVED BY:</b> Hgg	<b>DATE</b> 5/28/15	<b>TIME</b> 16:00

*B. pumilus* Lot 716707 Exp 10/16



chga

Test Information			
EPA Project No.	6-60		
Technicians Name	Nicole Griffin Gatchalian		
Recorders Name	Nicole Griffin Gatchalian		
PI	Shannon Serre		
Test Date	5/28/2015		
BIs into TSB	5/28/2015		
Test No.	BIs for WA 6-60 irradiated at 50 kGy		
BI Lot Number/Expiration Date	B. atrophaeus Lot 1163211 Exp 1/17		
BI Lot Number/Expiration Date	B. pumilus Lot 716707 Exp 10/16		
Results			
Date	6/4/2015	6/5/2015	6/5/2015
	Tube Result	Plate Result	Final Result
Sample ID			
WA 6-60 BI-B. atrophaeus DS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus WS-50-kGy	G	G	G
WA 6-60 BI-B. atrophaeus ODT-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus OLT-50-kGy	G	G	G
WA 6-60 BI-B. atrophaeus FS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus MS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus PBS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus BS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus PS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus OPS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus LS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus PPS-50-kGy	G	G	G
WA 6-60 BI-B. pumilus DS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus WS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus ODT-50-kGy	N	N	N
WA 6-60 BI-B. pumilus OLT-50-kGy	N	N	N
WA 6-60 BI-B. pumilus FS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus MS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus PBS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus BS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus PS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus OPS-50-kGy	N	N	N
WA 6-60 BI-B. pumilus LS-50-kGy	G	G	G
WA 6-60 BI-B. pumilus PPS-50-kGy	N	N	N
WA 6-60 BI-B. atrophaeus positive 1	G	G	G
WA 6-60 BI-B. atrophaeus positive 2	G	G	G
WA 6-60 BI-B. atrophaeus positive 3	G	G	G
WA 6-60 BI-B. pumilus positive 1	G	G	G
WA 6-60 BI-B. pumilus positive 2	G	G	G
WA 6-60 BI-B. pumilus positive 3	G	G	G
TSB Neg 1			
TSB Neg 2			
TSB Neg 3			
TSA Neg 1			
TSA Neg 2			
TSA Neg 3			
Initials of analyst	NGG	NGG	NGG

Key:  
G = growth  
N = no growth



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