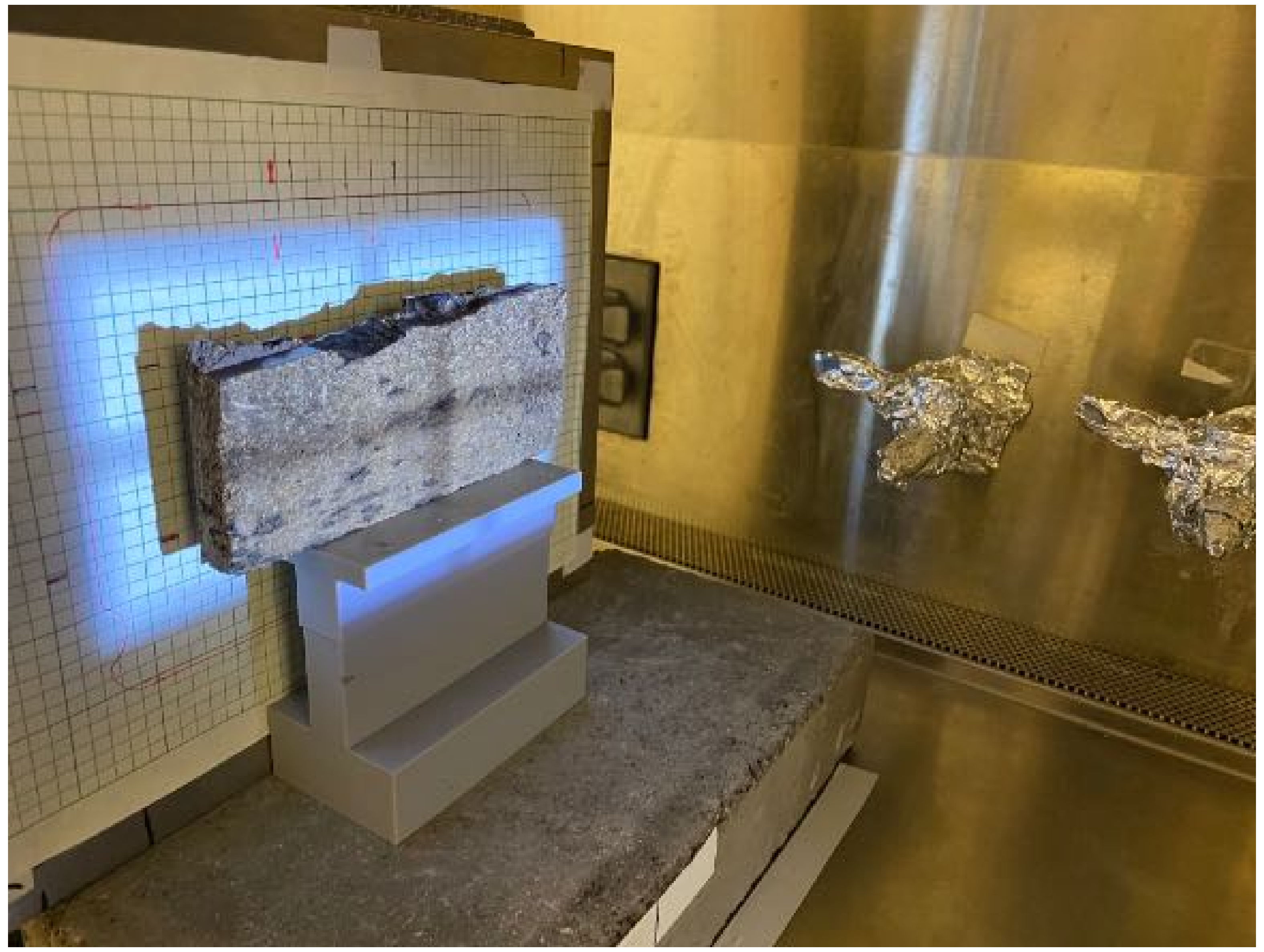
Evaluation of the capacity of melanin produced from *C. neoformans* to shield or attenuate X-rays (XR) via XR–WASOS Radiography

MELANIN DISK

MELANIN CUVETTES



Mycelium from NASA

Johns Hopkins University
Bloomberg School of Public Health
Department of Molecular Microbiology and Immunology

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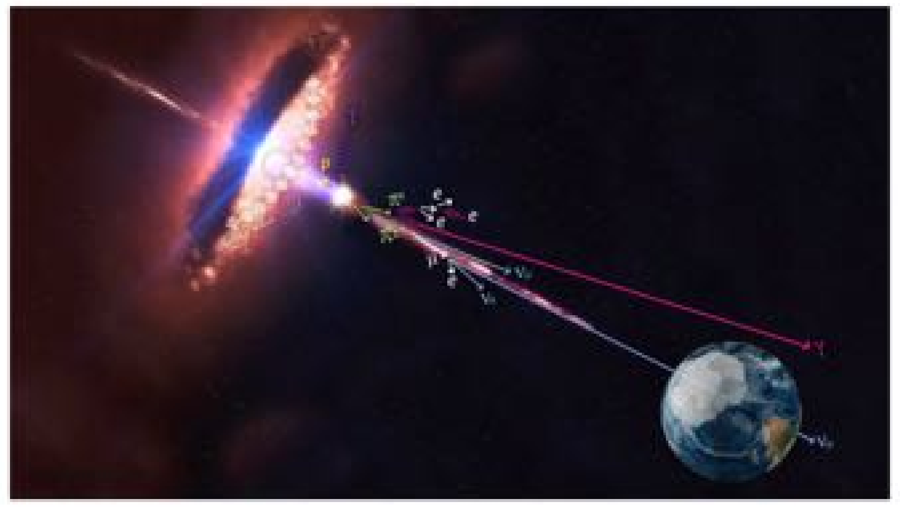
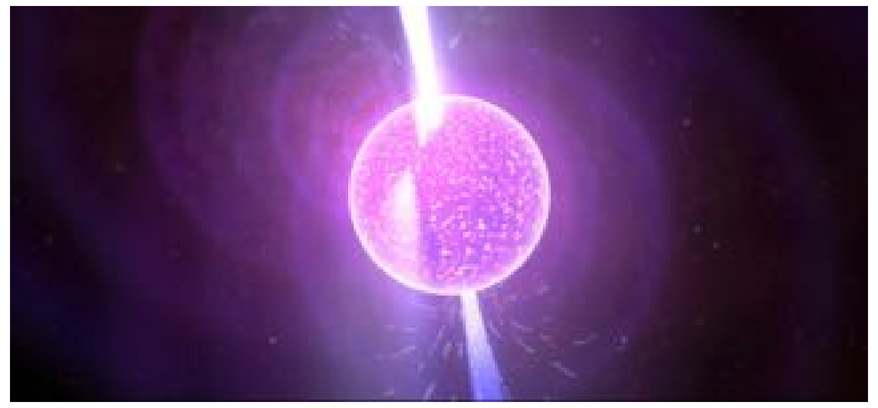
Arturo Casadevall's Group Meeting
Wednesday, April 26, 2023 | 11:00 AM EDT
W5316 | ZOOM Meetings

The electromagnetic spectrum is the range of frequencies generated by electromagnetic waves, and it is omnipresent in our daily lives.

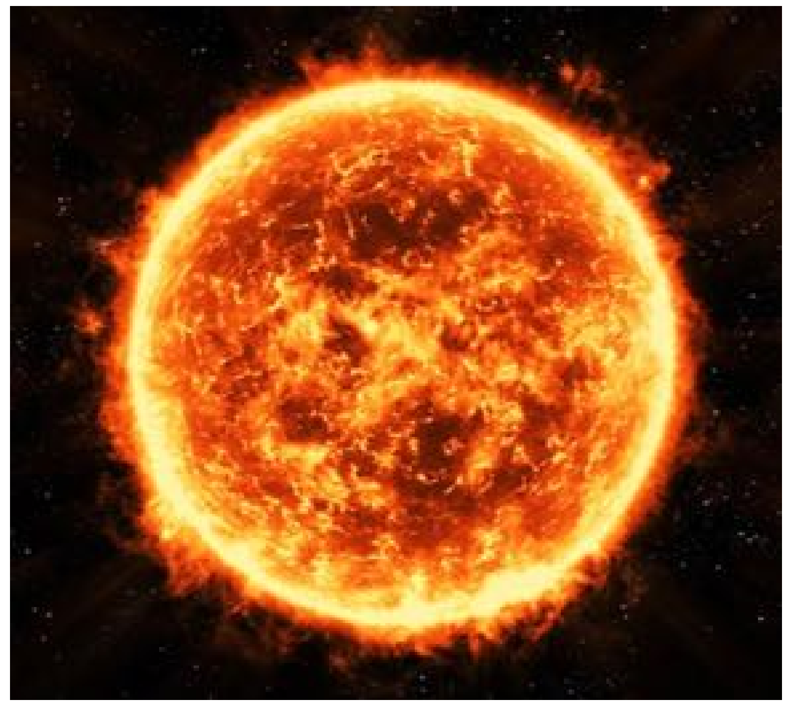
Blazar



Pulsar



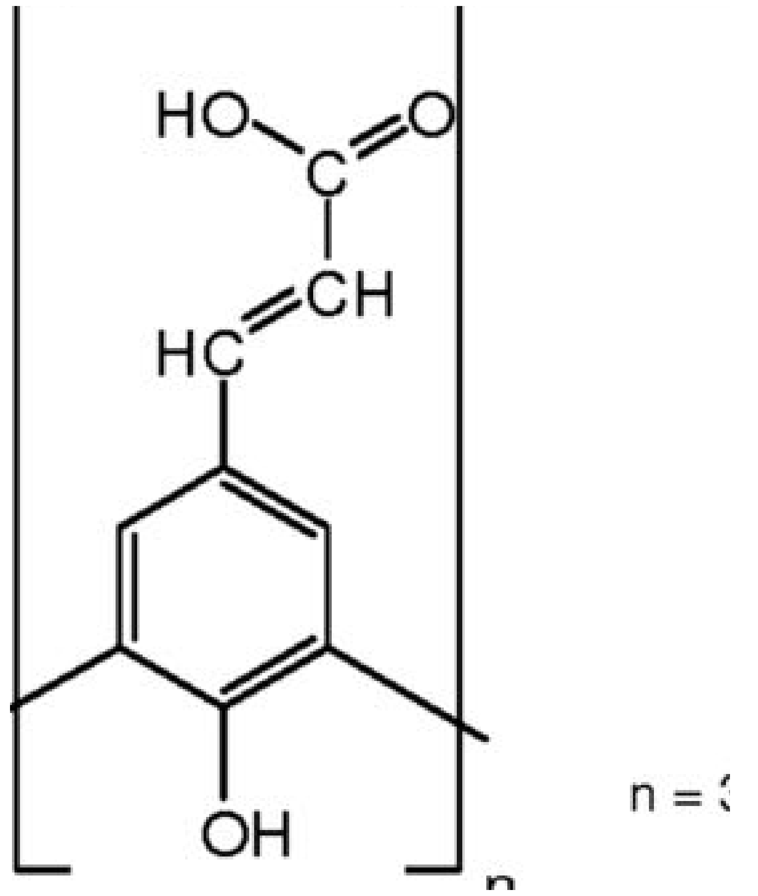
Sun



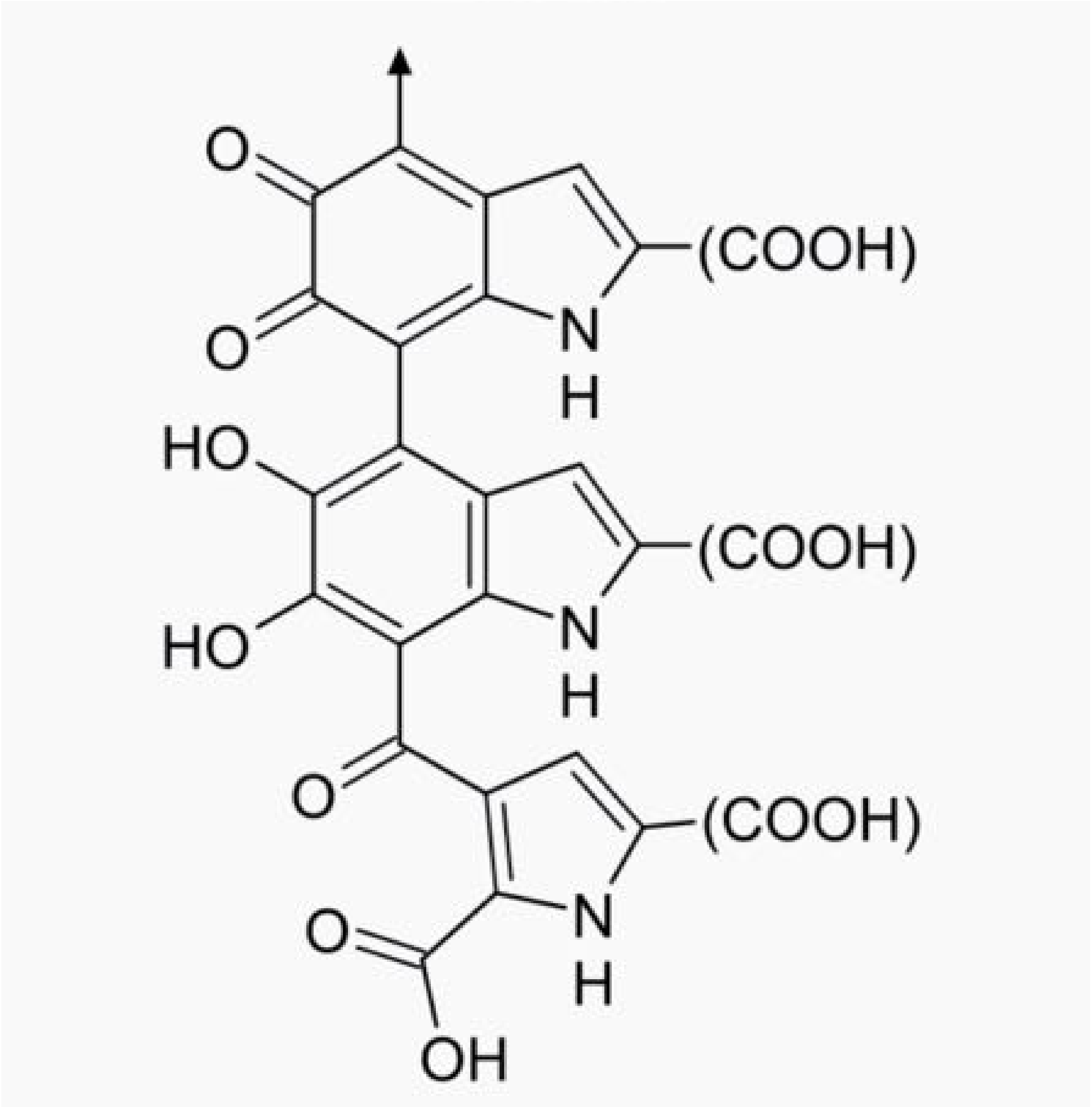
	Wavelength (m)	Frequency (Hz)	Photon Energy (eV)
Gamma Rays	10^{-12}	$10^{20} - 10^{24}$	$\geq 10^{6}$
X Rays	10^{-10}	$10^{17} - 10^{20}$	$10^{2} - 10^{5}$
Ultraviolet	10^{-8}	$10^{15} - 10^{17}$	$10^{1} - 10^{2}$
Visible	10^{-6}	10^{14}	$10^{0} - 10^{1}$
Infrared	10^{-5}	$10^{13} - 10^{14}$	$10^{-2} - 10^{0}$
Microwaves and Radiofrequency	$\leq 10^{-2}$	$\leq 10^{13}$	$\leq 10^{-2}$

The absorption or harvesting of energy from the electromagnetic spectrum is dependent upon how the waves interact with their environment, such as solids (e.g. plastics), gases in the atmosphere, and liquids (e.g. water or gasoline).

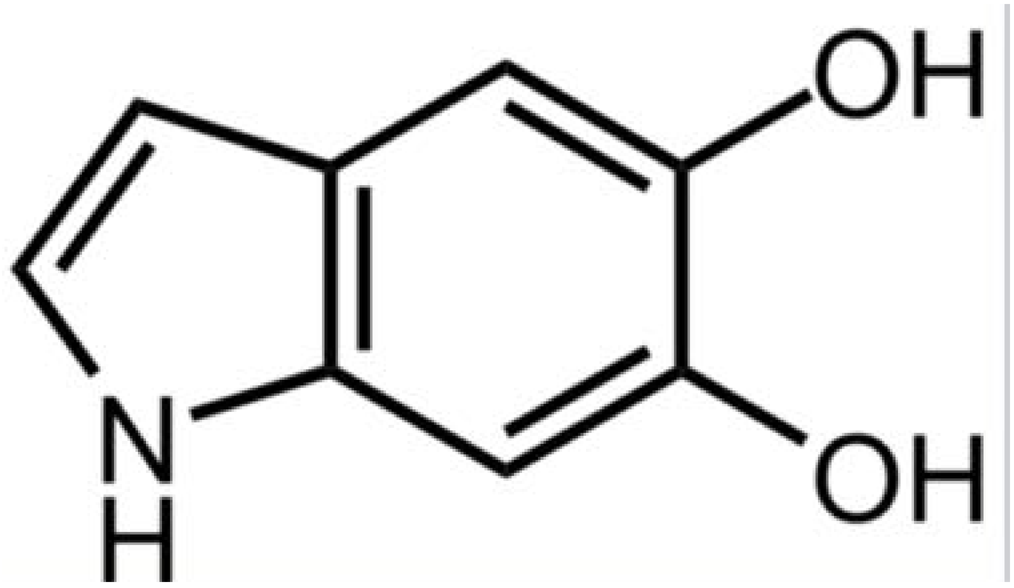
The unique chemical structure of melanins produced by the fungus *C. neoformans* makes it an ideal candidate for producing materials that are capable of absorbing, shielding, and harvesting energy from any region of the electromagnetic spectrum.



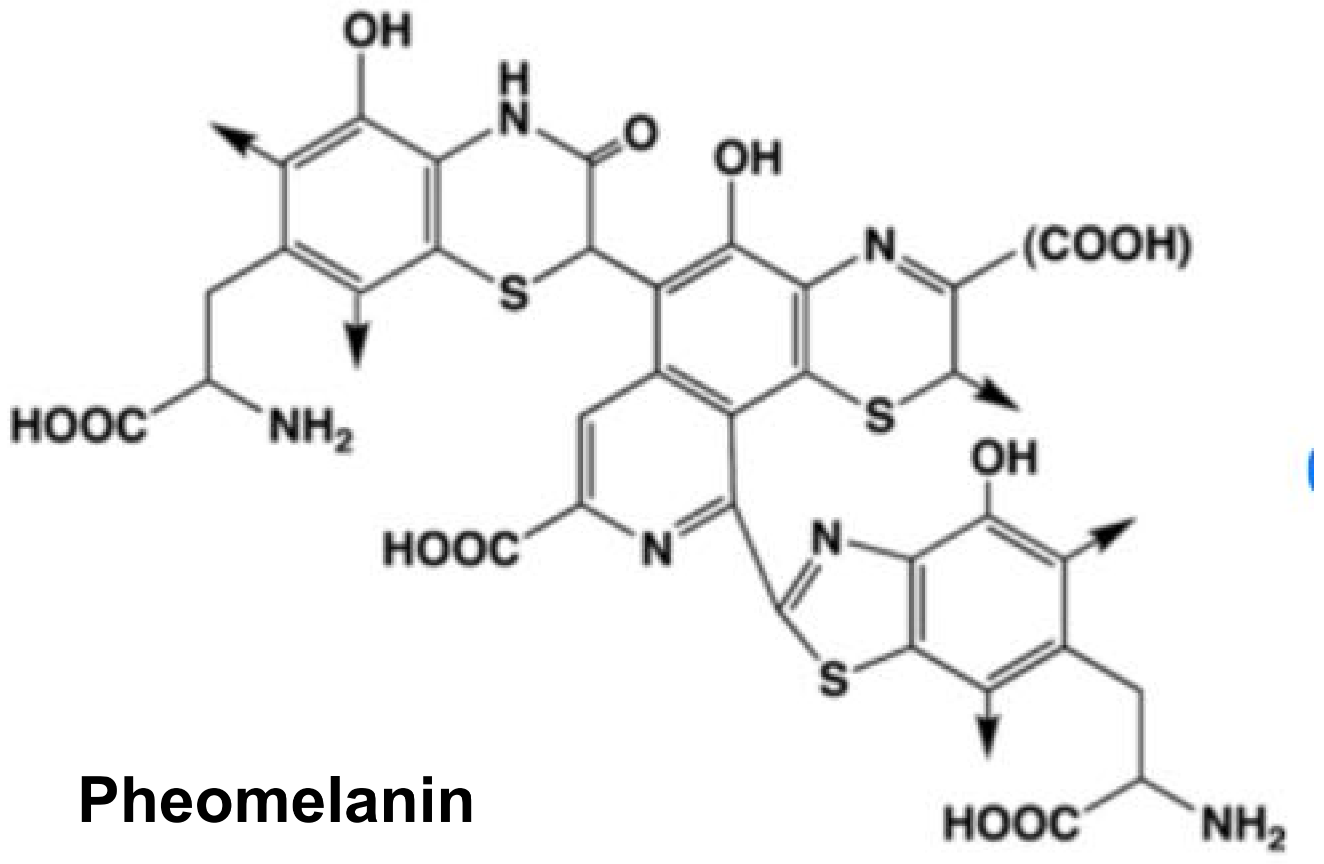
Allomelanin



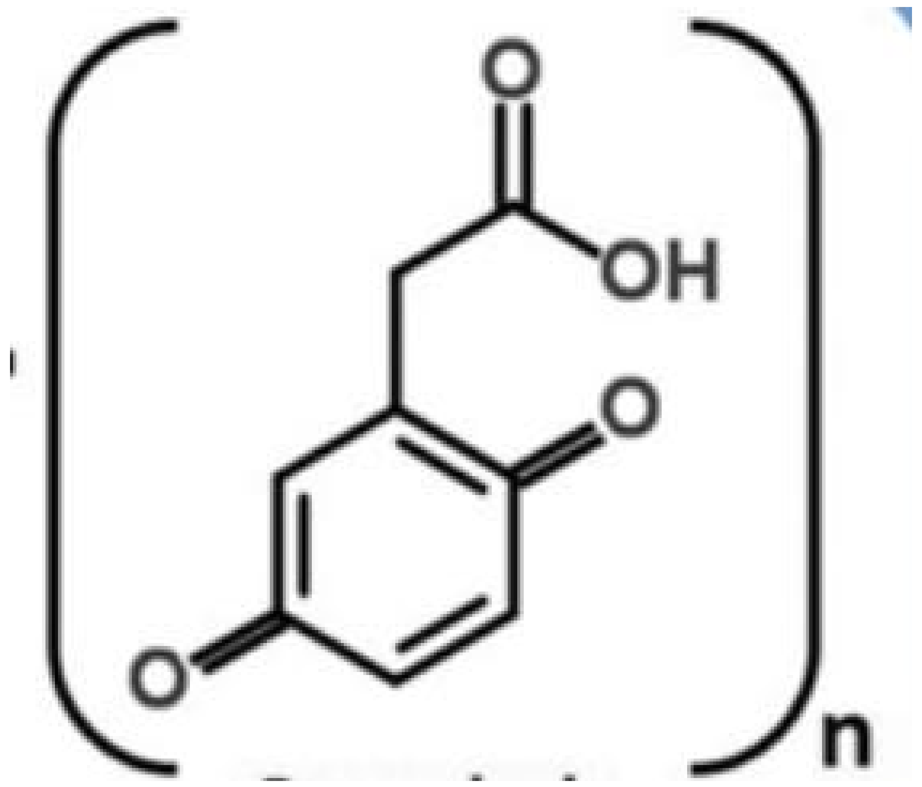
Eumelanin



Neuromelanin



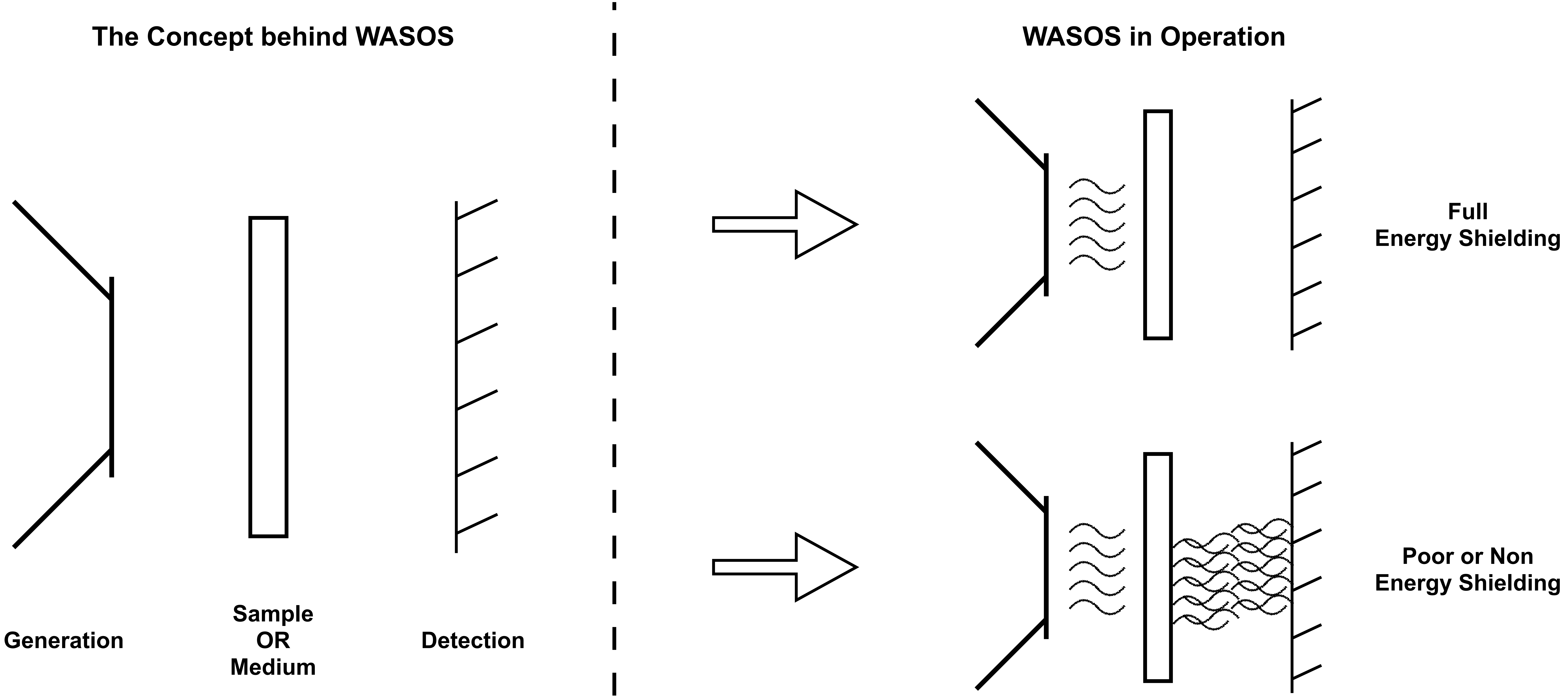
Pheomelanin



Pyomelanin

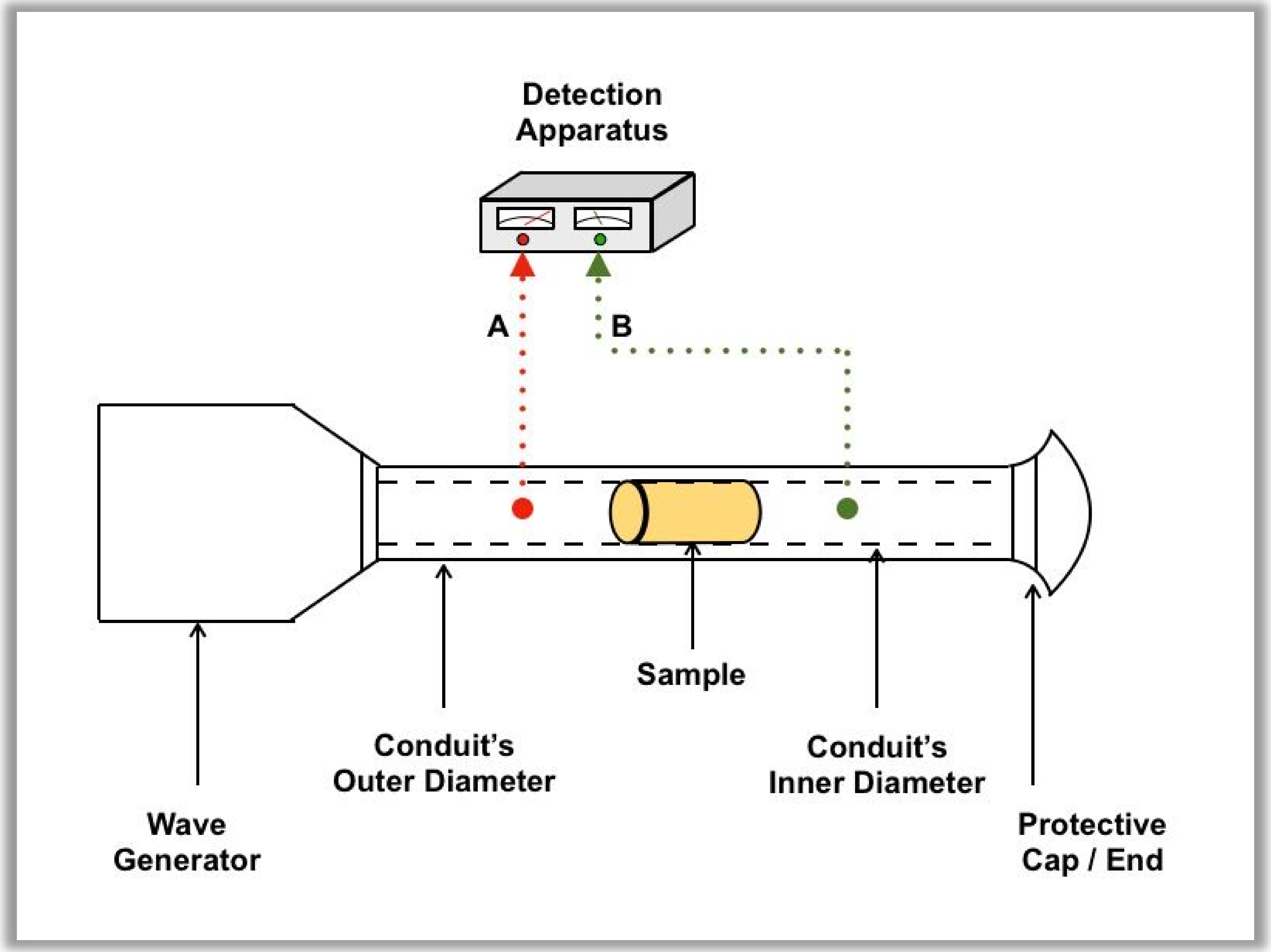
This project seeks to explore if and how the melanin produced by *C. neoformans* has the ability to protect and nurture us with energy from the electromagnetic waves coming from the entire spectrum.

We call the systems capable of doing this Wave Absorption/Shielding Observance Systems (WASOS) reflecting on the interaction between waves and melanins as materials that we want to observe.



This type of system is made possible by today's technological advancements, allowing us to observe waves from all regions of the electromagnetic spectrum.

Here is a vision for the future of a WASOS: sleek, modern, and optimized design.



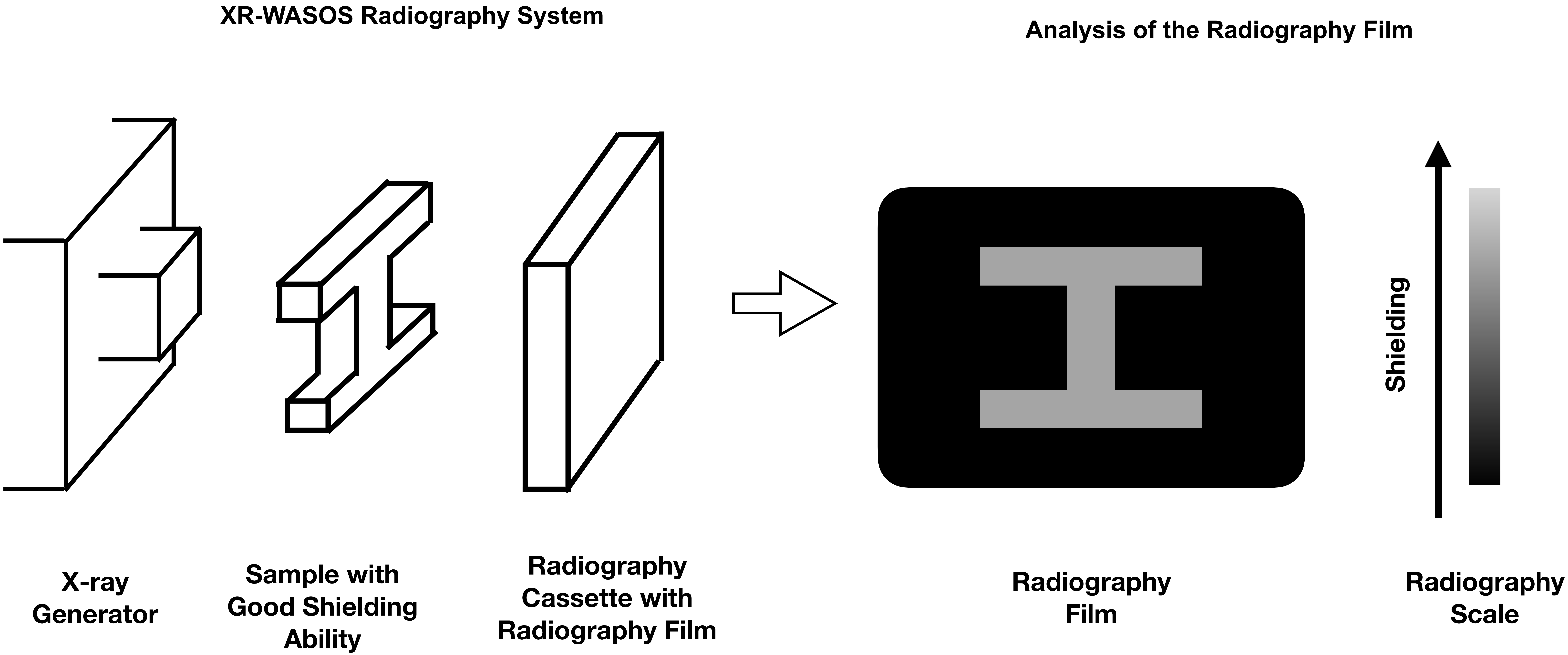
One should take into account that the design of every WASOS requires a specific type of generator, detector, and conduit that is suitable for each kind of wavelength.

We began by precisely identifying the design specifications of each WASOS, and organizing the parameters and equipment in a tabulated format.

WASOS Type	Frequency (Hz)	Types of Generator	Types of Detectors	Types of Conduit
MW	$10^9 – 10^{11}$	• Power Grid Tubes • Cross Field Amplifiers	• Peak Detectors • Network analyzers • Root Mean Square Detectors	• Black Steel • Aluminium
IR	$10^{11} – 10^{14}$	• Luminous Sources • Non-Luminous Sources	• Thermal Detectors • Photoconductivity Detectors	• Glass • Vantablack
VL	$10^{14} – 10^{14}$	• Discharge Lamps • Incandecent Lamps	• Basic Diode arrya • High-end Doide arrya	• Black Steel • Vantablck
UV	$10^{14} – 10^{16}$	• UV-ABlack Light • Argon Lamps	• Basic Diode arrya • High-end Doide arrya	• Polyethylene • Vantablack
XR	$10^{16} – 10^{19}$	• Single Phase Generator • Three Phase Generators	• Gas-Filled Detectors • Semiconductor Detectors	• Lead • Aluminium

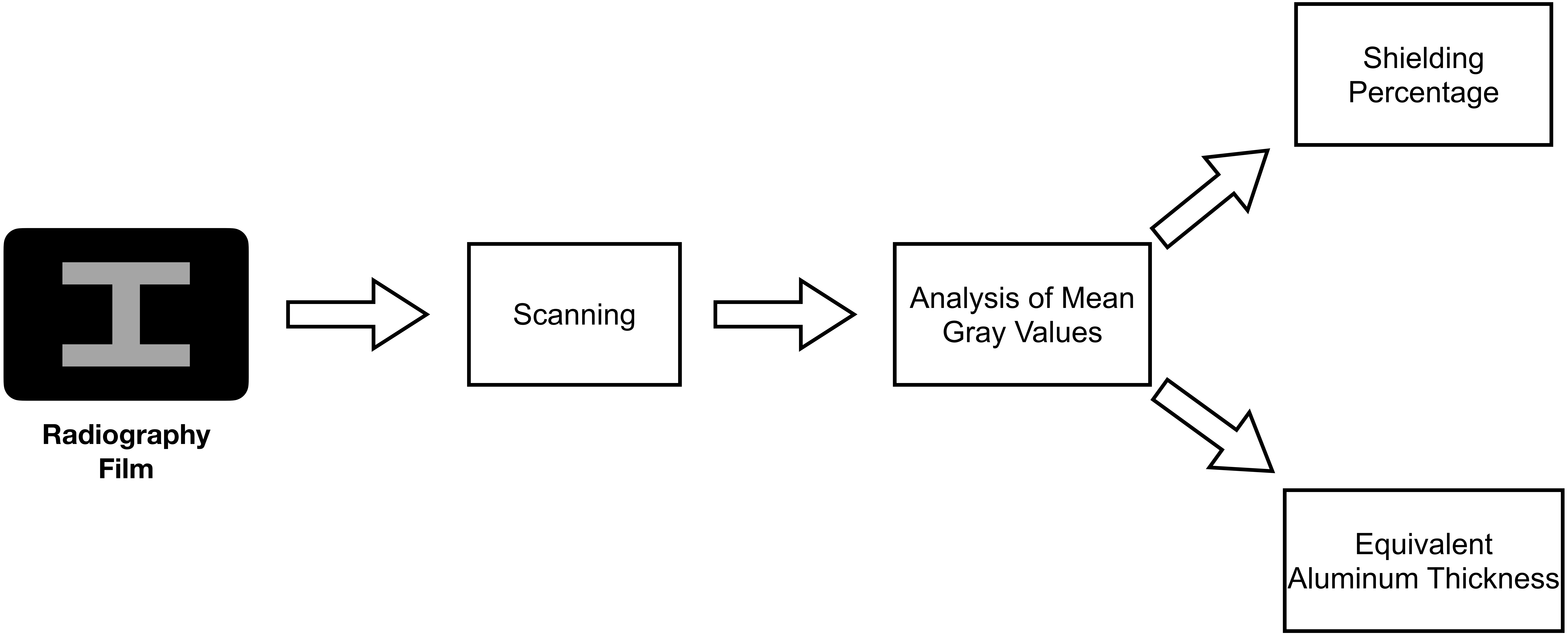
Where MW stands for microwave radiation, IR stands for infrared radiation, VL stands for visible light, UV stands for ultraviolet radiation, and XR stands for x-rays.

This presentation provides an in-depth overview of the XR-WASOS Radiography method and its capabilities.



The method allows us to use the XR-WASOS to analyze the radiography film and measure the shielding percentage and shielding equivalent aluminum (Al) thickness of our samples.

Here is the procedure for estimating the shielding percentage and equivalent aluminum thickness of our using XR-WASOS Radiography:

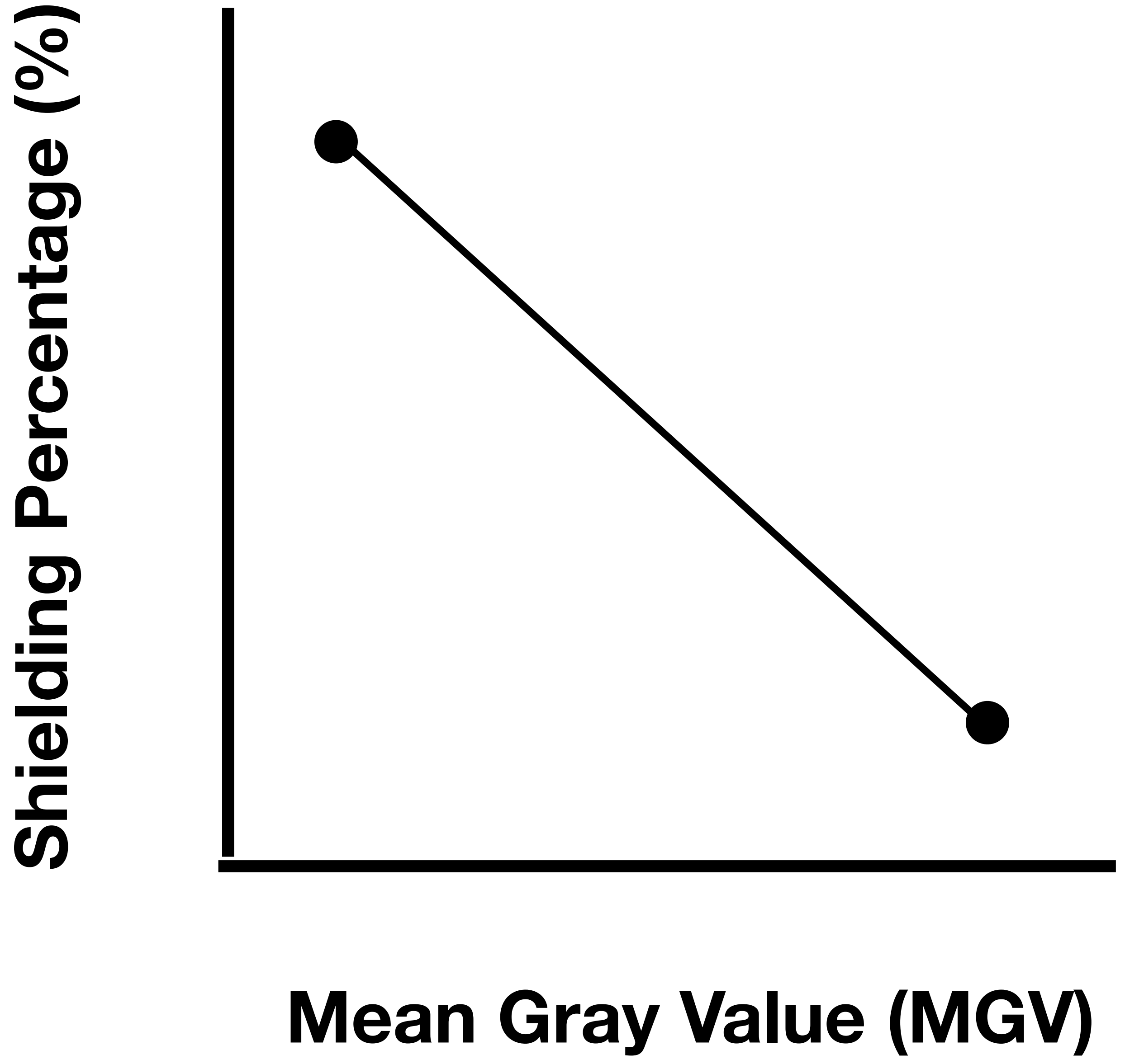


The main distinction between these techniques is that the shielding percentage is determined using a two-point simple calibration method, which is more analytical in nature, while the equivalent Al thickness is based on ASTM F640 – 20, and is more graphical in approach.

Here is how we calculate the shielding percentage of our samples.

Radiography Film no exposed to x-rays

Radiography Film Exposed to x-ray at 48 kVp for 3.33s



$$Y = m*X + b$$

Y > Shielding Percentage (%)

X > Mean Gray Value (MGV)

m > Slope (%/MGV)

b > Intercept (%)

Here is how we determine the maximum and minimum mean gray values under the shielding percentage technique.

Film no exposed to x-rays

Radiography Film no exposed to x-rays

Film Exposed to x-ray at 48 kVp for 3.33s

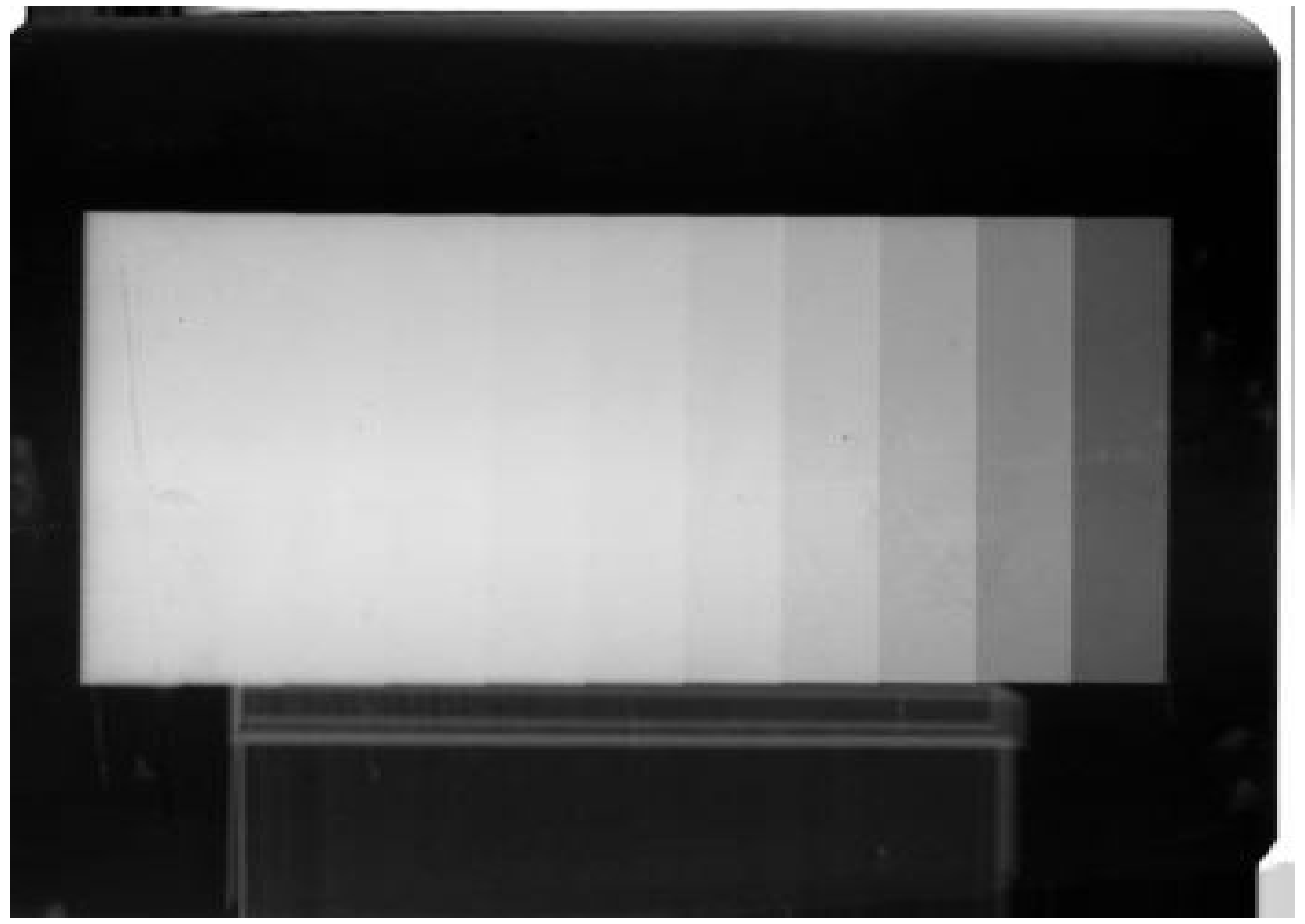
Radiography Film Exposed to x-ray at 48 kVp for 3.33s

Calibration Parameters for the Shielding Percentage Method

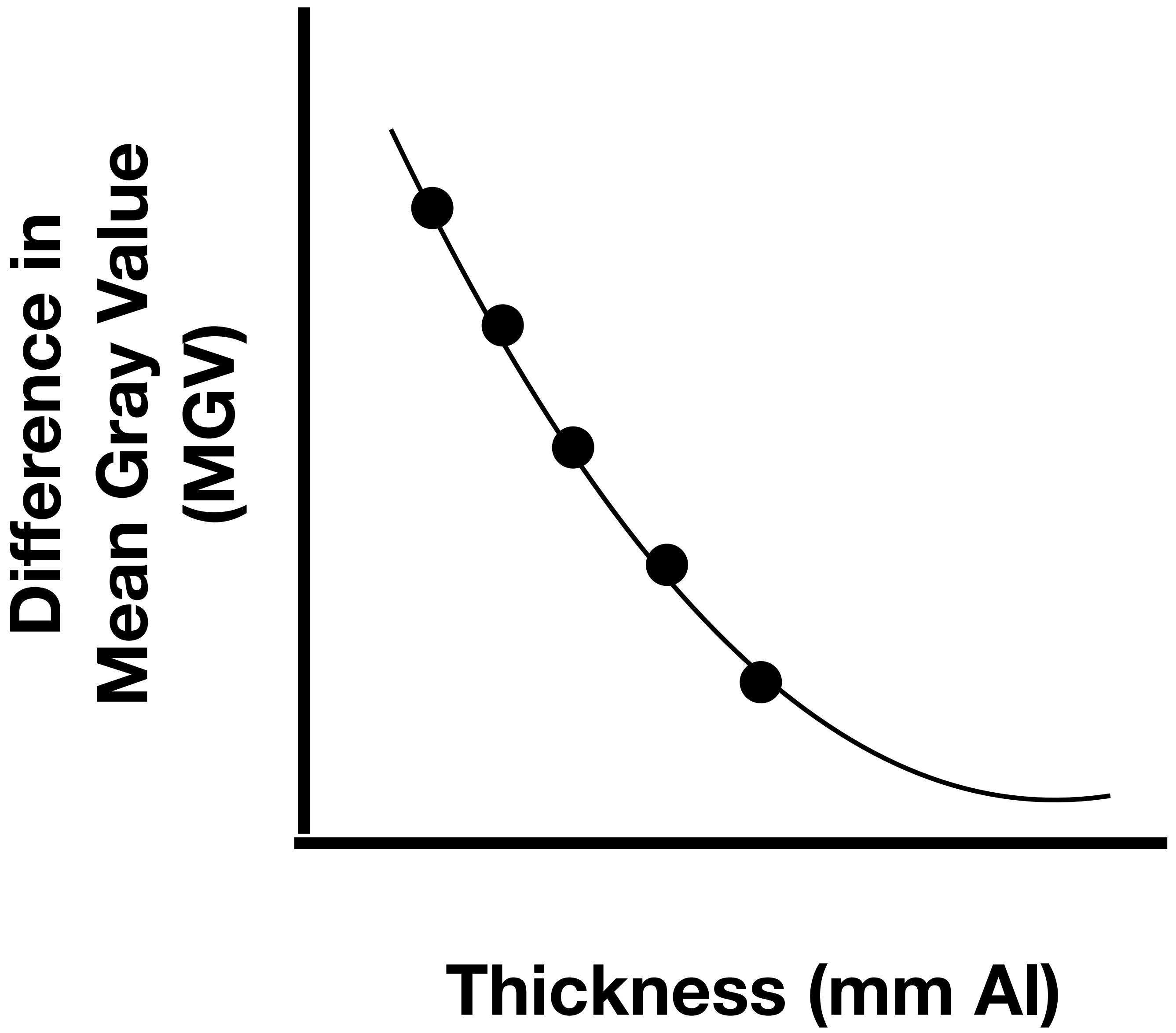
Parameter	Value	
Y (%)	0	100
X (MGV)	10.839	233.30
Slope (%/MGV)	0.450	
Intercept (%)	–4.872	

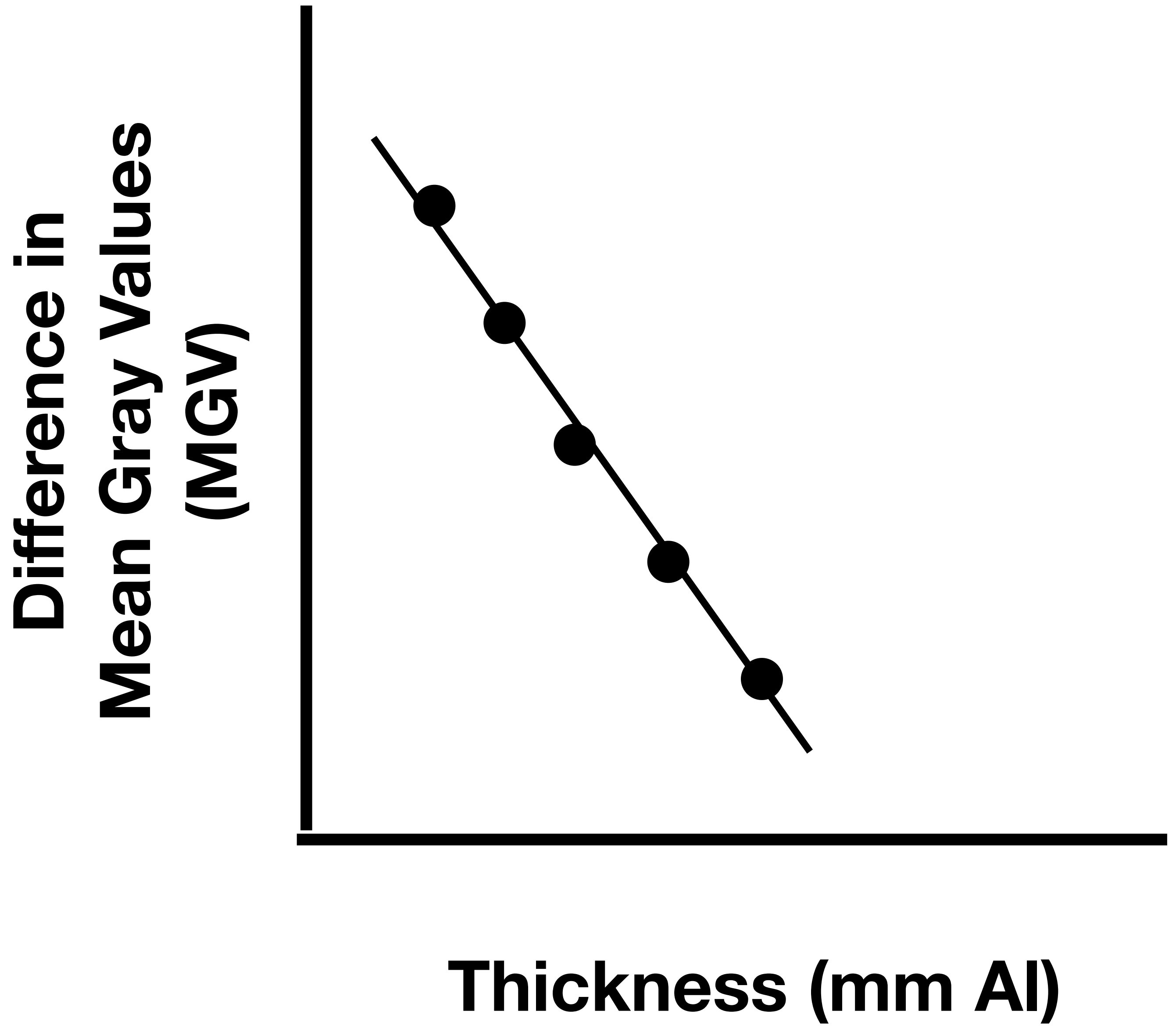
Here is how we estimate the equivalent Al thickness of our samples.

Al Step-Wedge



Radiograph of an Al Step-Wedge





$$Y = m*X + b$$

Y > Difference in MGV (MGV)

X > Thickness of the Al Step-Wedge (mm Al)

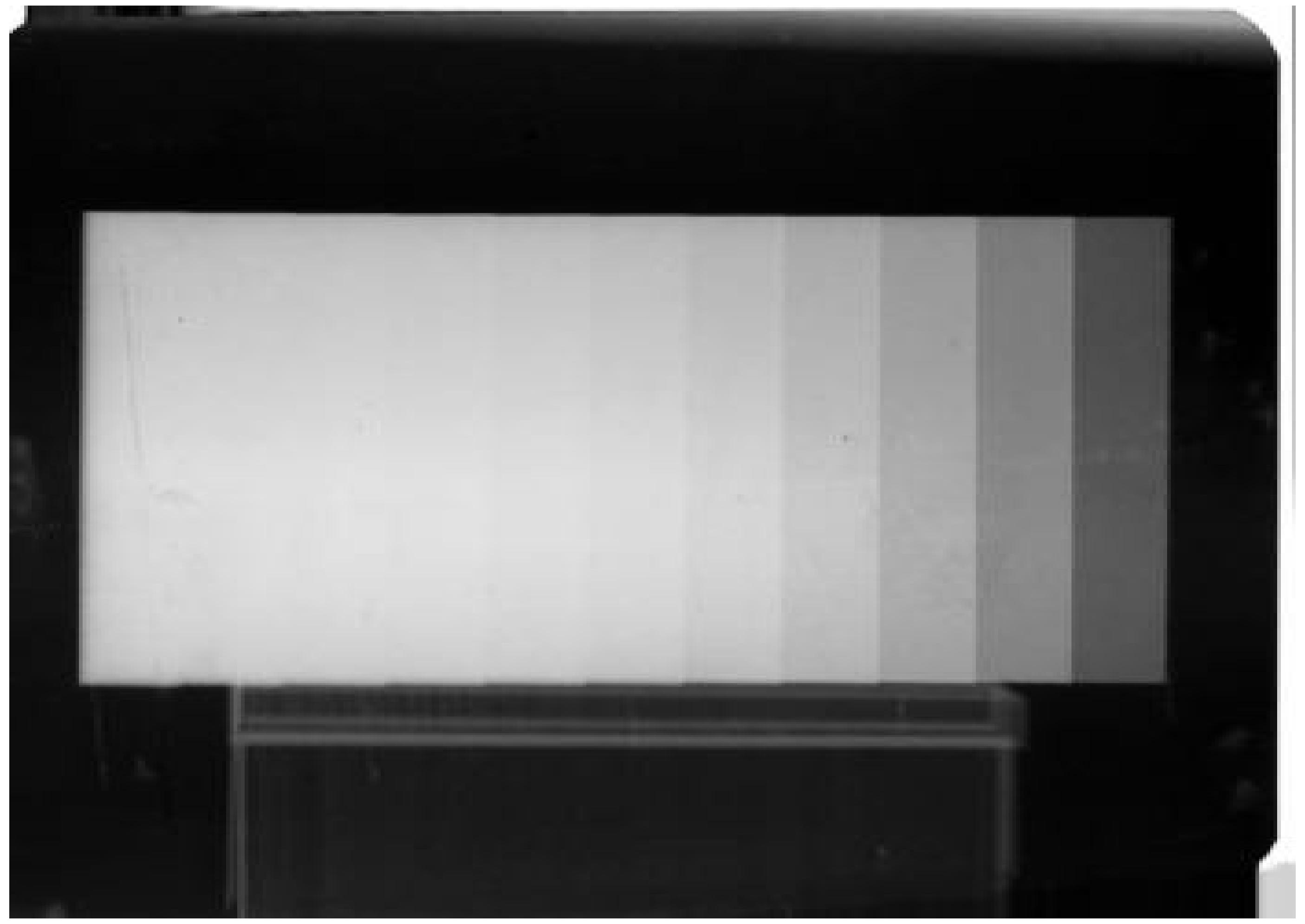
m > Slope (MGV/mm Al)

b > Intercept (MGV)

Difference in MGV = MGV for maximum x-rays exposure – MGV of sample's spot

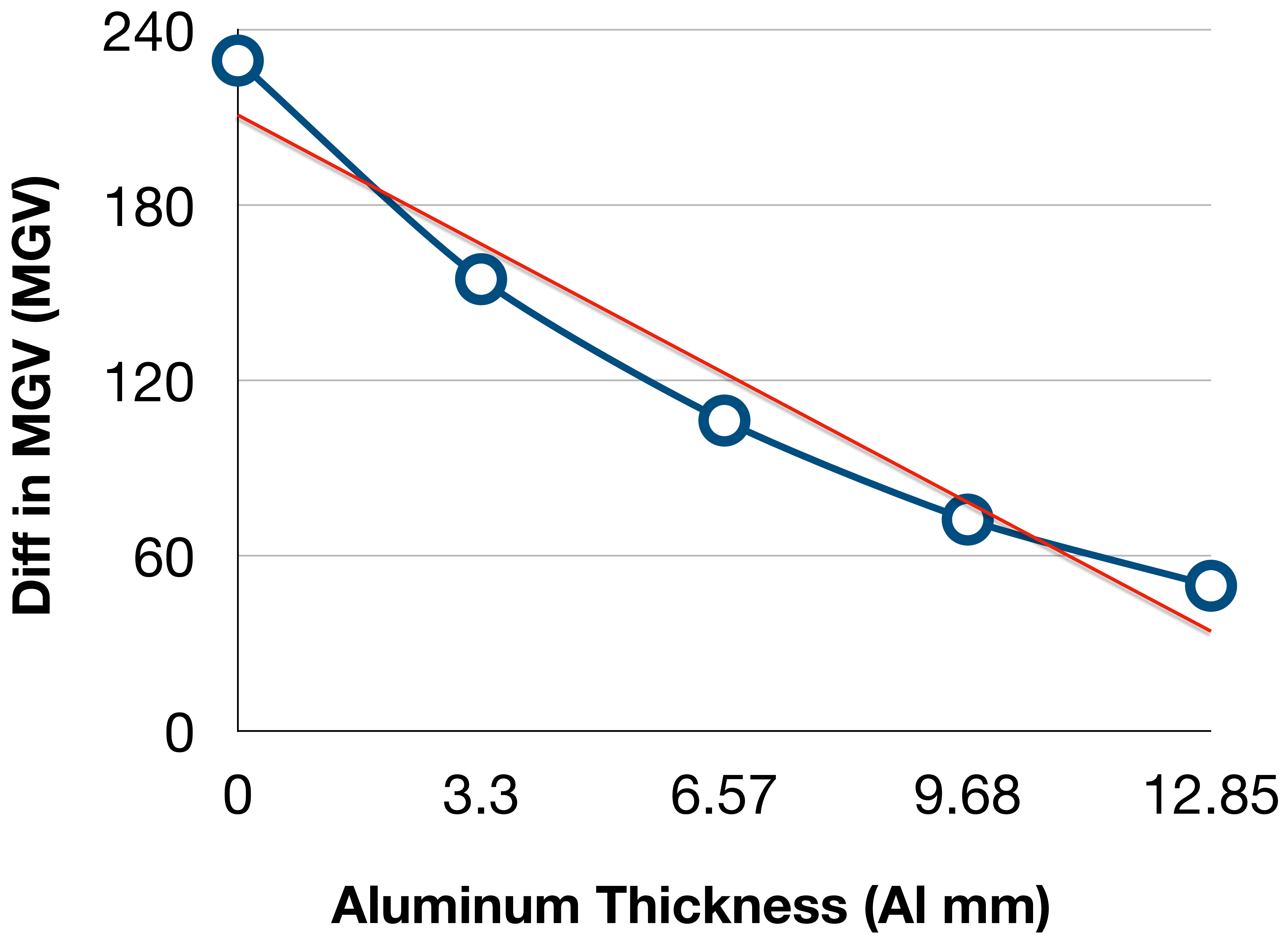
Here is how we can accurately calibrate XR-WASOS for measuring the equivalent Al thickness of our samples. This process ensures that our measurements are precise and reliable.

Al Step-Wedge



Scanned Radiography of the Al Step-Wedge

Calibration Curve of the Al Step-Wedge for the Equivalent Al Thickness Method

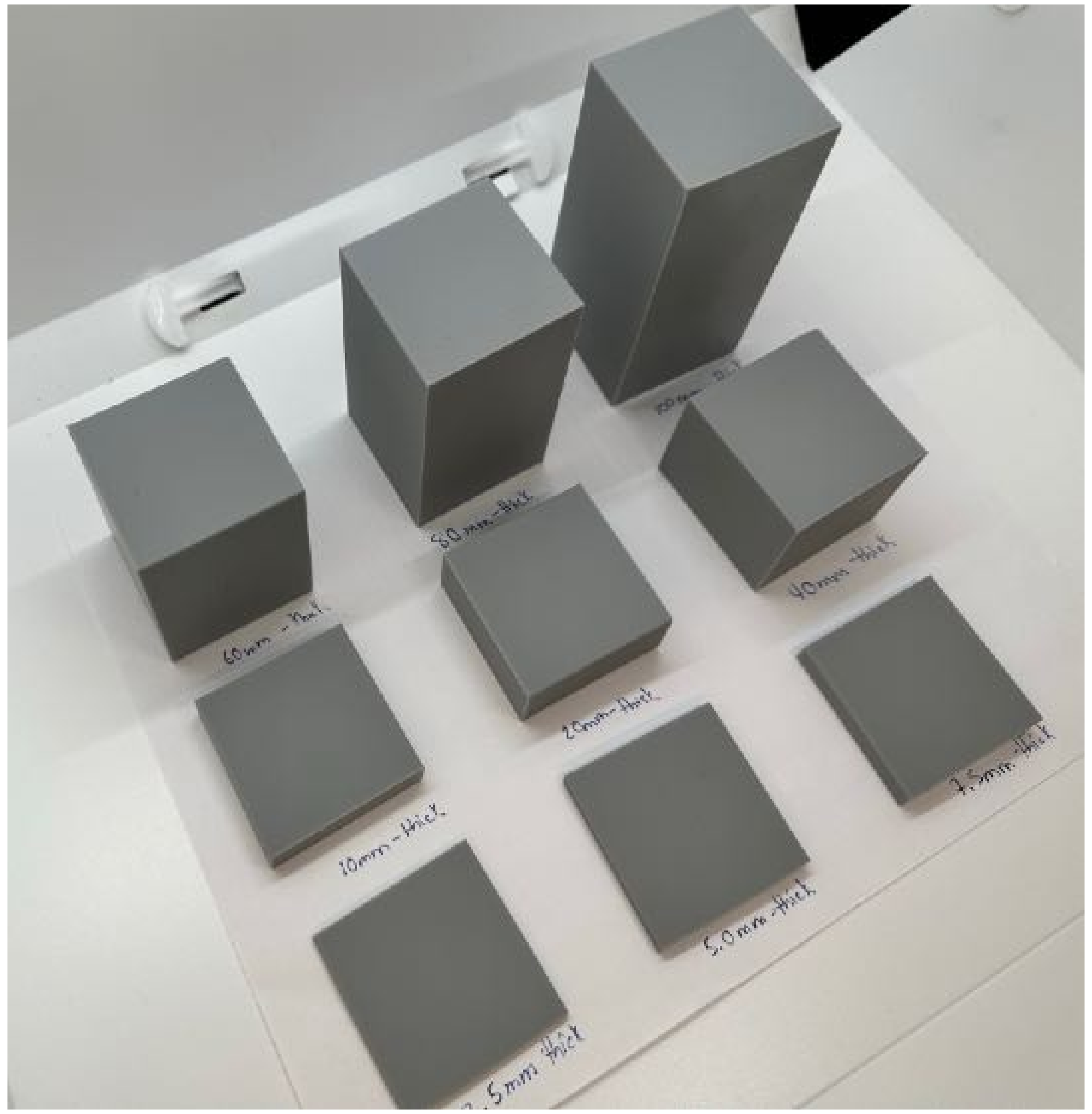


Y [MGV] = –13.809*X [mm Al] + 212..12

R^2 = 0.9545

One can analyze the shielding percentages and equivalent Al thicknesses for a diversity of using XR-WASOS Radiography.

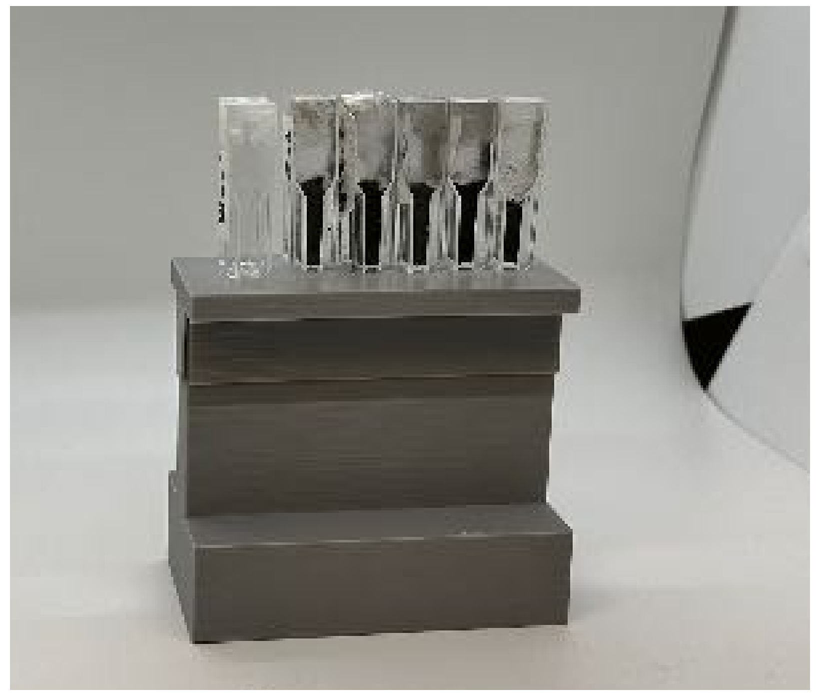
3D-Printed Blocks made of Gray PLA with Different Infill Percentages



3D-Printed Blocks made of Gray PLA with Different Thickness and 20% Infill Percent

Disk made of PLA-melanin

Compressed Mycelium from NASA

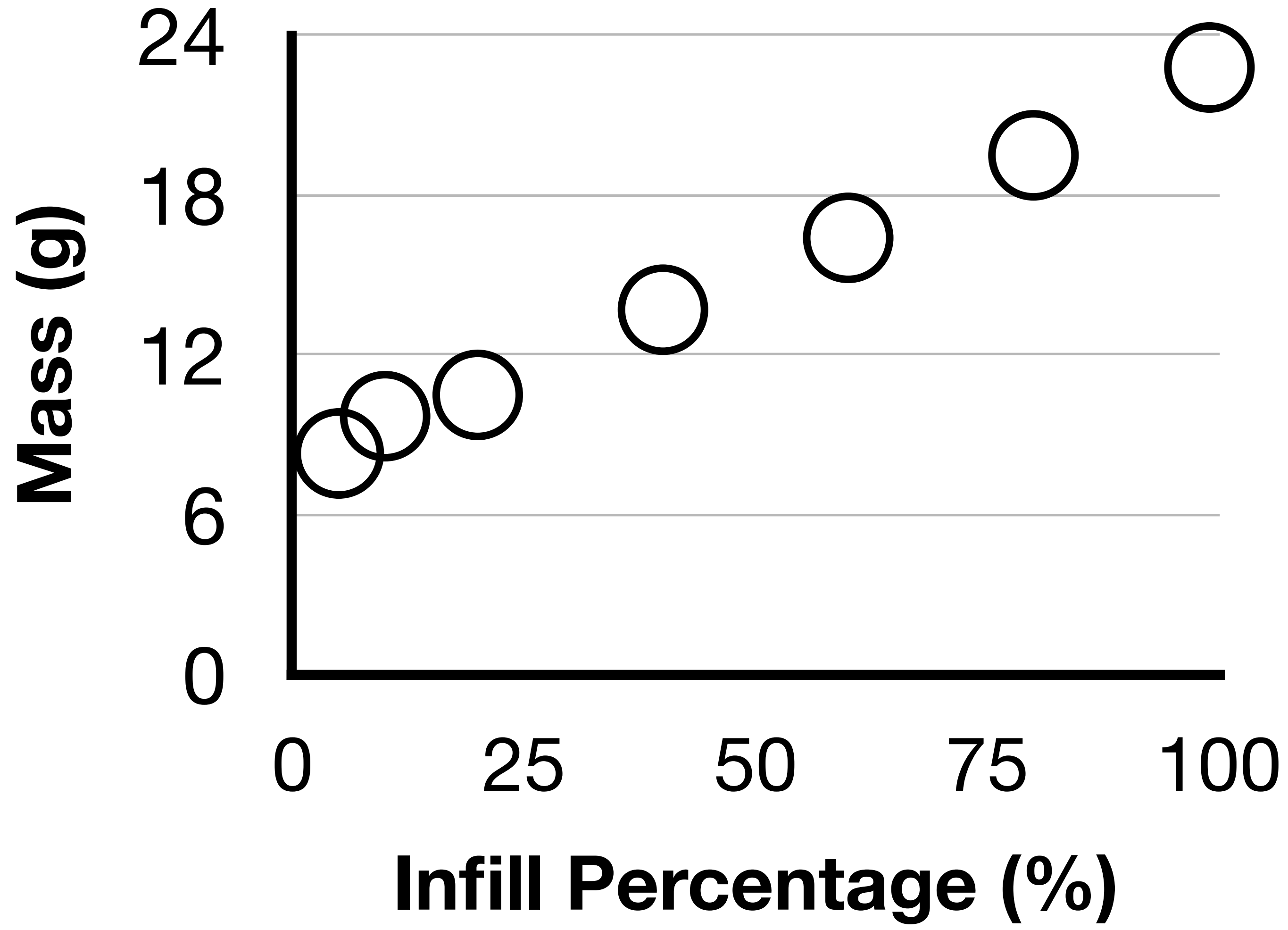


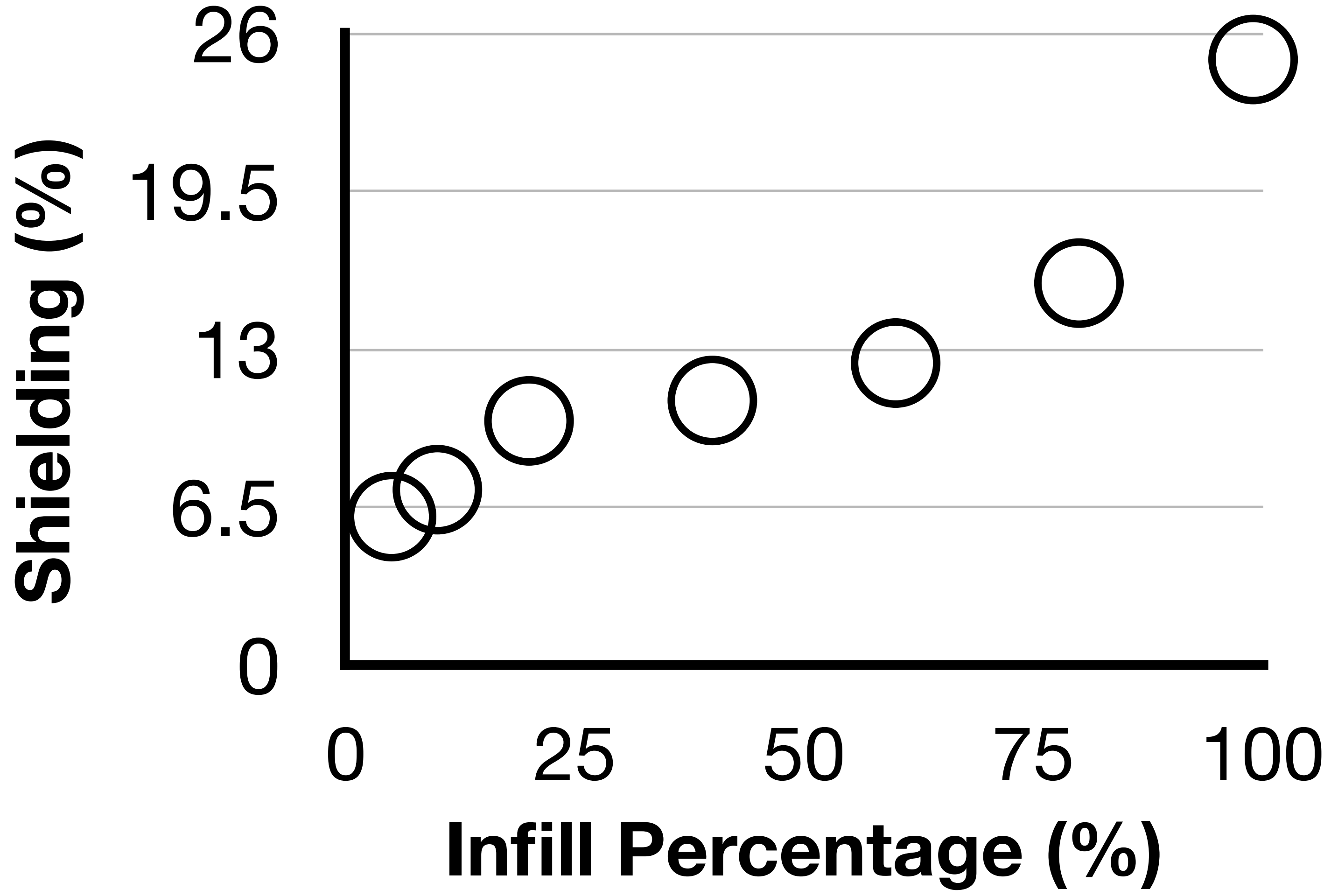
Cuvettes with Melanin Powders

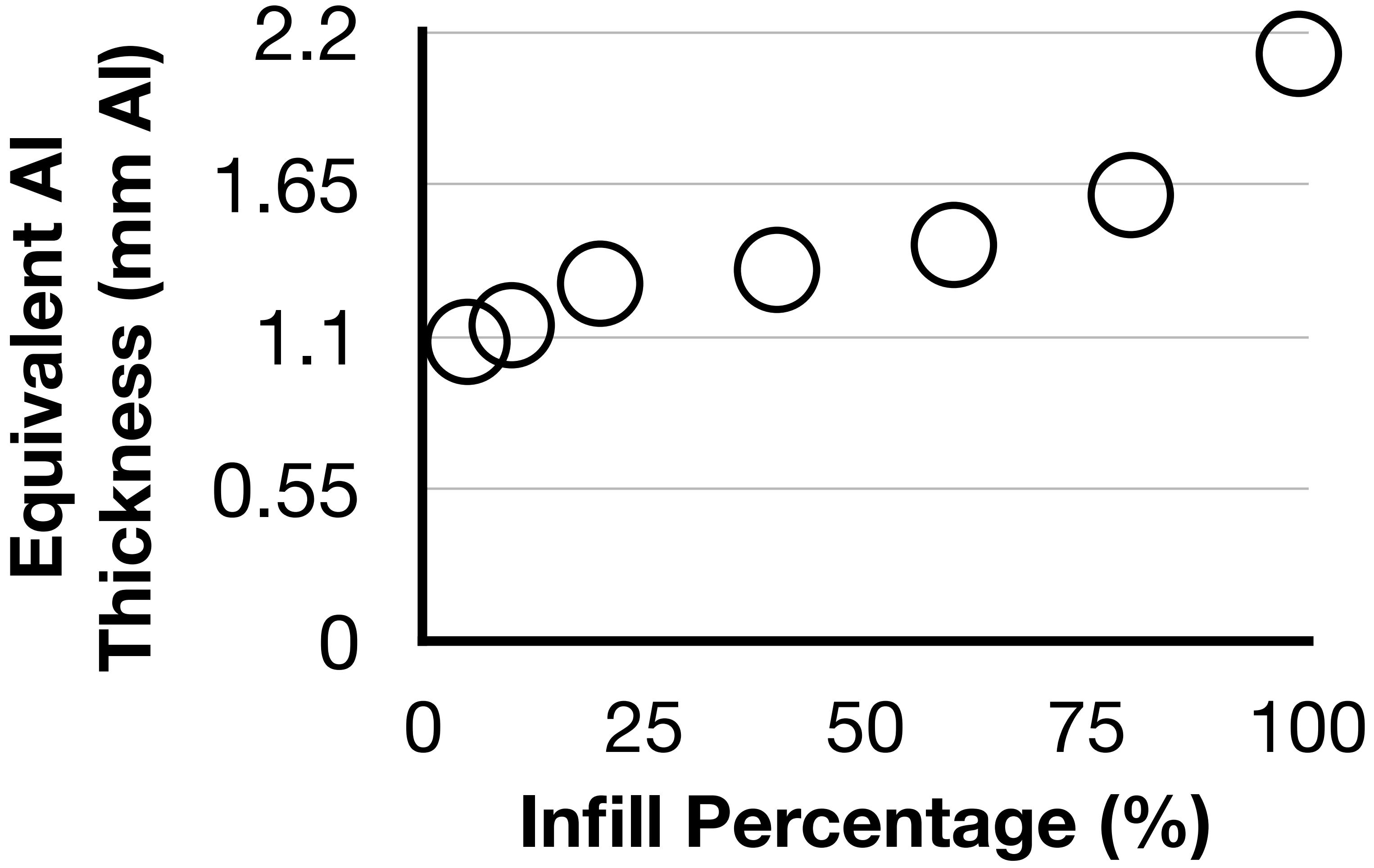
Cuvettes with Powders and Melanin from C. neoformans

The method demonstrated a high level of sensitivity to the sample's mass.

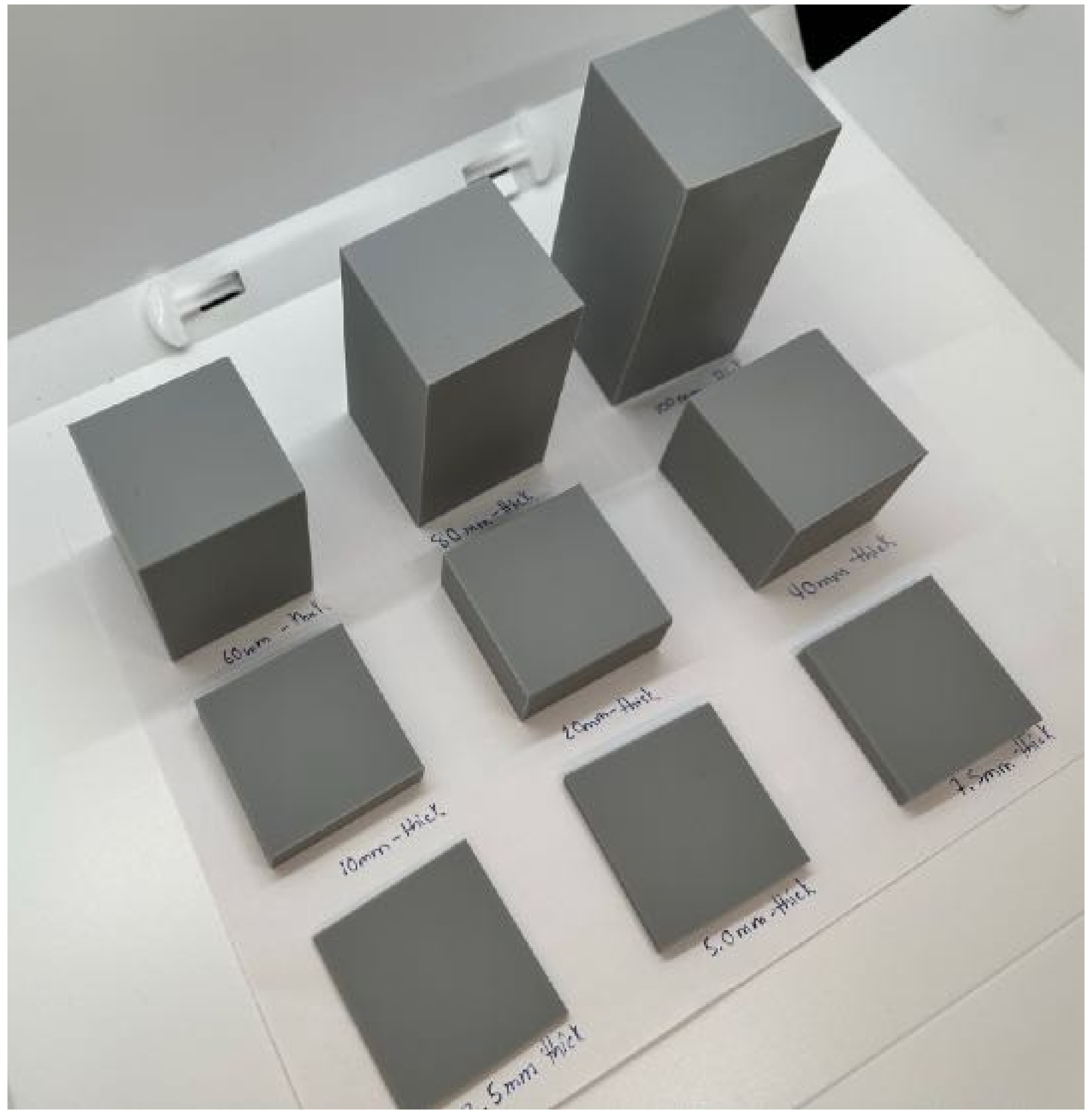
3D-Printed Blocks made of Gray PLA with Different Infill Percentages



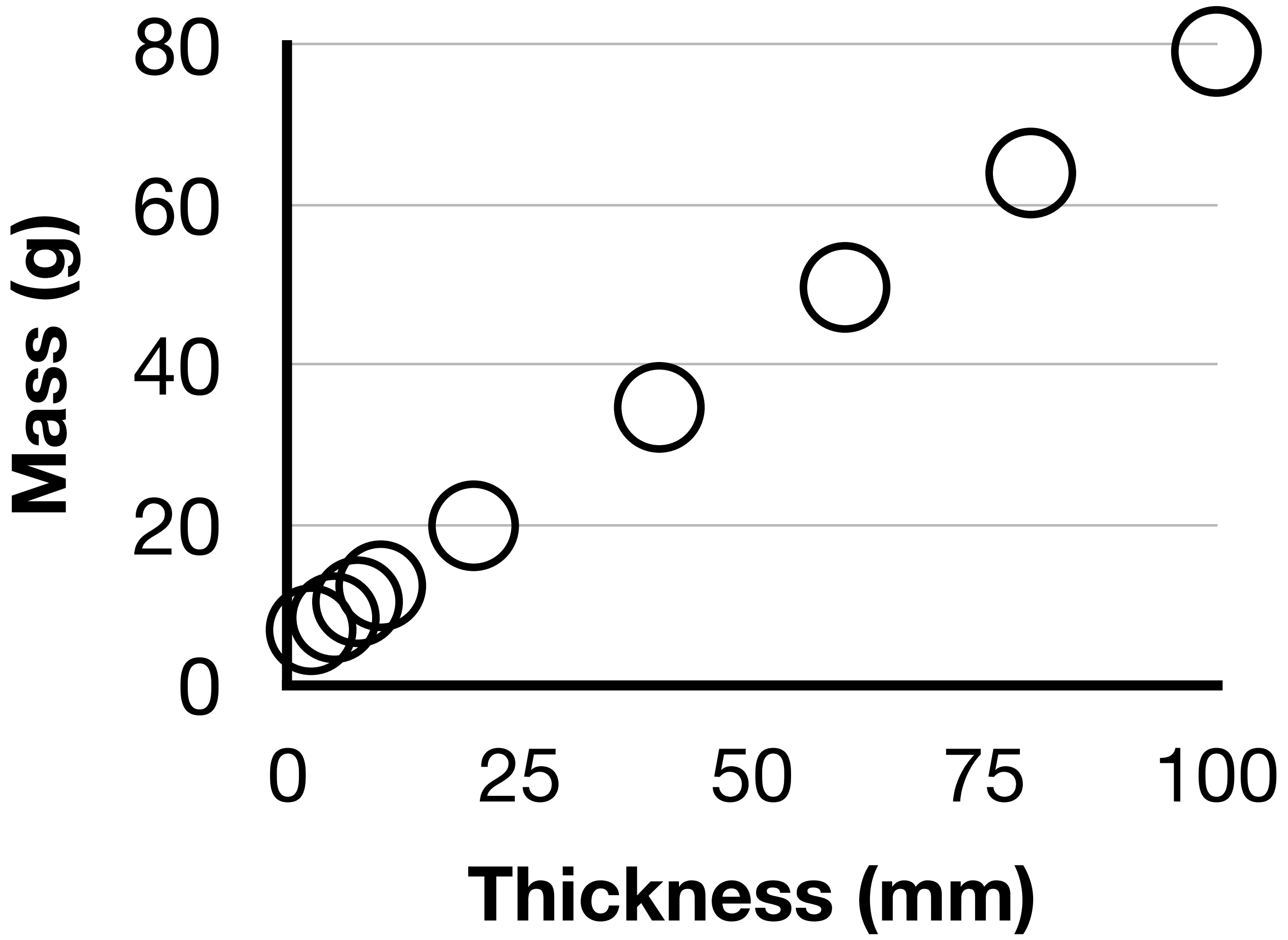


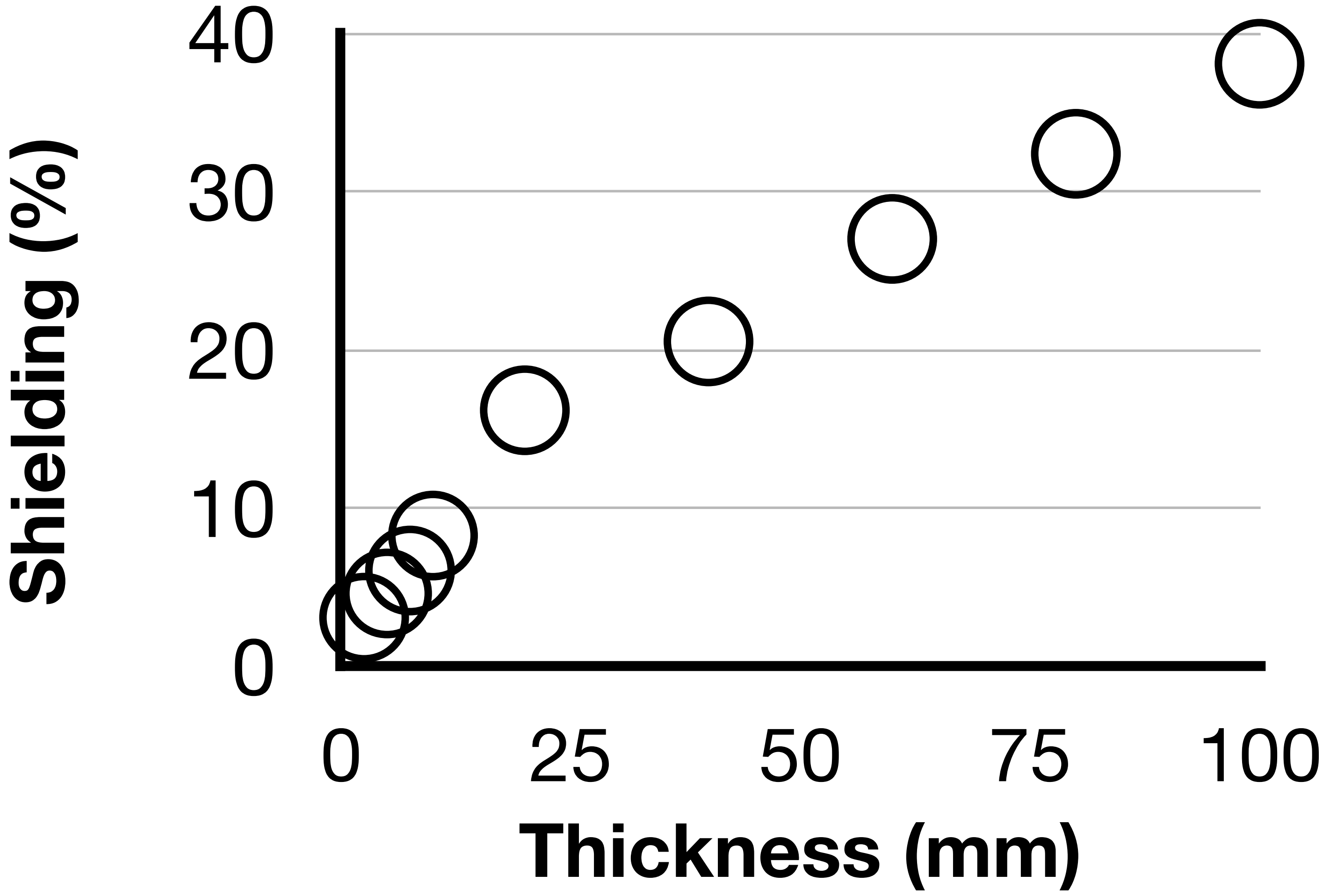


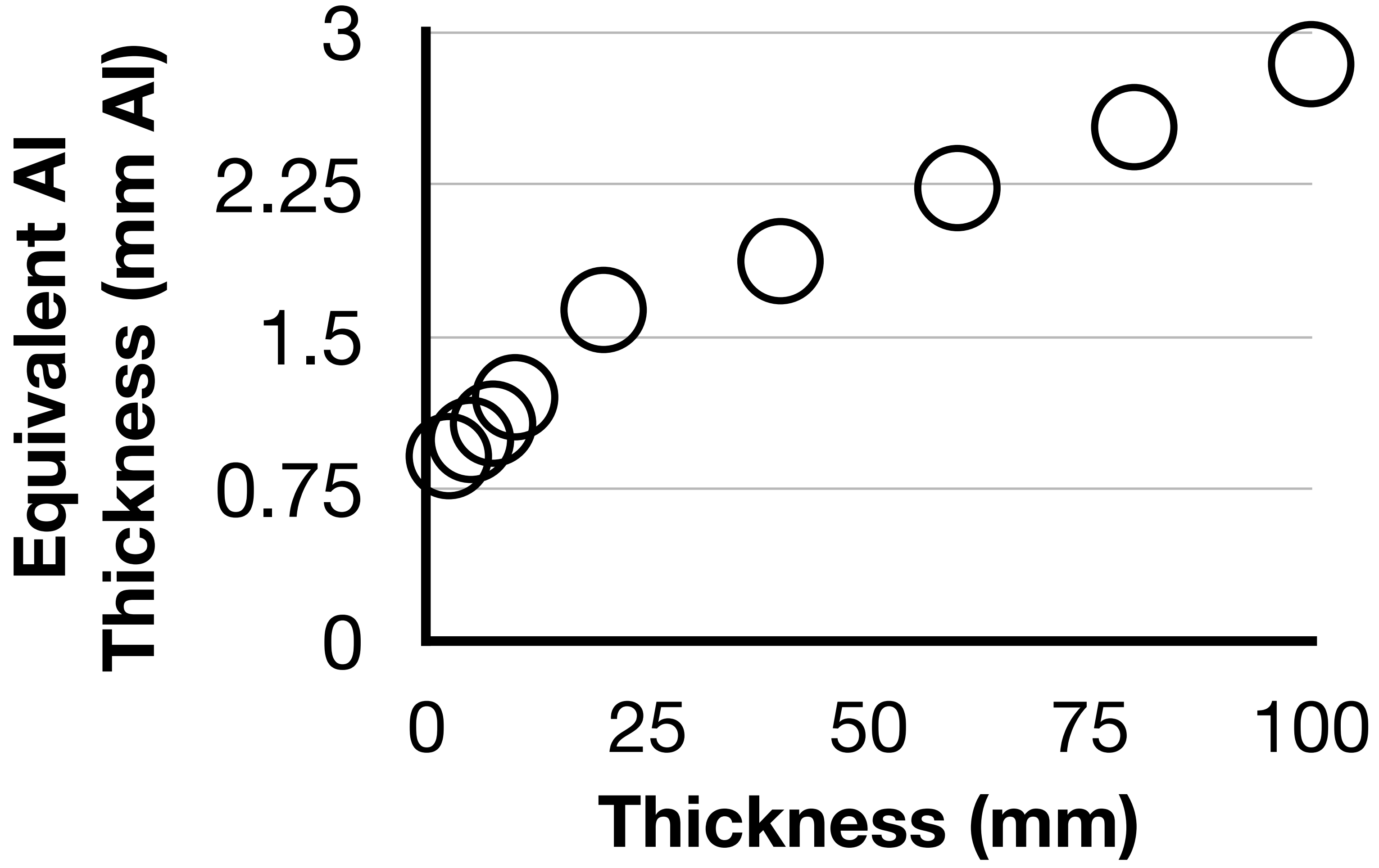
The method demonstrated a high level of sensitivity to the thickness sample's thickness.



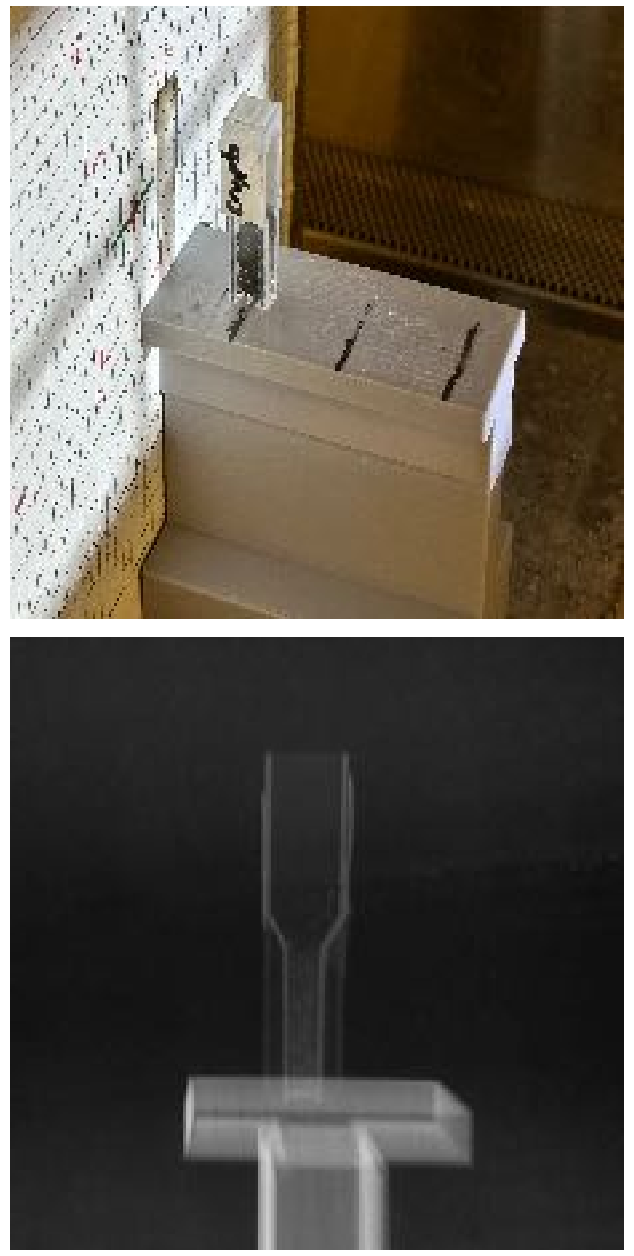
3D-Printed Blocks made of Gray PLA with Different Thickness and 20% Infill Percent

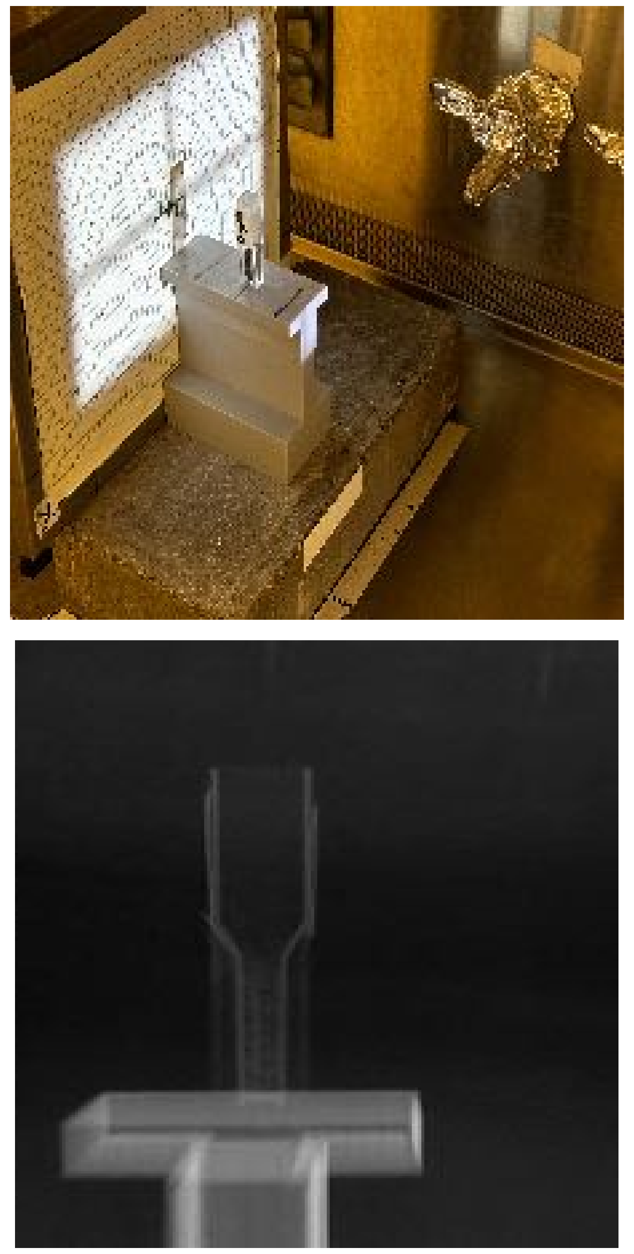


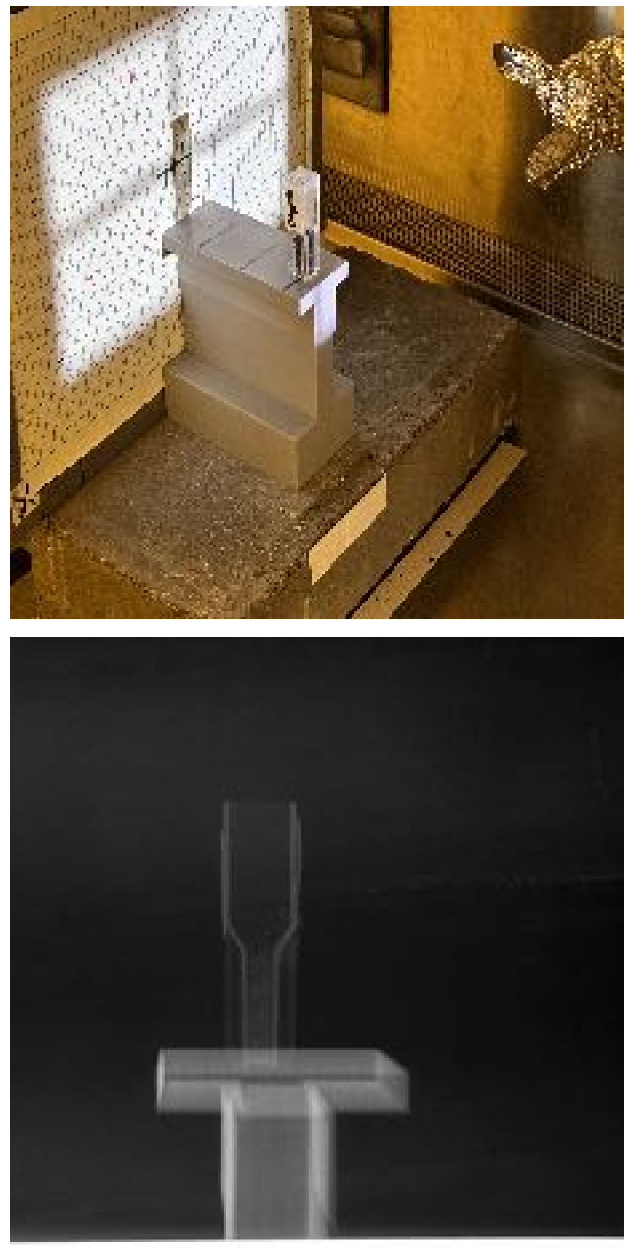




XR-WASOS radiography reveals no considerable variation in shielding values depending on the distance between the sample and the radiography cassette.





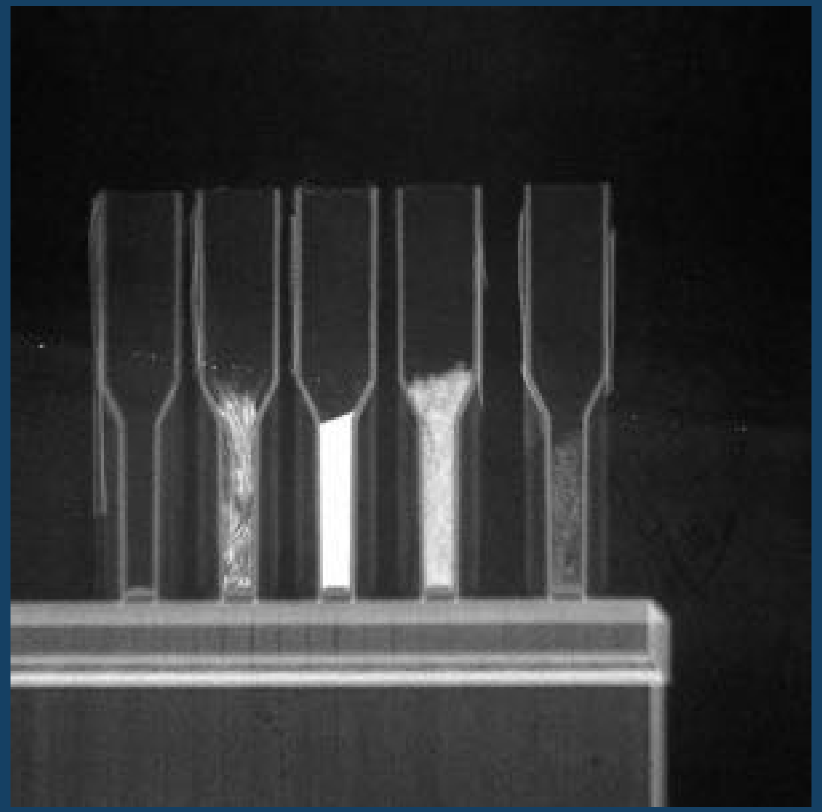


	Crypto (L-DOPA) 30mm	Crypto (L-DOPA) 60 mm	Crypto (L-DOPA) 90 mm
Mass (g)	2.610	2.610	2.610
Thickness (mm)	10.02	10.02	10.02
Shielding Percentage (%)	14.10	14.27	14.38
Equiv Al Thickness (mm Al)	1.74	1.77	1.79
CONTROL Shielding Percentage (%)	0.66	0.51	0.75
CONTROL Equiv Al Thickness (mm Al)	– 0.63	– 0.66	– 0.62

Preliminary analysis via XR-WASOS radiography has revealed that, when grouped together, cuvettes containing powders show that melanin produced from *C. neoformans* and other sources shields X-rays less effectively than melanin from *sepia* that has been hydrolyzed.

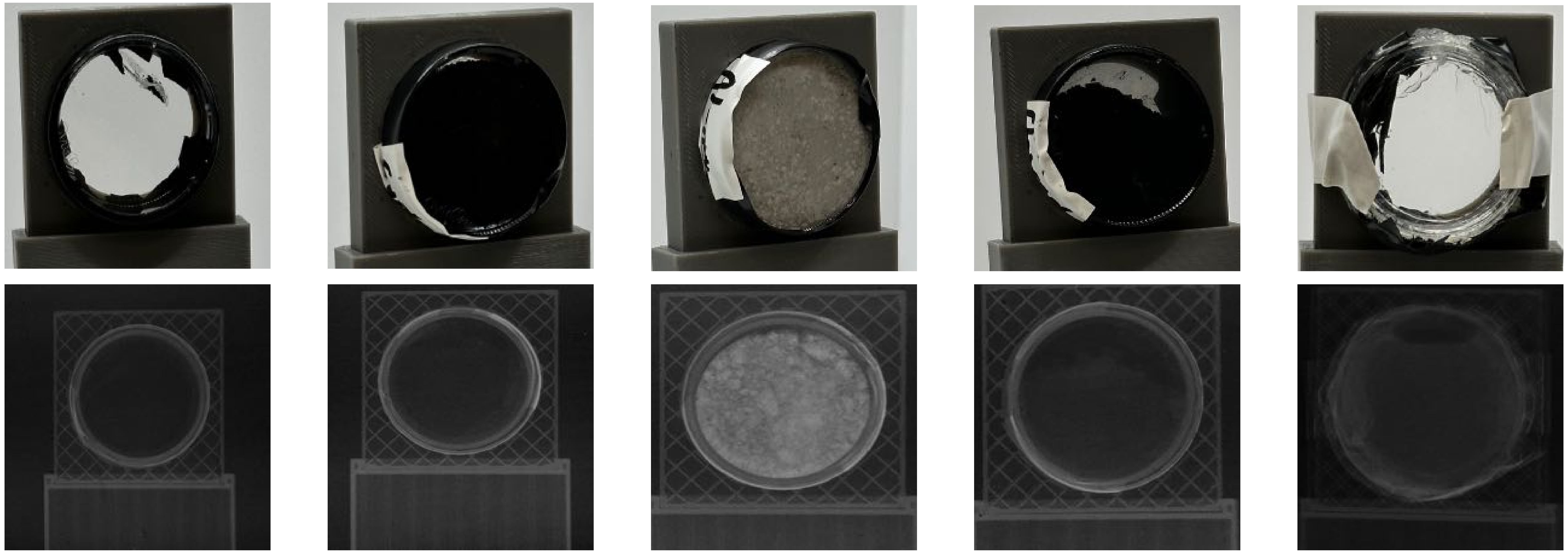
	Mass (g)	Thickness (mm)	Shielding Percentage (%)	Equiv Al Thickness (mm Al)
Air	2.435	10.02	4.72	0.09
Exophiala	2.736	10.02	10.12	1.04
Synthetic	2.897	10.02	12.65	1.49
Sepia (Lyophilized)	3.027	10.02	24.15	3.52
Sepia (Hydrolyzed and Lyophilized)	2.941	10.02	13.17	1.58
Crypto (L-DOPA)	2.610	10.02	10.99	1.19
CONTROL	——	——	0.90	– 0.59

We also discovered that when in groups, analysis revealed that cuvettes filled with powders of melanin produced from *C neoformans* did not shield x-rays as effectively as fiberglass, sand beach, or aluminum powder.



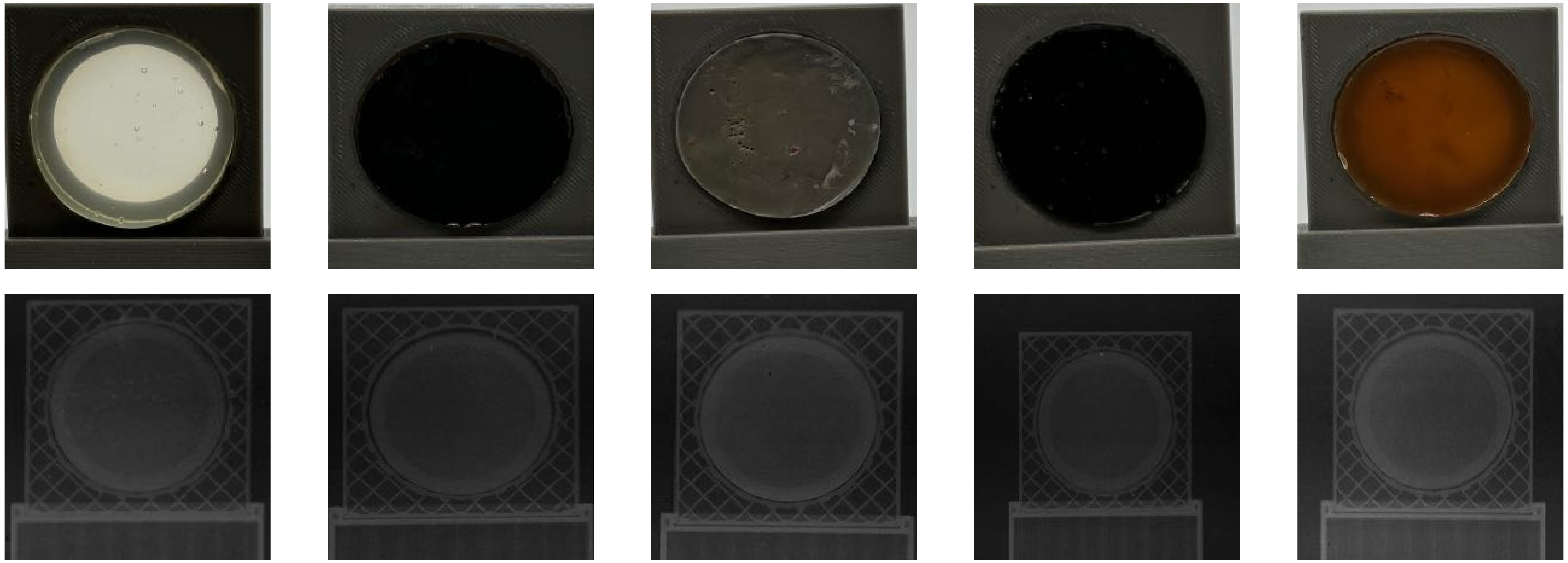
	Mass (g)	Thickness (mm)	Shielding Percentage (%)	Equiv Al Thickness (mm Al)
Air	2.435	10.02	17.26	2.30
Fiberglass	2.761	10.02	65.02	10.75
Beach's Sand	3.639	10.02	99.59	16.86
Aluminum Powder	3.151	10.02	85.10	14.30
Crypto (L-DOPA)	2.610	10.02	33.15	5.11
CONTROL	——	——	0.69	– 0.63

An analysis of powders in Petri dishes has revealed that melanin from *C neoformans* shields X-rays moderately well when compared to autoclaved charcoal and distilled water.



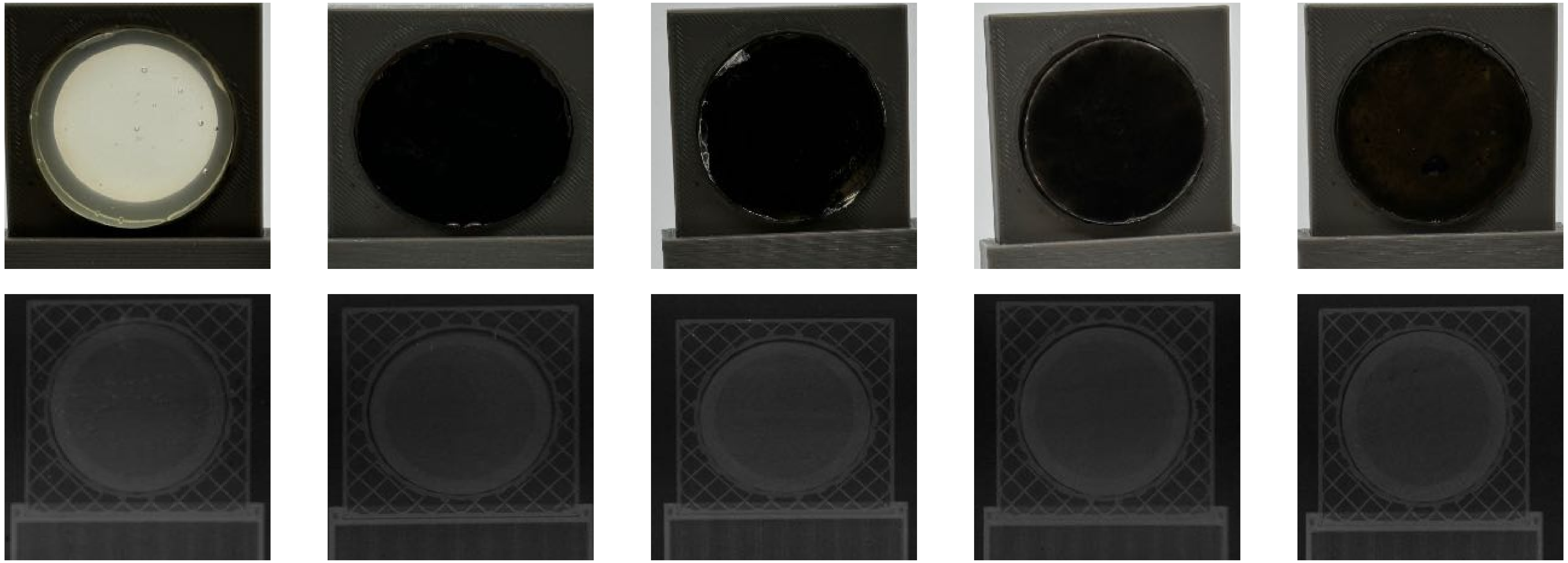
	Air	Crypto (L-DOPA)	Aluminum	Charcoal	Distilled Water
Mass (g)	5.188	6.856	12.100	7.169	15.623
Thickness (mm)	11.92	11.92	11.92	11.92	11.92
Shielding Percentage (%)	6.10	9.11	39.29	9.39	7.78
Equiv Al Thickness (mm Al)	0.33	0.86	6.19	0.91	0.63
CONTROL Shielding Percentage (%)	1.19	0.71	1.49	1.15	1.27
CONTROL Equiv Al Thickness (mm Al)	– 0.54	– 0.62	– 0.49	– 0.55	– 0.53

Analysis of PLA-Melanin disks indicates that the presence of *C neoformans* decreases the effectiveness of PLA to attenuate X-rays when compared to aluminum, charcoal, or polystyrene.



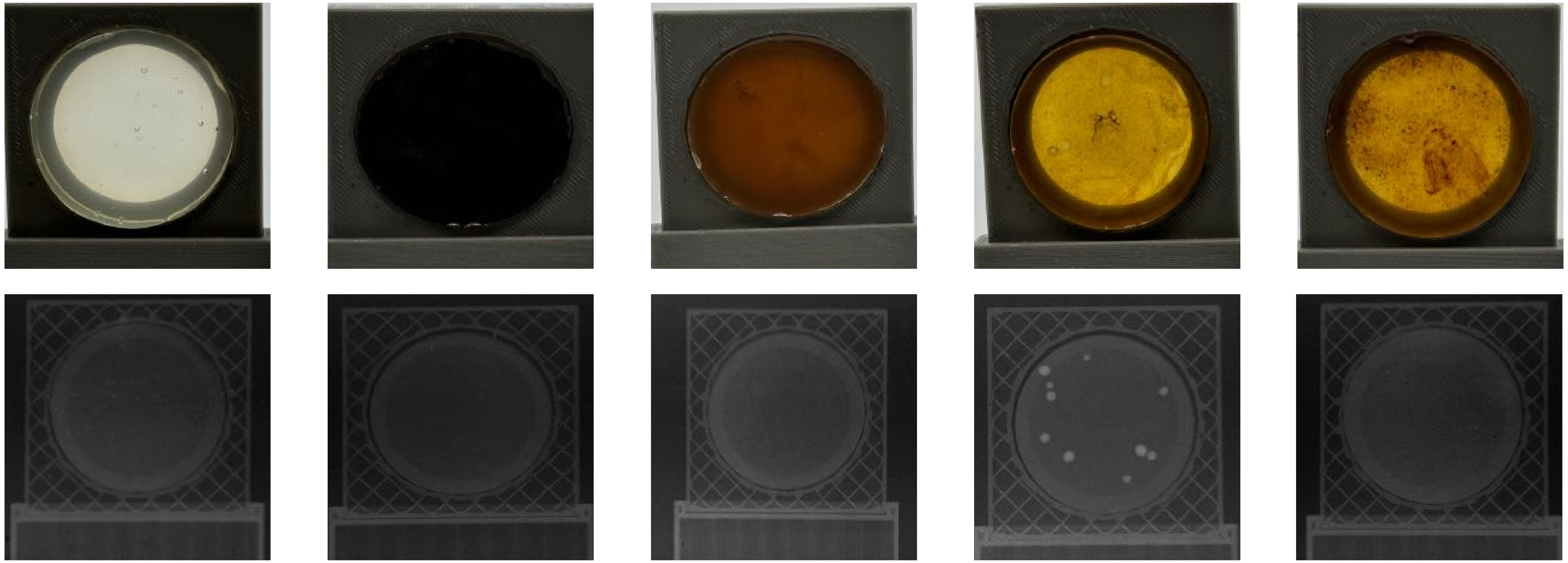
	PLA	PLA-Crypto	PLA-Aluminum	PLA-Charcoal	PLA-Polystyrene
Mass (g)	9.839	9.452	9.385	9.984	9.258
Thickness (mm)	6.93	6.66	6.56	6.97	6.18
Shielding Percentage (%)	11.89	8.56	11.89	9.94	16.44
Equiv Al Thickness (mm Al)	1.35	0.76	1.35	1.01	2.15
CONTROL Shielding Percentage (%)	0.95	0.63	0.49	0.70	1.01
CONTROL Equiv Al Thickness (mm Al)	– 0.58	– 0.64	– 0.66	– 0.63	– 0.57

An analysis of PLA-Melanin disks demonstrates that *C neoformans* has a decreased capacity to shield X-rays when compared to synthetic melanin, melanin from s*epia*, or melanin from e*xophiala*.



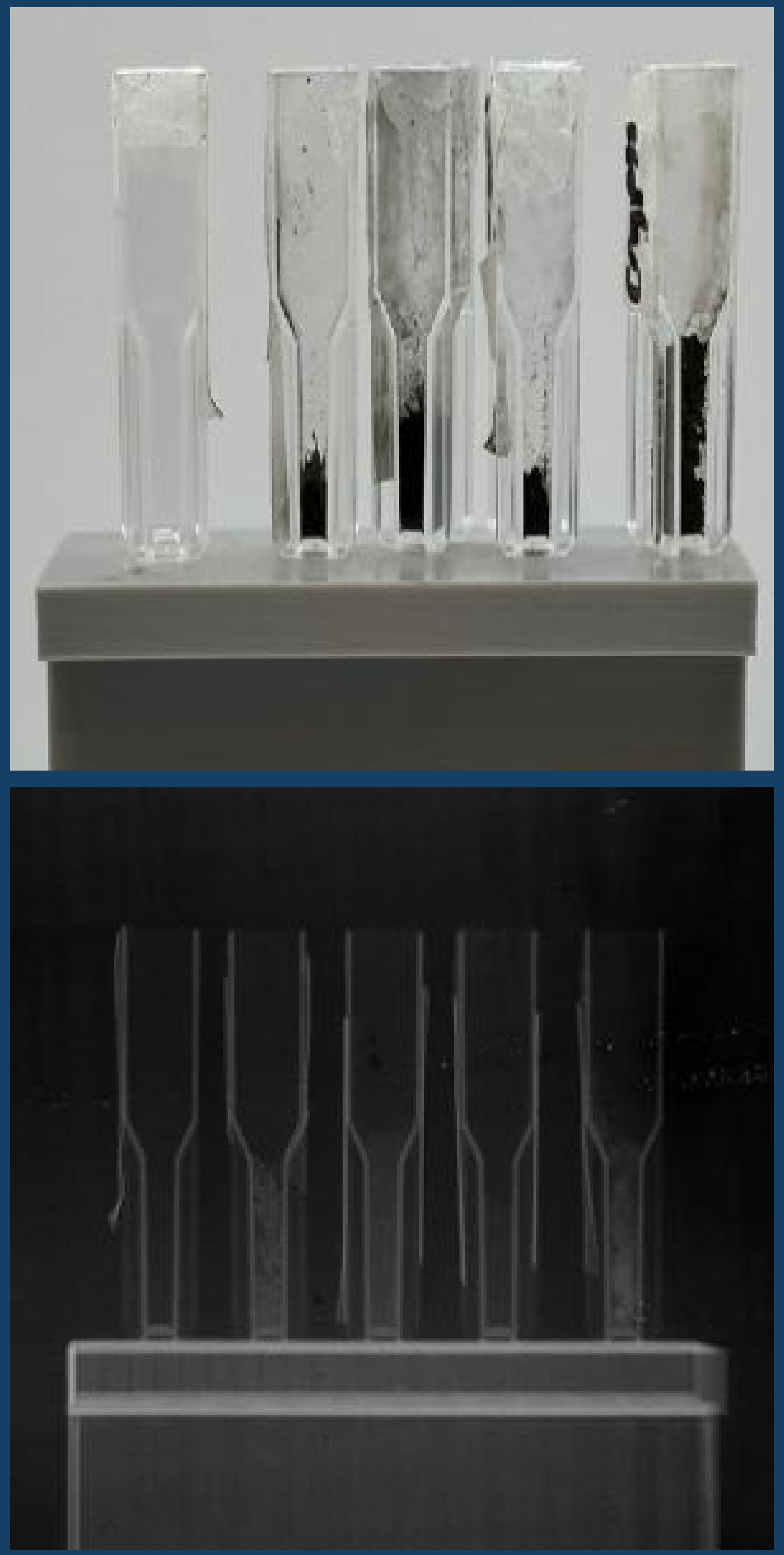
	PLA	PLA-Crypto	PLA-Sepia (Lyophilized)	PLA-Exophiala	PLA-Synthetic
Mass (g)	9.839	9.452	9.930	9.868	9.893
Thickness (mm)	6.93	6.66	7.45	6.88	6.83
Shielding Percentage (%)	11.89	8.56	11.82	10.03	10.08
Equiv Al Thickness (mm Al)	1.35	0.76	1.34	1.02	1.03
CONTROL Shielding Percentage (%)	1.19	0.71	1.27	0.77	0.99
CONTROL Equiv Al Thickness (mm Al)	– 0.54	– 0.62	– 0.53	– 0.61	– 0.58

An analysis of PLA disks has revealed that melanin from *C neoformans* reduces the effectiveness of PLA in X-ray shielding. This could be attributed to the differing binding of oxygen and carbon atoms when compared to polystyrene, silica gel, or sand beach as a blender.



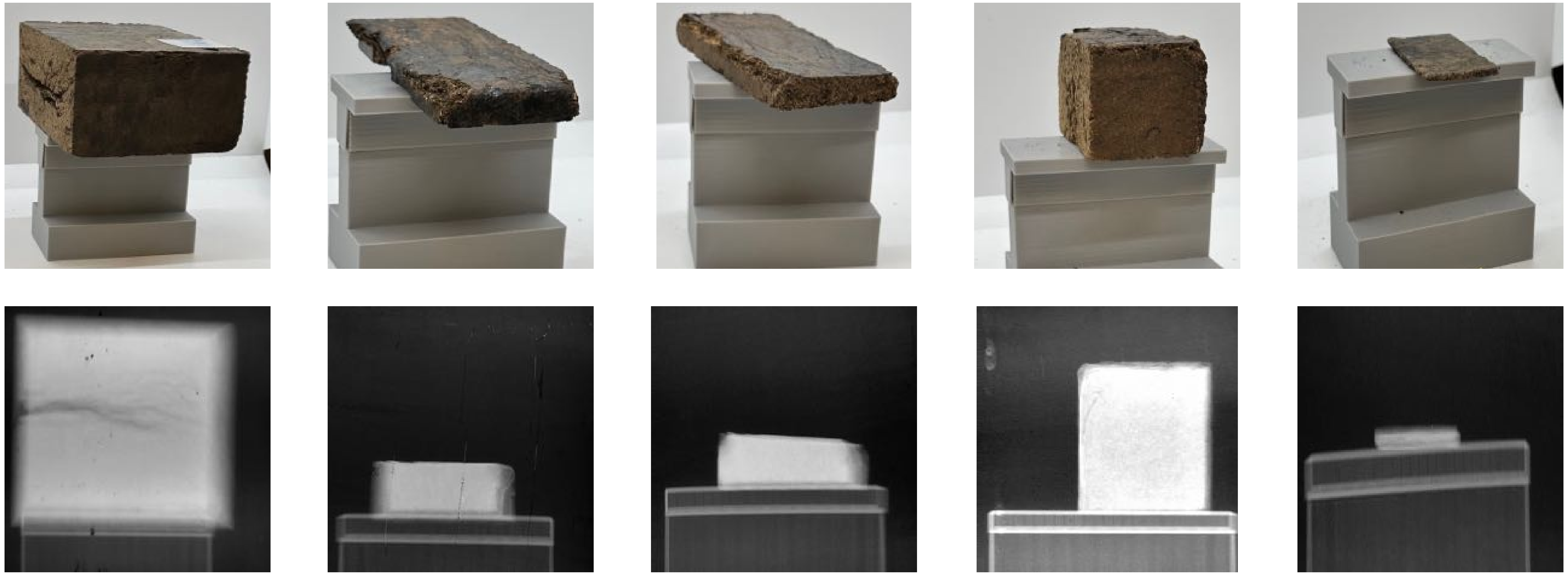
	PLA	PLA-Crypto	PLA-Polystyrene	PLA-Silica Gel	PLA-Sand's Beach
Mass (g)	9.839	9.452	9.258	9.447	9.755
Thickness (mm)	6.93	6.66	6.18	7.17	6.68
Shielding Percentage (%)	11.89	8.56	16.44	19.75	11.24
Equiv Al Thickness (mm Al)	1.35	0.76	2.15	2.74	1.24
CONTROL Shielding Percentage (%)	1.19	0.71	1.01	1.62	0.58
CONTROL Equiv Al Thickness (mm Al)	– 0.54	– 0.62	– 0.57	– 0.46	– 0.65

When in groups, analysis of cuvettes with powders shows melanin produced from *C. neoformans* and its doped forms might shield X-ray more or less depending on what other powder surrounds them.



	Mass (g)	Thickness (mm)	Shielding Percentage (%)	Equiv Al Thickness (mm Al)
Air	2.435	10.02	10.43	1.10
Crypto (L-DOPA) with Iron	2.422	10.02	20.10	2.81
Crypto (L-DOPA) with Zinc	2.460	10.02	17.52	2.35
Crypto (L-DOPA) with Copper	2.452	10.02	12.65	1.49
Crypto (L-DOPA)	2.610	10.02	19.43	2.69
CONTROL	——	——	0.53	– 0.66

An in-depth analysis of compressed mycelium has revealed that compressed melanin from *C neoformans* cloudless have a better chance for shielding us against x-rays.



	NASA 1	NASA 2	NASA 3	NASA 4	NASA 5
Mass (g)	662.7	69.0	67.4	91.3	5.5
Thickness (mm)	152.76	141.56	138.49	64.01	163.75
Shielding Percentage (%)	62.5	67.44	79.39	91.43	61.16
Equiv Al Thickness (mm Al)	10.30	11.18	13.29	15.42	10.06
CONTROL Shielding Percentage (%)	0.58	0.83	0.60	1.05	0.74
CONTROL Equiv Al Thickness (mm Al)	– 0.65	– 0.60	– 0.64	– 0.56	– 0.62

We can quantify the extent to which melanin produced by *C neoformans* can act as a shield against x-rays.

This was made possible by employing XR-WASOS Radiography in combination with two analysis techniques developed by Johns Hopkins University Bloomberg School of Public Health.

The technique we have developed allows us to compare the effectiveness of melanin produced from *C neoformans* in shielding x-rays compared to other materials, regardless of their mass or thickness.

The initial assessment of this method indicates that melanin from *C neoformans* can be optimized as a more effective x-ray shielding material.

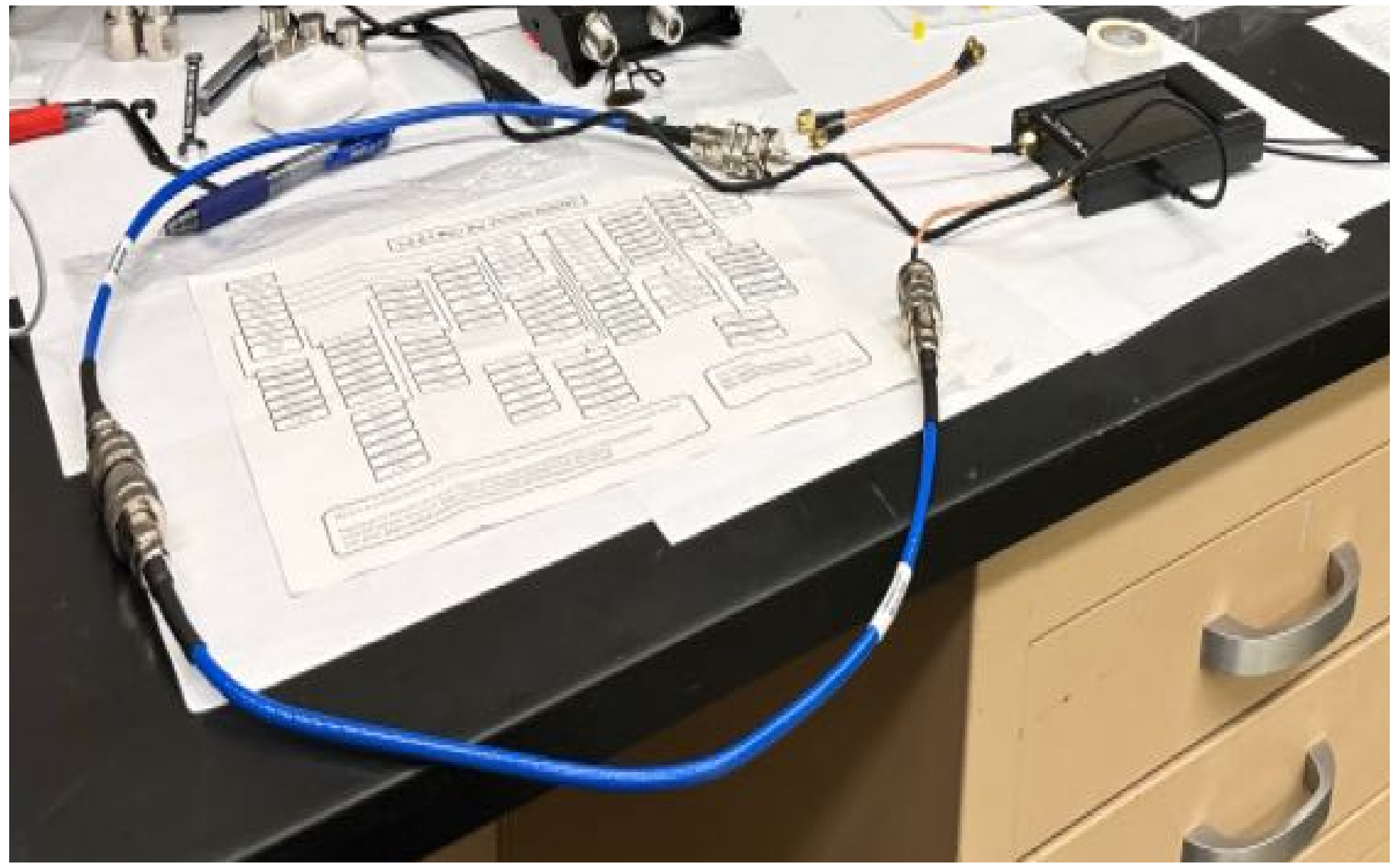
— — By changing how we synthesize it

— — By coupling it with other materials, selectively

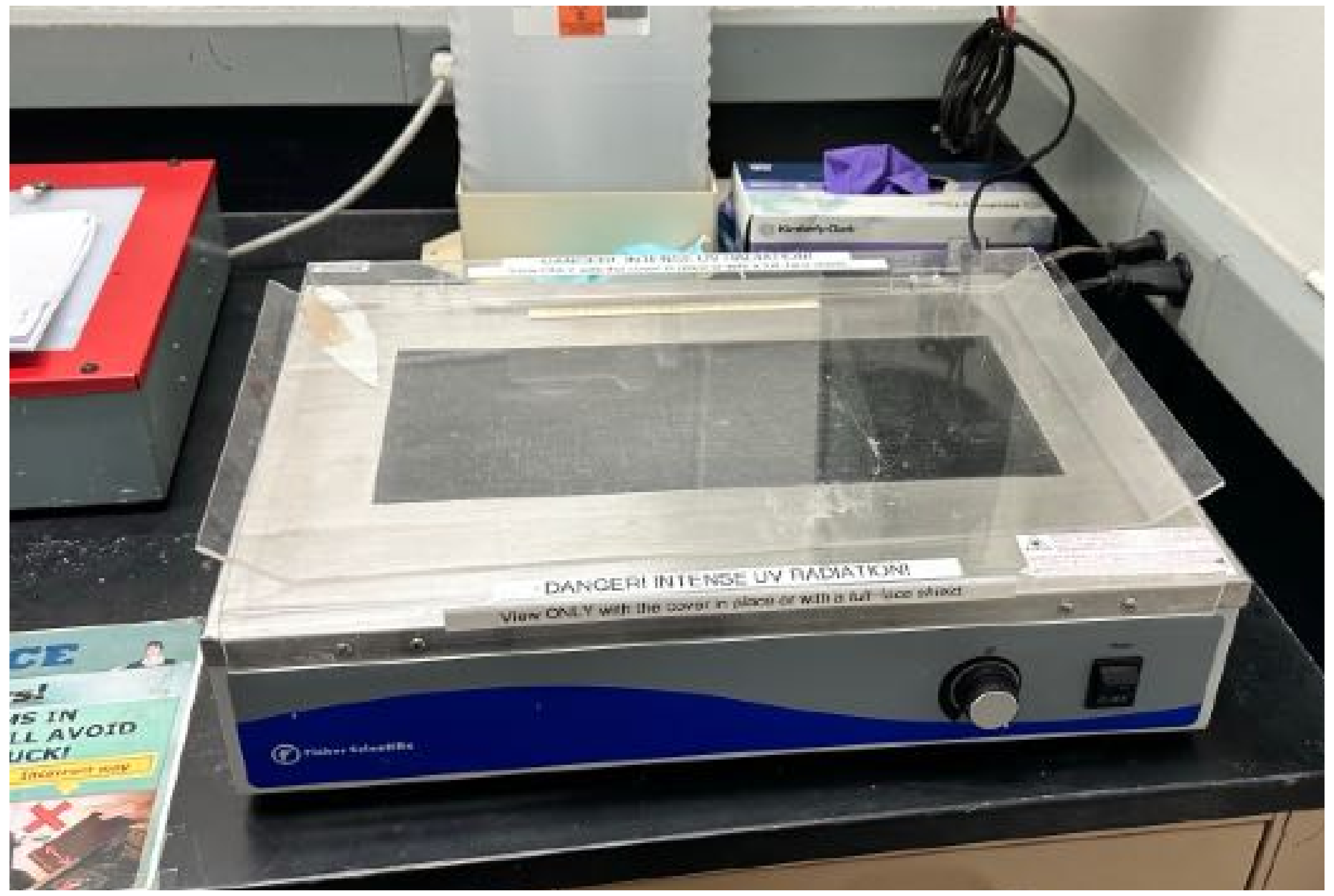
— — By compressing it, as is for the case of mycelium

Future Works

Optimizing the XR-WASOS



RF (MW)-WASOS



UV-WASOS Generator

Visible Red and NIR-WASOS Generator

Thank You!