CULTURAL HERITAGE

RESEARCH AND CONSERVATION UNIT (HERITAGE)

Blending Nuclear Science and technology in Cultural characterization and Preservation

Cultural Heritage Research and Conservation Unit (HERITAGE): Blending Nuclear Science and Technology in Cultural Characterisation and Preservation

Chief Editor: Mahdi E. M.
mahdiezwan@nm.gov.my

Design: Azlan Shah Nerwan Shah

Editorial Board: Hishamuddin Husain, Izura Izzudin, Suhaila Hani Ilias

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FOREWORD

Our shared cultural heritage is the thread that binds us across time and space. As we stand on the precipice of the future, it becomes increasingly imperative to understand, preserve, and celebrate the footprints of our ancestors. This is not just a book; it is a commitment of a remarkable group of individuals dedicated to unravelling the secrets of our past.

In these pages, you will embark on a journey with the Heritage Unit, an assembly of minds merging nuclear science with cultural preservation. Led by Hishamuddin Husain, this group is a beacon of innovation, pushing the boundaries of what is possible to safeguard our shared cultural legacy.

As you delve into this book, you will witness the human faces behind the technological marvels, each member contributing their unique skills and passion to the cause. The tools they employ are not just instruments but gateways to unlocking the mysteries of antiquity.

Current projects, collaborations, and many achievements showcased in this book vividly show the unit's dedication and relentless pursuit of knowledge. Our endeavours reflect our expertise's depth and commitment to continuous learning and global collaboration.

The output section is a testament to the Unit bringing together a collection of papers, reports, and publications embodying the spirit of exploration and discovery. This is not merely an archive but a living testament to the unit's impact on the field.

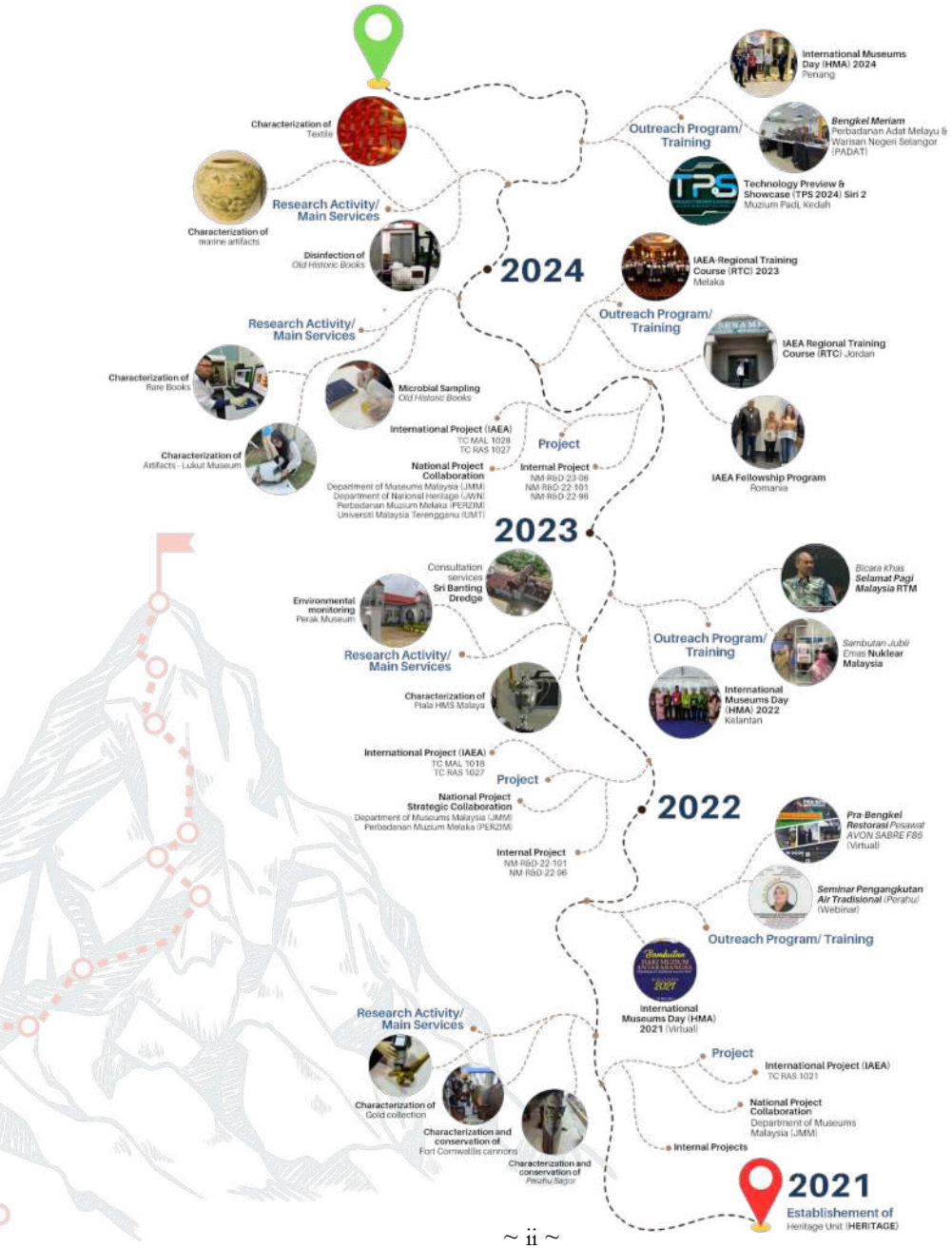
As we journey through these pages, we will glimpse the future where nuclear science and technology play an even more integral role in cultural heritage characterisation and preservation. The Heritage Unit not only looks back at history but looks forward with ambition and optimism, outlining future goals and inviting readers to be part of this transformative journey.

I extend my most profound appreciation to the team for their unwavering dedication and to the collaborators and partners sharing this vision. May this book inspire a newfound appreciation for the intersection of science and culture as we collectively unveil the rich tapestry of our heritage.

To the Heritage Unit, your work is a scientific endeavour and a gift to the country—a bridge across time that connects us all.

Dr Hishamuddin Husain, A.M.N.
Head of Cultural Heritage,
Research and Conservation Unit (HERITAGE),
Materials Technology Group,
Industrial Technology Division,
Malaysia Nuclear Agency.

OUR JOURNEY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INTRODUCTION

INTRODUCTION

The Heritage Unit (Heritage) operates as an integral component of the Materials Technology Group (MTEG), which is housed within the Industrial Technology Division of the Malaysian Nuclear Agency (Nuklear Malaysia). As a critical entity within Nuklear Malaysia, the Heritage Unit plays a pivotal role in advancing the field of cultural heritage characterisation and preservation through its multifaceted mission. Situated within the broader framework of the Ministry of Science, Technology, and Innovation (MOSTI), Nuklear Malaysia is tasked with spearheading initiatives aimed at harnessing nuclear technology for the betterment of society. Specifically, the Heritage unit is dedicated to conducting cutting-edge research and development endeavours focused on the advanced characterisation and preservation of cultural heritage artefacts. This includes employing state-of-the-art scientific techniques to delve into the intricate details of historical objects, shedding light on their composition, origin, and significance.

Furthermore, the Heritage unit offers comprehensive characterisation and investigation services tailored to the needs of researchers, curators, and conservators alike, facilitating a deeper understanding of cultural artefacts and their preservation requirements. Moreover, the unit serves as a beacon of knowledge and expertise, providing training and consultation opportunities for conservators seeking to leverage nuclear technology and related scientific methodologies in their conservation efforts. By fostering collaboration and knowledge exchange, the Heritage Unit endeavours to elevate the standards of cultural heritage preservation both domestically and internationally. Additionally, the unit is committed to promoting nuclear technology and scientific techniques within the broader cultural heritage community, advocating for their integration into research, conservation, and educational endeavours. Through its multifaceted approach, the Heritage Unit endeavours to safeguard and celebrate the rich tapestry of human history for generations to come.

The Heritage unit boasts a team of ten dedicated researchers and collaborates closely with esteemed national and international partners. Our collaborative efforts span various domains, including research and development, technical services and consultation, and public awareness initiatives. Notable partners in our network include esteemed institutions such as the Department of Museums Malaysia (JMM), the National Heritage Department (JWN), Melaka Museums Corporation (PERZIM), local universities, the Ministry of Science, Technology and Innovation (MOSTI), the Ministry of National Unity, the Ministry of Tourism, Arts and Culture (MOTAC) and the International Atomic Energy Agency (IAEA). We engage in numerous ongoing projects through these partnerships, fostering a dynamic exchange of expertise and resources.

We have significantly contributed to cultural heritage research and conservation as a unit. Our endeavours have resulted in the publication of scholarly books, research papers, and informative posters. Moreover, we have extensively analysed numerous artefacts using cutting-edge equipment and refined nuclear methods, enabling more profound insights into historical pieces.

Looking ahead, the Heritage unit is committed to expanding its scope and impact on cultural heritage characterisation and preservation. We aspire to bridge the gap between archaeology/cultural heritage and nuclear methods, paving the way for innovative approaches to heritage conservation. We aim to cultivate a new frontier of knowledge for Malaysia and the global community to embrace and benefit from.

Characterisation and Preservation of Cultural Heritage through Nuclear Science, Technology and Innovation

Bridging nuclear science and technology and cultural research and conservation, our vision is to be at the forefront of characterising and preserving Malaysia's cultural heritage. Through cutting-edge materials technology and a dedicated team, we aspire to unlock the secrets of the past, ensuring that the legacy of civilisations endures for generations to come.

Our mission is to harness the power of nuclear science and technology to explore, understand, and protect cultural heritage. We aim to be pioneers in the field, blending scientific expertise with a deep appreciation for the significance of preserving our shared human legacy.

Innovation: We strive to be at the forefront of technological advancements, pushing the boundaries of nuclear science for the betterment of cultural preservation.

Collaboration: Building strong partnerships with global institutions, researchers, and cultural organisations to foster a collaborative and inclusive approach to heritage preservation.

Integrity: Conducting our work with the utmost ethical standards, ensuring transparency, and maintaining the highest levels of professionalism.

Education: Sharing our knowledge and expertise with the broader community, promoting awareness of nuclear technology's critical role in preserving cultural heritage.

Join us as we unravel the mysteries of Malaysia's past, using nuclear innovation to secure a vibrant and enduring future for our cultural heritage.

CHAPTER 1:
THE PEOPLE

DR. HISHAMUDDIN HUSAIN
E-mail: hishamuddin@nm.gov.my

Hishamuddin, Head of the Heritage Unit since its inception in 2020, holds a PhD in Materials Science from the National University of Malaysia (UKM). He spearheads numerous national and international projects, including the collaboration on 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and the Application of Nuclear Techniques for Cultural Heritage Characterization, Conservation and Preservation (TC RAS 1021) with the IAEA focusing on artefact characterisation and preservation. He is one of the national counterparts in the IAEA TC MAL1018 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry'. At the national level, he leads collaboration projects with several agencies, such as the Department of Museums Malaysia, the National Heritage Department and PERZIM. With expertise in materials science, particularly in metallurgy and corrosion, Hishamuddin plays a pivotal role in artefact conservation via his expertise in neutron beams for cultural heritage research. In 2023, he successfully managed the Regional Training Course (RTC) TN-RAS1027-2300242 titled "The Application of Nuclear Techniques for Characterisation and Preservation of Artefacts Obtained from Shipwrecks," a collaborative effort by the Malaysian Nuclear Agency, Department of Museums Malaysia (JMM), Department of National Heritage (JWN), and Melaka Museums Corporation (PERZIM). This course fosters personal and professional growth, offering participants valuable knowledge and skills while promoting collaboration in the field. Additionally, he contributes as a secondary chief investigator in the IAEA 2 CRP projects related to Nuclear Forensics, Establishment of National Forensic Library (NFL) and Laboratory Procedure for Detection and Analysis of Gamma Emitting Radiation from Industrial Sealed Radioactive Source (Cs-137, Co-60 and Am-241) and Development of Method for Characterisation of Source Capsule and Container of Nuclear Gauges for Nuclear Forensic Purposes.

NADIRA KAMARUDIN
E-mail: nadira@nm.gov.my

Nadira, a member of the Heritage Unit since its inception in 2020, holds a Master's in Physics (Material Science) from the National University of Malaysia (UKM). She leads the PQRD project "Effect of Gamma Irradiation Towards Cellulose in Different Doses for Disinfection and Preservation of Cultural Heritage Artifacts," showcasing her dedication to material characterisation. Nadira's involvement extends to projects such as 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry' (TC MAL1018). Additionally, she contributes to the project 'Development of Method for Characterisation of Source Capsule and Container of Nuclear Gauges for Nuclear Forensic Purposes.' Her multifaceted contributions underscore her commitment to advancing scientific knowledge for cultural heritage preservation.

WILFRED @ SYLVESTER PAULUS
E-mail: wilfred@nm.gov.my

Wilfred, a member of the Heritage Unit since its inception in 2020, holds a Bachelor's in Nuclear Science from the National University of Malaysia (UKM). His project involvements include the 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry' (TC MAL1018). Wilfred specialises in material characterisation services, employing techniques such as X-ray diffractometer (XRD), X-ray fluorescence (XRF), Raman Spectroscopy, UV-Vis Spectroscopy, Fluorescence Spectroscopy, and Atomic Force Microscopy (AFM) for comprehensive artefact analysis.

IR. DR. MAHDI EZWAN MAHMOUD

E-mail: mahdiezwan@nm.gov.my

Mahdi, a member of the Heritage Unit since 2020, holds a DPhil in Engineering Science from the University of Oxford. His expertise lies in wood-based artefact consolidation using impregnation devices. His project involvements include 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry' (TC MAL1018). Mahdi serves as the Chief Editor of the Heritage Unit and is also involved in materials characterisation, having served as a consultant to the Sepang City Council on analysing their Dredging Ships.

DR. SITI AISHAH AHMAD FUZI

E-mail: aishahfuzi@nm.gov.my

Siti Aishah, a member of the Heritage Unit since its inception in 2020, holds a PhD in Physics from the National University of Malaysia (UKM). Leading the PQRD project titled 'Development of an Electrolysis System for Rust Removal,' Aishah specialises in artefact characterisations, focusing on metal, textile, and ceramic artefacts, focusing on traditional cultural practices to modern preservation techniques. Her project involvements include 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry' (TC MAL1018). Currently, she is refining her proficiency in instrument characterisation techniques such as X-ray diffractometer (XRD), X-ray fluorescence (XRF), Raman Spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), Field Emission Scanning Electron Microscopy (FESEM), UV-Vis Spectroscopy, and fluorescence spectroscopy.

DR. IZURA IZZUDDIN
E-mail: izura@nm.gov.my

Izura, a member of the Heritage Unit since 2020, holds a PhD in Physics from the National University of Malaysia (UKM). She contributes her expertise in material science to various preservation projects, including 'Improving the Utilization of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation (TC RAS 1027) and 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry (TC MAL1018), 'Development of an electrolysis system for Rust Removal' and 'Effects of Gamma Irradiation Towards Cellulose in Different Doses for Disinfection and Preservation of Cultural Heritage Artifacts'. During a one-month fellowship in Romania, she engaged in disinfection research using gamma irradiation for cultural heritage. Currently, Izura focuses on preserving papers and cellulose-based materials, particularly rare books, at the Taiping Museum. She studies the effects of gamma irradiation on cellulose and refines her material characterisation skills using techniques such as FTIR, FESEM, AFM, and Raman spectroscopy.

SUHAILA HANI ILIAS
E-mail: suhaila_hani@nm.gov.my

Suhaila, a member of the Heritage Unit since 2020, holds a Master's in Science (Applied Radiation) from the University of Putra Malaysia (UPM). Leveraging her expertise in applied radiation and material characterisation, she contributes to projects such as "Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation" (TC RAS 1027) and "Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry" (TC MAL1018). Formerly serving as the Financial Officer of RTC TN-RAS1027-2300242, Suhaila focuses on utilising Atomic Force Microscopy (AFM) and Raman Spectroscopy for artefact analysis alongside the Department of Museums (JMM) and National Heritage Department (JWN). She is currently studying the consolidation and impregnation of tropical woods and will attend a fellowship in this field.

DR. NURLIANA ROSLAN
E-mail: nurliana_r@nm.gov.my

Nurliana, a member of the Heritage Unit since 2020, holds a PhD in Chemistry from the University of Technology Malaysia (UTM). She specialises in synthesising organic and inorganic materials. She proficiently operates instruments like Field Emission Scanning Microscopy (FESEM), Ultraviolet-Visible spectroscopy (UV-Vis), Small Angle X-ray scattering (SAXS), Matrix-Assisted Laser Desorption (MALDI-TOF), X-ray diffraction (XRD), and Fourier-Transform Infrared Spectroscopy (FTIR). Her project involvement includes 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry' (TC MAL1018). Nurliana also participates in the PQRD project, "Effect of Gamma Irradiation Towards Cellulose in Different Doses for Disinfection and Preservation of Cultural Heritage Artifact" (NM-R&D-22-101). Currently, she focuses on studying the consolidation and impregnation of tropical woods and will attend a fellowship to explore these fields further.

JACQUELINE KONES
E-mail: jacqueline@nm.gov.my

Jacqueline has been a member of the Heritage Unit since its establishment in 2020. She holds a Bachelor's (Honours) degree in Chemistry from the University of Technology Mara (UiTM). Her project involvements include 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry" (TC MAL1018)'. She is also involved in cultural heritage characterisation, employing techniques such as X-ray fluorescence (XRF), Raman Spectroscopy, and UV-Vis spectroscopy. She actively participated in the International Museum Day 2023 alongside the Department of Museums (JMM).

NUR AQILAH SAPIEE
E-mail: nuraqilah@nm.gov.my

Nur Aqilah has been a member of the Heritage Unit since its establishment in 2020. She holds a Master's in Environmental Engineering from the University of Putra Malaysia (UPM). Her project involvements include 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and 'Strengthening National Capabilities and Infrastructure in Radioisotope and Radiation Technology: Prevention, Preservation, and Sustainability in Industry' (TC MAL1018). Currently, Aqilah characterises cultural heritage samples via techniques such as X-ray diffractometer (XRD), X-ray fluorescence (XRF), Raman Spectroscopy, UV-Vis Spectroscopy, Fluorescence Spectroscopy, and Atomic Force Microscopy (AFM). She actively participated in International Museum Day alongside the Department of Museums (JMM).

AZLAN SHAH NERWAN SHAH @ NINTIN
E-mail: azlanshah@nm.gov.my

Azlan has been a member of the Heritage Unit since 2022. Possessing a Master's degree in Engineering Geology from the University of Malaya (UM), he actively contributes his expertise in geology, soil characteristics, and geohazards to various projects, such as 'Improving the Utilisation of Nuclear Techniques for Cultural Heritage Characterisation, Consolidation, and Preservation' (TC RAS 1027) and 'Development of Radiation Crosslinked Low-Smoke Halogen-Free Flame Retardant Cables for Automotive and Construction Industry' (SRF). Azlan is refining his characterisation skills, focusing on utilising X-ray diffraction (XRD) and X-ray fluorescence (XRF) techniques to comprehensively analyse pottery excavated from a dig site in Perak.

CHAPTER 2:
THE TOOLS

The Heritage Unit personnel are adept at operating sophisticated scientific equipment and tools to characterise ancient artefacts accurately. These instrumental resources serve as linchpins in the unit's pursuits, providing invaluable insights into the elemental composition and structural intricacies of the artefacts under scrutiny. Such knowledge forms the cornerstone for formulating preservation methodologies and unravelling historical narratives pertinent to past epochs and prospective futures.

Central to the Heritage's analytical arsenal are instruments harnessing X-ray and electron/neutron beam technologies, offering qualitative and quantitative analysis modalities. Nonetheless, the meticulous preparation and safeguarding of samples are paramount, given the potential for alteration or irreversible damage during the analytical process.

While direct access to specific specialised equipment may be outside Heritage's purview, the unit maintains a comprehensive repository of available resources upon requisition. This chapter endeavours to furnish a meticulous exposition of the equipment at hand, elucidating their specifications, analytical capacities, preferred sample types, and the post-analytical condition of specimens. Through rigorous adherence to methodological precision, the Heritage ensures the judicious examination and safeguarding of cultural artefacts, preserving invaluable facets of human heritage for posterity.

2.1 List of Equipment for Cultural Heritage Analyses

Figure 1 lists the equipment available for cultural heritage analyses at the Heritage Unit. It is noteworthy that, apart from the UV-Vis Spectrometer and handheld spectrophotometer, the remaining equipment entails the irreversible alteration or potential destruction of samples, which may hold significant value for our or our clients' research endeavours. Additionally, while not directly managed by the Heritage Unit, five pieces of equipment remain accessible for studies pertinent to cultural heritage preservation.

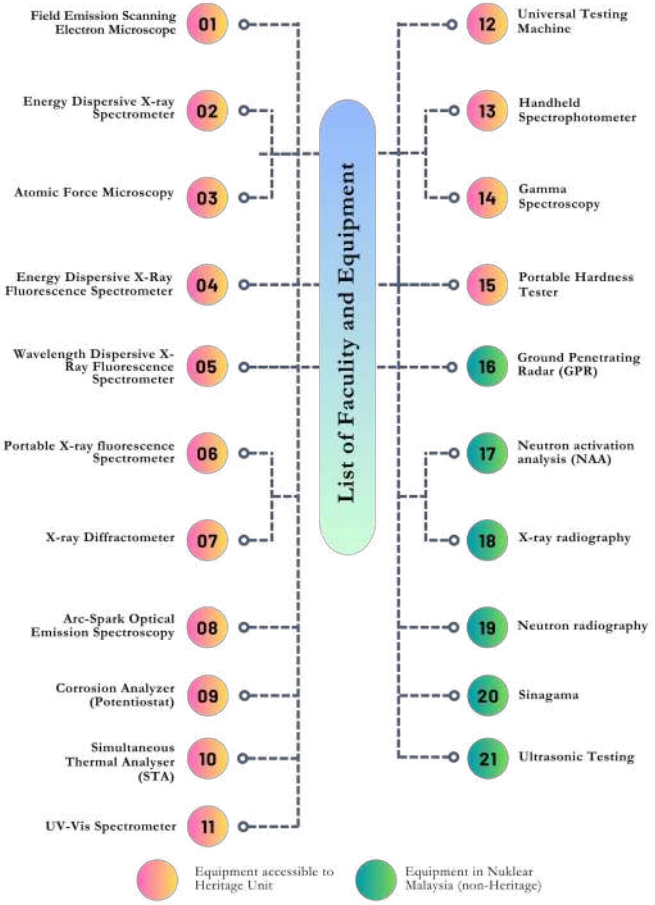


Figure 2.1: Inventory of utilised facility & equipment for cultural heritage studies

2.2 Equipment specification (Heritage)

This section details the specifications of the equipment directly controlled and accessible to the Heritage Unit and equipment not directly under this Unit for cultural heritage studies, covering the application of respective equipment.

Field Emission Scanning Electron Microscope (FESEM)
(Carl Zeiss, GeminiSEM 500)

Application

A field emission scanning electron microscope (FESEM) is specified for microstructural and elemental analysis. It can image surface and nanoscale structures at low beam energy to avoid beam damage while obtaining excellent material contrast. No coating is required for low kV imaging. Both energy dispersive spectroscopy (EDS) and wavelength dispersive spectroscopy (WDS) are integrated with the instrument. The field of interest includes nanoscience, bioscience, and industrial applications.

Energy Dispersive X-ray Spectrometer
(Oxford Instrument, X-Max 80)
*attached with the FESEM

Application

Energy Dispersive X-ray (EDX) is a system attached to the FE-SEM, facilitating both qualitative and quantitative analyses to identify the elemental composition of materials. It can detect elements from Beryllium (Be) to Uranium (U). EDX allows for element distribution mapping and real-time acquisition. The fields of interest include nanoscience, bioscience, and industrial applications. Samples must be in solid form. For non-conductive samples, platinum sputter coating ensures higher X-ray throughput, resulting in better spectrum quality.

Atomic Force Microscopy (Park Systems, XE-70)

Application

Atomic Force Microscopy (AFM) provides detailed information on surface morphology at the nanoscale, including topography, roughness, and surface properties. It is highly effective for characterising small samples in data storage, semiconductors, nanoscience, materials science, polymers, and electrochemistry. AFM also offers nanoindentation capabilities. Samples must be in solid form, with a size of up to 80 x 80 mm and a thickness of up to 20 mm. The sample mass can be up to 500 g.

Energy Dispersive X-Ray Fluorescence Spectrometer (Shimadzu, EDX-7000)

Application

The Shimadzu EDX-7000 Energy Dispersive X-Ray Fluorescence (EDXRF) Spectrometer is an analytical instrument used for elemental analysis across various materials. It is widely employed in industries such as environmental science, electronics, metallurgy, and pharmaceuticals to perform qualitative and quantitative analysis of elements from sodium (Na) to uranium (U). Its non-destructive testing capabilities make it ideal for analysing solid, liquid, and powdered samples without altering their physical or chemical properties. The instrument features advanced detector technology and a high-resolution X-ray detector, providing excellent sensitivity and resolution. It also supports compliance with international standards, making it a reliable tool for regulatory and quality control applications. With its intuitive software interface, the Shimadzu EDX-7000 simplifies data acquisition and analysis, ensuring efficient and reliable results in various analytical contexts.

Wavelength Dispersive X-Ray Fluorescence Spectrometer (Panalytical, Zetium)

Application

The Wavelength Dispersive X-ray Fluorescence Spectrometer is another powerful XRF instrument in our unit. Like EDXRF, the Zetium spectrometer excels in elemental analysis across various materials and industries, covering elements from Carbon (C) to Americium (Am). It is particularly valued for accurately quantifying elements from major to trace levels, including qualitatively determining lanthanide elements (rare earths). The WDXRF technique utilises crystal diffraction to disperse X-rays according to their wavelengths, allowing for superior spectral resolution and sensitivity compared to EDXRF. This capability makes it indispensable in mining, metallurgy, environmental monitoring, and pharmaceuticals. The Zetium spectrometer supports various sample types, including solids, powders, liquids, and thin films, and is equipped with advanced software for automated measurement and comprehensive data analysis. It achieves low-level detection (LLD) of elements in liquid media as low as 0.1 ppm, demonstrating its capability for sensitive and precise elemental analysis in diverse applications.

Portable X-Ray Fluorescence Spectrometer (Bruker, S1 TITAN)

Application

The Portable X-ray Fluorescence Spectrometer (Bruker, S1 TITAN) is a versatile analytical tool used across various industries for rapid elemental analysis. It can detect elements from Magnesium (Mg) to Uranium (U). The spectrometer is designed to measure solids, liquids, and powders directly in situ, offering flexibility and convenience for on-site analysis wherever materials are found or used. This capability enables real-time decision-making in diverse fields, supporting efficiency, compliance, and quality assurance across industrial and environmental applications.

X-ray Diffractometer
(PANalytical, X'Pert PRO MPD PW 3040/60)

Application

XRD is used to identify the crystalline phases present in a sample by comparing the results with the database of standards provided by the International Centre for Diffraction Data (ICDD). It is also employed to study phase transformations. It also determines materials' qualitative and quantitative structural information, including crystallite size, crystallinity, and lattice strain. Samples can be in the form of powders, bulk materials, or thin films. Coarse powders with large grains may be hand-ground or milled to finer powders before measurement.

Arc-Spark Optical Emission Spectroscopy
(OXFORD INSTRUMENTS, WAS FOUNDRY-MASTER)

Application

Arc-Spark Optical Emission Spectroscopy analyses metallic samples per relevant standards and norms, serving as a critical quality control tool in foundries and various industries. Proper sample preparation requires a smooth surface with a diameter greater than 3 cm. Zirconium oxide sandpaper with grit P40-P60 should be used for Fe-based samples, while Al-based samples should be lathed. It is essential to avoid overheating the samples during surface preparation.

Corrosion Analyzer (Potentiostat)
(GAMRY INSTRUMENTS, REFERENCE 600)

Application

A corrosion analyser (potentiostat) is essential for electrochemical and corrosion measures to assess various materials' corrosion behaviour in different environments. It determines the corrosion rate using techniques such as linear and dynamic polarisation. The samples must be flat, conductive materials with known density and equivalent weight for accurate measurements.

Simultaneous Thermal Analyzer (STA)
NETZSCH, STA 449 F3 Jupiter (with 2 furnaces)

Application

A Simultaneous Thermal Analyzer combines Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) to analyse the same sample concurrently. It measures mass changes and thermal effects within the temperature range of -150°C to 1600°C. This analysis can identify a sample's phase transformations, decomposition, condensation, pyrolysis, oxidation, and combustion. The analyser is equipped with microbalances, an electric furnace, gas control systems, cooling systems, and specialised hardware and software for comprehensive thermal analysis. Sample requirements include a typical measurement range of 10-20 mg, usually in powder form. The materials can be powders, solids, or liquids. Solid samples must have a flat, smooth surface with a less than 4 mm diameter.

UV-Vis Spectrometer
(Perkin Elmer, Lambda 35)

Application

The Perkin Elmer Lambda 35 UV-Vis Spectrometer measures the absorbance and transmittance of liquid and solid samples across the ultraviolet and visible spectral range. It is commonly applied in various fields to analyse the concentration of substances, study reaction kinetics, and characterise the optical properties of materials. For optimal performance, liquid samples should be clear, free from particulates, and have a volume greater than 3 ml, typically prepared in quartz or glass cuvettes. Solid samples should be flat, smooth, and appropriately sized to fit the sample holder, with films measuring 2 × 1.5 cm and powders covering a 1.7 cm diameter sample holder. The instrument has high-resolution optics and a wide wavelength range to provide accurate and reproducible results.

Universal Testing Machine
(Lloyd Instruments, LS 100)

Application

The Universal Testing Machine is a versatile and robust device for measuring materials' mechanical properties under various loading conditions. It is widely applied in industries to perform tensile, compression, flexural, and shear tests. This machine can accurately determine material properties like tensile strength, compressive strength, elongation, yield strength, and modulus of elasticity. With advanced software for data analysis and precise load cell technology, the LS 100 ensures high accuracy and repeatability in test results. Its wide load range and customisable fixtures make it suitable for testing a diverse array of materials, including metals, plastics, composites, and textiles, thereby aiding in quality control, material development, and compliance with international testing standards, following BS EN ISO, ASTM, and DIN standards.

Handheld Spectrophotometer

Application

The handheld spectrophotometers offer portability and flexibility, finding applications in various fields where on-site or non-destructive analysis is required. Typical applications include colour measurement in textiles, paints, and plastics, where precise colour matching and quality control are essential. Handheld spectrophotometers are valuable tools in environmental monitoring, enabling quick assessment of the colour of fibres, paints, and coatings due to chemical changes. Portability and versatility make handheld spectrophotometers indispensable for a wide range of applications requiring rapid, on-the-go analysis. Samples must be solid, with a minimum diameter of 11 mm and a flat surface, to ensure accurate measurement.

Ground Penetrating Radar (GPR)

Application

GPR is a geophysical method that uses radar pulses to image the subsurface. This nondestructive method uses electromagnetic radiation in the radio spectrum's microwave band (UHF/VHF frequencies) and detects the reflected signals from the subsurface structures. GPR can be applied in a variety of media, including rock, soil, ice, fresh water, pavements, and structures. In the right conditions, practitioners can use GPR to detect subsurface objects, changes in material properties, voids, and cracks.

Neutron Activation Analysis (NAA)

Application

The NAA technique is non-destructive and can detect various elements (Multielement). This technique involves qualitative and quantitative measurement of sample activation with neutrons and detecting activation products (radioisotopes). The laboratory uses the neutron irradiation facility the TRIGA MARK II Reactor provided for sample activation. A radionuclide's activity is measured using gamma spectrometry with a hyper-pure germanium (HPGe) detector. It can determine 30 to 40 elements in a sample at concentration levels from ppb to per cent.

X-ray Radiography

Application

X-ray radiography is a nondestructive imaging technique that uses ionising radiation to construct images of internal structures. This method is widely employed across various fields, such as medicine, industry, and security. X-ray radiography directs a beam of X-rays towards the examined object. These high-energy photons penetrate the object, and the amount of radiation absorbed or transmitted through different materials within the object varies based on their density and composition. A detector on the opposite side captures the transmitted radiation, producing an image representing the object's internal structure.

Neutron Radiography

Application

Neutron radiography, akin to X-ray radiography, relies on neutron interactions with materials to produce detailed images of their internal structures. The neutrons are sourced from the TRIGA MARK II Reactor.

Sinagama

Application

SINAGAMA Irradiation Plant uses ionising energy from gamma radiation from a Cobalt-60 source. It is the first government facility to be certified with ISO 9001 since 1991. Currently known as SINAGAMA, the plant is certified with MS ISO 9001:2008 and ISO 13485:2003. The plant has been a tax-exempt area since 1999. On 1 April 2004, a new plant, JS10000 (IR-219), was installed and commissioned for further improvement. It can simultaneously irradiate various products that require different doses.

CHAPTER 3:
PROJECTS AND ACTIVITIES

The Heritage Unit won grants for various national and international projects. It also works with many national and international partners in various capacities, such as research collaborators, event organisers, technical consultants, and clients/vendors. This chapter intends to detail the Heritage Unit's many activities.

3.1 International Projects

The table below lists the international projects and collaboration between the Heritage Unit and our global partners in cultural heritage consolidation and preservation works.

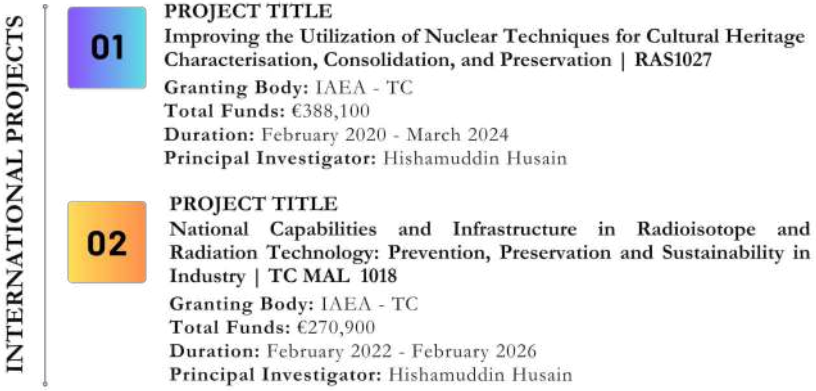


Figure 3.1: International Involvement of the Heritage Unit

As delineated in the table above, the preeminent patron of Heritage Unit's global initiatives is none other than the International Atomic Energy Agency (IAEA), an esteemed organisation committed to the peaceful advancement of atomic science and energy under the auspices of the United Nations (UN). The endeavours undertaken by the Heritage Unit resonate profoundly with the overarching mission of the IAEA, which seeks to foster the peaceful dissemination and application of atomic technology for the collective betterment of humankind.

3.2 National Projects

Figures 3.2 and 3.3 below list the national projects and collaboration between the Heritage Unit and our inter-government partners in cultural heritage consolidation and preservation.

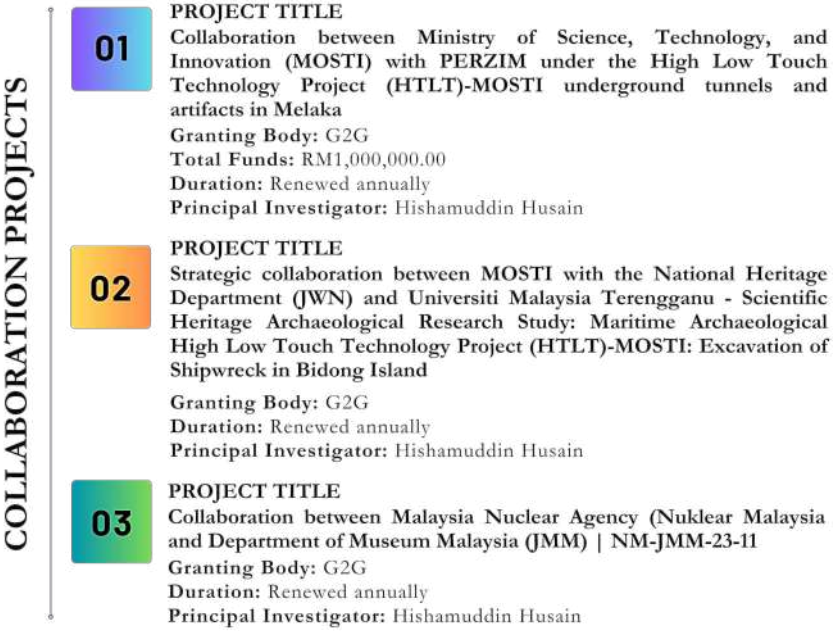


Figure 3.2: Collaboration projects involvement of the Heritage Unit

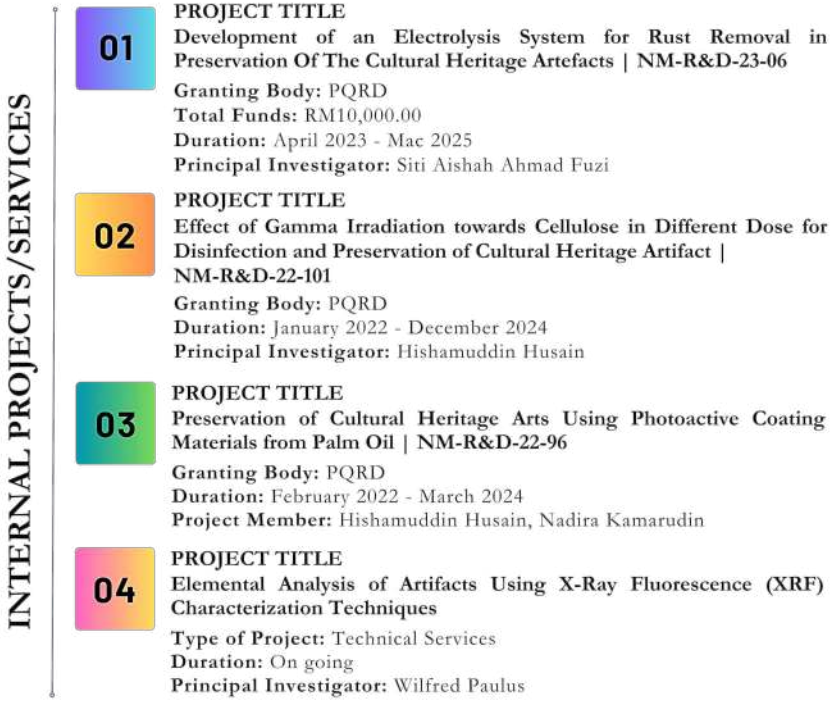


Figure 3.3: Internal/service projects involvement of the Heritage Unit

As indicated by the figure above, the Heritage Unit's collaborative efforts extend extensively across national and state museums and universities, underscoring its broad national reach. Furthermore, the projects entail the specialised use of nuclear technology, marking a distinctive niche within cultural heritage preservation. Positioned at the vanguard, the Heritage Unit spearheads the pioneering development and application of nuclear techniques to preserve and consolidate cultural heritage artifacts.

CHAPTER 4:
OUTPUT

The Heritage Unit has been active since January 2020. Thanks to the projects and funding we have received, we have produced a healthy output of written materials and organised and hosted activities and fellowships. This chapter explores the production of the Heritage Unit in great detail.

4.1 Funds

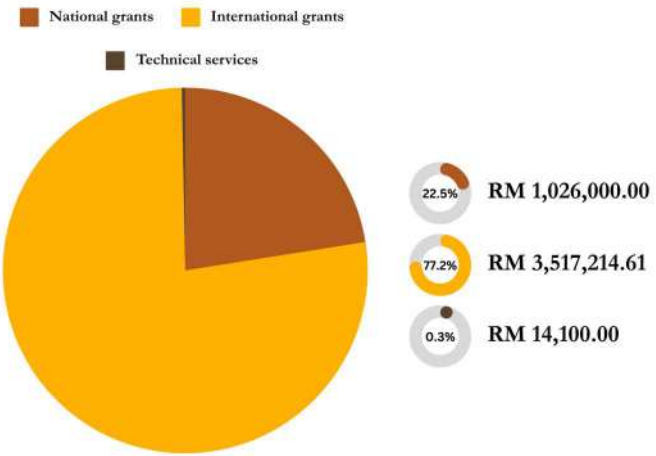


Figure 4.1: The breakdown of the funds granted to the Heritage Unit

Figure 4.2: Breakdown of the Heritage Unit's output (2020-2023)

The Heritage Unit obtained funds from the IAEA totalling RM3,517,214.61, from the Pre-Qualification Research and Development (PQRD) fund of Nuklear Malaysia and government funds totalling RM1,026,000.00, and from the provision of technical services totalling RM14,100 (Figure 4.1). This amounts to RM4,557,314.61 in funds the Heritage Unit has access to for cultural heritage preservation and consolidation works.

Figure 4.2 illustrates the Heritage Unit's output breakdown, showcasing its diverse engagements and contributions. Notably, the Heritage Unit demonstrates activity as invited speakers (19), where our esteemed personnel have been sought after to share insights on utilising nuclear techniques for characterising and preserving wood- and paper-based artefacts.

Furthermore, the Heritage Unit is currently involved in six ongoing projects spanning various disciplines, indicative of our broad scope of research interests. Additionally, we provide technical services, produce technical reports, and conduct training programmes, numbering 7 and 9, respectively. Moreover, the Heritage Unit boasts three active collaborations with esteemed national organisations. In terms of publications, we have collectively published six papers and authored two books, underscoring our commitment to scholarly dissemination.

The Heritage Unit remains poised for continued activity over the next three years, buoyed by available funding and the progressive nature of ongoing projects. Notably, our focus is on enhancing expertise in artefact consolidation, a niche area, through collaborative initiatives with international partners facilitated by fellowships under the auspices of the IAEA. The knowledge acquired from these partnerships will be effectively transferred and implemented at the Heritage Unit, aligning with our mission to effectively address Malaysia's artefact preservation needs. For further information on these achievements, please consult the Appendix.

CHAPTER 5:
LOOKING FORWARD

The Heritage Unit has undeniably emerged as a vanguard in employing nuclear techniques to safeguard and fortify our nation's invaluable heritage. Since its inception, the Heritage Unit has tirelessly pursued domestic and international collaborative ventures, forging robust partnerships with esteemed institutions and organisations dedicated to cultural preservation.

Tracing the Heritage Unit's trajectory reveals its success is intricately interspersed with its unwavering commitment to scholarly pursuit and knowledge dissemination. Through the collective efforts detailed in preceding chapters, the Heritage Unit has expanded its networks and spearheaded ground-breaking research initiatives that have significantly advanced the field of cultural heritage preservation.

Central to the Heritage Unit's endeavours is its relentless pursuit of technical excellence among its personnel. With a keen focus on leveraging cutting-edge technologies, such as X-rays and electron microscopy, for artifact characterisation, the Heritage Unit stands at the forefront of innovation in this domain. However, recognising the evolving landscape of cultural preservation, the unit is now poised to embark on ventures to acquire expertise in artifact consolidation—a crucial step in safeguarding fragile artifacts for posterity.

As the Heritage Unit charts its course forward, it remains steadfast in its commitment to documenting and disseminating its findings. The Heritage Unit seeks to showcase its achievements and contribute to the broader discourse surrounding cultural heritage preservation and consolidation through peer-reviewed publications and meticulously crafted books.

Moreover, the Heritage Unit's vision extends beyond scholarly pursuits, encompassing a deep-seated commitment to fostering meaningful collaborations with its current partners, including entities such as the Department of Museums (JMM), the Organization of Museums Melaka (PERZIM), and the International Atomic Energy Agency (IAEA). While these partnerships have yielded significant dividends, the Heritage Unit is now poised to deepen its engagement through cross-training initiatives, joint facility development, and collaborative projects to enhance cultural heritage preservation techniques.

In navigating its multifaceted mission, the Heritage Unit remains resolute in its dedication to excellence. As it continues to nurture talent, propel innovation, and propagate the field of cultural heritage preservation and consolidation locally and globally, the Heritage Unit stands as a beacon of dedication and innovation—a custodian of our rich cultural legacy entrusted with safeguarding it for generations to come. The figure shows the roadmap of the Heritage Unit within ten years.

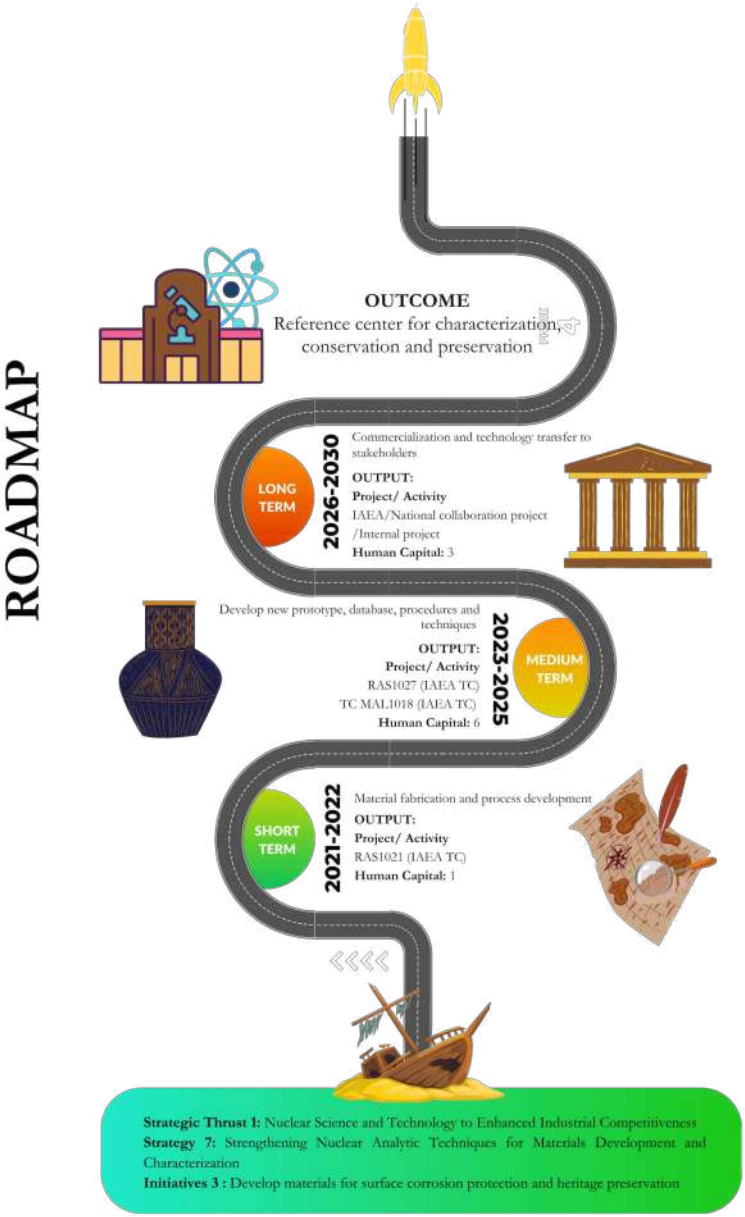


Figure 5.1: Roadmap of Heritage Unit within ten years (2021–2030)

ACKNOWLEDGEMENT

We extend our heartfelt gratitude to the International Atomic Energy Agency (IAEA) for generously funding our projects, enabling us to advance our research and contribute to cultural heritage preservation.

Our sincere appreciation also goes to the Malaysia Nuclear Agency and MOSTI for their steadfast support and financial assistance, which have been instrumental in realising our endeavours.

We are deeply thankful to the Department of Museum Malaysia (JMM) for their invaluable partnership, which has allowed us to showcase our work through poster presentations and engage in collaborative efforts to further cultural heritage initiatives.

Special thanks are due to the state government of Melaka for their collaboration, which has enriched our projects and broadened our impact in preserving cultural heritage.

Last but not least, we express our gratitude to the dedicated personnel of the Heritage Unit, whose unwavering dedication and hard work have been integral to our achievements and progress.

APPENDIX

A. Books

No	*Title*	*Publisher/Year*
1.	Coffee Table Book	Malaysian Nuclear Agency, 2022
2.	Proceeding for Seminar on Application of Nuclear Science and Technology in Characterization and Conservation of Artifacts	Malaysian Nuclear Agency, 2022

B. Journal Papers/Conference Proceedings

No	*Title*	*Journal*
1.	*Teknik Nuklear dan Iradiasi bagi Pencirian dan Disinfeksi artifak kayu terendam air* (waterlogged wood)	Malaysia Museums Journal (MMJ) Vo. 40
2.	*Suhu dan Kelembapan Relatif: Satu Tinjauan Kawalan Persekitaraan pada Koleksi Rangka Pengebumian Gua Cha di Muzium Negara*	Malaysia Museums Journal (MMJ) Vo. 40
3.	Authentication of Historic Metal Threads using Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray (EDX)	Malaysia Museums Jurnal Vol. 38, 2021
4.	Characterization and conservation of cultural heritage artifacts	Dewan Kosmik Special Edition, pg. 42-43
5.	Proceeding for Seminar on Application of Nuclear Science and Technology in Characterization and Conservation of Artifacts	ISSN: 978-967-2706-08-3
6.	Preliminary Study on the Effectiveness of The Electrolysis Process at Different Voltage for Steel Artifact Conservation	AIP Conference Proceedings, AMCT 2022

C. Technical Reports

No	*Title*	*Code*
1.	Report on Temperature and Humidity Measurement and Microorganism Sampling based on Sampling on 15-16 February 2023 Perak Museum, Taiping	NUKLEARMALAYSIA/A(AP)/2023/3(S)

No	*Title*	*Code*
2.	Preliminary Report on the Condition of Rare Books and the Environment of the Perak Museum Library	NUKLEARMALAYSIA/A(AP)/2023/3(S).
3.	Report on Heavy Metal Content in Rare Books in the Perak Museum Library Based on Sampling	NUKLEARMALAYSIA/A(AP)/2023/4(S)
4.	Optical Microscopic Examination of Gugusan Adela	NUKLEARMALAYSIA/A(AP)/2023/9(S)
5.	Elemental analysis of Dredging Ship (Sepang City Council)	NUKLEARMALAYSIA/A(AP)/2023/1(S)
6.	The Application of Nuclear Techniques for Characterisation and Preservation of Artefacts Obtained from Shipwreck	NUKLEARMALAYSIA/L/2023/142
7.	*Laporan Penilaian Awal Kondisi Buku Nadir dan Persekitaran Perpustakaan Muzium Perak*	NUKLEARMALAYSIA/A(AP)/2022/1(S)
8.	Laporan Pencirian Bahan Koleksi Emas menggunakan Kaedah Saintifik	2021
9.	*Laporan Teknikal Perahu Sagor*	2024

D. Technical Services

No.	*Service*	*Requester*	*Request Code*	*Type of sample*	*Earning (RM)*
1.	FESEM	Izuddin, I.	38060100I2024000374	Pottery	2100
2.	EDXRF	Classified	38060100I2023003194; 38060100I2023003199	Pottery	800
3.	EDXRF	Fuzi, S.A.A.	38060100I2023005473	Metal Plate	500
4.	FESEM	Husain, H.	38060100I2022003461	Pottery	3600
5.	EDXRF	Husain, H.	38060100I2022001643	Metal	2000
6.	Raman	Husain, H.	38060100I2022003462	Wood	600
7.	Raman	Kamarudin, N.	38060100I2022005728	Textile	4500

E. Invited Speakers

No.	*Title*	*Event*	*Date*
1.	*Demontrasi Pencirian dan Pemuliharaan Artifak Warisan Budaya*	Technology Preview & Showcase (TPS 2024) Siri 2	13–14 June 2024
2.	Radiation Protection Measures During Preservation of Cultural Heritage (CH) Artifact	Radiation Protection Conference & Workshop 2023	29 Aug 2023
3.	Scanning Electron Microscopy and Energy Dispersive X-ray analysis: Application in Artifact Characterization	The Application of Nuclear Techniques for Characterization and Preservation of The Artifacts Obtained from The Shipwreck	24 Oct 2023
4.	International Training Course on Introduction to Nuclear Forensic	IAEA Training Course:	4–8 Aug 2023
5.	Presentation of Dredging-Ship related Characterization Techniques	Sepang City Council	22 Sept 2023
6.	Midterm review Meeting RAS 1027 (Bangkok)	IAEA-RAS	13–19 Aug 2023
7.	Presentation of technical proposals	Perzim Workshop	8–10 March 2023
8.	Scientific methods in the study of ceramic artefacts	Ceramic Artifact Conservation and Restoration Course 2023	16 Aug 2023
9.	Symposium on Application of radiation techniques for cultural heritage research 2022	Basic Introductory Workshop on Scientific Studies on State Museum Collections Terengganu	3 -6 Oct 2023
10.	*Pengenalan kepada Kajian dan Teknik Saintifik dalam bidang Pencirian dan Konservasi*	*Bengkel Pengenalan Asas Kajian Saintifik ke Atas Koleksi Muzium Negeri Terengganu*	3 -6 Oct 2023
11.	Proposed Application of Technology in the Archaeo-Tourism Sector in Melaka	Underground Tunnel Research Project Direction Workshop and Maritime Archeology of Malacca Island: Under the	8–10 March 2023

No.	*Title*	*Event*	*Date*
		touch HTLT, Pulau Besar, Malacca	
12.	Introduction of the Malaysian Nuclear Agency - Importance in Assisting Maintenance Cultural Heritage	Preventive and Curative Clothing Care Workshop	17–21 Oct 2022
13.	An introduction to the Malaysian Nuclear Agency and the application of nuclear science and technology in the study and conservation of artifacts	Presentation on Stage Taste of Malaysia's Family Aspiration Tour Program, Kedah	2-4 Sept 2022
14.	Application of Nuclear Techniques in Textile Conservation	Clothing Care Workshop Preventive and Curative Practices	17-21 Oct 2022
15.	Teknologi Nuklear dalam Pemulihan Khazanah Warisan Negara	*Program Selamat Pagi Malaysia (RTM)*	16 June 2022
16.	Archaeological research using nuclear research reactor in Malaysia	Symposium on Application of Radiation Techniques for Cultural Heritage Research 2022	22–23 March 2022
17.	*Teknik Nuklear dan Radiasi bagi Pencirian dan Disinfeksi Artifak Kayu Terendam Air*	*Seminar Pengangkutan Air Tradisional (Perahu)*	28 Sept 2021
18.	*Pra-Bengkel Restorasi Pesawat AVON SABRE F86 anjuran Jabatan Muzium Malaysia* (Virtual)	Virtual Program organized by JMM	9–10 Aug 2021
19.	Panel experts	*Bicara Santai@Muzium: Kuasa Emas*	18 July 2021

F. Poster Presentation

No.	*Title*	*Event*	*Date*
1.	Power of Gamma Radiation for Rare Books Disinfection	HMA 2024	16 – 22 May 2024
2.	Application of Nuclear Science and Technology in Cultural Heritage Studies	HMA 2024	16 – 22 May 2024
3.	Consolidation of Culture Heritage Artifacts using Nuclear Technique	HMA 2024	
4.	Conservation of Old Cannons	HMA 2024	16 – 22 May 2024
5.	Digital Radiographic Imaging for Historical Artifacts	HMA 2024	
6.	Consolidation of Culture Heritage Artifacts using Nuclear Technique	HMA 2024	
7.	Gamma Radiation Effect Towards Cellulose Based Artifacts	RTC 2023	
8.	Materials Characterization of Artifacts	RTC 2023	23 – 27 Oct 2023
9.	Implication of Environment Factors towards Preservation of Artifacts	RTC 2023	
10.	Application of Nuclear Science and technology in Cultural Heritage studies	HMA 2023	
11.	Preserving the past: Harnessing the power of Gamma radiation for Artifact Disinfection	HMA 2023	
12.	Consolidation of cultural heritage artifacts using nuclear technique	HMA 2023	31 July – 5 Aug 2023
13.	The environmental impact on the preservation of artifacts	HMA 2023	
14.	Digital radiographic imaging for historical artifacts	HMA 2023	
15.	Nuclear technology in metal threads analysis	HMA 2023	
16.	Conservation of old cannons	HMA 2023	
17.	Unveiling artifacts; age with nuclear techniques	HMA 2023	

No.	*Title*	*Event*	*Date*
18.	Cannon study and conservation	HMA 2022	19 – 26 June 2022
19.	Radiographic imaging in the study of historical artifacts	HMA 2022	
20.	Applications of nuclear science and technology in textile studies	HMA 2022	
21.	Study of air dust sampling and disinfection of rare books	HMA 2022	
22.	Application of Nuclear science and technology in the study and conservation of artifacts	HMA 2022	19 – 26 June 2022
23.	*Aplikasi Sains dan Teknologi Nuklear dalam Kajian dan Konservasi Artifak*	*Program Jelajah Aspirasi Keluarga Malaysia*	2–4 Sept 2022
24.	Heritage Treasures Research and Conservation Unit poster for the 50th anniversary celebration Malaysian Nuclear Agency	*Ulangtahun 50 tahun Agensi Nuklear Malaysia*	5 Sept–5 Oct 2022
25.	Preliminary Study on the Effectiveness of the Electrolysis Process at Different Voltage for Steel Artifact Conservation	AMCT 2022	23–24 August 2022

G. Training Courses/Outreach programs

No.	*Event*	*Date*
1.	International Museum Day 2024	16–22 May 2024
2.	Bengkel Meriam anjuran Perbadanan Adat Melayu & Warisan Negeri Selangor (PADAT)	4–8 March 2024
3.	Science and Technology in Preservation of Cultural Heritage Artifacts Colloquium	28–29 Feb 2024
4.	IAEA Fellowship Program - Romania	1–30 Nov 2023
5.	Conservator Camp 2023	4–5 Nov 2023
	Regional Training Course: The Application of Nuclear Techniques for Characterization and Preservation of The Artifacts Obtained from The Shipwreck	23–27 Oct 2023
6.	Regional Training Course on Cultural Heritage: "From Excavation Site to Museum Display	3 – 7 Sept 2023
7.	National Museum 60 years celebration exhibition	30 Aug–3 Sept 2023

No.	*Event*	*Date*
	Midterm review Meeting RAS 1027 (Bangkok)	13 – 19 Aug 2023
8.	International Museum Day 2023	31 July–5 Aug 2023
9.	Kursus Konservasi dan Restorasi Artifak Seramik 2023	16 – 17 Aug 2023
10.	Workshop for providing and strengthening ISO/IEC 17025:2017 documentation	5–8 June 2023
11.	IAEA Advanced Training Course on Characterization, Dating and Data Interpretation of Natural Heritage Materials and Objects (Virtual)	17–21 Oct 2022
12.	*Bengkel Konservasi Tekstil*	17–21 Oct 2022
13.	*Bengkel Pengenalan Asas Kajian Saintifik ke atas Koleksi Muzium Negeri Terengganu*	3–6 Oct 2022
14.	Conference on Advanced Materials Characterization Techniques (AMCT) 2022	23–24 Aug 2022
15.	International Museum Day 2022	19– 26 June 2022
16.	IAEA Workshop on Innovative Accelarator Science and Technology Approaches to Sustainable Heritage Management (Virtual)	13–16 June 2022
17.	Symposium on Application of Radiation Technology for Cultural Heritage Research (Virtual)	22–23 March 2022
18.	*Kursus Lanjutan Pengendalian Sistem Aliran Sintesis Benzena bagi Pentarikhan Karbon*	3–10 Dec 2021
19.	Joint IAEA-ANSTO Workshop on Nuclear and Isotopic Techniques for Cultural Heritage	6–9 Dec 2021
20.	Lawatan Industri dan Perbincangan di Jabatan Muzium Malaysia bersama pihak BTS	2 Dec 2021
21.	TC Regional Workshop on Radiation Technologies for Cultural Heritage Preservation	22–26 Nov 2021
22.	*Seminar Pengangkutan Air Tradisional (Perahu)*	28 Sept 2021
23.	Atom for Peace Seminar (Virtual)	22 Sept 2021
24.	Training Workshop on Advanced X-Ray Techniques for Characterization of Valuable Samples and Objects (Virtual)	6–10 Sept 2021
25.	*Pra-Bengkel Restorasi Pesawat AVON SABRE F86 anjuran Jabatan Muzium Malaysia* (Virtual)	9–10 Aug 2021
26.	*Bicara Santai@Muzium: Kuasa Emas*	18 July 2021
27.	*Kolukium Pelajar Industri bersama Jabatan Muzium Malaysia*	16 July 2021
28.	Virtual Event – Regional TC Training Course on Mathematical Modelling for Radiation Processing	6–8 July 2021
29.	Cultural Heritage under the Microscope: Getting to the Fine Detail with Advanced Elemental Analysis by Scanning Electron Microscope	26 June 2021
30.	Virtual Workshop on Radiation Technology for Industry and Environments	19–22 April 2021

No.	*Event*	*Date*
31.	Trace Elements and Mineralization: The Benefits of Combining Micro-XRF and SEM-EDS/WDS (Virtual)	13 April 2021

H. List of Facility and Equipment

Available equipment in the Cultural Heritage Unit		*Destructive*	*Non-destructive*	*Specific size of a sample*
1.	Field Emission Scanning Electron Microscope	√		√
2.	Energy Dispersive X-ray Spectrometer	√		√
3.	Atomic Force Microscopy	√		√
4.	Energy Dispersive X-Ray Fluorescence Spectrometer	√		√
5.	Wavelength Dispersive X-Ray Fluorescence Spectrometer	√		√
6.	Portable X-ray fluorescence Spectrometer	√		
7.	X-ray Diffractometer	√		√
8.	Arc-Spark Optical Emission Spectroscopy	√		
9.	Corrosion Analyzer (Potentiostat)	√		√
10.	Simultaneous Thermal Analyser (STA)	√		√
11.	UV-Vis Spectrometer		√	√
12.	Universal Testing Machine	√		√
13.	Handheld Spectrophotometer		√	
Other available equipment in Nuclear Malaysia utilised for cultural heritage study				
14.	Ground Penetrating Radar (GPR)		√	
15.	Neutron activation analysis (NAA)	√		√
16.	X-ray radiography	√		
17.	Neutron radiography	√		√
18.	Sinagama	√		

I. Sample Posters/Photographs

Gamma Radiation Effect Towards Cellulose Based Artifacts

Overview

Gamma radiation is often used for disinfection and sterilization processes due to its ability to penetrate materials and disrupt the DNA or molecular structure of microorganisms. When it comes to cellulose materials, such as paper or textiles, exposure to gamma radiation for disinfection purposes can have both positive and negative effects.

Positive Effects

Microbial Inactivation: Gamma radiation effectively kills or inactivates bacteria, viruses, and other microorganisms present on or within cellulose materials. This is particularly useful for sterilizing medical supplies, food packaging, or cultural heritage artifacts.

Reduced Biological Degradation: By eliminating or reducing the microbial load, gamma radiation can contribute to the preservation of cellulose materials. This is important for preventing biological degradation, such as mold growth, which can be a significant concern in archival or storage environments.

Negative Effects

Structural and Color Changes: Gamma radiation can induce chemical changes in cellulose molecules, leading to structural alterations. This may result in the yellowing or browning of the material over time.

Weakening of Fibers: Prolonged or high-dose exposure to gamma radiation may weaken the cellulose fibers, affecting the mechanical strength and integrity of the material. This is a concern for items where structural stability is crucial.

Cross-Linking: Gamma radiation can induce cross-linking between cellulose molecules, altering the material's properties. Excessive cross-linking may lead to increased brittleness.

FESEM Micrograph

Table 1: Radiation dose of samples

Sample Name	Dose (kGY)
Control	Not Irradiated
A	12.5
B	17
C	23.3
D	25.9
E	33
F	43.2
I	60.8
J	82.5
O	120

Fig. 1: Control (not irradiated)

Fig. 2: Sampel A (12.5 kGy)

Fig. 3: Sampel O (120kGy)

The micrographs shows the radiation damage shown as dryness and roughness of surface with the increasing of applied dose

Color Meter

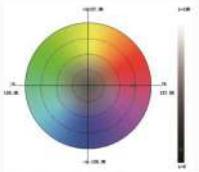


Fig. 3: Color Difference Chart for Sampel O (120kGy)

Table 2: Color Difference Table for Each Sample

Name	L*	a*	b*
control	92.83	-1.41	-3.64
A	92.36	-0.39	-3.15
B	92.43	-0.43	-3.19
C	92.15	-0.52	-2.92
D	92.25	-0.51	-2.68
E	92.09	-0.54	-2.58
F	92.3	-0.61	-1.81
I	92.21	-0.58	-1.58
J	91.9	-0.73	-0.81
O	91.89	-0.59	-0.65

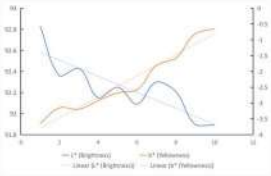


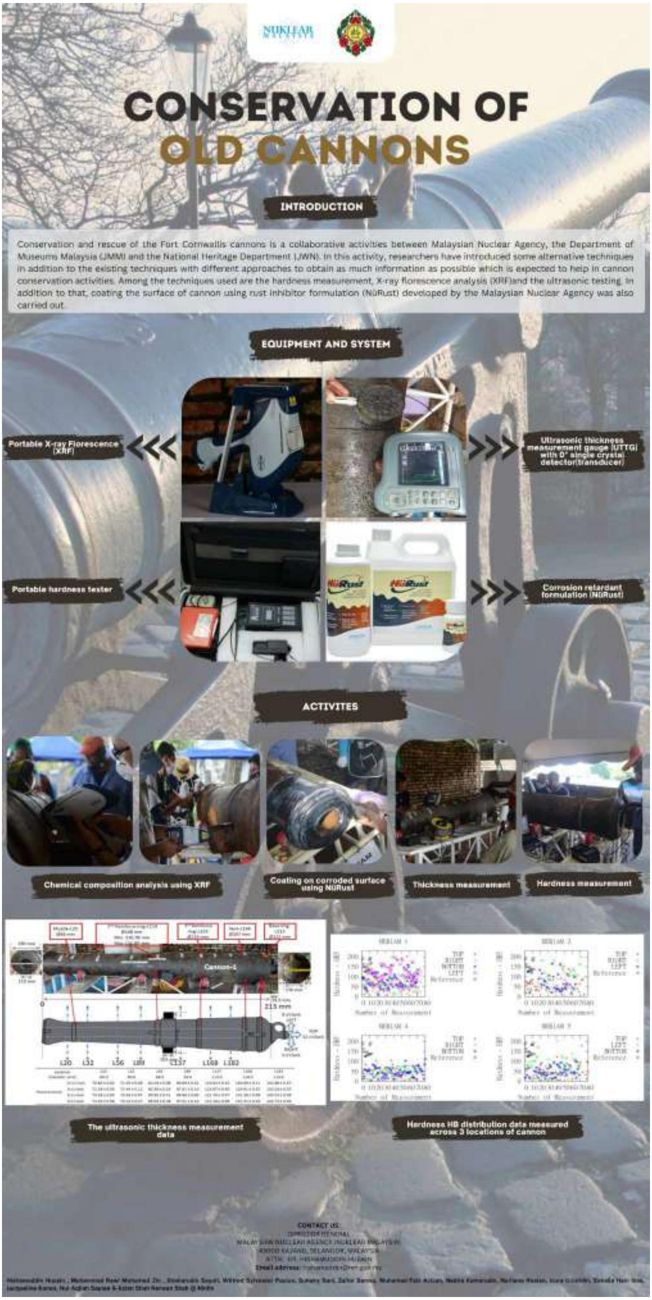
Fig. 4: The brightness decreases while the yellowness of the sample increases with the increasing of applied dose

Conclusion

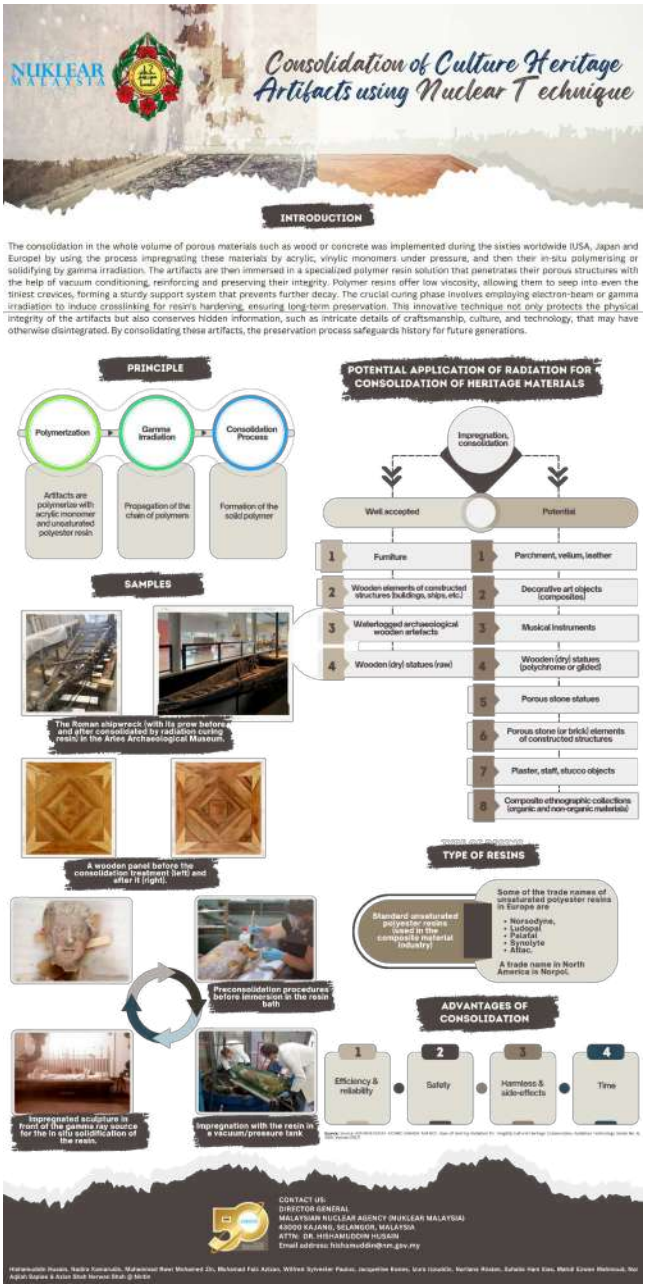
In summary, the use of gamma radiation for disinfection of cellulose materials involves a trade-off between microbial inactivation and potential damage to the material itself. Careful consideration of radiation dosage and duration is essential to strike a balance between achieving disinfection goals and preserving the structural integrity of the cellulose.

Contact us for more information:

hisham.usm@anm.gov.my
nadira@mmedv.my
https://www.nuclearmalaysia.gov.my



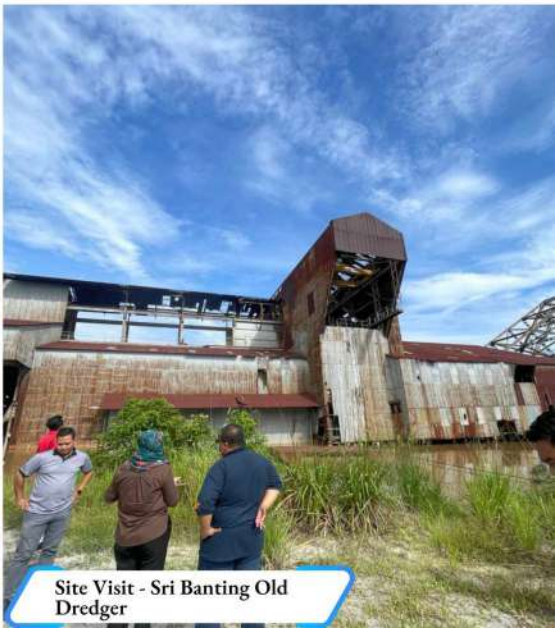
CONSERVATION OF
OLD CANNONS
INTRODUCTION
Conservation and rescue of the Fort Cornwallis cannons is a collaborative activities between Malaysian Nuclear Agency, the Department of Museums Malaysia (JMM) and the National Heritage Department (JWN). In this activity, researchers have introduced some alternative techniques in addition to the existing techniques with different approaches to obtain as much information as possible which is expected to help in cannon conservation activities. Among the techniques used are the hardness measurement, X-ray florescence analysis (XRF)and the ultrasonic testing. In addition to that, coating the surface of cannon using rust inhibitor formulation (NüRust) developed by the Malaysian Nuclear Agency was also carried out.
EQUIPMENT AND SYSTEM
Portable X-ray Florescence (XRF)
Ultrasonic thickness measurement gauge (UTTG) with 0° single crystal detector(transducer)
Portable hardness tester
Corrosion retardant formulation (NüRust)
ACTIVITES
Chemical composition analysis using XRF
Coating on corroded surface using NüRust
Thickness measurement
Hardness measurement
Cannon-1
213 mm
The ultrasonic thickness measurement data
Hardness HB distribution data measured across 3 locations of cannon
CONTACT US:


NUKLEAR MALAYSIA
Consolidation of Culture Heritage Artifacts using Nuclear Technique
INTRODUCTION
The consolidation in the whole volume of porous materials such as wood or concrete was implemented during the sixties worldwide (USA, Japan and Europe) by using the process impregnating these materials by acrylic, vinylic monomers under pressure, and then their in-situ polymerising or solidifying by gamma irradiation. The artifacts are then immersed in a specialized polymer resin solution that penetrates their porous structures with the help of vacuum conditioning, reinforcing and preserving their integrity. Polymer resins offer low viscosity, allowing them to seep into even the tiniest crevices, forming a sturdy support system that prevents further decay. The crucial curing phase involves employing electron-beam or gamma irradiation to induce crosslinking for resin's hardening, ensuring long-term preservation. This innovative technique not only protects the physical integrity of the artifacts but also conserves hidden information, such as intricate details of craftsmanship, culture, and technology, that may have otherwise disintegrated. By consolidating these artifacts, the preservation process safeguards history for future generations.
PRINCIPLE
Polymerization
Gamma Irradiation
Consolidation Process
Artifacts are polymerize with acrylic monomer and unsaturated polyester resin
Propagation of the chain of polymers
Formation of the solid polymer
SAMPLES
The Roman shipwreck (with its prow before and after consolidated by radiation curing resin) in the Arles Archaeological Museum.
A wooden panel before the consolidation treatment (left) and after it (right).
Preconsolidation procedures before immersion in the resin bath
Impregnated sculpture in front of the gamma ray source for the in situ solidification of the resin.
Impregnation with the resin in a vacuum/pressure tank
POTENTIAL APPLICATION OF RADIATION FOR CONSOLIDATION OF HERITAGE MATERIALS
Impregnation, consolidation
Well accepted
1 Furniture
2 Wooden elements of constructed structures (buildings, ships, etc.)
3 Waterlogged archaeological wooden artefacts
4 Wooden (dry) statues (raw)
Potential
1 Parchment, vellum, leather
2 Decorative art objects (composites)
3 Musical instruments
4 Wooden (dry) statues (polychrome or gilded)
5 Porous stone statues
6 Porous stone (or brick) elements of constructed structures
7 Plaster, staff, stucco objects
8 Composite ethnographic collections (organic and non-organic materials)
TYPE OF RESINS
Standard unsaturated polyester resins used in the composite material industry
Some of the trade names of unsaturated polyester resins in Europe are:
• Norsodyne,
• Ludopal
• Palatal
• Synolyte
• Aflac.
A trade name in North America is Norpol.
ADVANTAGES OF CONSOLIDATION
1 Efficiency & reliability
2 Safety
3 Harmless & side-effects
4 Time
CONTACT US:
DIRECTOR GENERAL
MALAYSIAN NUCLEAR AGENCY (NUKLEAR MALAYSIA)
43000 KAJANG, SELANGOR, MALAYSIA
ATTN: DR. HISHAMUDDIN HUSAIN
Email address: hishamuddin@nm.gov.my

International Museum Day 2023 Sarawak

Midterm review Meeting RAS 1027 (Bangkok)

IAEA Fellowship Program - Romania



Site Visit - Sri Banting Old Dredger

Conservator Camp 2023

IAEA Regional Training Course (RTC) 2023 Melaka

Cultural Heritage Artifacts Colloquium 2024

GLOSSARY

A

AFM: 6, 8, 10, 15

D

DSC: 18

E

EDS: 14
EDXRF: 15, 16

F

FESEM: 7, 8, 9, 14
FTIR: 7, 8, 9

G

GPR: 20

I

IAEA: 2, 5, 24, 29, 31, 33
ICDD: 17

J

JMM: 2, 5, 8, 9, 10, 31, 33
JWN: 2, 5, 8

L

LLD: 16

M

MOSTI: 2

P

PERZIM: 2, 5, 31
PQRD: 6, 7, 9, 29

R

RTC: 5, 8

S

STA: 18

T

TGA: 18

U

UKM: 5, 6, 7, 8
UM: 10
UN: 25
UTM: 9
UV-Vis: 6, 7, 9, 10, 13, 19

X

X-ray: 6, 7, 9, 10, 12, 14, 15, 16, 21, 22, 31
XRD: 6, 7, 9, 10, 17
XRF: 6, 7, 9, 10, 16

W

WDS: 14
WDXRF: 16