THE APPLICATION OF NUCLEAR TECHNIQUES FOR CHARACTERIZATION AND PRESERVATION OF ARTIFACTS OBTAINED FROM SHIPWRECKS

The Application of Nuclear Techniques for the Characterization and Preservation of Artifacts Obtained from Shipwrecks

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FOREWORD

The Regional Training Course (RTC) workshop, titled "The application of nuclear techniques for characterization and preservation of artifacts obtained from shipwreck," took place at the Hatten Hotel in Melaka from 23rd to 27th October 2023, organized by the International Atomic Energy Agency (IAEA). At national level, the Malaysian Nuclear Agency organized this remarkable event in collaboration with the Department of Museums Malaysia, supported by Department of National Heritage and Melaka Museum Corporation (PERZIM).

The primary objective of this workshop was to equip delegates with the knowledge and skills required to employ nuclear techniques in characterising and preserving artifacts retrieved from underwater shipwrecks. Thirty-three (33) delegates from a diverse array of seventeen countries, including Bangladesh, Cambodia, Indonesia, Iran, Iraq, Jordan, Lebanon, Myanmar, Oman, Pakistan, Palestine, the Philippines, Singapore, Thailand, Vietnam, France, and Malaysia, came together for this intellectual voyage. The program featured thirteen informative oral presentations, complemented by field trips and hands-on activities at the Kota Lukut Museum (Negeri Sembilan), the shipwreck site in Melaka and the Malaysian Nuclear Agency.

The resounding success of this program is evident, as it provided delegates with invaluable insights into the methodologies and techniques underpinning the preservation of shipwrecked artifacts through comprehensive oral and poster presentations. Additionally, the demonstration during field trips allowed delegates to examine these approaches and the associated instruments closely. Notably, this workshop fostered a vibrant atmosphere of networking and knowledge sharing among delegates, which is expected to spawn collaborative research endeavours within the overarching ambit of cultural heritage preservation under the auspices of the IAEA. The organisers are fervently optimistic that this workshop is but the first instalment in a series dedicated to the noble cause of safeguarding our cultural heritage for generations to come.

This book is a tangible testament to the wealth of collective knowledge cultivated and generously shared among the workshop's esteemed delegates. It represents an invaluable written repository of a pivotal facet of cultural heritage preservation. Our primary objective is to disseminate this knowledge to the broader public, with the sincere intention of sparking interest and fostering a deeper appreciation for this vital field.

Hishamuddin Husain, PhD
Course Director
3rd January 2025
Malaysia

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CHAPTER 1
BACKGROUND

1. BACKGROUND

Nuclear technology has witnessed a century of remarkable achievements in energy production, medical treatment, and materials characterization. The once-elusive and enigmatic realms of science were rendered accessible thanks to nuclear technology's discovery and continual refinement. This remarkable innovation has forged numerous uncharted pathways for scientific exploration.

One of nuclear technology's lesser-known and seldom-discussed applications is preserving our cultural heritage, specifically focusing on solid artifacts. In the context of this book, "artifacts" encompass an array of materials, including pottery, ships, and various archaeological sites. Many of these relics have been unearthed from antiquity, but the limitations of past technologies hindered a comprehensive understanding of their historical significance.

The proliferation of nuclear technology and its derived techniques has endowed seemingly ordinary artifacts with a profound historical tapestry. X-rays, for instance, can deconstruct an artifact, unveiling its intricate constituents and shedding light on the mysteries of our past societies. Meanwhile, gamma rays serve as a guardian, arresting the relentless march of bacteria and fungi that threaten to disintegrate invaluable and delicate artifacts.

Moreover, nuclear techniques can perform miraculous restoration on damaged artifacts, enabling us to glimpse into the minds of our forebears. This is particularly crucial in regions where the harsh climate takes a toll on ancient and fragile treasures. Following restoration, scholars from diverse backgrounds can comprehensively analyse these artifacts, further unravelling the mysteries of bygone eras.

This book presents the collaborative efforts of scholars who straddle the realms of science and art. Traditionally seen as disparate disciplines, these scholars have deftly found a harmonious middle ground where their scientific expertise complements the insights of historians and artists. Together, they orchestrate the renaissance of our past, a tantalising journey that beckons all to explore and appreciate.

CHAPTER 2

CULTURAL HERITAGE CHARACTERIZATION AND PRESERVATION

2. CULTURAL HERITAGE CHARACTERIZATION AND PRESERVATION

This chapter embarks on a meticulous and multifaceted journey into the realm of cultural heritage characterization and preservation, casting a spotlight on the subjects that came under scrutiny during the IAEA-sponsored workshop titled "The Application of Nuclear Techniques for Characterization and Preservation of Artifacts Obtained from Shipwrecks." Held between 23rd and 27th October 2023, it served as an intellectual crucible where experts and scholars converged to unravel the intricate tapestry of preserving our historical treasures.

As we navigate through this chapter, we begin with a compelling exploration of the maritime history of the Malay Peninsula, which bears witness to a plethora of shipwrecks scattered beneath its waves. These submerged vessels are poignant testimonies to the stories of seafaring civilizations and maritime trade routes. We delve into the challenges and opportunities inherent in uncovering and preserving the secrets locked within these underwater time capsules.

A central pillar of our discussion revolves around applying nuclear sources and techniques, which emerge as indispensable tools to safeguard and restore retrieved artifacts. Gamma rays, neutrons, and X-rays, harnessed with precision and care, can unveil the concealed details of these relics. They enable us to peer beneath the layers of history, transcending the boundaries of time and the encroachment of decay, allowing us to capture the essence of moments long past.

Further segments of this chapter illuminate the unique and intricate facets of cultural heritage preservation. We delve into the meticulous care taken to preserve geoarchaeological sites, ceramic potteries, and waterlogged wood, each presenting its challenges and rewards. Through the discerning lens of nuclear and imaging techniques, we explore the historical significance and witness the scientific ingenuity that underpins these endeavours.

These discussions underscore the vital role of collaborative research and technological innovation in cultural heritage preservation. The convergence of expertise from diverse fields, including archaeology, science, and technology, drives these achievements. Ultimately, this chapter serves as a testament to the power of human curiosity, ingenuity, and cooperation in the timeless pursuit of preserving our cultural legacy for generations yet unborn.

2.1 Ancient Shipwrecks in Malay Archipelagos Waters

Name: Hasrizal Shaari
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In the heart of the Malay Archipelago, where the azure waters of the South China Sea caress the shores of Malaysia, lies a treasure trove of history submerged beneath the waves. These waters hold the secrets of ancient maritime trade routes, where Chinese junks, Thai vessels, and Southeast Asian ships once sailed, laden with precious cargo. Today, these sunken relics provide a window into the past, offering invaluable insights into the rich tapestry of cultures and civilizations that once thrived in this maritime crossroads.

Malaysia, with its vibrant history, boasts a significant number of underwater archaeological sites. Governed by the National Heritage Act (Akta 645), these underwater cultural heritage sites are scattered across the Malaysian waters, ranging from the ancient port of Malacca to the sunken Bidong Shipwreck, each with its unique story.

Malaysian waters house a diverse array of shipwrecks, each representing a different era and purpose. Ancient shipwrecks dating back centuries provide glimpses into the maritime trade networks of the Malacca Sultanate and the Majapahit and Srivijaya kingdoms. World War-era shipwrecks are silent witnesses to the turbulent times of the past century. Foreign fishing vessels and forfeited shipwrecks add to the mosaic of maritime history found beneath the waves.

According to maritime historian Flecker, ancient maritime trade routes in the South China Sea were bustling with activity between the 13th and 17th centuries. Three distinct ship types dominated these waters: the majestic Chinese Junk, the traditional South China Sea vessels, and the Southeast Asian lashed lug ships. These vessels, with their unique designs, facilitated trade, cultural exchange, and the movement of people across the archipelago.

Excavating these sunken treasures is no small feat. The Bidong Shipwreck, located within the National Heritage Zone, required a massive operation involving skilled divers and meticulous recording of artifacts. Preservation and storage are vital aspects of these endeavors, ensuring these artifacts are protected for future generations.

While these shipwrecks offer invaluable insights, they also pose challenges. Overloaded ships, unpredictable sea conditions, accidents, wars, and miscalculations have led to the sinking of these vessels. The discovery of remnants, such as burnt wood fragments and stoneware containers, sheds light on the challenges faced by ancient mariners. Techniques like X-Ray Fluorescence (XRF) analysis reveal the composition of these artifacts, providing clues about their origin and purpose.

Strewn across the Malaysian waters are protected zones, such as Pulau Upeh in Melaka and Bidong Island in Terengganu, where these underwater cultural heritage sites are safeguarded. Understanding the significance of these sites not only enriches our historical knowledge and emphasizes the importance of preservation and conservation efforts.

As we delve into the depths of Malaysia's underwater cultural heritage, we embark on a fascinating journey through time. These shipwrecks, with their tales of trade, exploration, and cultural exchange, offer a glimpse into the past that is both awe-inspiring and humbling. By unraveling the mysteries of these ancient vessels, we connect with the seafaring souls of our ancestors, appreciating the enduring legacy of maritime heritage in the Malay Archipelago. The slides in the upcoming section detail the work done on this.

National Heritage Act(Akta 645)
PART IX Underwater Cultural Heritage

Section 61
Discovery of underwater cultural heritage

Section 62
Possession, custody or control of moveable underwater cultural heritage

Section 63
Declaration of underwater cultural heritage

Section 64
Protected zone

Section 65
Salvage and excavation works to be licensed

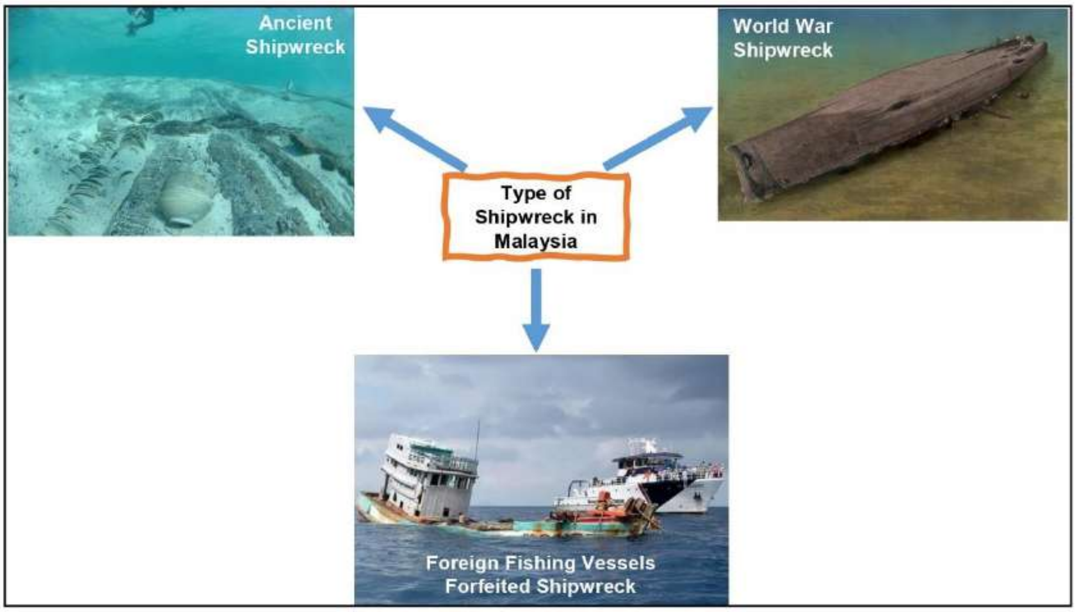
Section 66
Ownership of underwater cultural heritage found during survey, salvage and excavation

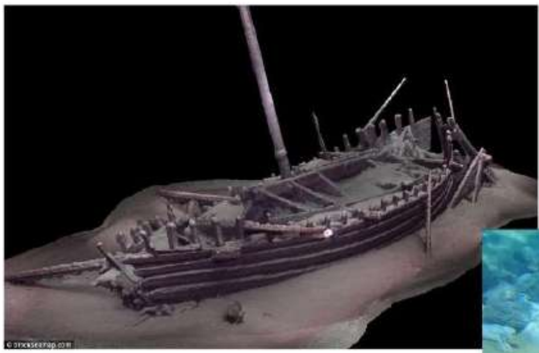
Archaeological Sites in Malaysia

ARCHAEOLOGY SITES IN MALAYSIA

NO	STATES	SITES		TOTAL
		LAND	UNDERWATER	
1	KEDAH	57	4	61
2	PERLIS	67	-	67
3	PULAU PINANG	6	5	11
4	KELANTAN	47	4	51
5	TERENGGANU	17	6	23
6	PAHANG	109	17	126
7	PERAK	208	6	214
8	WP KUALA LUMPUR	2	-	2
9	WP PUTRAJAYA	-	-	-
10	SELANGOR	33	7	40
11	NEGERI SEMBILAN	47	14	61
12	MELAKA	41	31	72
13	JOHOR	39	24	63
14	WP LABUAN	8	8	16
15	SARAWAK	39	11	50
16	SABAH	18	10	28
	GRAND TOTAL	738	149	887

Sources: Department of National Heritage (JWN), Malaysia

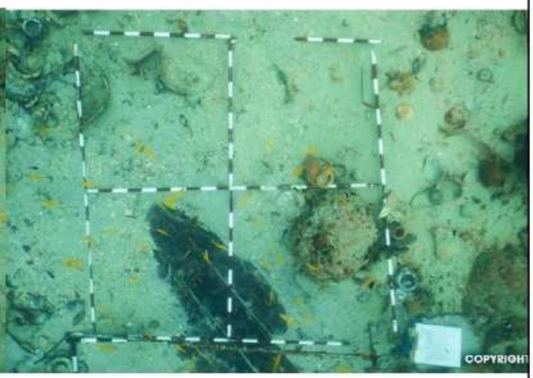




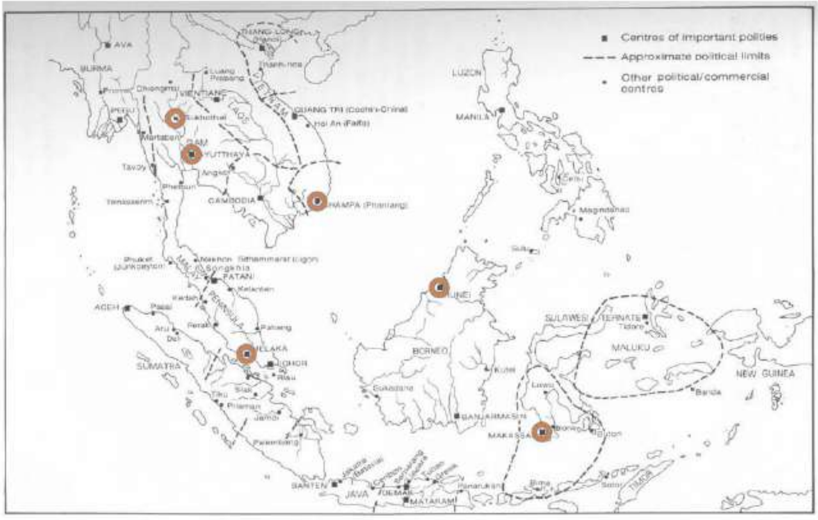
Ancient

Shipwrecks

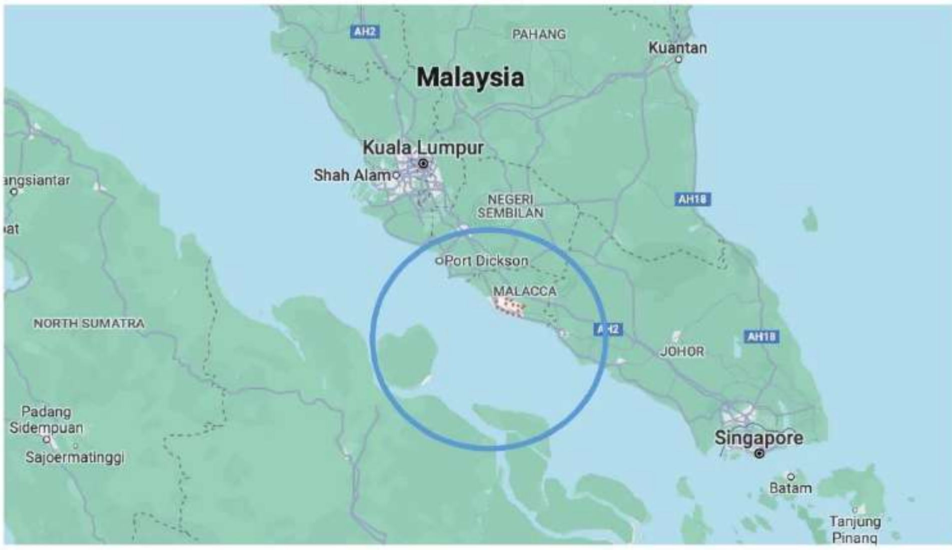
In Reality: Shipwrecks Discovery in Malay Archipelagos are embedded in the subsurface layer of the seabed

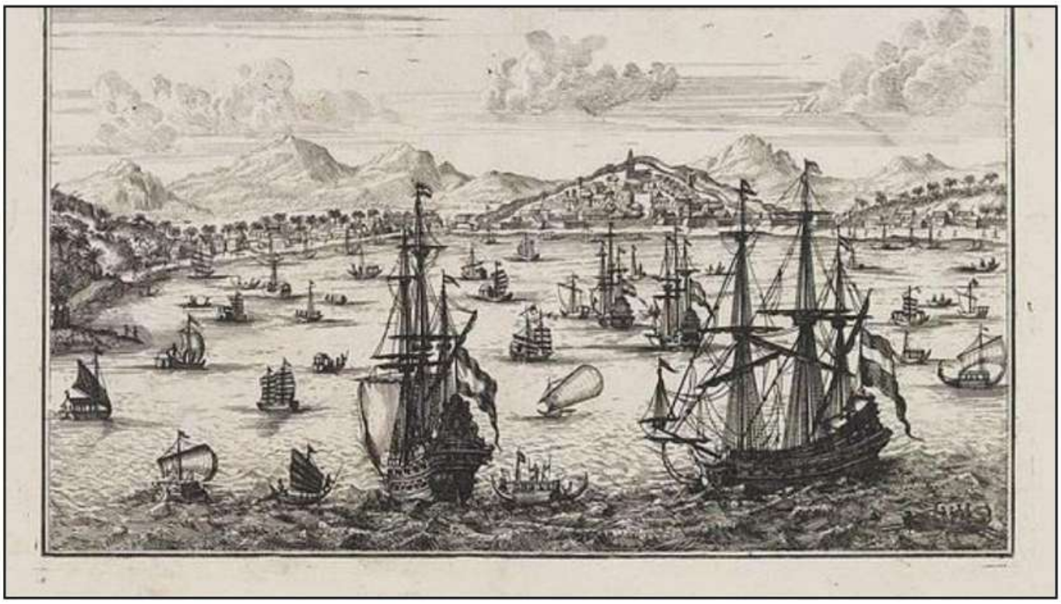


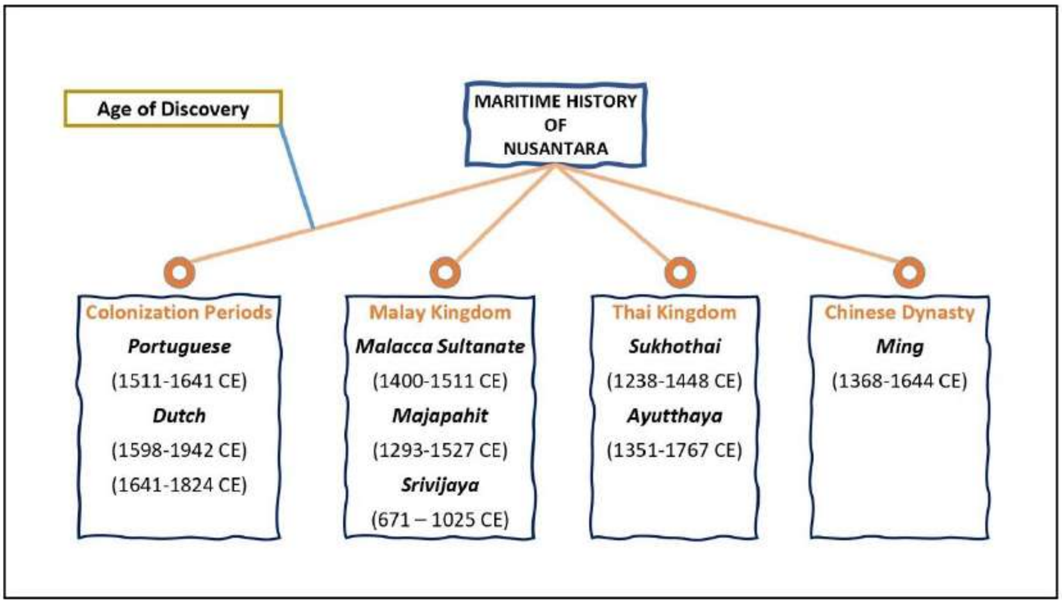
Center of Government in Malay Archipelagos
And Maritime History



Map of Alam Melayu or The Malay Archipelago with centers of government (Source: Anthony Reid: 1988: 90)







Type of Ancient Maritime Ship in Malay Archipelagos

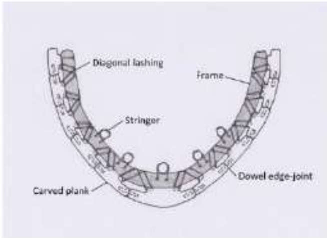
Type of Ancient Maritime Ship in Malay Archipelagos

According to Flecker (2015), between the 13th and 17th centuries, three varieties of ships actively utilised the SCS trade route:

1) **Chinese Junk**
2) **SCS Tradition (Thai)**
3) **Lashed lug (Southeast Asian)**

(1)

(2)



(3)

Table 2. Shipwrecks in China and Southeast Asia with documented structure

Shipwreck Designation	Century	Type (Origin)
Turiang Wreck, Malaysia	15th	Chinese Junk
Bakau Wreck, Indonesia	15th	South China Sea Tradition
Royal Nanhai Wreck, Malaysia	15th	South China Sea Tradition
Pandanan Wreck, Philippines	15th	South China Sea Tradition
Pataya Wreck, Thailand	15th–16th	South China Sea Tradition
Hoi An Wreck, Vietnam	15th–16th	South China Sea Tradition
Ko Kradat Wreck, Thailand	16th	South China Sea Tradition
Lingga (Indonesia)		Lash-lug
Klang Aow (Central Gulf of Thailand) Wreck, Thailand	16th	South China Sea Tradition
Binh Thuan Wreck, Vietnam	17th	Chinese Junk
Vung Tau Wreck, Vietnam	17th	Chinese Lorcha

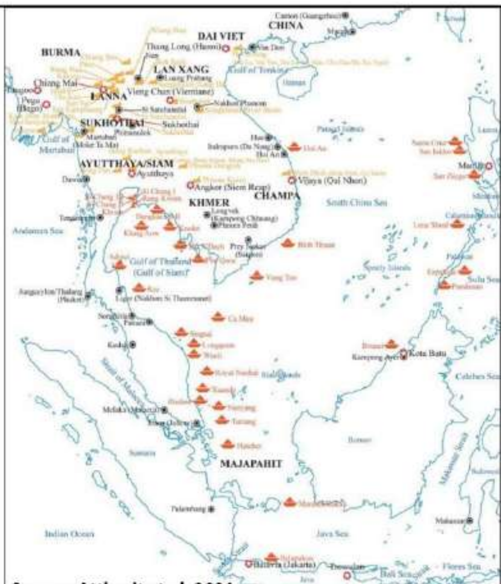
Modified after Flecker (2015)

How About Malay Ships?

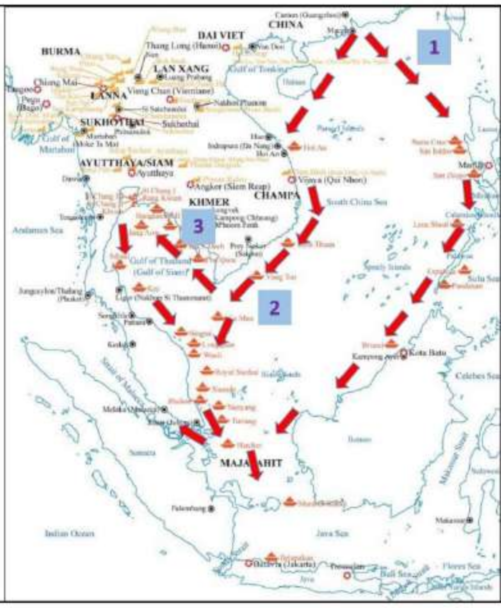
Pinisi

Malay Jong

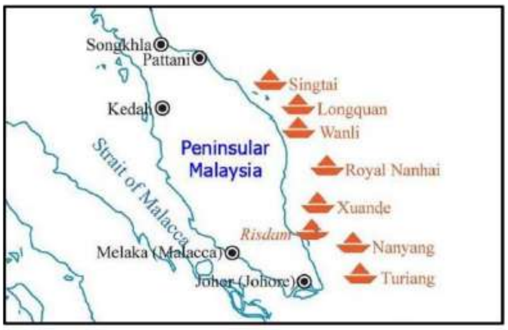
Bedar



Source: Atthasit et al, 2021



Shipwrecks in the East Coast Peninsular Malaysia (Monsoon Civilization)



- Malaysian waters are important for trading route
- Located in between Northeast and Southwest Monsoon blow

Bidong Shipwreck Excavation Project
(UMT-UZ-MA-JWN)

Discovery and Excavation of Artifacts from the Bidong Shipwreck, Malaysia

Baharim Mustapa, Rafidah Razali, Kamarul Redzuan Muhamed, Badri Shah Abdul Ghani, Muhazam Mohamed, Ruzairy Arbi, Farizah Ideris, Khairil Amri Abd Ghani, Azizi Ali, Fatin Izzati Minhat, Muhammad Hafeez Jeofry, Baszley Bee Basrah Bee, and Hasrizal Shaari

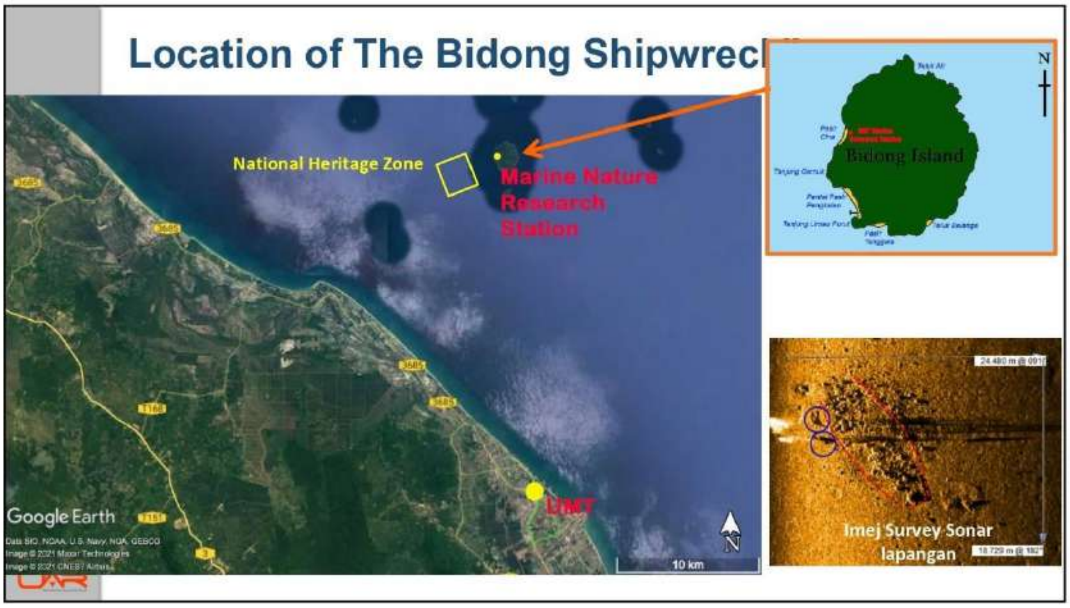
ABSTRACT

DEVELOPMENT OF UNDERWATER ARCHAEOLOGY IN MALAYSIA

Submitted to International Journal of Nautical Archaeology

The Preliminary Dating of the Bidong Shipwreck, Malaysia

Introduction




Rescuing & Recording

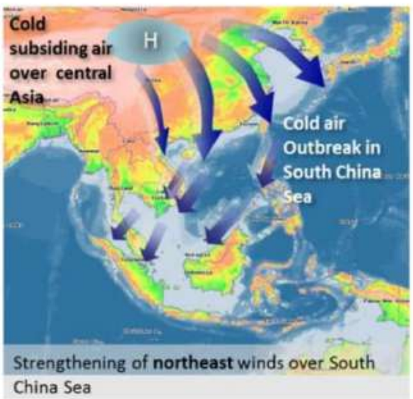

Rescuing & Recording
Massive Operation
• Involved ~25 Divers
• 2760 Man-hours


Preservation & Storage

Factors that caused the sinking of the ancient ship

Sailing of Ships from China or the Thai Kingdom occurs during the Northeast Monsoon Season

Sea Condition

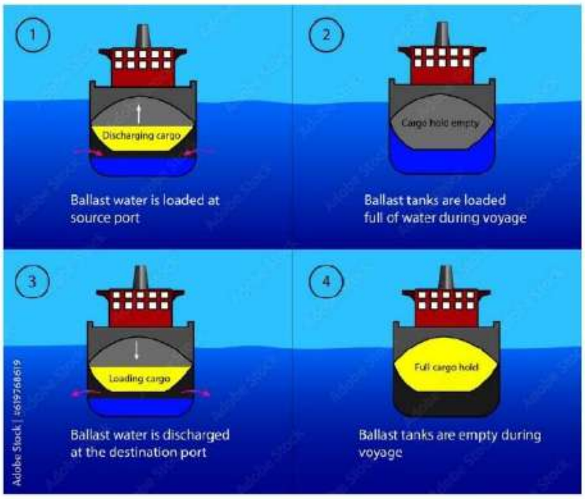


Overloaded

The Ancient Merchant Ship Compartments

- No Ballast Tank.
- Do now know the specific maximum weight of the cargo.
- The stability of the ship depends on the arrangement of the cargo.

Stability of modern merchant ship – Ballast Tank



Miscalculation

The illustration of the ship sinking because it hit the Great Barrier Reef, Australia

War

The battle between Dutch-Portuguese at Malacca Port in 1606

Fire Accident

Burning Ship due to fire accident

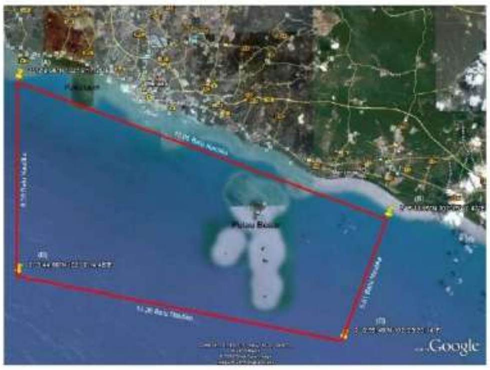
In the case of the Bidong Shipwreck

- Burning wood fragments
- Small stoneware container clinging to melted metals.
- X-Ray Fluorescence (XRF) shows the concentration of elements are iron (27.86%) > silicon (24.87%) > aluminium (0.73%) > sulphur (0.71%) > potassium (0.24%).
- The high content of iron and silicon in the analysed melted metal suggests that there is a mixture between elements from melted metal (iron) and also the element from stoneware which is silicon.
- In general, the melting points of iron alloys and steel occur at higher temperatures, between 1,205°C and 1,370 °C

Heritage Protected Zone

UNDERWATER CULTURAL HERITAGE
PROTECTED ZONE IN MALAYSIA

Labuan, Federal Territory Protected Zone



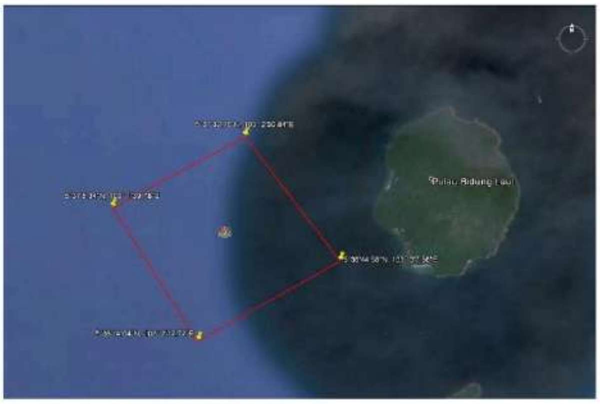
Pulau Upeh, Melaka Protected Zone

UNDERWATER CULTURAL HERITAGE
PROTECTED ZONE IN MALAYSIA

Tanjung Tuan, Melaka Protected Zone

Tioman, Pahang Protected Zone

UNDERWATER CULTURAL HERITAGE PROTECTED ZONE IN MALAYSIA



Bidong Island, Terengganu Protected Zone

Conclusion

- Shipwreck study is very important;
  - to know the past information about the ancient maritime trading routes
  - to understand about underwater cultural heritage values
  - to protect, preserve, and conserve the national underwater cultural heritage
- Malay Archipelagos is very important in east-west maritime trading activities

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2.2 Discovery of Shipwreck and Policy related to Underwater Cultural Heritage in Malaysia

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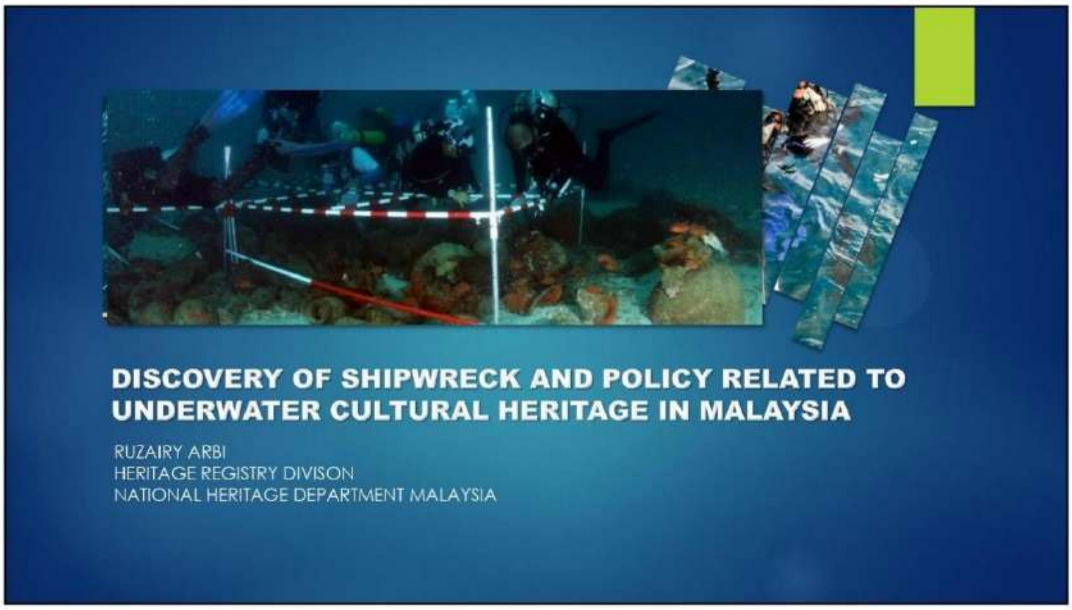
The maritime landscape of Malaysia is a mirror reflecting the nation's historical significance as a pivotal maritime center, with its waters serving as a repository for a trove of submerged historical narratives. Unseen by most, these undersea vestiges hold the tales of ancient trade, cultural exchanges, and the evolution of seafaring in the region. The emergence of maritime archaeology within Malaysia has, in recent years, surfaced a myriad of underwater cultural heritage (UCH) that beckons scholarly attention and protection.

In the quest to chart the historical course of Malaysia's maritime prowess, researchers have delved into the depths to discover shipwrecks that serve as time capsules. These underwater sites are rich with artifacts like ceramics, coins, and navigational instruments that date back centuries. For instance, the revelation of an ancient shipwreck near Pulau Melaka has been pivotal, furnishing evidence of the nation's trading heritage with the discovery of coins tracing back to the reign of Sultan Mahmud and even to the colonial currencies of the Dutch and Portuguese eras. Moreover, the excavation of 'Ding Ware' porcelain bowls offers concrete proof of historical transnational trade and cultural interplay.

Despite the excitement of these findings, the conservation of Malaysia's UCH is fraught with obstacles. The allure of underwater treasures has not only piqued the interest of historians but also looters, who threaten the integrity of these sites. The relentless drive of modern development, manifested in land reclamation and sand dredging operations, coupled with the adverse impacts of climate change, poses additional risks to preserving these submerged historical assets.

Confronted with these perils, there has been a marked response from both governmental and non-governmental entities. Legal frameworks have been reformed to fortify the protection of UCH, and international partnerships have been invigorated. For example, the UNESCO 2001 Convention on the Protection of the Underwater Cultural Heritage, which Malaysia ratified in 2009, serves as a foundation for legislative and protective measures. The slides in the upcoming section detail the work done on this.


DISCOVERY OF SHIPWRECK AND POLICY RELATED TO UNDERWATER CULTURAL HERITAGE IN MALAYSIA
RUZAIRY ARBI
HERITAGE REGISTRY DIVISON
NATIONAL HERITAGE DEPARTMENT MALAYSIA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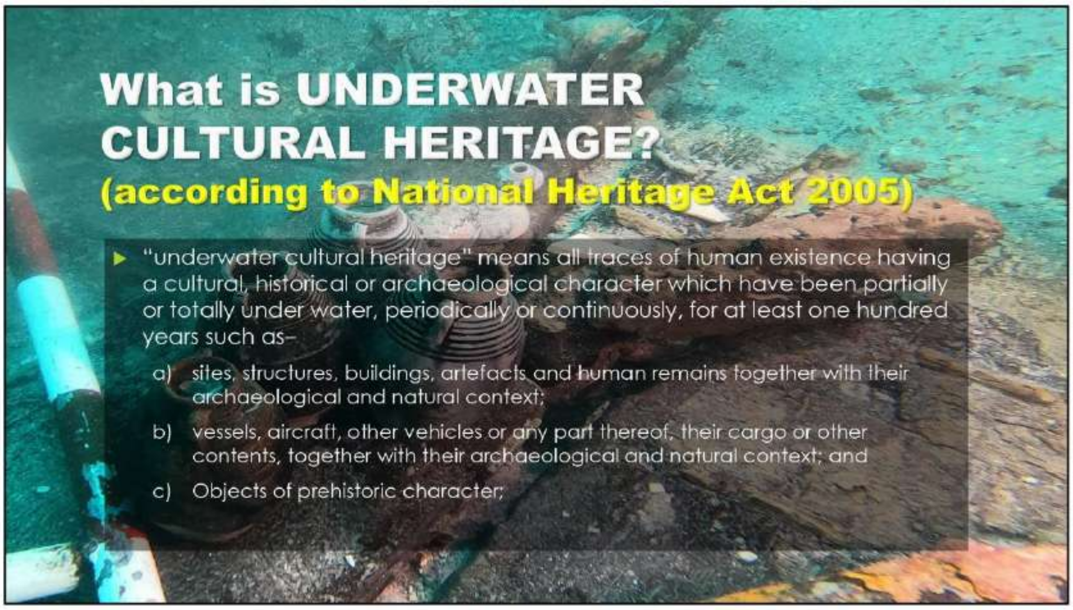
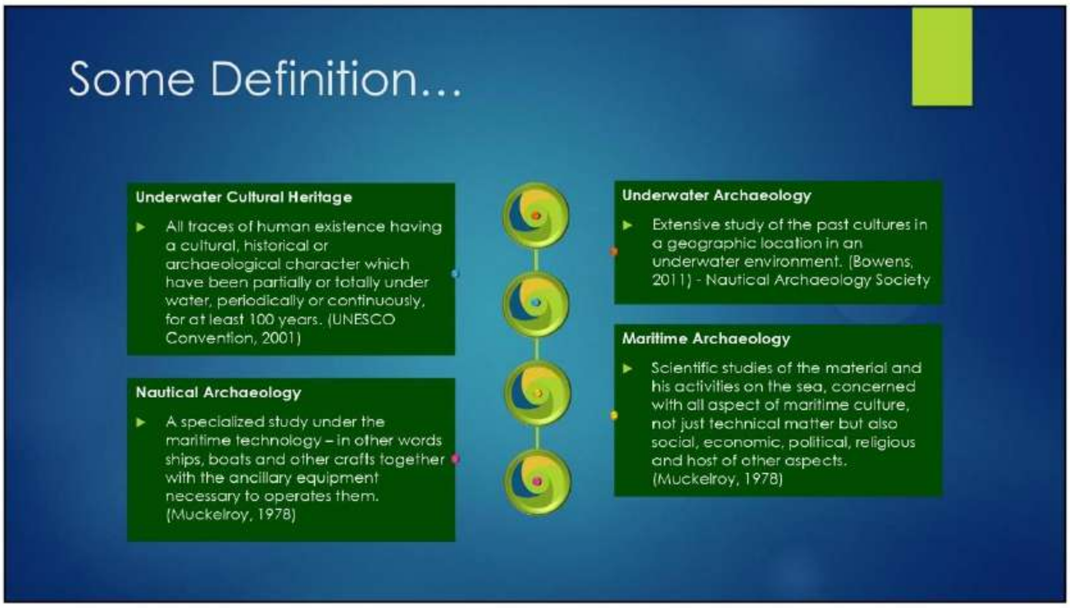
1. INTRODUCTION
2. DEFINITION
3. SITE INVENTORIES
4. LAWS AND POLICIES – UNDERWATER CULTURAL HERITAGE
5. RESEARCH AND METHODOLOGY
6. PROTECTED ZONE
7. WRECK SITES
8. COLLAB0RATION
9. WAY FORWARD

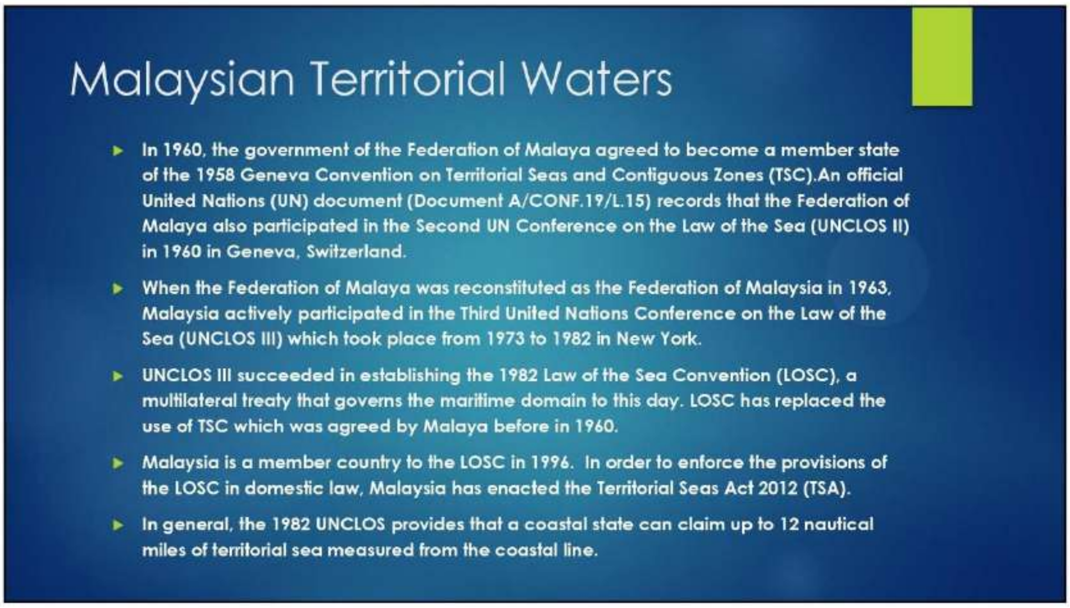

Introduction
FEDERATION OF MALAYSIA
Peninsular Malaysia
States of Sarawak & Sabah on Pulau Borneo
Island of Labuan
with about 1900 nautical miles of shore and about 160,000 nautical miles of the territorial waters.


Peninsular Malaysia at the Crossroad
1
Peninsular Malaysia is one of the busiest early maritime trading centres since it is located strategically between two main trade networks in the East and in the West, and at time when navigation depended on the regularity of seasonal monsoon winds.
2
At least as early as 1st century sea travel between India and China was well established, ships plying the major east-west routes mingled with vessels involved in busy intra-regional commerce. Sea lane through the area is often referred to as 'silk route'
3
Malay peninsula offered a number of ports that became famous at various times over the century.
e.g.: Kedah is one of the earliest, Pahang, Terengganu, Tioman and Melaka.
4
Until today, the peninsula is still seen as a significant shipping lane for most shipping activities have to ply the Straits of Melaka
5
Besides that, Northern Borneo also important in as early 7th century - 15th century shipping from mainland Southeast Asia and East Asia usually passed through its port en route to the Philippines and local trading centres


Wrecks in Malaysian Waters
1
Over 50 wrecks has been firmly identified which dates to as early as 3rd century AD.
2
However, recently a Malaysian scholar estimated over 6,000 wrecks were believed to lie in the waters of Malaysia.
3
More than 20 of the wrecks had been surveyed and few have been excavated.
4
Historic Wrecks comprise of trading vessels (Portuguese, Dutch and Chinese junks) and warships (Portuguese, Dutch, WWII British and Japanese).


What is UNDERWATER CULTURAL HERITAGE?
(according to National Heritage Act 2005)
"underwater cultural heritage" means all traces of human existence having a cultural, historical or archaeological character which have been partially or totally under water, periodically or continuously, for at least one hundred years such as–
a) sites, structures, buildings, artefacts and human remains together with their archaeological and natural context;
b) vessels, aircraft, other vehicles or any part thereof, their cargo or other contents, together with their archaeological and natural context; and
c) Objects of prehistoric character;





Code	States	Total Wreck Site/ Shipwreck (=159)	Historical (=77)	WW I (=2)	WW II (=35)	≤ 100Y (=45)
02	KEDAH	7	4			3
03	PULAU PINANG	9		2	4	3
04	PERAK	5	1			4
05	SELANGOR	7	2			5
08	NEGERI SEMBILAN	14	12			2
09	MELAKA	31	24			6
10	JOHOR	23	8		2	13
11	KELANTAN	5	1		3	1
12	PAHANG	21	11		5	5
13	TERENGGANU	8	4		3	1
14	SARAWAK	11	1		8	2
15	SABAH	11	5		6	
16	WILAYAH PERSEKUTUAN LABUAN	8	4		4	

WWII Sites/Shipwreck in Malaysian Territorial Waters

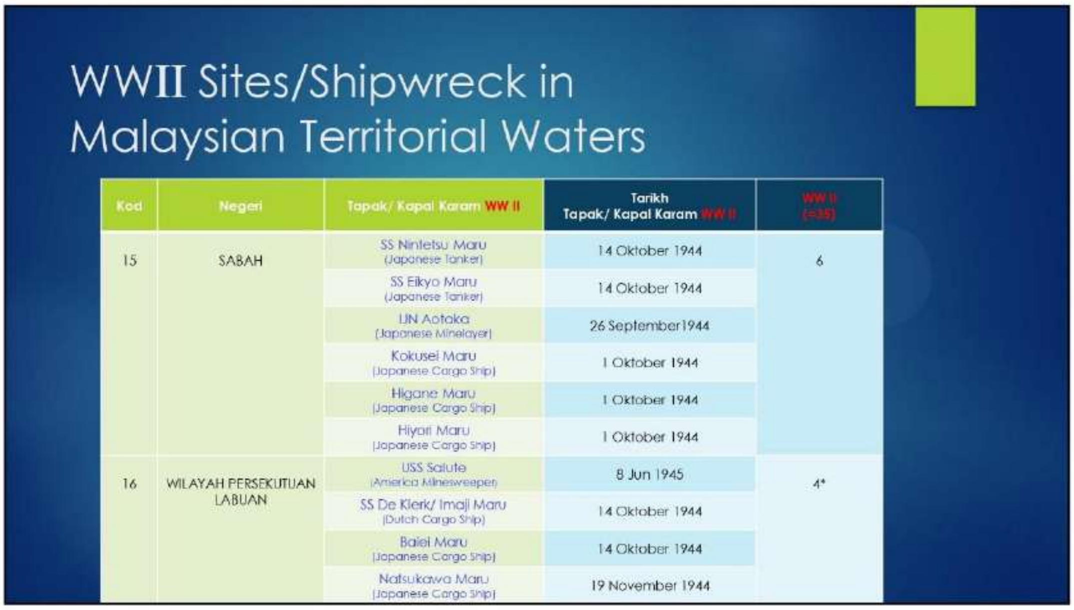
Kod	Negeri	Tapak/ Kapal Karam WW II	Tarikh Tapak/ Kapal Karam WW II	WW II (=35)
03	PULAU PINANG	IJN Chosa Maru (Japanese Gunboat)	20 Ogos 1943	4
		IJN Kuma (Japanese Light Cruiser)	11 Januari 1944	
		IJN Haguro (Myoko Class)	16 Mei 1945	
		Taiwan Vessel	1944	
10	JOHOR	HMS Strategem P-234 (British Submarine)	22 November 1944	2
		Nichinan Maru (Japanese Tanker)	11 November 1944	
11	KELANTAN	MS Awazisan Maru (Japanese Troop Transport)	8 Disember 1941	3
		HNLMS O-20 (Dutch Submarine)	19 Disember 1941	
		IJN Destroyer Shigure (Japanese Battleship)	24 Januari 1941	

WWII Sites/Shipwreck in Malaysian Territorial Waters

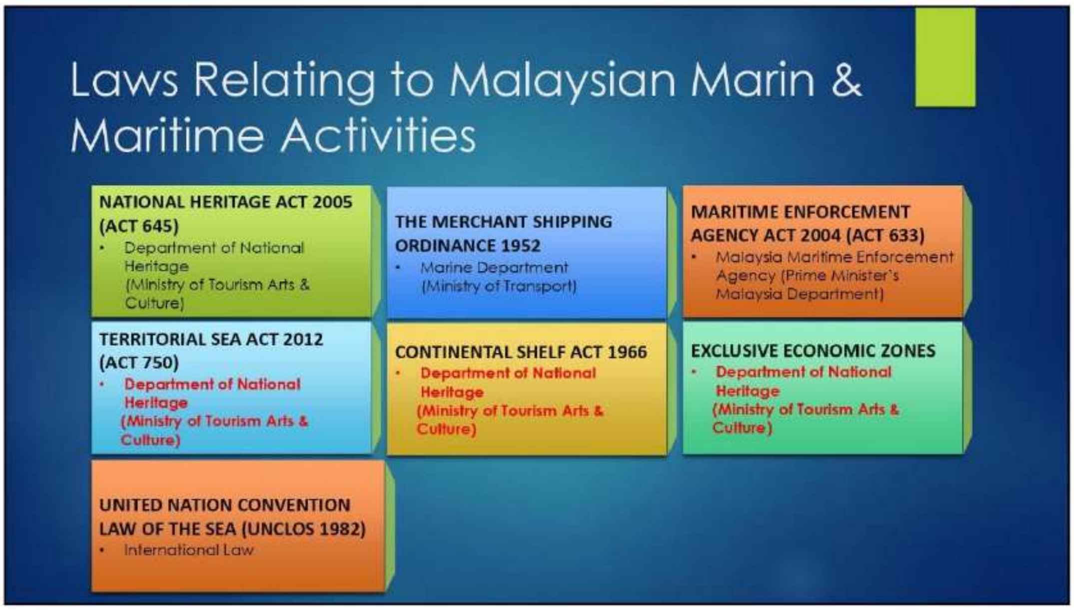
Kod	Negeri	Tapak/ Kapal Karam WW II	Tarikh Tapak/ Kapal Karam WW II	WW II (=35)
12	PAHANG	HMS Prince of Wales (British Battleship)	10 Disember1941	5
		HMS Repulse (British Battle-cruiser)	10 Disember1941	
		HMS Banka (British Minesweeper)	10 Disember1941	
		HNLMS O-16 (Dutch Submarine)	15 Disember1941	
		HNLMS K-XVII (Dutch Submarine)	21 Disember1941	
13	TERENGGANU	Japanese Wreck (Chendering)	(Penyelidikan 1980-an, kerjasama JMA-TLDM tak dapat diteruskan kerana arus bawah air yang kuat)	3
		IJN Hatsutaka (Japanese Minelayer)	16 Mei 1945	
		*IJN Hirashima/ Yurijima (Japanese Minelayer)	14 Januari 1945	

WWII Sites/Shipwreck in Malaysian Territorial Waters

Kod	Negeri	Tapak/ Kapal Karam WW II	Tarikh Tapak/ Kapal Karam WW II	WW II (=35)
14	SARAWAK	Atago Maru (Japanese Merchant Ship)	28 November 1944	8
		Katori Maru (Japanese Merchant Ship)	24 Disember1941	
		IJN Sagiri (Japanese Destroyer)	24 Disember1941	
		Hiyoshi Maru (Japanese Merchant Ship)	23 Disember1941	
		HNLMS K-XVI (Dutch Submarine K-XIV Class)	24 Disember1941	
		HIJMS Shinonome (Japanese Destroyer)	17 Disember1941	
		Yuho Maru (Japanese Merchant Ship)	26 November 1941	
		*IJN Hirashima/ Yurijima (Japanese Minelayer)	14 Januari 1945	



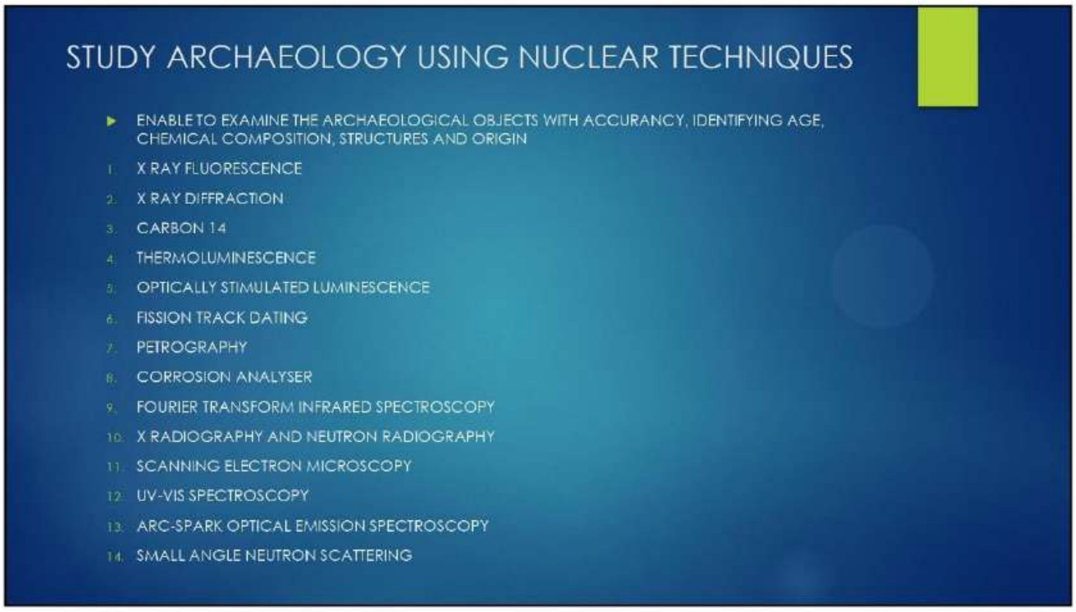
Kod	Negeri	Tapak/ Kapal Karam WW II	Tarikh Tapak/ Kapal Karam WW II	WW II (=35)
15	SABAH	SS Nintetsu Maru (Japanese Tanker)	14 Oktober 1944	6
		SS Eikyo Maru (Japanese Tanker)	14 Oktober 1944	
		IJN Aotaka (Japanese Minelayer)	26 September1944	
		Kokusei Maru (Japanese Cargo Ship)	1 Oktober 1944	
		Higane Maru (Japanese Cargo Ship)	1 Oktober 1944	
		Hiyori Maru (Japanese Cargo Ship)	1 Oktober 1944	
16	WILAYAH PERSEKUTUAN LABUAN	USS Salute (America Minesweeper)	8 Jun 1945	4*
		SS De Klerk/ Imaji Maru (Dutch Cargo Ship)	14 Oktober 1944	
		Baiei Maru (Japanese Cargo Ship)	14 Oktober 1944	
		Natsukawa Maru (Japanese Cargo Ship)	19 November 1944	



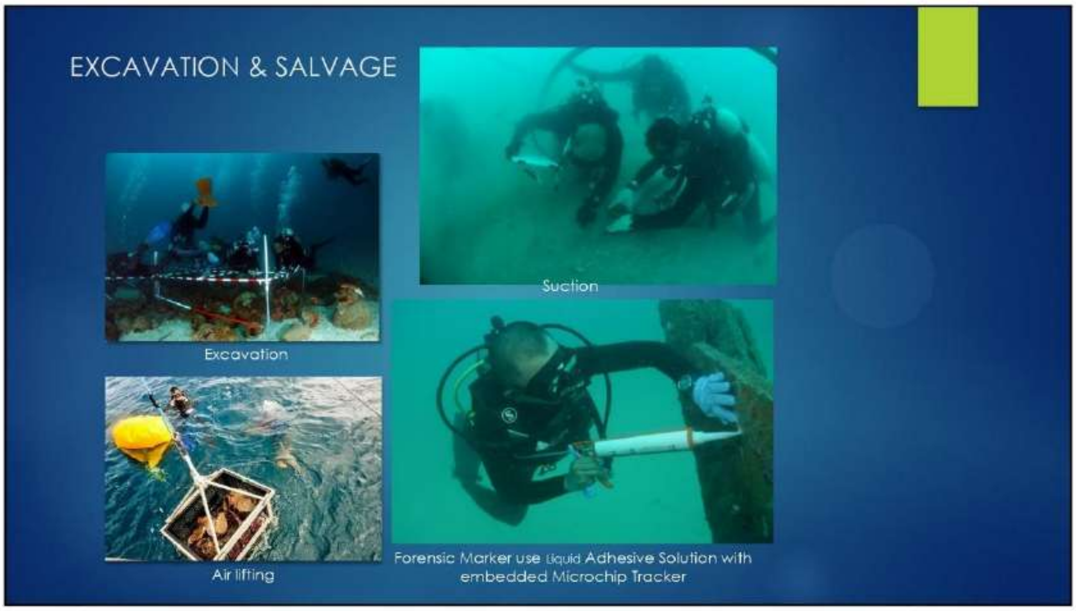

Research & Methodology in Underwater Archaeology
1) Survey Geophysic
Magnetometer
Side Scan Sonar
Multi Beam
Seismic
Bathymetry
Sub-bottom Profiler
Metal Detector
GPS
Ground Penetrating Radar
Earth Resitivity Meter and Electrical Imaging System
2) Salvage
Excavation
Air Lifting
Mapping
Photogrammetry
Plotting
Recording
Sampling
Dredging
Probe
Grabbing
3) Conservation
In-situ
Wreck conservation
Artifact conservation
Repository
Zoning
Exhibition
Reconstruction
Restoration


Underwater Cultural Heritage – Need statement
LITERATURE STUDY/REPORT/CHANCE FINDS
UNDERWATER SURVEY – SPOTTED AREAS
DIVING & SALVAGE
CONSERVATION - CURATIVE AND PREVENTIVE
COMPREHENSIVE REPORT AND STUDY (DOCUMENTATION)
RECONSTRUCT, RESTORE AND DRAWING
EXHIBITION – ARTIFACTS AND MODEL OR REPLICA
SITE – REGULAR MONITORING & INFORMATION BOARD
ENFORCEMENT

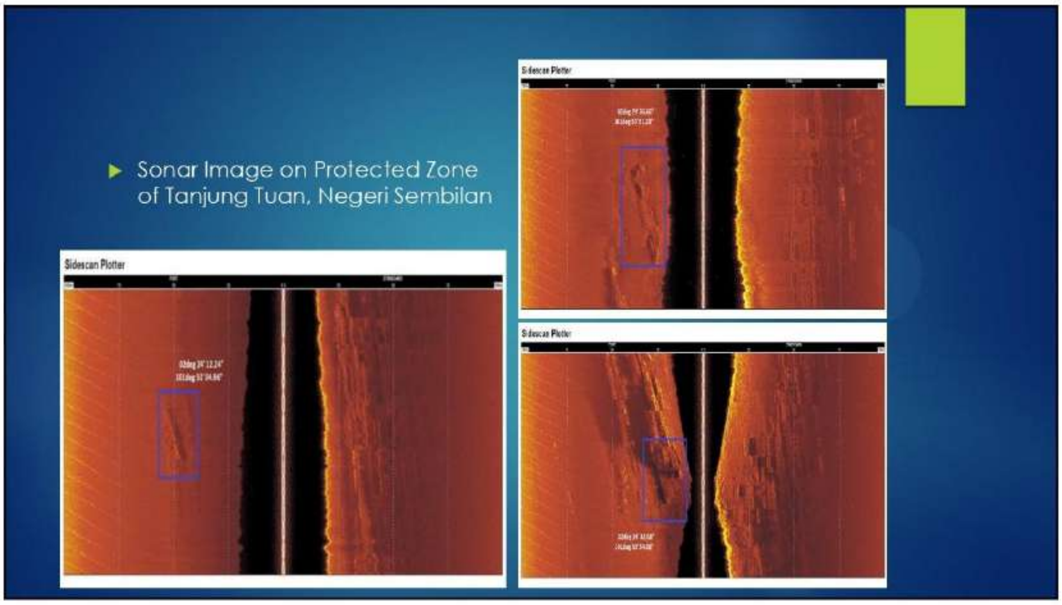

THE SCIENTIFIC METHODS USED IN UNDERWATER CULTURAL HERITAGE/ ARCHAEOLOGY RESEARCH
CONSERVATION – CURATIVE AND PREVENTIVE
CONSOLIDATION
DISINFECTION
RESTORATION
PROVENANCING
DATING
VERIFICATION OF AUTHENTICITY


STUDY ARCHAEOLOGY USING NUCLEAR TECHNIQUES
ENABLE TO EXAMINE THE ARCHAEOLOGICAL OBJECTS WITH ACCURANCY, IDENTIFYING AGE, CHEMICAL COMPOSITION, STRUCTURES AND ORIGIN
1. X RAY FLUORESCENCE
2. X RAY DIFFRACTION
3. CARBON 14
4. THERMOLUMINESCENCE
5. OPTICALLY STIMULATED LUMINESCENCE
6. FISSION TRACK DATING
7. PETROGRAPHY
8. CORROSION ANALYSER
9. FOURIER TRANSFORM INFRARED SPECTROSCOPY
10. X RADIOGRAPHY AND NEUTRON RADIOGRAPHY
11. SCANNING ELECTRON MICROSCOPY
12. UV-VIS SPECTROSCOPY
13. ARC-SPARK OPTICAL EMISSION SPECTROSCOPY
14. SMALL ANGLE NEUTRON SCATTERING


Geophysic Survey
Magnetometer
Side Scan Sonar
Multibeam
Bathymetry
Sub Bottom Profiler
Metal Detector


EXCAVATION & SALVAGE
Excavation
Suction
Air lifting
Forensic Marker use Liquid Adhesive Solution with embedded Microchip Tracker


Fieldwork & Conservation

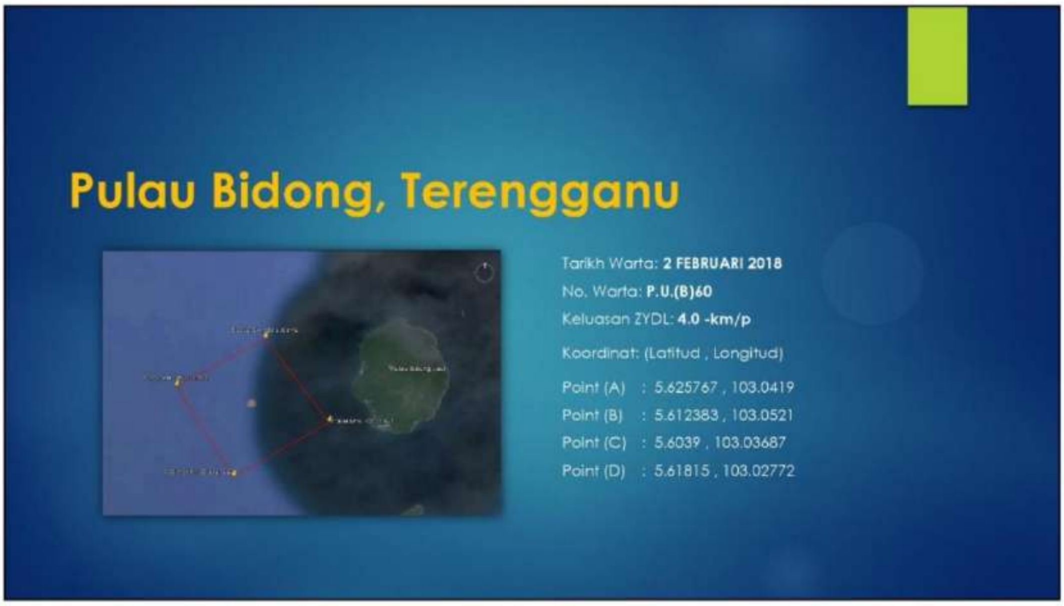

Sonar Image on Protected Zone of Tanjung Tuan, Negeri Sembilan
Sidescan Plotter
Sidescan Plotter
Sidescan Plotter


PROTECTED ZONE IN MALAYSIA
Tanjung Tuan, Melaka
Tarikh Warta: 10 MEI 2011
No. Warta: P.U.(B)255
Keluasan ZYDL: 141.40-km/p
Koordinat: (Latitud , Longitud)
Point (A) : 2.466667 , 101.78333
Point (B) : 2.466667 , 101.82667
Point (C) : 2.403333 , 101.82667
Point (D) : 2.403333 , 101.93333
Point (E) : 2.343333 , 101.93333
Point (F) : 2.343333 , 101.78333
Google

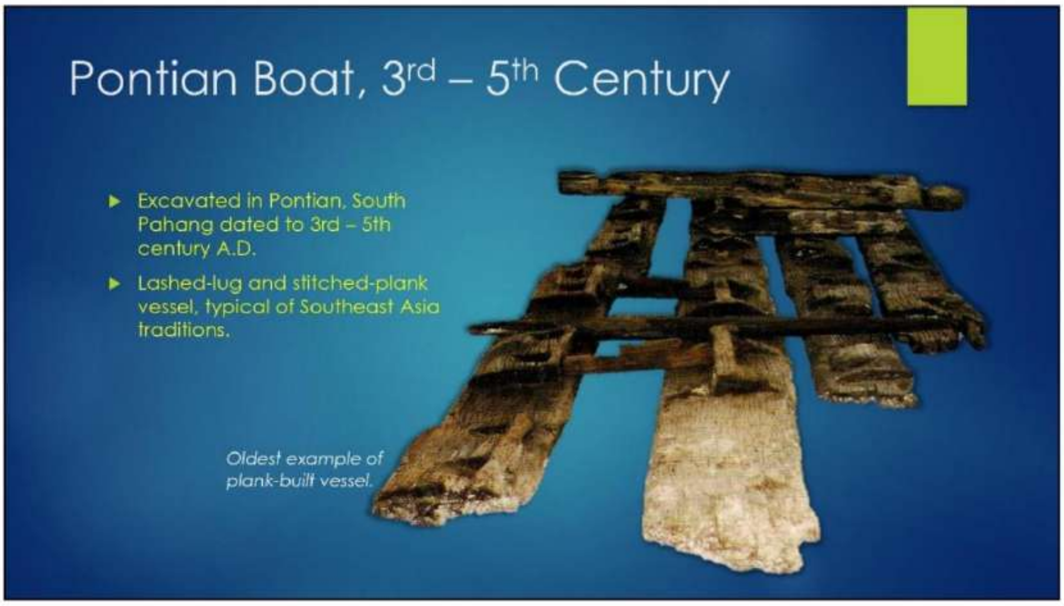

Pulau Upeh & Pulau Besar, Melaka
Tarikh Warta: 10 MEI 2011
No. Warta: P.U.(B)255
Keluasan ZYDL: 364.47-km/p
Koordinat: (Latitud , Longitud)
Point (A) : 2.202489 , 102.15482
Point (B) : 2.103319 , 102.42152
Point (C) : 2.015414 , 102.38893
Point (D) : 2.062497 , 102.15402
Google

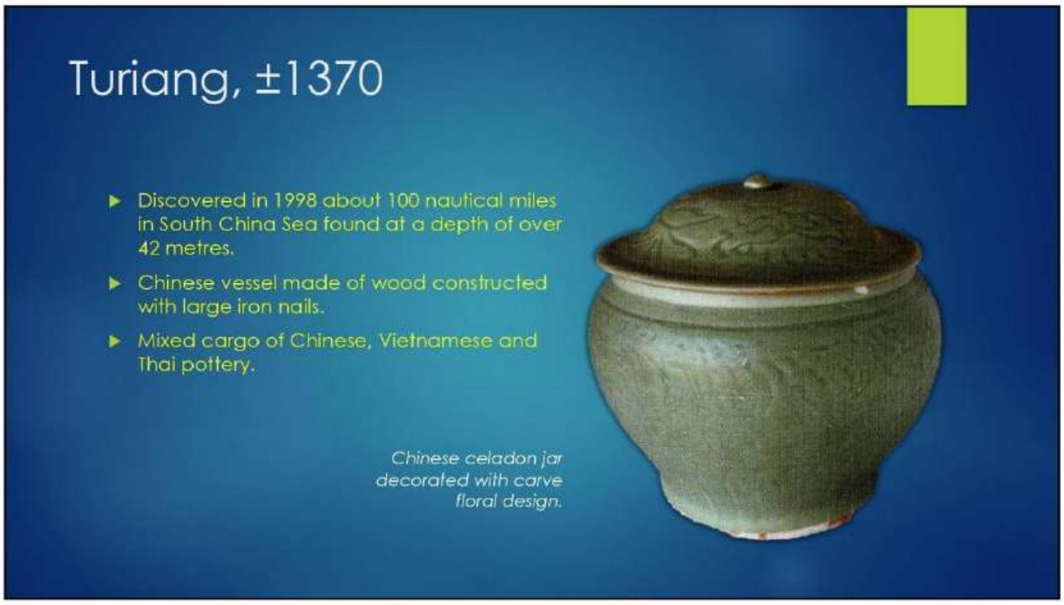

Pulau Tioman, Pahang
Tarikh Warta: 10 MEI 2011
No. Warta: P.U.(B)255
Keluasan ZYDL: 7048.60-km/p
Koordinat: (Latitud , Longitud)
Point (A) : 2.780228 , 103.52248
Point (B) : 2.860222 , 103.78122
Point (C) : 2.909978 , 103.95717
Point (D) : 3.037533 , 104.31317
Point (E) : 2.371644 , 104.73195
Point (F) : 2.296089 , 104.36474
Point (G) : 2.016672 , 104.19548
Point (H) : 1.916947 , 104.13255
Google

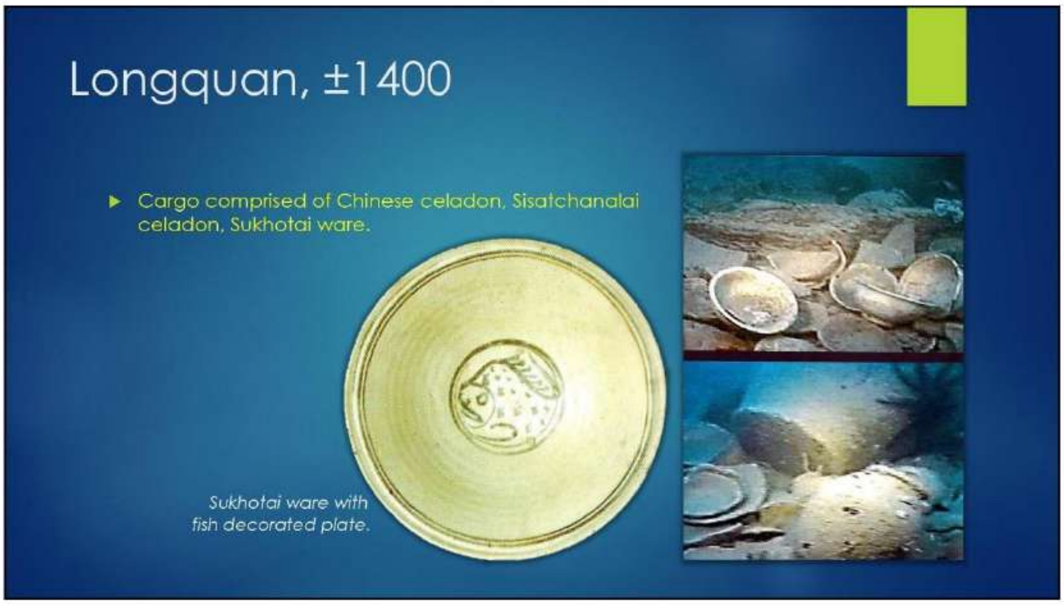

Wilayah Persekutuan Labuan
Tarikh Warta: 23 SEPTEMBER 2011
No. Warta: P.U.(B)508
Keluasan ZYDL: 526.24-km/p
Koordinat: (Latitud , Longitud)
Point (A) : 5.128069 , 115.29863
Point (B) : 5.129539 , 115.08574
Point (C) : 5.289617 , 115.00063
Point (D) : 5.289758 , 115.17151
Point (E) : 5.382308 , 115.25661
Point (F) : 5.413956 , 115.25692
Point (G) : 5.415206 , 115.29984
Google

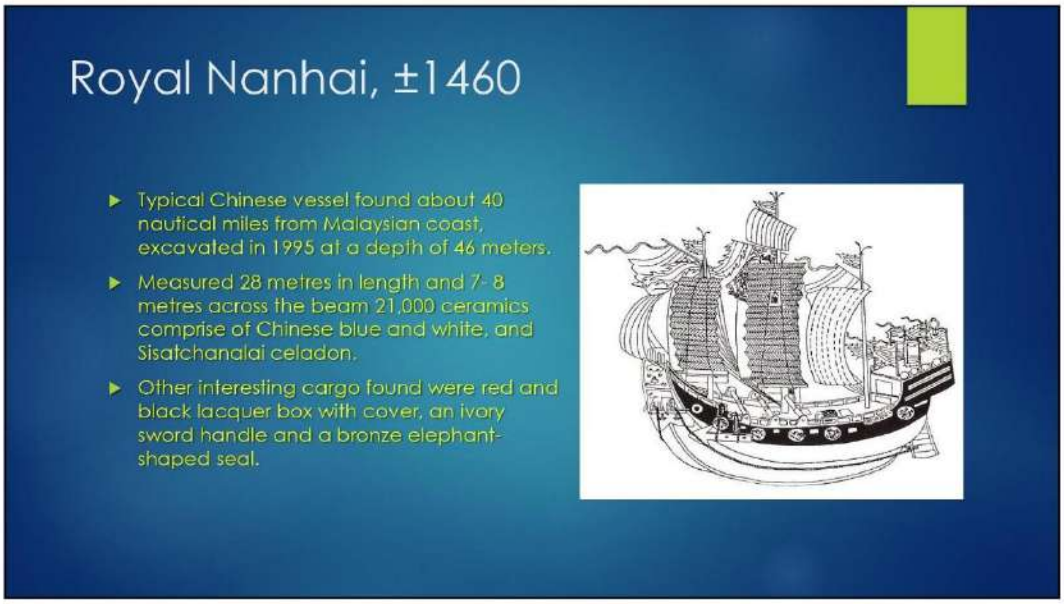

Pulau Bidong, Terengganu
Tarikh Warta: 2 FEBRUARI 2018
No. Warta: P.U.(B)60
Keluasan ZYDL: 4.0 -km/p
Koordinat: (Latitud , Longitud)
Point (A) : 5.625767 , 103.0419
Point (B) : 5.612383 , 103.0521
Point (C) : 5.6039 , 103.03687
Point (D) : 5.61815 , 103.02772

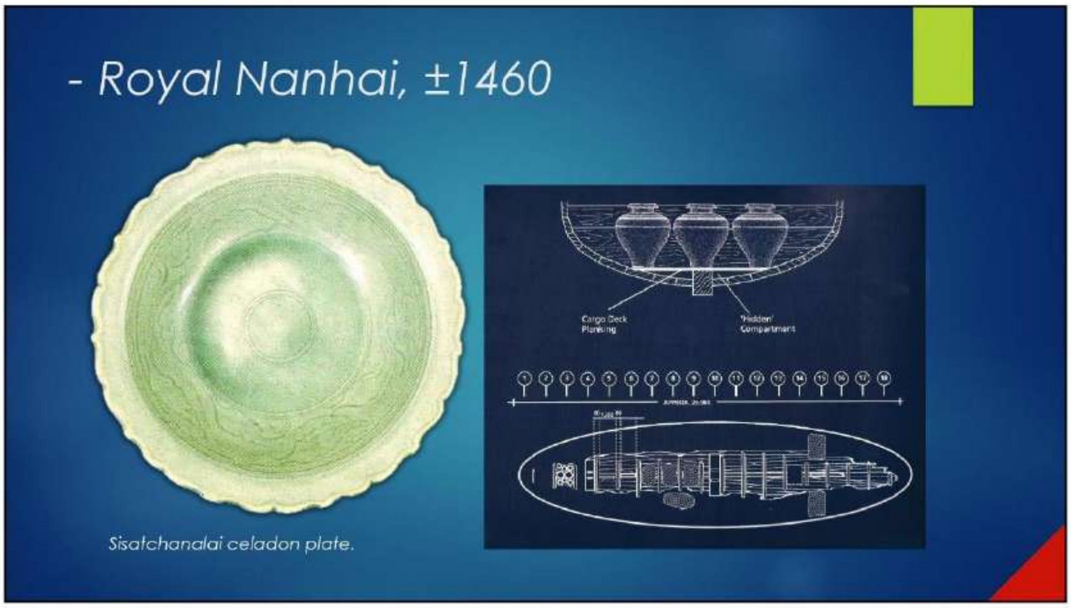

The Approximate Location of Shipwrecks in Peninsular Malaysia
Singtai
Longquan
Terengganu
MALAYSIA
Royal Nanhai
Kuantan
Nassau
P. Klang
Xuande
Risdam
Melaka
Diana
Mersing
Nanyang
Desaru
J. Bharu
Turiang
SUMATRA


Pontian Boat, 3rd – 5th Century
Excavated in Pontian, South Pahang dated to 3rd – 5th century A.D.
Lashed-lug and stitched-plank vessel, typical of Southeast Asia traditions.
Oldest example of plank-built vessel.

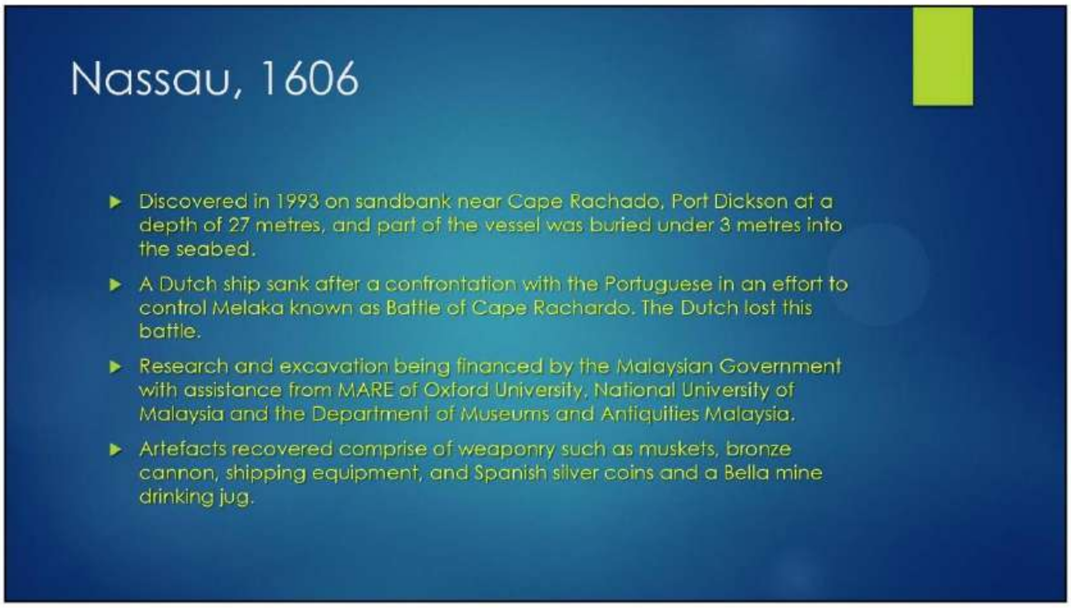

Turiang, ±1370
Discovered in 1998 about 100 nautical miles in South China Sea found at a depth of over 42 metres.
Chinese vessel made of wood constructed with large iron nails.
Mixed cargo of Chinese, Vietnamese and Thai pottery.
Chinese celadon jar decorated with carve floral design.

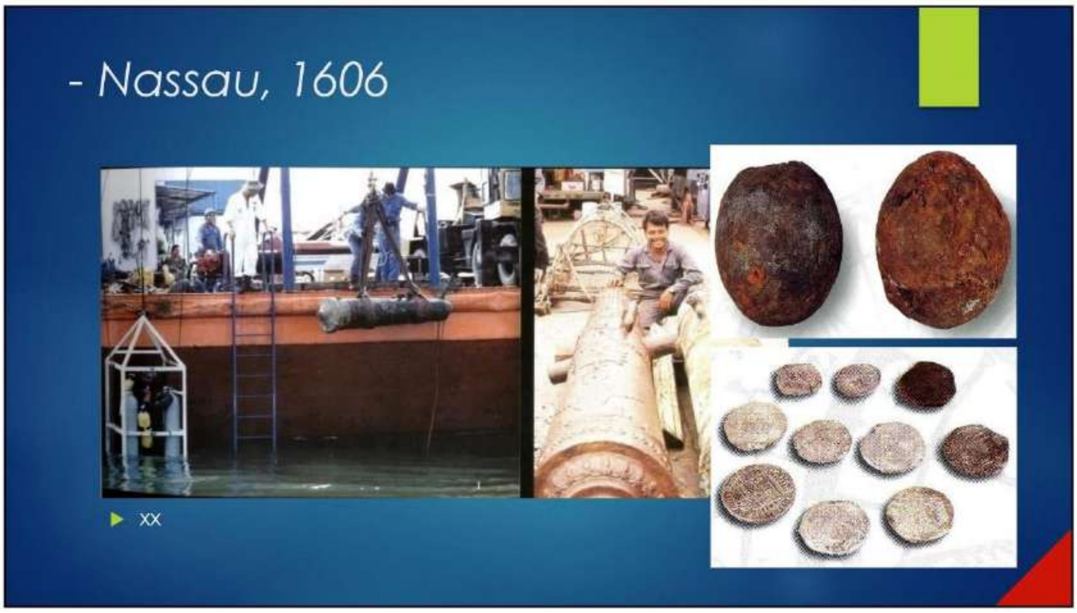

Longquan, ±1400
Cargo comprised of Chinese celadon, Sisatchanalai celadon, Sukhotai ware.
Sukhotai ware with fish decorated plate.


Royal Nanhai, ±1460
Typical Chinese vessel found about 40 nautical miles from Malaysian coast, excavated in 1995 at a depth of 46 meters.
Measured 28 metres in length and 7- 8 metres across the beam 21,000 ceramics comprise of Chinese blue and white, and Sisatchanalai celadon.
Other interesting cargo found were red and black lacquer box with cover, an ivory sword handle and a bronze elephant-shaped seal.

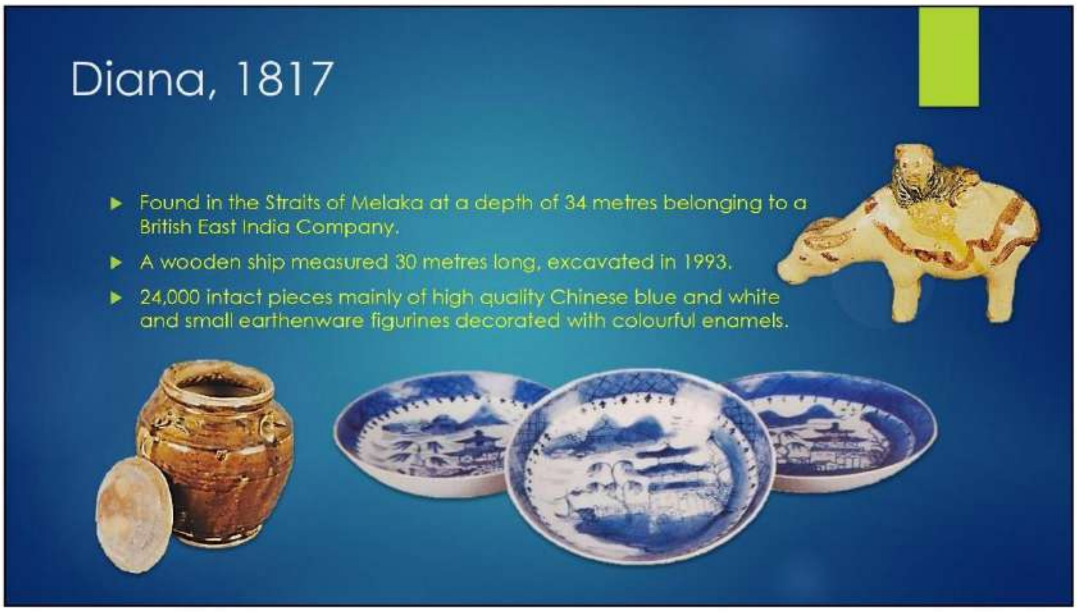

- Royal Nanhai, ±1460
Sisatchanalai celadon plate.


Singtai, ±1550
Excavated in 2001 12 nautical miles from Redang Island at a depth of 53 metres.
Vessel of about 22 metres long, construction include bulkheads joined by wooden dowels, typical Southeast Asian ship.
Cargo mainly of Thai storage jars and Sisatchanalai covered box.
Jar from the Thai Maenam Noi kiln.
Black decorated covered box from Sisatchanalai kiln.


Nassau, 1606
Discovered in 1993 on sandbank near Cape Rachado, Port Dickson at a depth of 27 metres, and part of the vessel was buried under 3 metres into the seabed.
A Dutch ship sank after a confrontation with the Portuguese in an effort to control Melaka known as Battle of Cape Rachardo. The Dutch lost this battle.
Research and excavation being financed by the Malaysian Government with assistance from MARE of Oxford University, National University of Malaysia and the Department of Museums and Antiquities Malaysia.
Artefacts recovered comprise of weaponry such as muskets, bronze cannon, shipping equipment, and Spanish silver coins and a Bella mine drinking jug.

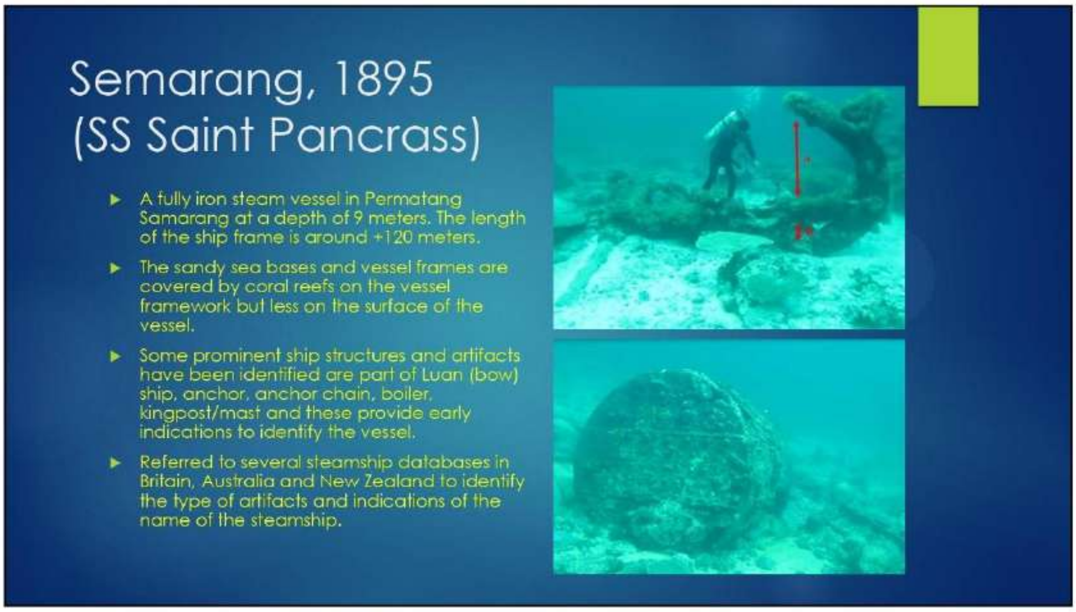

- Nassau, 1606
xx

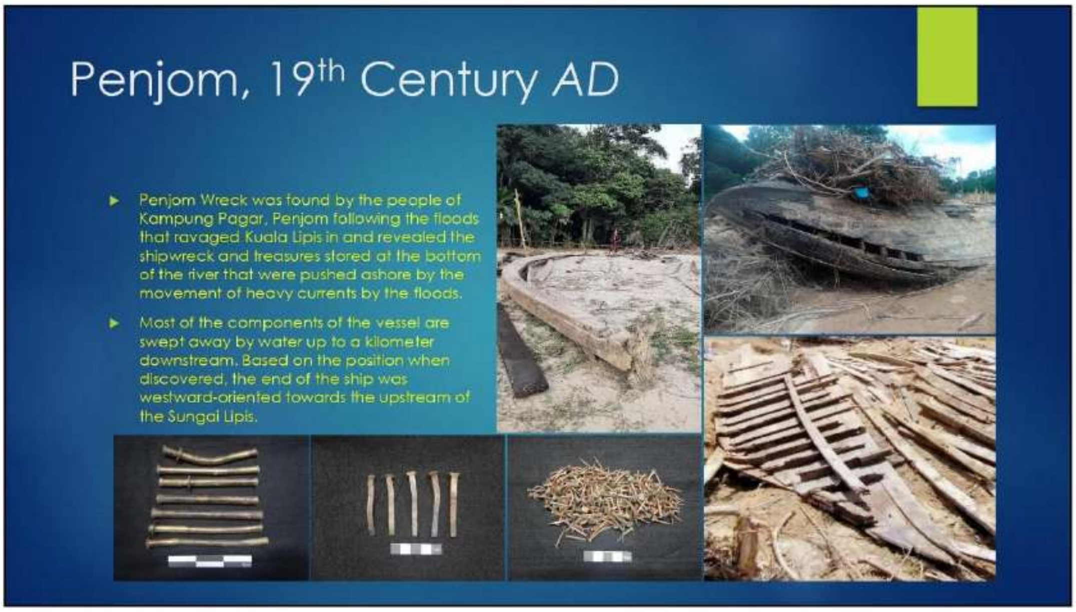

Risdam, 1727
Dutch East India Company ship found about 2 nautical miles from Mersing coast in Johor.
Cargo include Thai stoneware, over 120 tin ingots with a VOC mark over it, nearly 90 elephant tusks.
Model of Risdam.
Source: gemeentehuis Hoorn.
Tin ingot from Risdam shipwreck.
Storage jar of Maenam Noi kiln recovered from Risdam Wreck.

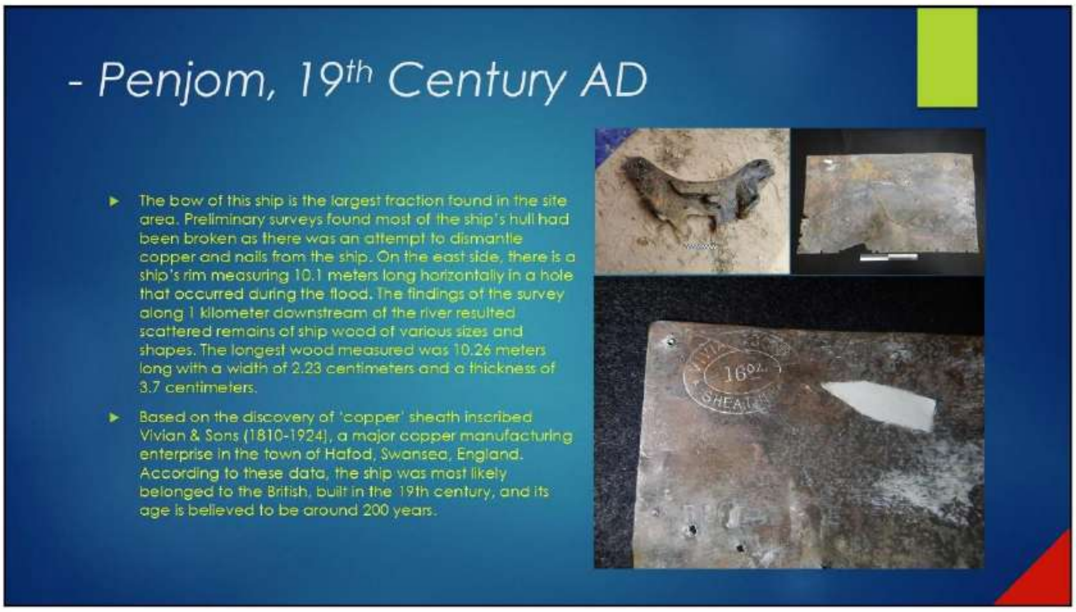

Diana, 1817
Found in the Straits of Melaka at a depth of 34 metres belonging to a British East India Company.
A wooden ship measured 30 metres long, excavated in 1993.
24,000 intact pieces mainly of high quality Chinese blue and white and small earthenware figurines decorated with colourful enamels.

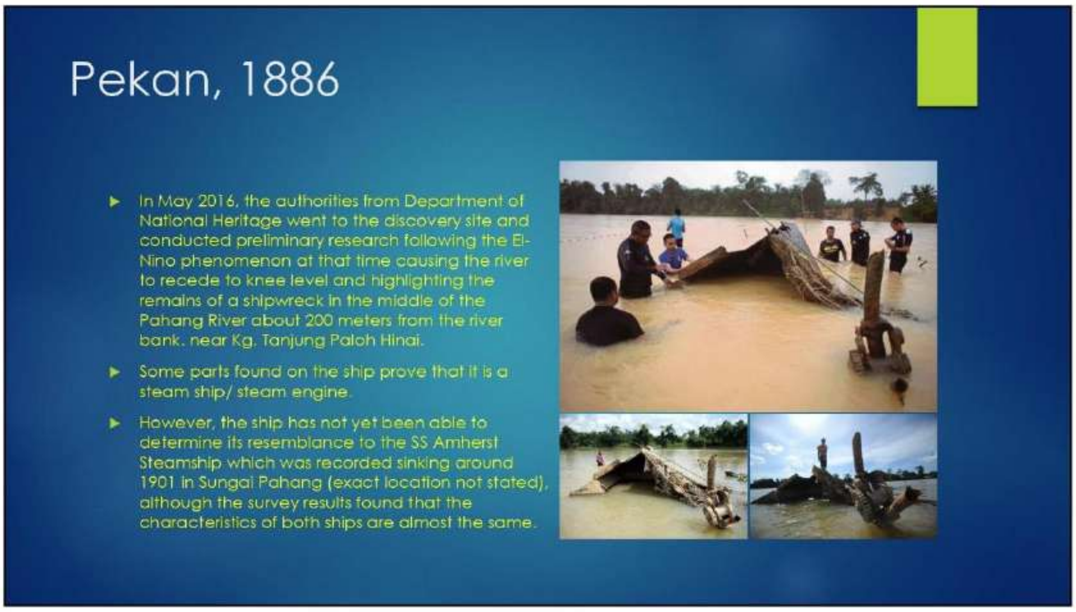

Desaru, ±1830
Found in 2001 at a depth of 20 metres some 2 nautical miles from Desaru coast in Johor.
Wooden vessel some 30 metres long.
Cargo include Chinese blue and white from both Jingdezhen and Dehua, Yixing teapots and Guandong stoneware.
Over 70,000 artefacts recovered with over 25,000 spoons form the main bulk of the collections.

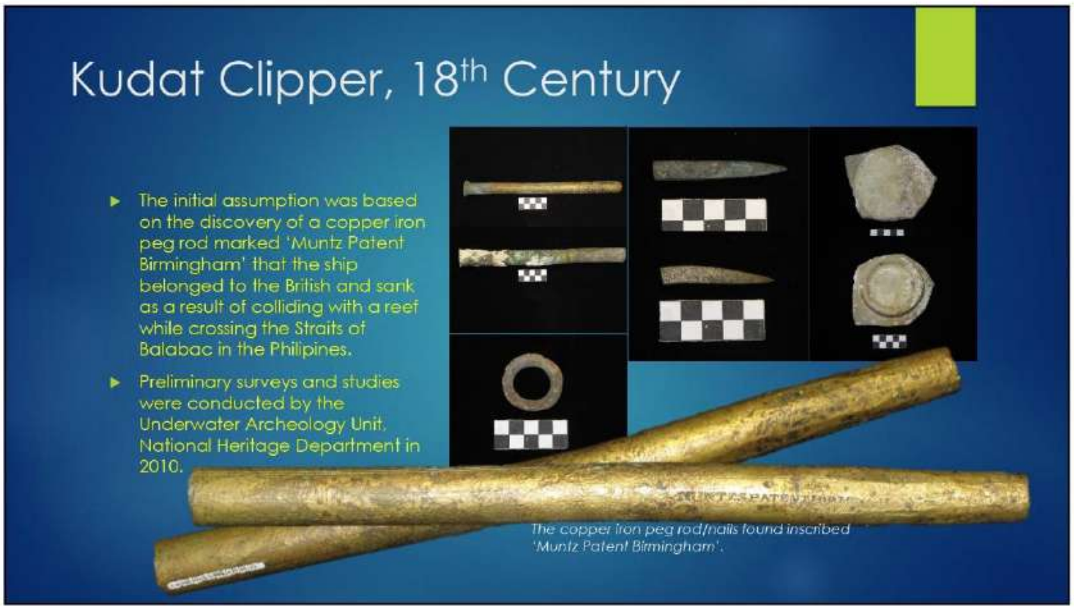

- Desaru, ±1830
Handling artefact for packaging: Yixing teapot from Desaru shipwreck
Wood maintainance work from Desaru shipwrecks


Semarang, 1895 (SS Saint Pancrass)
A fully iron steam vessel in Permatang Samarang at a depth of 9 meters. The length of the ship frame is around +120 meters.
The sandy sea bases and vessel frames are covered by coral reefs on the vessel framework but less on the surface of the vessel.
Some prominent ship structures and artifacts have been identified are part of Luan (bow) ship, anchor, anchor chain, boiler, kingpost/mast and these provide early indications to identify the vessel.
Referred to several steamship databases in Britain, Australia and New Zealand to identify the type of artifacts and indications of the name of the steamship.


Penjom, 19th Century AD
Penjom Wreck was found by the people of Kampung Pagar, Penjom following the floods that ravaged Kuala Lipis in and revealed the shipwreck and treasures stored at the bottom of the river that were pushed ashore by the movement of heavy currents by the floods.
Most of the components of the vessel are swept away by water up to a kilometer downstream. Based on the position when discovered, the end of the ship was westward-oriented towards the upstream of the Sungai Lipis.


- Penjom, 19th Century AD
The bow of this ship is the largest fraction found in the site area. Preliminary surveys found most of the ship's hull had been broken as there was an attempt to dismantle copper and nails from the ship. On the east side, there is a ship's rim measuring 10.1 meters long horizontally in a hole that occurred during the flood. The findings of the survey along 1 kilometer downstream of the river resulted scattered remains of ship wood of various sizes and shapes. The longest wood measured was 10.26 meters long with a width of 2.23 centimeters and a thickness of 3.7 centimeters.
Based on the discovery of 'copper' sheath inscribed Vivian & Sons (1810-1924), a major copper manufacturing enterprise in the town of Hafod, Swansea, England. According to these data, the ship was most likely belonged to the British, built in the 19th century, and its age is believed to be around 200 years.


Pekan, 1886
In May 2016, the authorities from Department of National Heritage went to the discovery site and conducted preliminary research following the El-Nino phenomenon at that time causing the river to recede to knee level and highlighting the remains of a shipwreck in the middle of the Pahang River about 200 meters from the river bank, near Kg. Tanjung Paloh Hinai.
Some parts found on the ship prove that it is a steam ship/ steam engine.
However, the ship has not yet been able to determine its resemblance to the SS Amherst Steamship which was recorded sinking around 1901 in Sungai Pahang (exact location not stated), although the survey results found that the characteristics of both ships are almost the same.

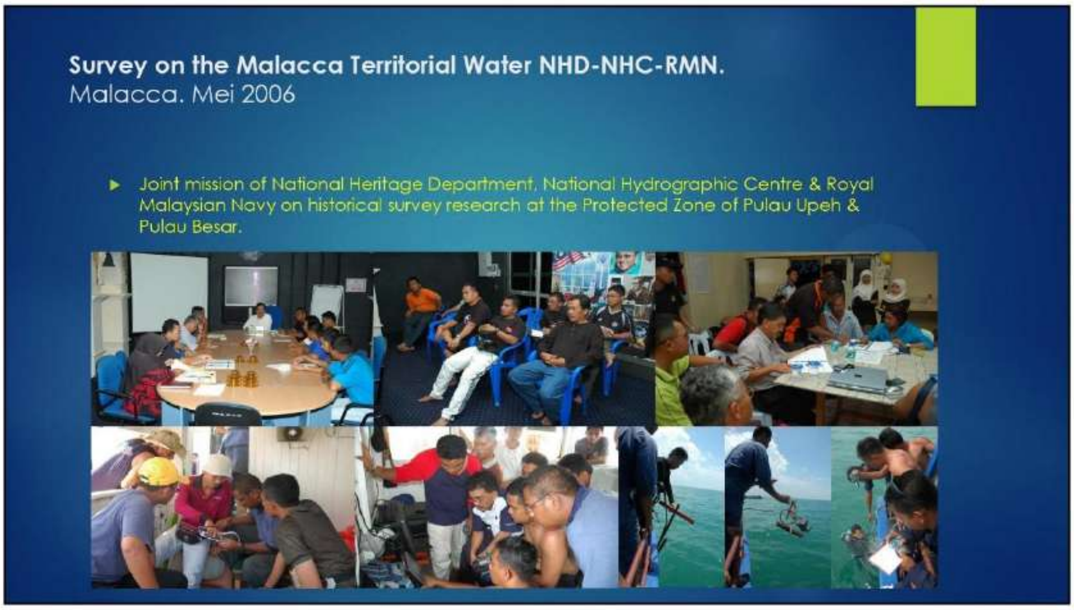

Kudat Clipper, 18th Century
The initial assumption was based on the discovery of a copper iron peg rod marked 'Muntz Patent Birmingham' that the ship belonged to the British and sank as a result of colliding with a reef while crossing the Straits of Balabac in the Philipines.
Preliminary surveys and studies were conducted by the Underwater Archeology Unit, National Heritage Department in 2010.
The copper iron peg rod/nails found inscribed 'Muntz Patent Birmingham'.


Pulau Melaka, 14th – 15th Century
Melaka Island or the original name of Java Island is an island that has been reclaimed. According to its history, Java Island has witnessed several episodes of war during the conquest of Kota Melaka.
Record written by Rev. Fr. Rene Edouardo Cardon (1877-1948) in his paper 'The Portuguese of Melaka' revealed that the Ilha das Naos or Pulo Malaca was referred to Pulau Melaka or Pulau Java. The island is home to the 'Naos de Trato' or large trade carracks going to or coming from China and Japan.
Year 2021 findings - The structure of an old ship and a number of artifacts from the era of Melaka Sultanate were discovered in the area of Pulau Melaka as a result of archaeological studies and excavations conducted by the National Heritage Department.


- Pulau Melaka, 14th – 15th Century
The study found that an old shipwreck was found in the mud about 1.5 meters deep and it is estimated that about 100 coins were found around the site and almost half of the coins found were from the era of Sultan Mahmud 1488-1511 while the rest are, VOC type Dutch currency and Portuguese currency. A small -sized complete porcelain bowl was also found in the shipwreck discovery area known as 'Ding Ware' which was made around the 8th to 14th century AD at a depth of 1.5 meters and the rest was found in the surface area.


Defining the Risk…
Land reclamation
Sand dredging
Looters/relic hunters
Commercial exploitation
Non-scientific salvage/excavation
Fish Net – Trawlers
Illegal Salvagers
Military Dumping Areas
Climate Change


Joint Collaboration
FEDERAL LEVEL
1. DEPARTMENT OF MUSEUMS MALAYSIA
2. MALAYSIA NUCLEAR AGENCY
3. NATIONAL ARCHIVES OF MALAYSIA
4. NATIONAL HYDROGRAPHIC CENTRE, MALAYSIA
5. MARINE DEPARTMENT
6. MALAYSIA MARITIME ENFORCEMENT AGENCY
7. MARINE POLICE DEPARTMENT
8. MARITIME INSTITUTE OF MALAYSIA
9. MINISTRY OF FINANCE
10. UNIVERSITIES
STATE LEVEL
1. STATE SECRETARY
2. STATE EXECUTIVE COUNCIL – HERITAGE, CULTURE, & TOURISM
3. STATE MUSEUMS
INTERNATIONAL LEVEL
1. UNESCO
2. SPAFA – SEAMEO REGIONAL CENTRE FOR ARCHAEOLOGY AND FINE ARTS
3. ICOMOS – THE INTERNATIONAL COUNCIL ON MONUMENT AND SITES


Survey on the Malacca Territorial Water NHD-NHC-RMN.
Malacca. Mei 2006
Joint mission of National Heritage Department, National Hydrographic Centre & Royal Malaysian Navy on historical survey research at the Protected Zone of Pulau Upeh & Pulau Besar.


Joint Mission to O-16 & K-XVII, Malaysia-Netherland. Tioman Island, Territorial Waters, July 2019
Malaysia- Netherlands Joint Diving Mission to verify the condition of alleged Dutch war graves of vessels believed to have sunk in the Second World War, 15 December 1941 (O-16) and 21 December 1941 (K-XVII) within 30 nautical miles off Tioman Island.


Next Joint Mission - Malaysia-Netherlands. Tanjung Datu . Tumpat - Territorial Waters, 2024
Malaysia and Netherlands are to embark on a the Joint Diving Mission to verify the precise location and condition of the two (2) submarines which are believed to have sunk in the Dutch war graves of vessels during the Second World War, respectively on 19 December 1941 (O-20) off the coast of Kelantan and (K-XVI) off the coast of Sarawak, Borneo.


Underwater Archaeology Research on Pulau Bidong, JWN-UMT. Stesen Penyelidikan UMT, Pulau Bidong, Terengganu. Oktober 2017
Joint collaboration between National Heritage Dept. & UMT on underwater archaeology salvage at the Protected Zon Pulau Bidong whereby 306 artefacts were recovered.


Royal Malaysian Navy – Mawilla 1, foiled Viets attempt, JWN-NAVY.
Tanjung Gelang, Coast of Kuantan. 25 November 2014
The Royal Malaysian Navy (RMN) successfully foiled the attempt of a group of foreign fishermen from Vietnam who tried to pilfer the treasures of British shipwreck HMS Prince of Wales and HMS Repulse from the Second World War about 60 nautical miles from the coast of Kuantan.


Malaysian Maritime Enforcement Agency detained a Viets boat, JWN-APMM. Tanjung Gelang, Coast of Kuantan. 25 August 2015
On August 25, 2015; the Malaysian Maritime Enforcement Agency (APMM) detained a Vietnamese boat at a position 66.9 nautical miles north of Tanjung Gelang, Kuantan because it was believed to have stolen artefacts from a British warship that sank in Malaysian waters. The British Government then handed over artefacts and ship components of the warships HMS Repulse and HMS Prince of Wales on 18 Mac 2016 to be placed at the Port Dickson Army Museum.


PoW & Repulse, WW2 Shipwreck
- Case of Tanjung Belungkor 2023
The National Heritage Department (JWN) has received a complaint report regarding the discovery of the human bones and object of a ship believed to be the British warship, HMS Prince of Wales and HMS Repulse at 60 nautical miles off the of Kuantan territorial waters which has been salvaged by Chinese Vessel and taken to the jetty in Tanjung Belungkor, Johor.As a result, investigation is carried out NHD with Royal Malaysia Police Force, Maritime Enforcement Agency Malaysia and Royal Navy Malaysia, it was found that a number of ship objects were found, including iron plates, anchors, engines, bullets, bombs, ship propellers and copper which are believed to be part of the salvaged ship components.

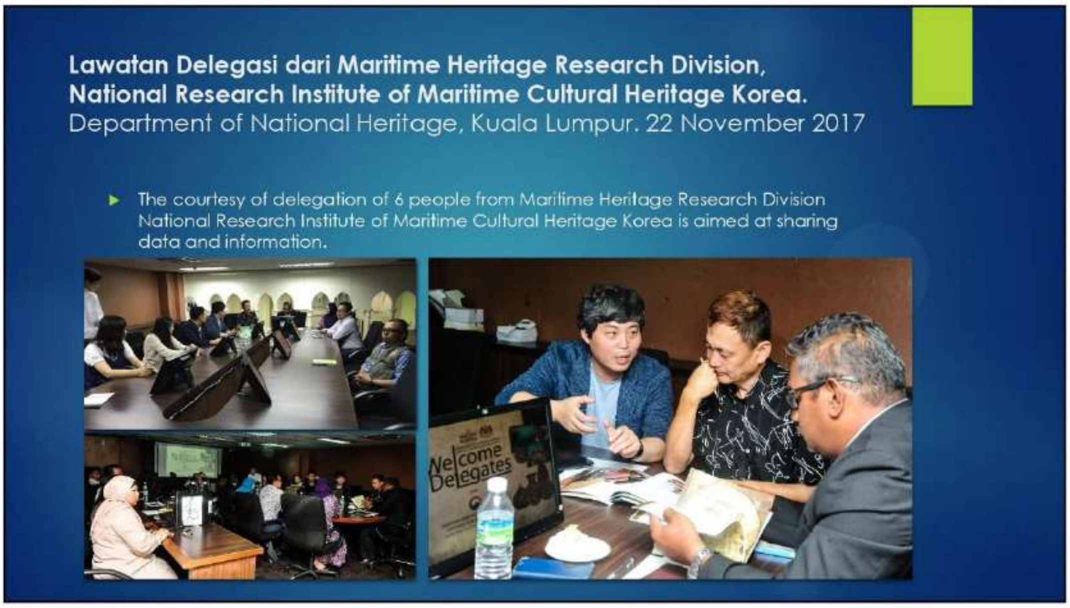

PoW & Repulse, WW2 Shipwreck
- Case of Tanjung Belungkor 2023
Nation / NEWS
DODGY DREDGER 'NOTORIOUS' IN THE REGION
Save the wrecks before it is too late, warn heritage experts


PoW & Repulse, WW2 Shipwreck
- Case of Tanjung Belungkor 2023


Asean Underwater Archaeology Workshop on Alternative Solution and Extended Frontier. Mannok Shipwreck Site, Klaeng Rayong, Thailand. 1-18 March 2016
Train local underwater archaeologists as well as ASEAN countries on the actual method of carrying out underwater archeological excavation work and systematic data collection techniques.


Conference on the Protection Underwater Cultural Heritage. Makassar, Indonesia. 19-20 September 2017
ASEAN - UNESCO Conference
on the Protection of Underwater
Cultural Heritage
Makassar, Indonesia | 19-20 September 2017


First Meeting of International Scientific Committee of Indentured Labour Route Project.
Republic of Mauritius. 30 October – 2 November 2017


Lawatan Delegasi dari Maritime Heritage Research Division, National Research Institute of Maritime Cultural Heritage Korea.
Department of National Heritage, Kuala Lumpur. 22 November 2017
The courtesy of delegation of 6 people from Maritime Heritage Research Division National Research Institute of Maritime Cultural Heritage Korea is aimed at sharing data and information.
Welcome Delegates

Asean Underwater Archaeology Workshop on Applying GIS in Underwater Archaeology.
Chantaburi, Thailand. 19-26 February 2018

Seminar on Malaysia International Dive Expo (MIDE).
Kuala Lumpur. 4-6 May 2018

International Conference on Archaeology.
Miri & Niah National Park, Sarawak.
26-28 September 2019

- Participation of 250 participants and 8 presenters from within the country and 10 from abroad from Thailand, Cambodia, Vietnam, Japan, and Australia. The program was implemented for three days beginning with two days of conference sessions and one day for site visit to Niah cave.


Forum On Safeguarding and Reviving The Shared Maritime Cultural Heritage of Southeast Asia.
Jakarta & Belitung, Indonesia. 4-9 November 2019


Bual Suvarnadhipa: Kapal Karam Penjom.
ZOOM by IKATAN x ICOMOS Malaysia. 5 August 2021
The discussion of the 18th century vessel frame was found after the flood tide in Kampung Pagar, Pahang, Pahang in early 2021.
SIRI WEBINAR ARKEOLOGI DAN WARISAN ALAM MELAYU 2021/2022
BUAL SURVARNADVIPA
KAPAL KARAM PENJOM
5 OGOS 2021
PENGANJUR BERSAMA
DENGAN KERJASAMA
PAM


Bengkel Garis Panduan dan SOP Arkeologi.
ZOOM by Archaeology Division, DNH.
7-8 September 2021


Books & Articles
(2013). Pulau Kelumpang, Kuala Selinsing, Perak. Warisan Arkeologi Malaysia. Kuala Lumpur: Jabatan Warisan Negara. (42)
(2013). Warisan Kebudayaan Bawah Air di Malaysia. Warisan Arkeologi Malaysia. Kuala Lumpur: Jabatan Warisan Negara. (72)
(2013). Perisytiharan Zon Yang Dilindungi. Warisan Arkeologi Malaysia. Kuala Lumpur: Jabatan Warisan Negara. (74)
(2013). Kapal Karam di Perairan Malaysia. Warisan Arkeologi Malaysia. Kuala Lumpur: Jabatan Warisan Negara. (78-81)


Books & Articles
PROSIDING SEMINAR ARKEOLOGI KEBANGSAAN KE-4 2018
Mohd. Rohaizat Abdul Wahab, & Zuliskandar Ramli (2018). Persilangan Teori dan Pembuktian Asal Usul Perahu di Alam Melayu. Prosiding Seminar Arkeologi Kebangsaan ke-4 2018. Kuala Lumpur: Jabatan Warisan Negara. (338)
Yazid Othman, & Farizah Ideris (2018). Bandar Diraja Pekan Pahang: Penyelamatan dan Penggalian Haram Relik Arkeologi. Prosiding Seminar Arkeologi Kebangsaan ke-4 2018. Kuala Lumpur: Jabatan Warisan Negara. (388)


Books & Articles
JURNAL Warisan
Asyaari Muhammad (2016). Arkeologi Maritim di Kawasan Perairan Pulau Bidong, Terengganu: Pra-Tinjauan. Jurnal Warisan. Jilid 1, Bil.1, Kuala Lumpur: Jabatan Warisan Negara. (180)
Ruzairy Arbi (2021). Safeguarding Malaysia's Underwater Cultural Heritage: The Legal Framework. Malaysia: A Maritime Nation. Jilid 1, Bil.3, Kuala Lumpur: Maritime Institute of Malaysia. (279)
MALAYSIA A MARITIME NATION

Books & Articles

- Ruzairy Arbi (2019). **Pemuliharaan dan Pemeliharaan Warisan Arkeologi Malaysia.** *Bicara Arkeologi*. Siri Kenali Arkeologi No.1, Kuala Lumpur: Jabatan Warisan Negara. (44)
- Mohd. Rohaizat Abdul Wahab (2019). **Penemuan Simbol Universal Pelaut Pada Perahu Tradisional Melayu di Pantai Timur Semenanjung Malaysia.** *Bicara Arkeologi*. Siri Kenali Arkeologi No.1, Kuala Lumpur: Jabatan Warisan Negara. (74)
- Baszley Bee Basrah Bee (2019). **Ikonografi Kapal Karam: Merentas Zaman Dalam Menjelaskan Arkeologi Maritim dan Sejarah Maritim.** *Bicara Arkeologi*. Siri Kenali Arkeologi No.1, Kuala Lumpur: Jabatan Warisan Negara. (93)

Underwater Archaeology in Malaysia: Current & Future

- To strengthen legal enforcement to protects underwater cultural heritage.
- The establish a research station to carry out relevant works such as nautical, maritime archaeology, ceramic institute, etc.
- To create of public awareness regarding underwater cultural heritage.
- To collaborate of an action plan for further international cooperation-joining research and set up database network regarding underwater cultural heritage.
- To explore of new methods and techniques for survey, excavation, salvage and conservation.

Conclusion

- The Malaysian authorities are fully aware of the activities of underwater treasure hunters and have already taken steps to curb looting using our existing marine enforcement agency, marine police and naval forces.
- We are now ready to conduct any research, survey and excavation based on our capacity and support from local and foreign experts by cooperating with various agencies including universities and non-governmental agencies.
- Hopefully all these participations, guides and cooperation from all departments and agencies will enhance skills and knowledge in order to preserve our underwater cultural heritage sites in Malaysia.
- By establishing regional cooperation in term of marine archaeological research and training would be an important step towards safeguarding our common underwater cultural heritage.


Thank You

2.3 Application of Nuclear Techniques for Characterization and Preservation of Artifacts: Principle and Application of Nuclear Techniques for Artifact Preservation

Name: Laurent Cortella
Date of Presentation: 23rd October 2023
Email: laurent.cortella@cea.fr

Our cultural heritage is a testament to the human experience, a legacy that connects us to our past and shapes our understanding of the world. As guardians of this heritage, we face the constant challenge of preserving artifacts that, over time, become fragile and vulnerable to decay. To safeguard these treasures, science has provided us with a tool that might seem more at home in a medical setting or a science fiction novel than a museum: gamma radiation.

Gamma radiation is commonly associated with medical treatments and energy production, but its application in conserving cultural artifacts is a lesser-known yet significant facet. This innovative approach to conservation uses gamma rays to both disinfect and consolidate fragile items, ensuring that they endure for future generations to admire. But as with any technology, it’s crucial to understand the intricacies and implications of its use.

To appreciate the utility of gamma rays in conservation, we must first understand their nature. Gamma rays are a form of electromagnetic radiation, similar to visible light or X-rays, but with much higher energy. This high energy makes gamma rays adept at penetrating materials. This property can be harnessed to eliminate biological threats, such as bacteria and insects, that would otherwise degrade artifacts over time.

The process of gamma disinfestation utilizes these rays to target and eradicate these biological pests, effectively halting their destructive impact. The doses used are cumulative and calculated with precision to ensure effectiveness without compromising the artifact's integrity. However, this treatment is not without its side effects. For instance, a common consequence is the darkening of transparent materials. Fortunately, this is often reversible, at least to some degree, restoring the artifact closer to its original state.

Yet, not all effects are so easily remedied. High doses of gamma radiation can lead to the loss of mechanical properties or analytical information irreversible changes. This poses a significant concern, as it may alter the very essence of the artifact, stripping away not just its physical stability but also its historical context.

In the domain of gamma consolidation, the application of gamma rays serves to strengthen the physical structure of artifacts, especially those comprising organic materials like wood or textiles. The process can alter some fundamental physical properties of these items, and unlike gamma disinfestation, the effects are not reversible. Subsequent interventions to restore or repair the artifacts are often compromised, so deciding to use gamma consolidation is a matter of ethical consideration.

The ethical dilemma arises from the irreversible nature of these interventions. Once an artifact undergoes gamma consolidation, its original state can never be fully reclaimed, and future conservation efforts may be limited. It's a path taken cautiously and only when other conservation methods fall short. Such a choice is typically reserved for situations where the artifact is in dire straits—where it's the last chance for survival, like saving a polychromed wooden sculpture on the brink of collapse or preserving the functionality of complex composite items.

In the case of archaeological finds, such as artifacts composed of metal and waterlogged wood, gamma radiation can be the key to preventing further deterioration. Moreover, after the treatment, maintaining a special conservation environment is crucial to ensure the longevity of these pieces.

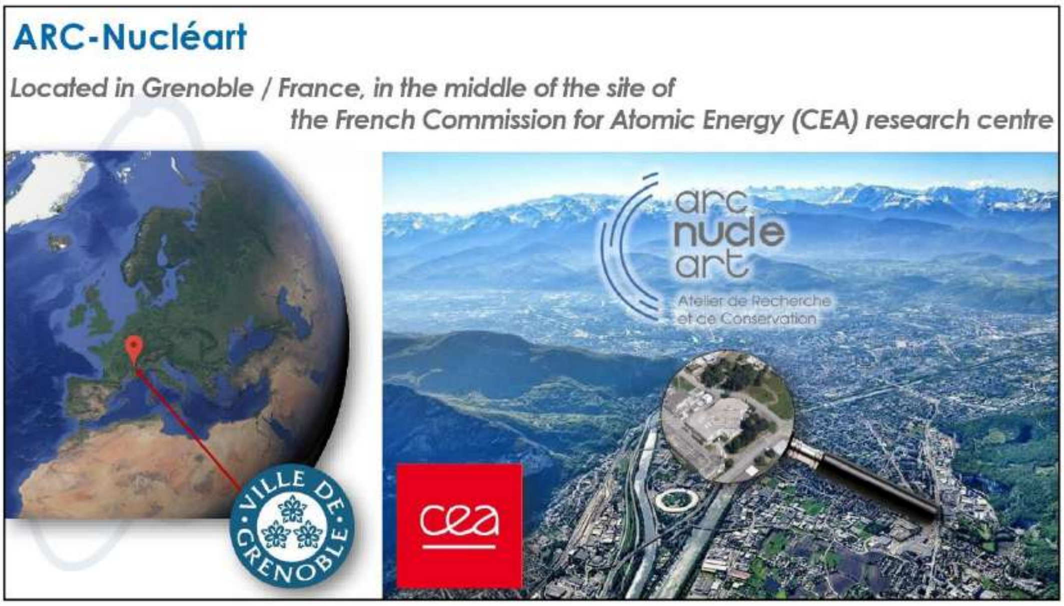
The use of gamma radiation in conservation is justified when it's the best available solution to maintain the integrity of an artifact. It is not a first-line treatment but rather a last resort, a delicate balance between the potential risks and the imperative of preservation. The goal is to keep the artifact as close to its original condition for as long as possible.

For non-specialists, understanding the concept of nuclear treatments in conservation may seem daunting. However, it's simplified when one considers that the primary variable in these treatments is radiation dosage. The success of the intervention depends on precise dose calculations and optimisations that limit the undesired side effects.

As we move forward, the diversity of conservation techniques continues to grow, offering us a spectrum of methods to honor the uniqueness of each heritage piece. Gamma radiation is not a panacea for all conservation woes but rather another tool in our arsenal, a testament to our ingenuity and commitment to cultural preservation.

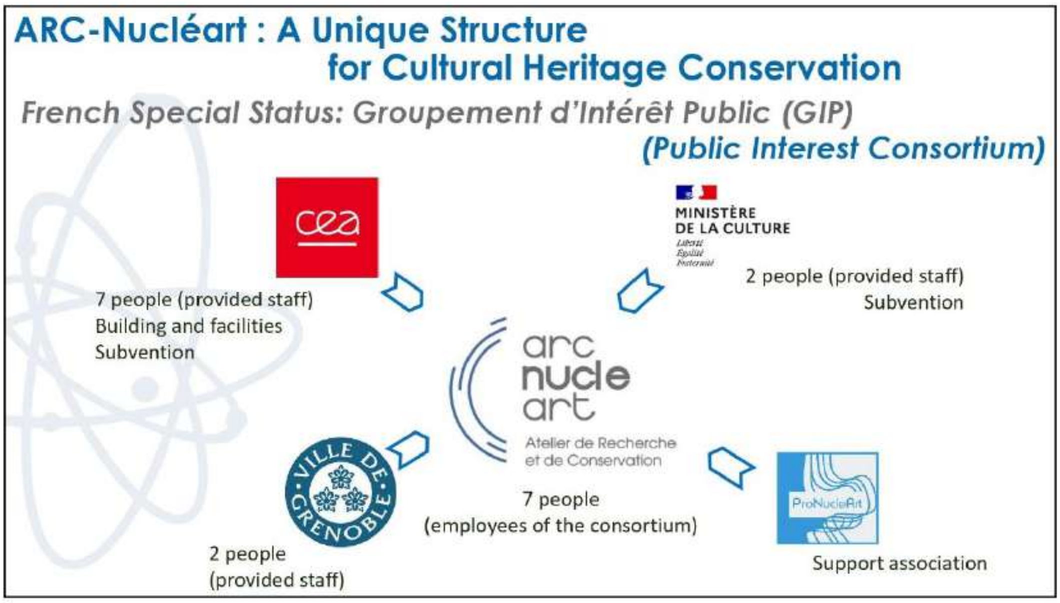
In conclusion, the application of nuclear techniques in preserving cultural artifacts provides us with an interesting compromise. While not without its risks and ethical considerations, gamma radiation offers a means to stabilize and save our heritage, ensuring that the stories and achievements of our ancestors endure. As we harness the power of gamma rays, we hold a mirror to the past, reflecting not only the artifacts themselves but also our dedication to preserving the narrative of humanity. The slides in the upcoming section detail the work done on this.

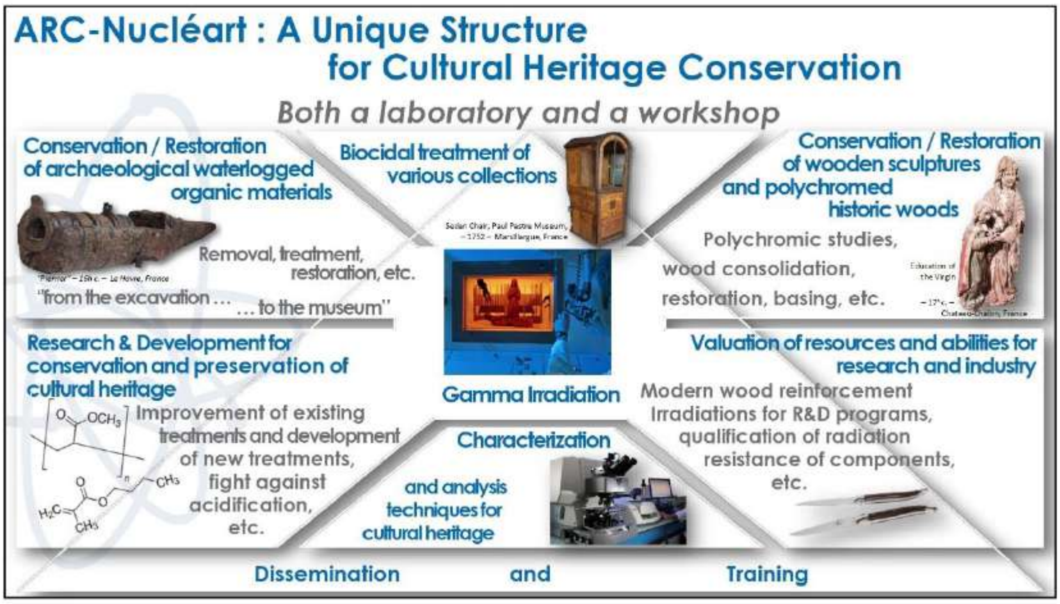

Irradiation of polychrome wooden sculptures
(Angels and Apostles – 17th c. – Le Pegue, France) for insect eradication
Application of Nuclear Techniques for Characterization and Preservation of Artifacts
Principle and application of nuclear techniques for artifact preservation
arc nucle art
Atelier de Recherche et de Conservation
Melaka, 2023 October 23th-27th
Laurent CORTELLA, from
for
IAEA


ARC-Nucléart
Located in Grenoble / France, in the middle of the site of the French Commission for Atomic Energy (CEA) research centre
arc nucle art
Atelier de Recherche et de Conservation
VILLE DE GRENOBLE
cea


ARC-Nucléart
Arose in the 70's from the idea of using "nuclear" techniques for heritage conservation
Marquetry parquet floor, J.F Hache – 18th c. – Grenoble
Virgin and Child – 14th c. – Flavigny-sur-Ozerain, France
Le Fauve, Ossip Zadkine – 1921 – Grenoble, France
Italian chair – 19th c. – Lyon, France


ARC-Nucléart
Arose in the 70's from the idea of using "nuclear" techniques for heritage conservation


ARC-Nucléart : A Unique Structure for Cultural Heritage Conservation
French Special Status: Groupement d'Intérêt Public (GIP)
(Public Interest Consortium)
cea
7 people (provided staff)
Building and facilities
Subvention
MINISTÈRE DE LA CULTURE
2 people (provided staff)
Subvention
arc nucle art
Atelier de Recherche et de Conservation
7 people
(employees of the consortium)
VILLE DE GRENOBLE
2 people
(provided staff)
ProNucleArt
Support association


ARC-Nucléart : A Unique Structure for Cultural Heritage Conservation
Both a laboratory and a workshop
Conservation / Restoration of archaeological waterlogged organic materials
Removal, treatment, restoration, etc.
"from the excavation … … to the museum"
Biocidal treatment of various collections
Conservation / Restoration of wooden sculptures and polychromed historic woods
Polychromic studies, wood consolidation, restoration, basing, etc.
Research & Development for conservation and preservation of cultural heritage
Improvement of existing treatments and development of new treatments, fight against acidification, etc.
Gamma Irradiation
Characterization and analysis techniques for cultural heritage
Valuation of resources and abilities for research and industry
Modern wood reinforcement
Irradiations for R&D programs, qualification of radiation resistance of components, etc.
Dissemination and Training


ARC-Nucléart : A Unique Structure
for Cultural Heritage Conservation
Both a laboratory and a workshop
3000 m² facilities : irradiation facility, large scale freeze-dryers, impregnation tanks (large scale, up to 14 meters long), restoration workshops, storage rooms, chemical and biological analysis laboratories


ARC-Nucléart : An Unique Structure
for Cultural Heritage Conservation
Both a laboratory and a workshop
A multidisciplinary team of 18 people: biologist, chemists, physicists, technicians, mechanic, photographer, conservators, curator, administrative


ARC-Nucléart : A Unique Structure
for Cultural Heritage Conservation
IAEA Collaborating Centre
To provide expertise and to enhance the use of Radiation Technology for Cultural Heritage Preservation (biocidal treatment and consolidation with radio-curable resin)
• Service for treatment of cultural heritage artifacts by ionizing radiation, including at international level
• Research, improvement of existing treatments and development of new processing
• Dissemination and training
IAEA
ARC-Nucléart
IAEA Collaborating Centre
for
Preservation of Cultural Heritage Using Radiation Processing
2023 - 2027

IAEA Promoting Nuclear Techniques for Cultural Heritage

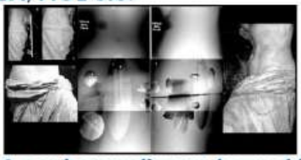
Comprehensive characterization

- Age, Composition, etc.

XRF, IBA, PIGE etc.

Structural Analysis by NDT

- Internal Observation



X ray & neutron radiography and tomography

Curative Conservation

- Disinfestation/Desinfection and consolidation

Biocidal treatment, radio-curing

IAEA Promoting Nuclear Techniques for Cultural Heritage

Supported by different Coordinated Research Programs (CRP)

- Nuclear Analytical techniques in Archaeological Investigations (1996~2000)
- Applications of Nuclear Analytical Techniques to Investigate the Authenticity of Art Objects (2004~2009)
- Application of Large Sample Neutron Activation Analysis Techniques for Inhomogeneous Bulk Archaeological Samples and Large Objects (2008~2012)
- Application of Two- and Three-Dimensional neutron imaging with Focus on Cultural Heritage research (2012~2018)
- Developing radiation treatment methodologies and new Resin Formulation for Consolidation and Preservation of Archived Materials and Cultural Heritage Artifacts (2015~2020)
- **Development and implementation of CH preservation using ionizing radiation technology (2022-2026)**

Bangladesh, Brazil, Croatia, Cuba, Egypt, France, Hungary, Italy, Japan, Poland, Portugal, Republic of Korea, Romania, Thailand, Tunisia, Türkiye, and Vietnam

IAEA Promoting Nuclear Techniques for Cultural Heritage

Numerous international and regional initiatives

2017 – IAEA Technical Meeting on Developing Strategies for Safe Analysis of Paintings and Paint Materials, Amsterdam.

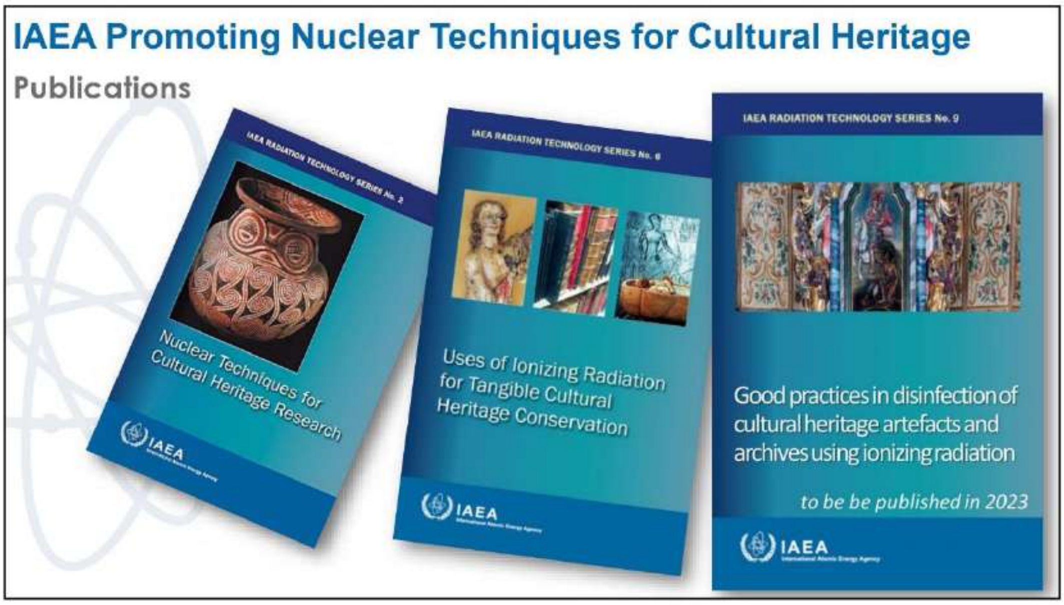
2018 – IAEA Technical Meeting on Strategies for the Preservation and Consolidation of Cultural Heritage Artifacts through Radiation Processing, Zagreb.

2019 – IAEA Regional Training Course on the Use of Radiation Techniques for Cultural Heritage Preservation and Consolidations, Yogyakarta.

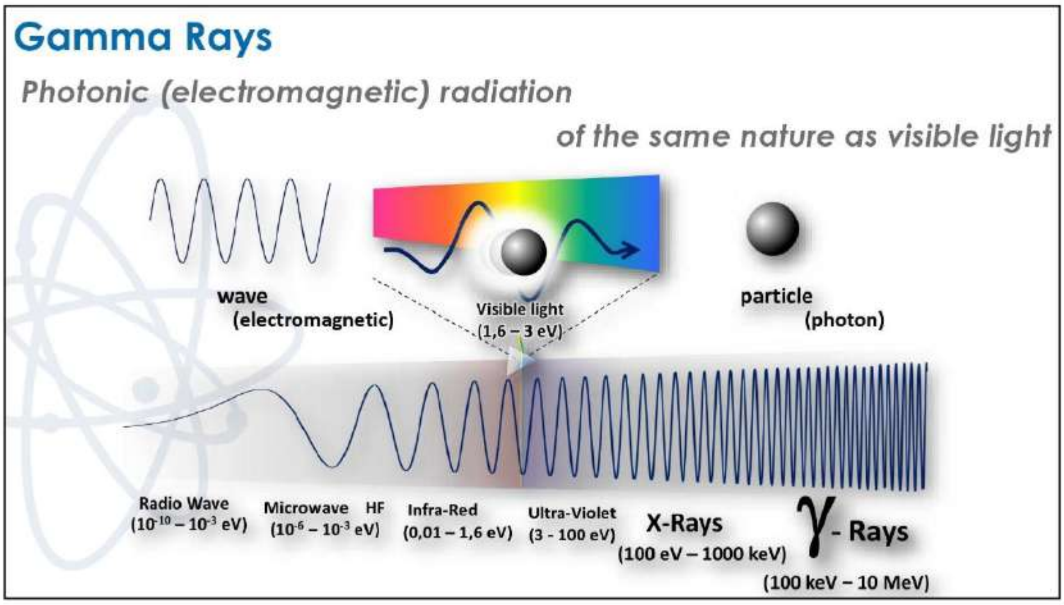
2020 – IAEA Virtual Workshop on Conservation of Paper-Based Material in Cambodia, Phnom Penh.

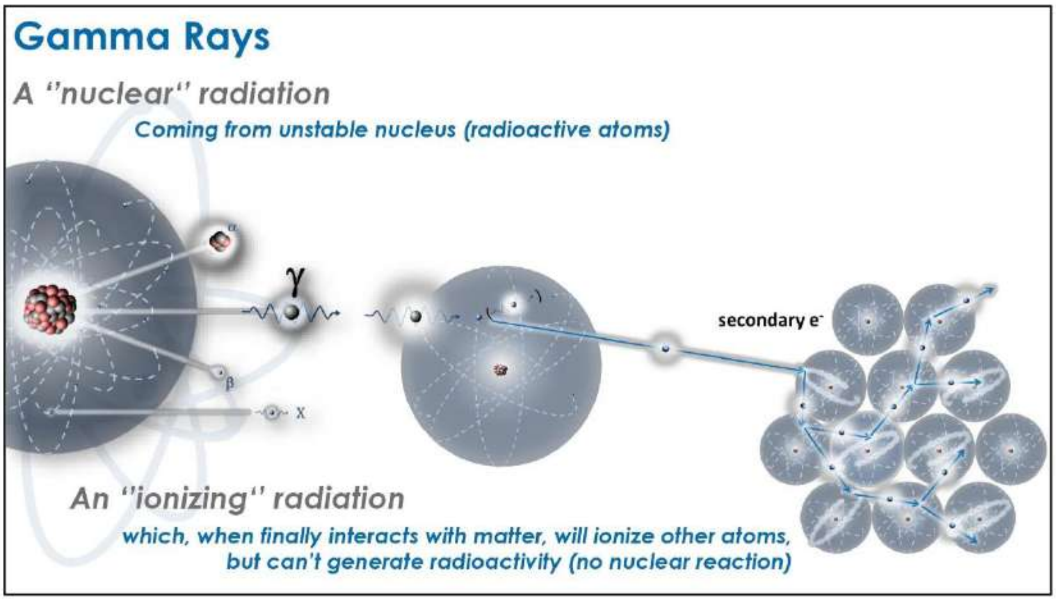
2021 – IAEA Virtual Regional Training Course on Preservation of Cultural Heritage Objects and Archived Materials using Ionizing Radiation, São-Paulo.

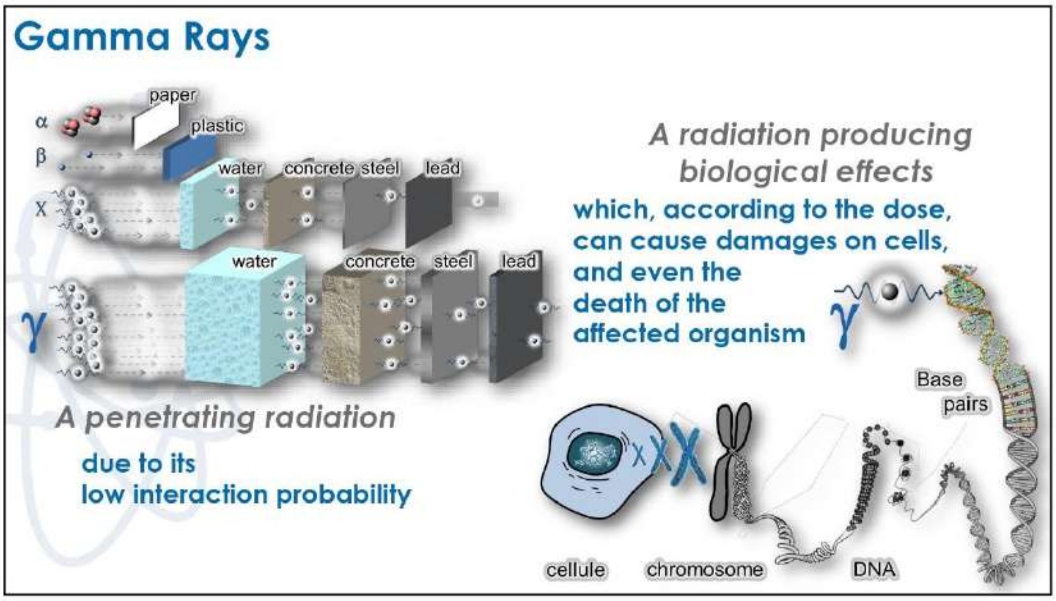
2021 – IAEA Technical Meeting on Radiation Technologies for Cultural Heritage Preservation and IAEA Regional Workshop on Radiation Technologies for Cultural Heritage Preservation, Grenoble.

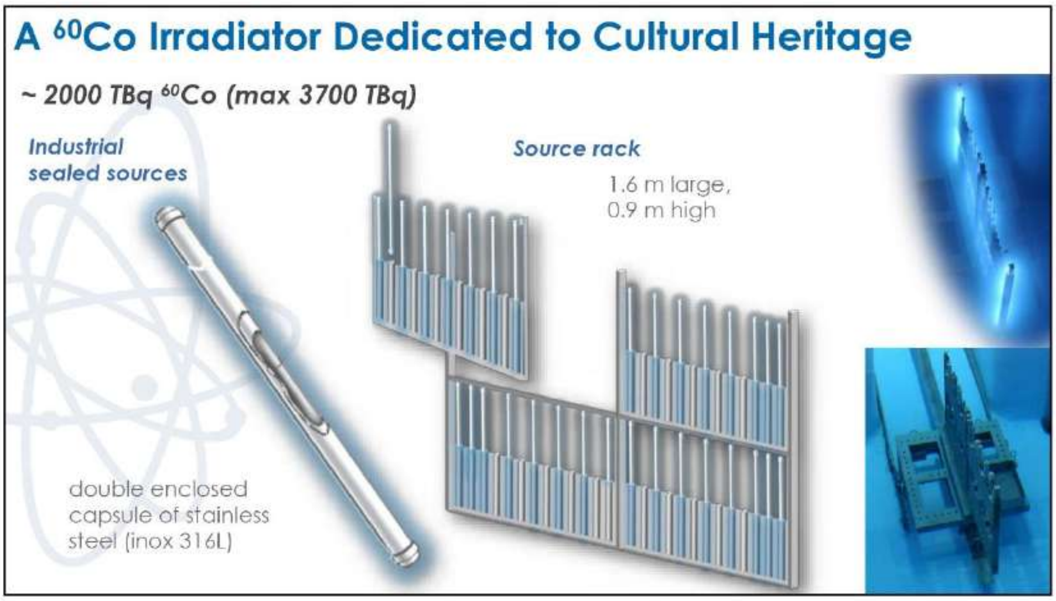

IAEA Promoting Nuclear Techniques for Cultural Heritage
Publications
Nuclear Techniques for Cultural Heritage Research
IAEA
Uses of Ionizing Radiation for Tangible Cultural Heritage Conservation
IAEA
IAEA RADIATION TECHNOLOGY SERIES No. 9
Good practices in disinfection of cultural heritage artefacts and archives using ionizing radiation
to be be published in 2023
IAEA


IAEA Promoting Nuclear Techniques for Cultural Heritage
RAS1027 "Improving the Utilization of Nuclear Techniques for Cultural Heritage Characterization, Consolidation, and Preservation"
Bangladesh – Brunei Darussalam – Cambodia – Indonesia – Iraq –Jordan – Kuwait - Lebanon – Malaysia – Mongolia – Myanmar – Oman – Pakistan – Philippines – Qatar - Saudi Arabia – Singapore - Sri Lanka - Syrian Arab Republic – Thailand – Vanuatu -Viet Nam – Yemen
• Group Scientific Visit
to ARC-Nucléart, 03-07 July 2023
• Regional Coordination Meeting
September 2023, Bangkok, Thailand
Atelier de Recherche et de Conservation

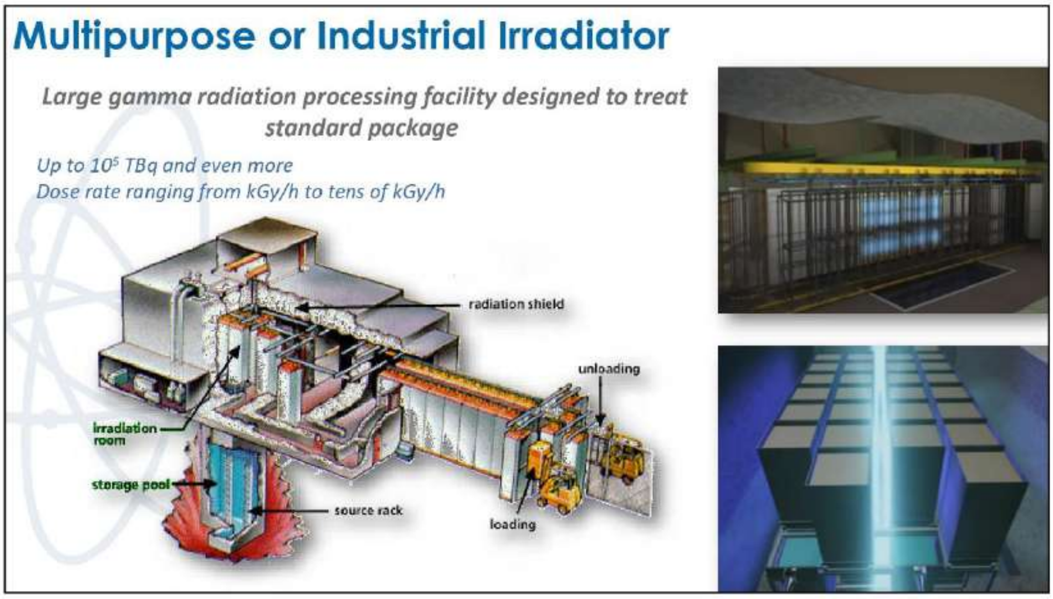

Gamma Rays
Photonic (electromagnetic) radiation
of the same nature as visible light
wave
(electromagnetic)
Visible light
(1,6 – 3 eV)
particle
(photon)
Radio Wave
(10^{-10} – 10^{-3} eV)
Microwave HF
(10^{-6} – 10^{-3} eV)
Infra-Red
(0,01 – 1,6 eV)
Ultra-Violet
(3 - 100 eV)
X-Rays
(100 eV – 1000 keV)
γ- Rays
(100 keV – 10 MeV)

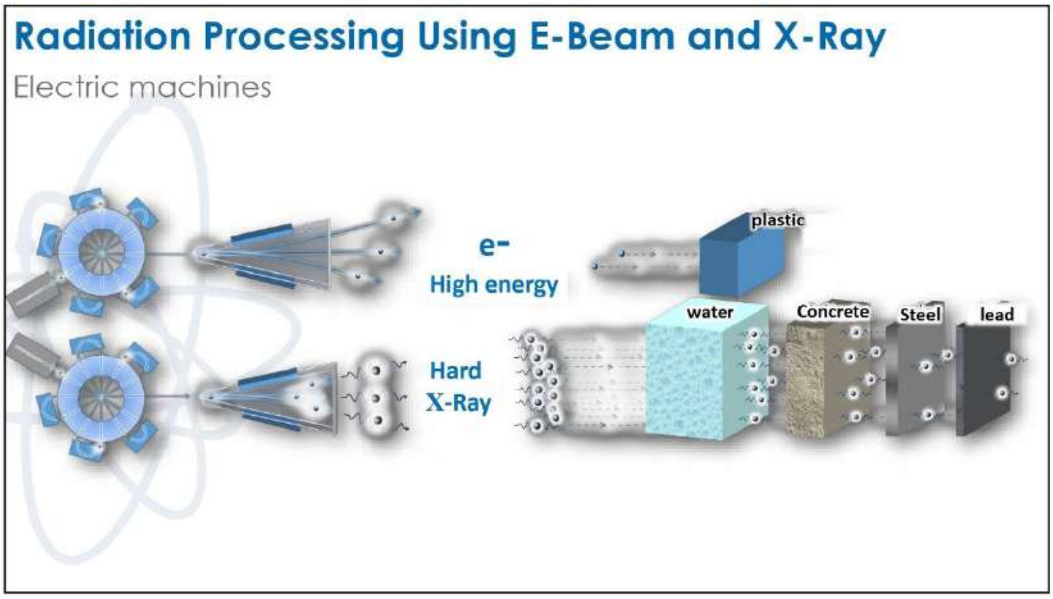

Gamma Rays
A "nuclear" radiation
Coming from unstable nucleus (radioactive atoms)
γ
β
X
secondary e⁻
An "ionizing" radiation
which, when finally interacts with matter, will ionize other atoms,
but can't generate radioactivity (no nuclear reaction)

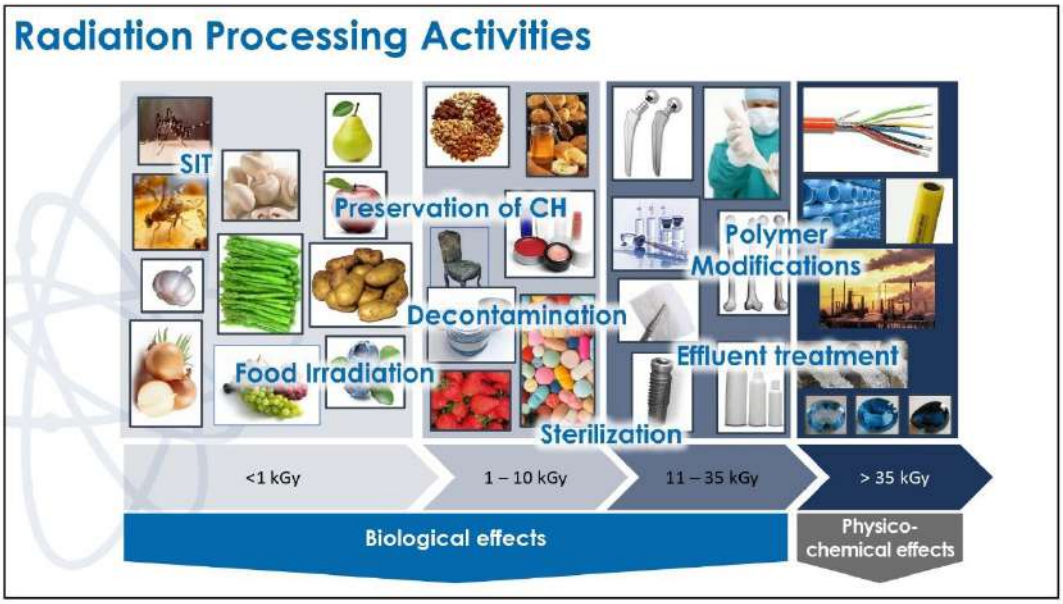

Gamma Rays
α
β
X
γ
paper
plastic
water
concrete
steel
lead
A penetrating radiation
due to its
low interaction probability
A radiation producing
biological effects
which, according to the dose,
can cause damages on cells,
and even the
death of the
affected organism
Base
pairs
cellule
chromosome
DNA


A 60Co Irradiator Dedicated to Cultural Heritage
~ 2000 TBq 60Co (max 3700 TBq)
Industrial
sealed sources
Source rack
1.6 m large,
0.9 m high
double enclosed
capsule of stainless
steel (inox 316L)


A ^{60}Co Irradiator Dedicated to Cultural Heritage
Pool irradiator
Dose rate ranging from hundreds of Gy/h to few kGy/h


Multipurpose or Industrial Irradiator
Large gamma radiation processing facility designed to treat standard package
Up to 10^5 TBq and even more
Dose rate ranging from kGy/h to tens of kGy/h
radiation shield
unloading
irradiation room
storage pool
source rack
loading


Radiation Processing Using E-Beam and X-Ray
Electric machines
plastic
e-
High energy
water
Concrete
Steel
lead
Hard
X-Ray



Definition: Cultural Heritage

What is meant by "cultural heritage"?

The term "cultural heritage" encompasses several main categories of heritage:

Cultural heritage

- Tangible cultural heritage:
  - *movable cultural heritage (paintings, sculptures, coins, manuscripts)*
  - immovable cultural heritage (monuments, archaeological sites, and so on)
- Intangible cultural heritage: oral traditions, performing arts, rituals

Natural heritage

- natural sites with cultural aspects such as cultural landscapes, physical, biological or geological formations

Unesco-database-of-national-cultural-heritage-laws / FAQ

United Nations Educational, Scientific and Cultural Organization

Definition: Conservation-Restoration

Resolution on a terminology for conservation

- Conservation *(preservation)*:

  all measures and actions aimed at safeguarding tangible cultural heritage while ensuring its accessibility to present and future generations. Conservation embraces preventive conservation, remedial conservation and restoration.

  - Preventive conservation:

    all measures and actions aimed at avoiding and minimizing future deterioration or loss. They are carried out within the context or on the surroundings of an item, but more often a group of items, whatever their age and condition. These measures and actions are indirect – they do not interfere with the materials and structures of the items.

  - **Remedial *(or interventive)* conservation:**

    all actions directly applied to an item or a group of items aimed at ***arresting current damaging*** processes or ***reinforcing their structure***.

  - Restoration:

    all actions directly applied to a single and stable item aimed at facilitating its appreciation, understanding and use.

New Delhi 2008

ICOM-CC (International Council Of Museum - Committee for Conservation)

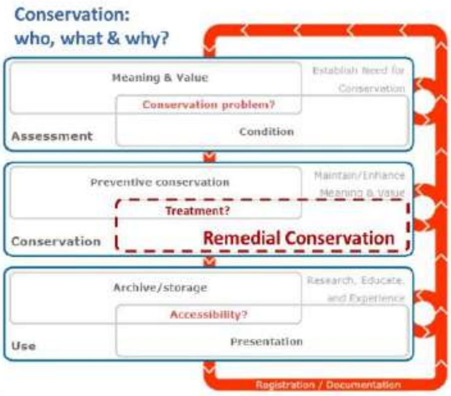
Process of Cultural Heritage Conservation

Remedial conservation:

"all actions directly applied to an item or a group of items aimed at arresting current damaging processes

or

reinforcing their structure"



Terminology
15th Triennial Conference,
New Delhi,
22-26 September 2008 ICOM-CC

Radiation for Cultural Heritage Conservation

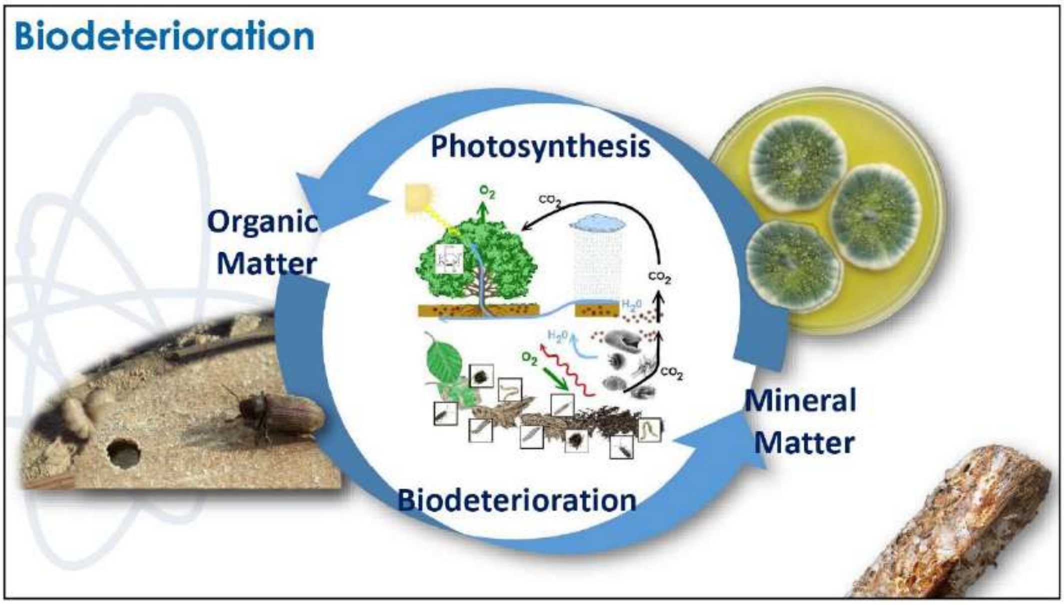
Remedial conservation:

arresting current damaging processes

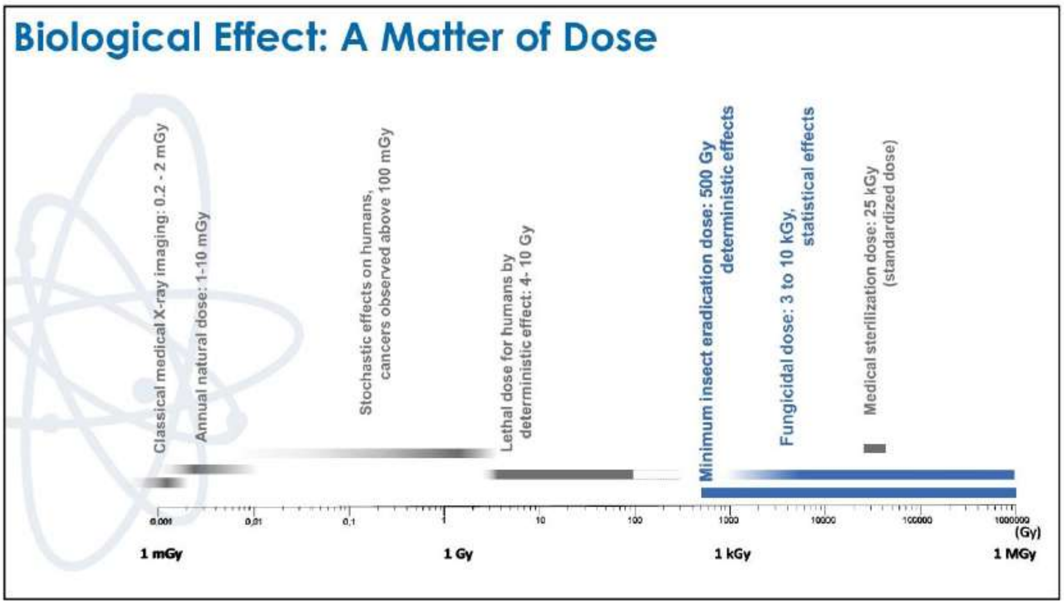
Biocidal treatment by simple exposure to gamma rays

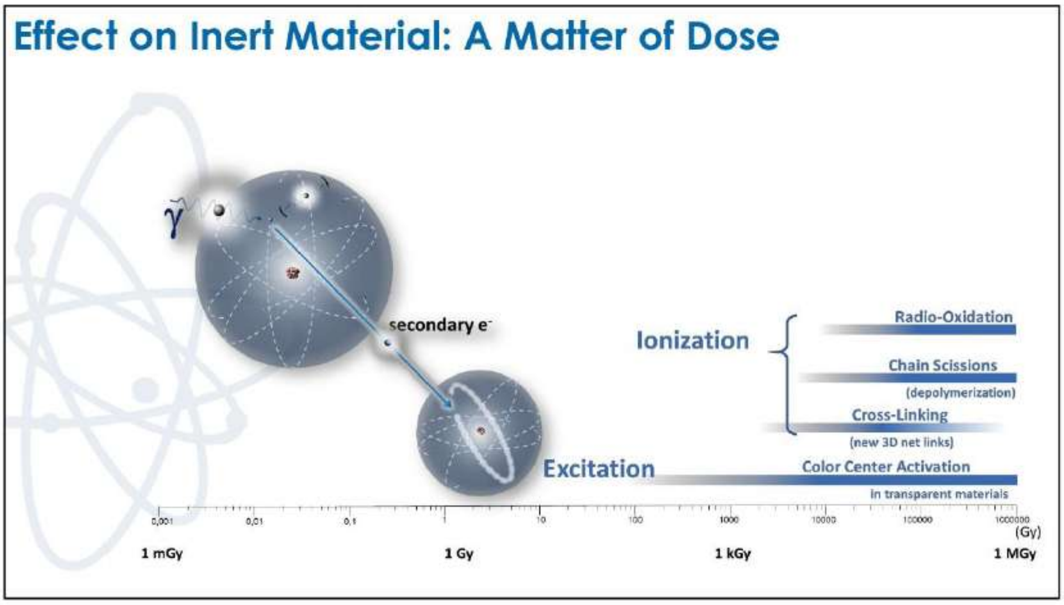
reinforcing their structure

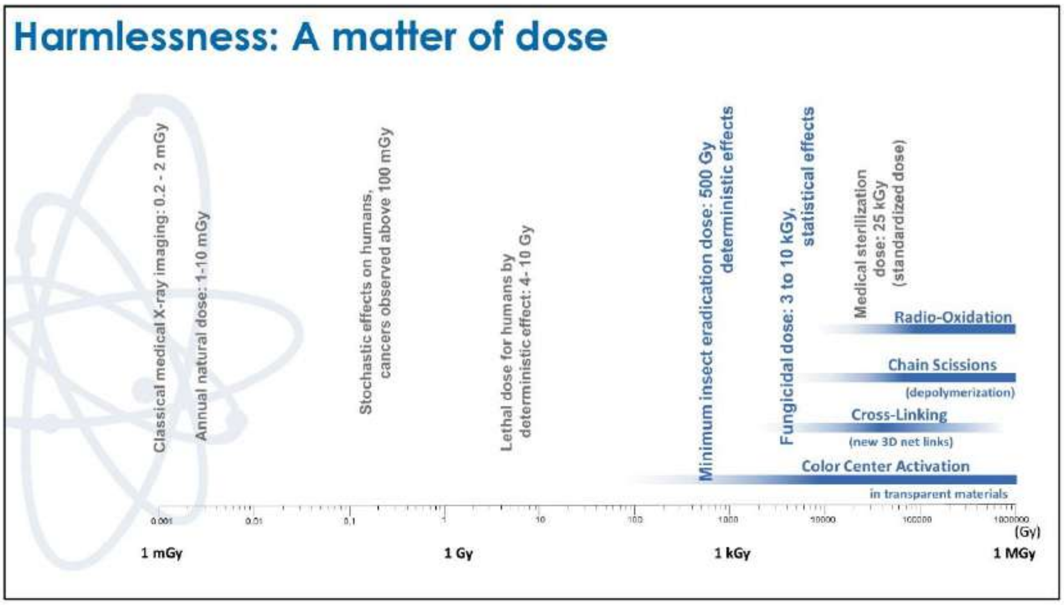
Consolidation with radio-curable resins


Biodeterioration
Photosynthesis
Organic Matter
Mineral Matter
Biodeterioration


Biocidal treatment
by simple exposure to gamma rays

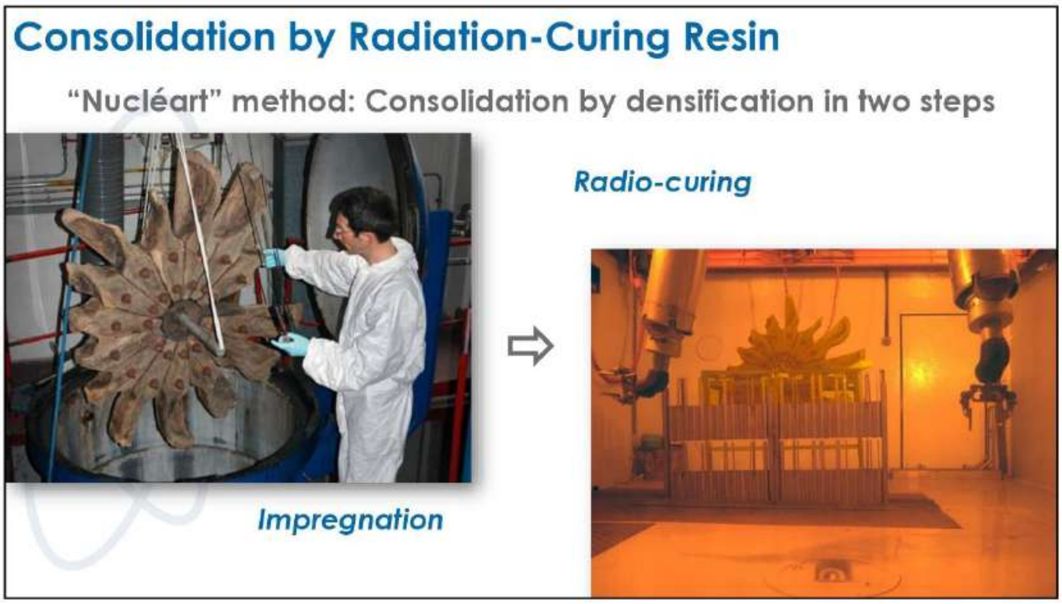

Biological Effect: A Matter of Dose
Classical medical X-ray imaging: 0.2 - 2 mGy
Annual natural dose: 1-10 mGy
Stochastic effects on humans, cancers observed above 100 mGy
Lethal dose for humans by deterministic effect: 4- 10 Gy
Minimum insect eradication dose: 500 Gy deterministic effects
Fungicidal dose: 3 to 10 kGy, statistical effects
Medical sterilization dose: 25 kGy (standardized dose)
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy

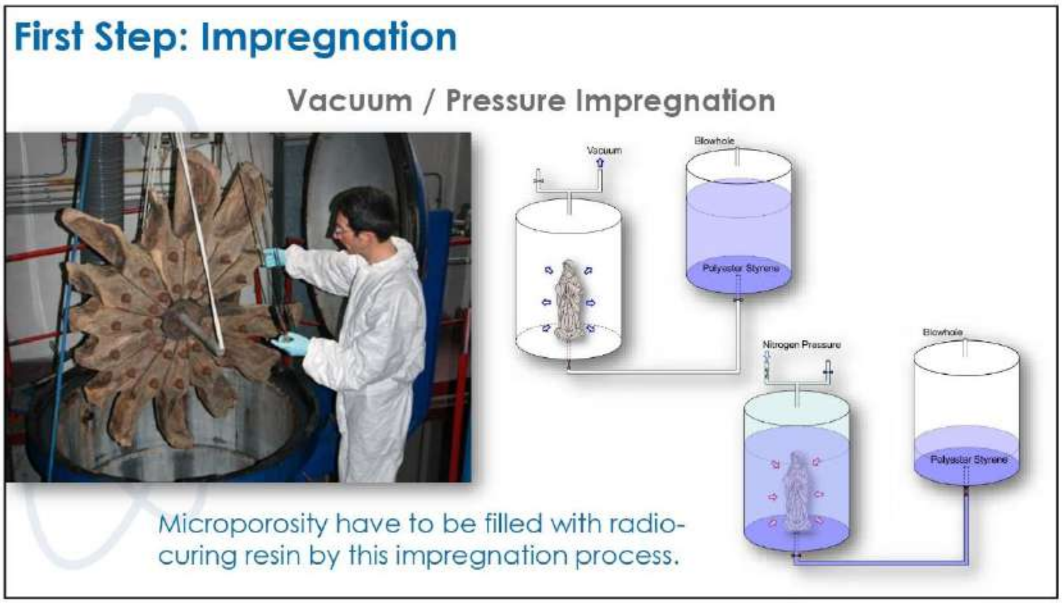

Effect on Inert Material: A Matter of Dose
γ
secondary e⁻
Ionization
Radio-Oxidation
Chain Scissions
(depolymerization)
Cross-Linking
(new 3D net links)
Excitation
Color Center Activation
in transparent materials
0,001
0,01
0,1
1
10
100
1000
10000
100000
1000000
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy


Harmlessness: A matter of dose
Classical medical X-ray imaging: 0.2 - 2 mGy
Annual natural dose: 1-10 mGy
Stochastic effects on humans, cancers observed above 100 mGy
Lethal dose for humans by deterministic effect: 4- 10 Gy
Minimum insect eradication dose: 500 Gy deterministic effects
Fungicidal dose: 3 to 10 kGy, statistical effects
Medical sterilization dose: 25 kGy (standardized dose)
Radio-Oxidation
Chain Scissions
(depolymerization)
Cross-Linking
(new 3D net links)
Color Center Activation
in transparent materials
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy


Thousands of Collections Treated for Disinfestation
• Furniture
• Paintings
• Wooden sculptures
• Books and archives
• Ethnological artefacts
• Modern Art
• Musical instruments
• Natural history specimens

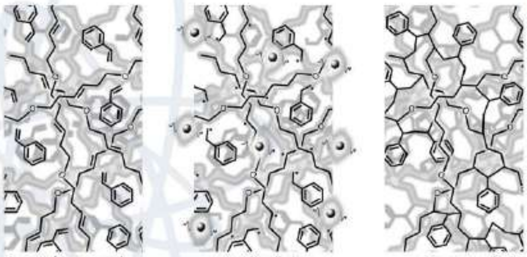

Some uncommon customers
• Frozen baby mammoth
• Mummies
AU PUY-EN-VELAY RENCONTREZ LES MAMMOUTHS


Consolidation by Radiation-Curing Resin
"Nucléart" method: Consolidation by densification in two steps
Radio-curing
Impregnation

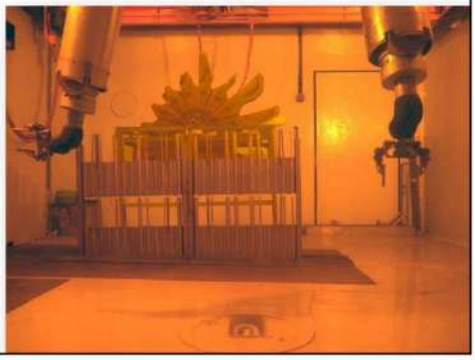

First Step: Impregnation
Vacuum / Pressure Impregnation
Vacuum
Blowhole
Polyester Styrene
Nitrogen Pressure
Blowhole
Polyester Styrene
Microporosity have to be filled with radio-curing resin by this impregnation process.

Second step: Radio-curing

Radio-induced cross-linking by gamma irradiation



Solidification of the impregnated resin staying in microporosity



Irreversible Method: Must Be Justified

- "Last chance" technic
- Conservation of the function
- Archaeological waterlogged wood

Official Deontology for Cultural Heritage

Historical and general ethical rules are provided by international organizations:

- *"Convention concerning the protection of the world cultural and natural heritage"*
  UNESCO (United Nations Educational, Scientific and Cultural Organization)
- *"Code of Ethics for Museums"*
  ICOM (International Council Of Museum)

Guidelines for professional can be provided by professional organizations:

- *"E.C.C.O. Professional Guidelines"*
  ECCO (European Confederation of Conservator-Restorers Organization)
- *"Code of Ethics and Guidelines for Practice"*
  AIC (American Institute for Conservation)

Goal and Ethic of Remedial Conservation

*"All remedial conservation is intended primarily **to stabilize or retard the deterioration** of the heritage and **to diminish future risk** without compromising its **material and historical integrity**."*

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Conservation- -Restoration of Cultural Heritage in less than 1000 words...

"The conservator-restorer [...]

- [...] is personally **responsible** to the owner, to the heritage and to society.
- [...] shall respect the aesthetic, historic and spiritual significance and the physical **integrity** of the cultural heritage [...]
- [...] should **limit** the treatment to only that which is necessary
- [...] use only products, materials and procedures, which[...] will **not harm** the cultural heritage[...] and be as easily and completely **reversible** as possible.
  - should [...] **document**[ed...] any conservation / restoration intervention [...]

E.C.C.O.

Professional Guidelines (II) Code of Ethics
Art. 3 ; 5 ; 8 ; 9 ; 10

Justification – Limitation Principle

Management of the risk

- *Is the intervention **justified** (better than alternative, including doing nothing),*
- *Is the level of the intervention **optimized** to keep the artifact "**as close to its original**" within the efficiency requirements that will ensure that it will be for "**as long as possible**".*
- *Is the intervention **limited** to the minimum,*
  *"**only what is necessary**".*

Here, the risk regards the unlike deterioration of the cultural significance of heritage

Harmlessness Principle

- *Interventive action, as any active process that intends to have effective results, can not be completely without consequences.*

Harmlessness shall only be considered as an ideal objective one may approach.

- It is of first importance however, to accumulate the best **knowledge** of potential **sides effects**, in order to limit them and to evaluate if they are acceptable or not.

Reversibility Principle

- Contrary to the second principle of thermodynamic
- Implicit acceptation of harmfulness.
- Although it is regarded as crucial by the proponents of deontology, this principle is also very often regarded as only theoretical by many practitioners.

Some practical points:

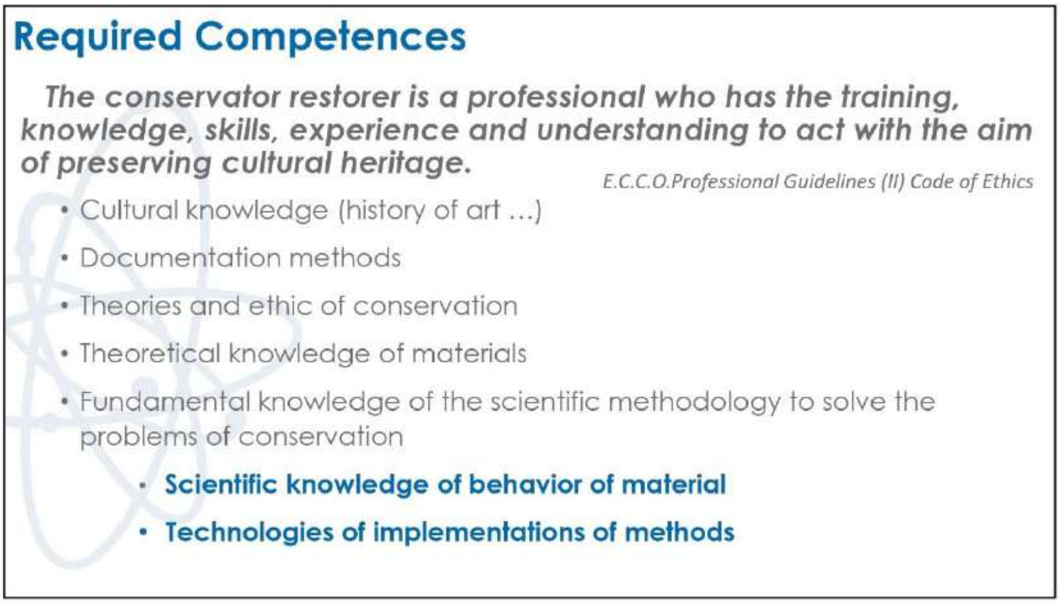
- *Theoretical reversibility doesn't mean practical reversibility, particularly when applying to a whole object*
- *Irreversible treatments could impede new conservation operations restoration to follow, even local intervention*
    - *If not reversible, added material (e.g. for reinforcement) should pollute future analysis, even on samples.*

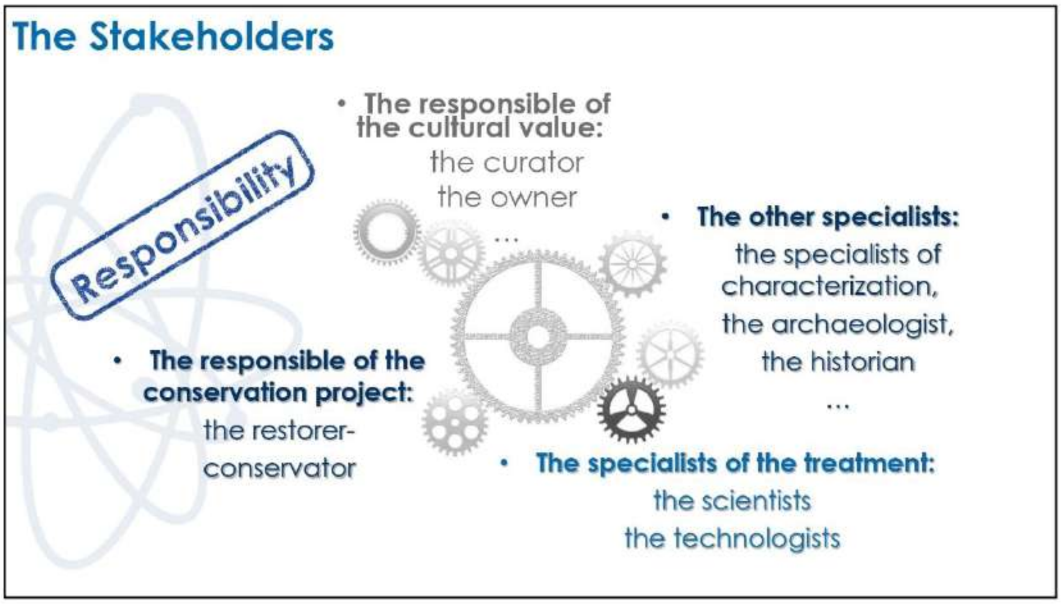
Conservation Issues

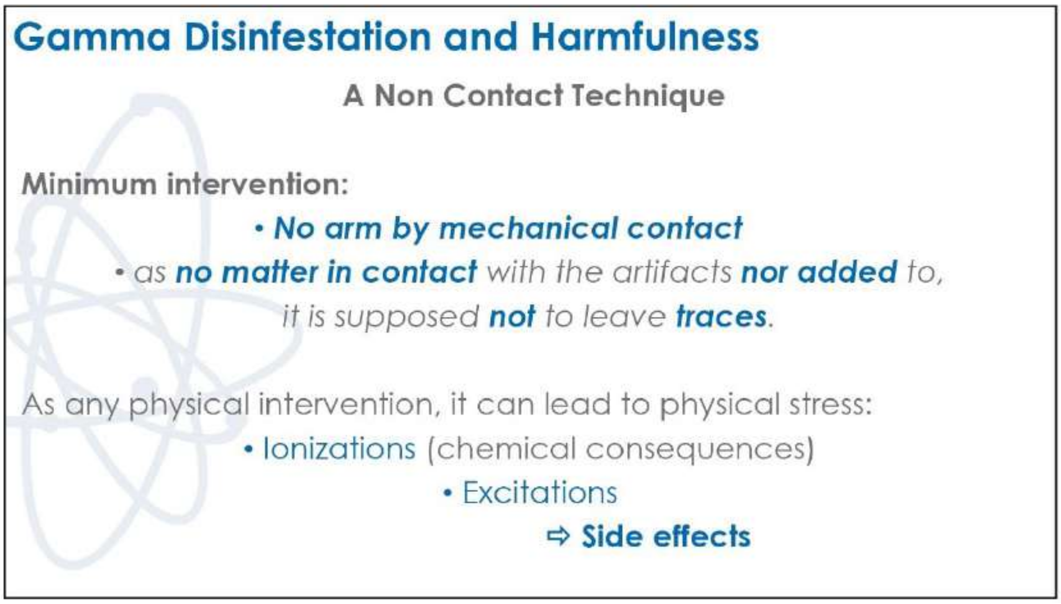
Historical Value – Aesthetic Value – Physical Nature

Methodology of the Conservation-Restoration

- Examination and documentation (state report)
- Diagnostic:
  Is there any matter with the artifact? What is it?
- Conservation-restoration objectives:
  Which significance has to be preserved? (the conservation issue)
- **Conservation-restoration project:**
  How this significance can be preserved?
- **Conservation-restoration realization:**
  Is the realization conform to the project?
    - **Control and evaluation of the treatment, documentation:**
      How did the treatment reach the objectives ?
      Is there actually any change after treatment?


Required Competences
The conservator restorer is a professional who has the training, knowledge, skills, experience and understanding to act with the aim of preserving cultural heritage.
E.C.C.O.Professional Guidelines (II) Code of Ethics
• Cultural knowledge (history of art …)
• Documentation methods
• Theories and ethic of conservation
• Theoretical knowledge of materials
• Fundamental knowledge of the scientific methodology to solve the problems of conservation
• Scientific knowledge of behavior of material
• Technologies of implementations of methods


The Stakeholders
Responsibility
• The responsible of the cultural value:
the curator
the owner
…
• The other specialists:
the specialists of characterization,
the archaeologist,
the historian
…
• The responsible of the conservation project:
the restorer-conservator
• The specialists of the treatment:
the scientists
the technologists


Gamma Disinfestation and Harmfulness
A Non Contact Technique
Minimum intervention:
• No arm by mechanical contact
• as no matter in contact with the artifacts nor added to,
it is supposed not to leave traces.
As any physical intervention, it can lead to physical stress:
• Ionizations (chemical consequences)
• Excitations
⇨ Side effects

Gamma Disinfestation and Justification

Is disinfestation justified?

- only if disinfestation is justify!
  - if **curative** disinfestation is needed

Is *gamma* disinfestation justified rather than other techniques?

- **Reliability**
  - *Treatment through packaging,*
    - *Cold treatment,*
      - *When alternative treatment could arm*

Gamma Disinfestation and Limitation

***Treatment shall be limited to* only what is necessary**

- Threshold for insect eradication
- No threshold for fungicidal treatments (how much is necessary?)

No clear definition of unacceptable limits

(concept of acceptable adverse* side effects *is not part of ethic)

- depends not only on physico-chemical properties of target materials, but also on significance of the artifacts

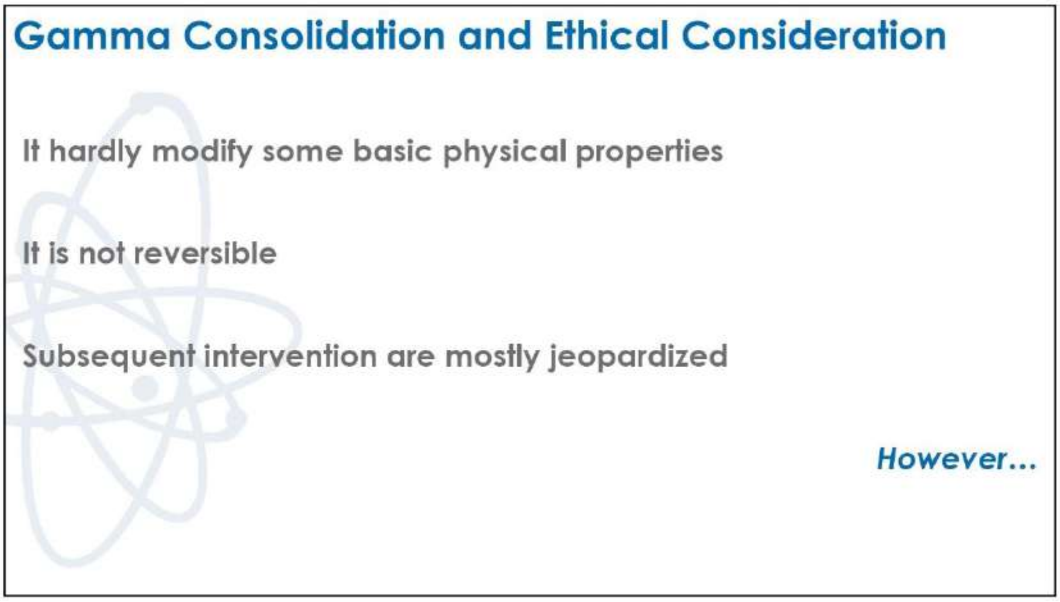
As doses have to be considered as cumulative, treatment shall be limited to only one

Gamma Disinfestation and Reversibility

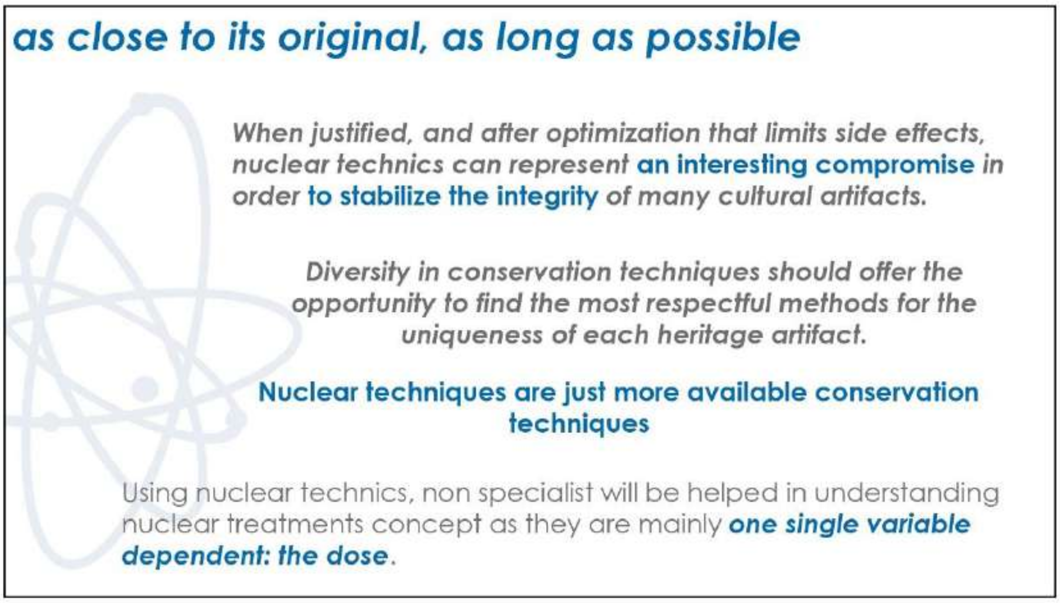
Expected biocidal effect is irreversible

***About* side effects:**

- First side effect, ***darkening of transparent material***, is almost always reversible or at least partially **reversible**,
- at the contrary, ***loss of mechanical property or of analytical information*** at very high doses is always totally **irreversible**.


Gamma Consolidation and Ethical Consideration
It hardly modify some basic physical properties
It is not reversible
Subsequent intervention are mostly jeopardized
However…


Gamma Consolidation and Justification
Justified as the best compromise:
"no better alternative technics can save the integrity"
Some concrete cases:
• last chance for polychromed wooden sculpture,
• conservation of functionality,
• composite metal and waterlogged wood in archeological artifacts,
• special conservation environment after treatment.


as close to its original, as long as possible
When justified, and after optimization that limits side effects, nuclear technics can represent an interesting compromise in order to stabilize the integrity of many cultural artifacts.
Diversity in conservation techniques should offer the opportunity to find the most respectful methods for the uniqueness of each heritage artifact.
Nuclear techniques are just more available conservation techniques
Using nuclear technics, non specialist will be helped in understanding nuclear treatments concept as they are mainly one single variable dependent: the dose.


Thank you for your attention

2.4 Analysis of Cultural Heritage Using Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT)

Name: Mohd Fitri Abdul Rahman
Date of Presentation: 23rd October 2023
Email: fitri@nm.gov.my

Cultural heritage, with its diverse artifacts, often hides secrets that challenge historians and archaeologists. In recent years, advanced scientific techniques have revolutionized how we uncover these mysteries, shedding light on ancient civilizations and their creations. One such groundbreaking method is Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT), a powerful tool that enables scientists to analyze cultural artifacts non-destructively.

Imagine a 700-year-old stone adorned with carvings and inscriptions, shrouded in mystery about its origin and composition. This artifact, the Inscribed Stone "*Batu Bersurat*," was discovered in Terengganu, Malaysia. Thanks to NIPGAT, scientists embarked on a scientific journey to unravel its secrets.

NIPGAT emits neutrons into a sample material, stimulating gamma rays through interactions with the elements present. This technique allows researchers to identify components and their percentages within the analyzed material, providing valuable insights into its composition. What sets NIPGAT apart is its non-destructive nature, making it a safe and effective method for cultural heritage analysis.

In the case of the Inscribed Stone "*Batu Bersurat*," scientists from the Malaysian Nuclear Agency, in collaboration with the International Atomic Energy Agency (IAEA), conducted a comprehensive study using NIPGAT. The stone, listed as a high-value antiquity by UNESCO, had puzzled researchers due to the lack of scientific data about its composition and origin.

Through meticulous geological studies, researchers examined the stone's shape, surface, grain size, color, and other physical properties. They also explored various locations, such as rivers and waterfalls, to collect samples of similar stones. These samples, including granite and dolerite, were analyzed using NIPGAT to compare their compositions with that of the Inscribed Stone.

The results were astounding. NIPGAT analysis revealed distinct patterns in the elemental composition of the Inscribed Stone, setting it apart from other samples. Elements like aluminum (Al), silicon (Si), and titanium (Ti) displayed unique signatures, providing valuable clues about the stone's origin.

The study's findings challenged historical accounts, revealing that the Inscribed Stone was made of dolerite, not granite, as previously reported. Dolerite, a dark-colored igneous rock, was commonly used in ancient civilizations for various purposes, including sculptures and monuments.

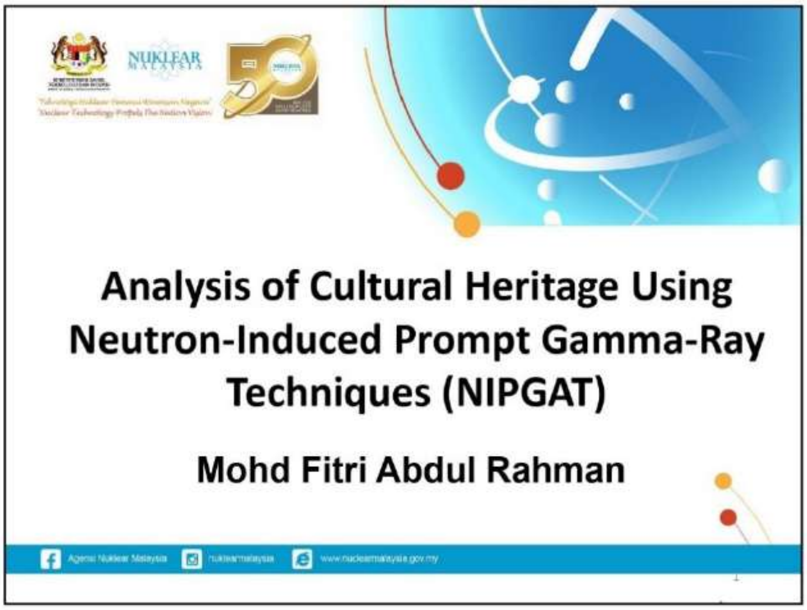
This breakthrough showcases the power of NIPGAT in rewriting history and deepening our understanding of ancient cultures. By analyzing the elemental composition of artifacts, scientists can trace their origins, decipher their purpose, and appreciate the craftsmanship of ancient civilizations.

NIPGAT's applications extend beyond historical artifacts. Scientists utilize this technique to analyze metals, alloys, semiconductors, geological and environmental samples, biological specimens, and even rare earth elements in ores. Its versatility and non-destructive nature make it a valuable tool in various scientific fields.

In addition to its analytical capabilities, NIPGAT contributes to the preservation of cultural heritage. By understanding the composition of artifacts, conservators can develop appropriate preservation methods, ensuring these treasures endure for future generations to admire and learn from.

The study of cultural heritage using techniques like NIPGAT exemplifies the marriage of science and history, unraveling the mysteries of our past one artifact at a time. As technology advances, the secrets of ancient civilizations become more accessible, enriching our knowledge and appreciation of human history.

In conclusion, NIPGAT is a testament to human ingenuity, enabling us to delve into the past with unprecedented precision. Through its non-destructive analysis, we can preserve the integrity of cultural artifacts while unraveling their stories. As we continue to explore the depths of our heritage, NIPGAT will undoubtedly play a pivotal role in uncovering the hidden gems of our shared history. The slides in the upcoming section detail the work done on this.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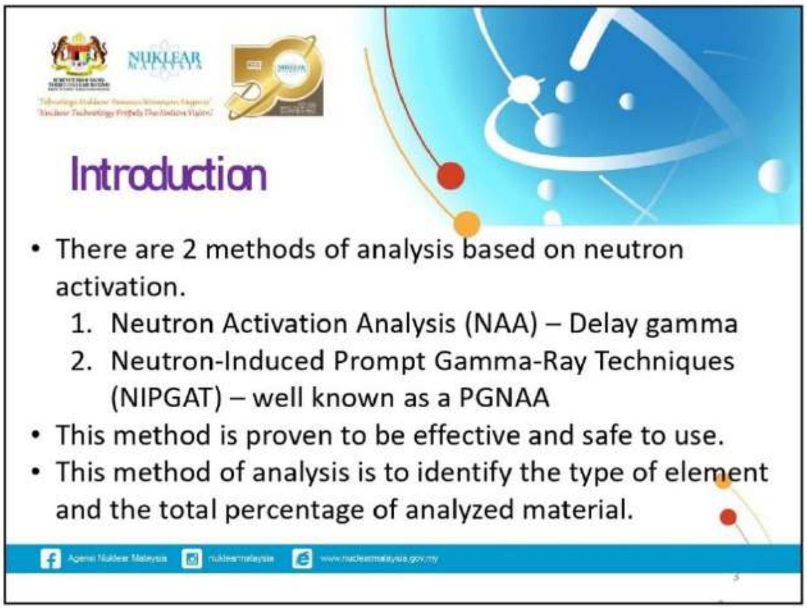
Analysis of Cultural Heritage Using Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT)
Mohd Fitri Abdul Rahman


NUKLEAR MALAYSIA
Content:
1. Introduction
2. Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT)
3. Case Studies
4. Summary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Introduction
• There are 2 methods of analysis based on neutron activation.
1. Neutron Activation Analysis (NAA) – Delay gamma
2. Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT) – well known as a PGNAA
• This method is proven to be effective and safe to use.
• This method of analysis is to identify the type of element and the total percentage of analyzed material.

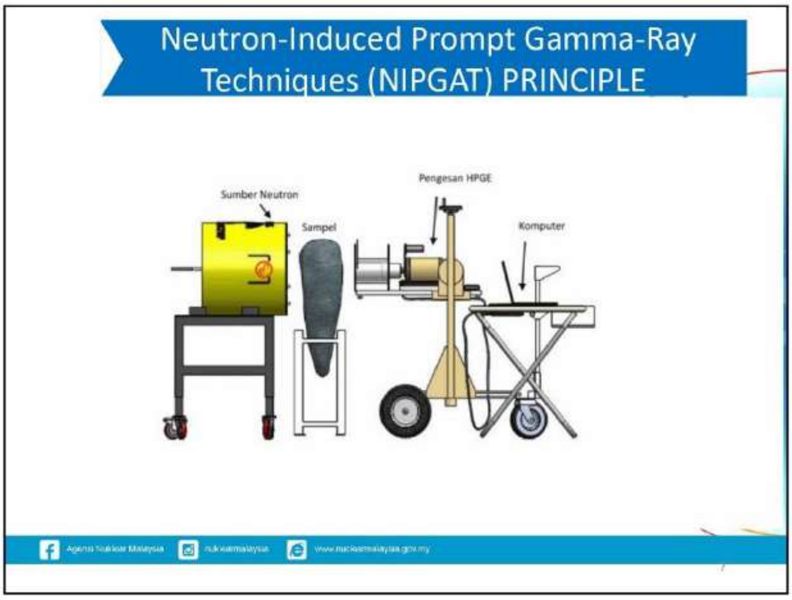
Introduction

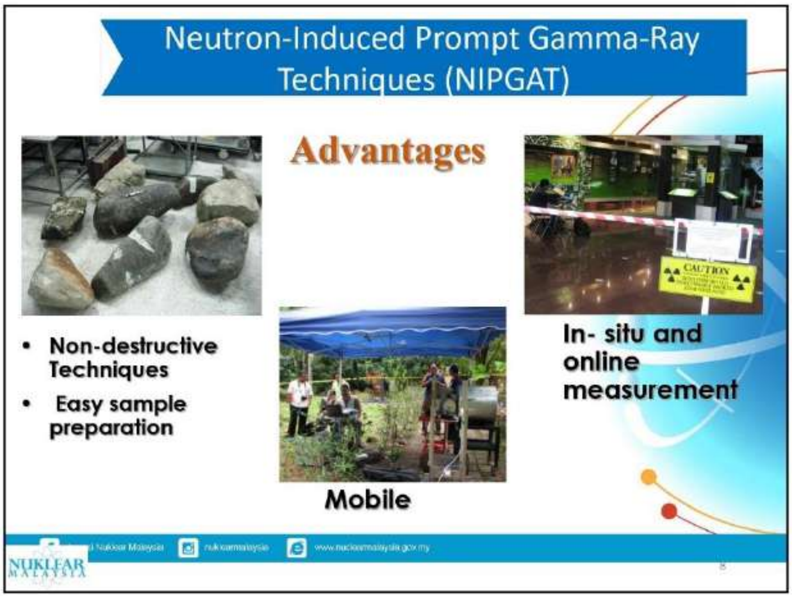
- Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT) method is essentially similar to the NAA method.
- The difference is; NAA is Reactor Base but NIPGAT using radioisotope and its equipment portable and can be taken to the field

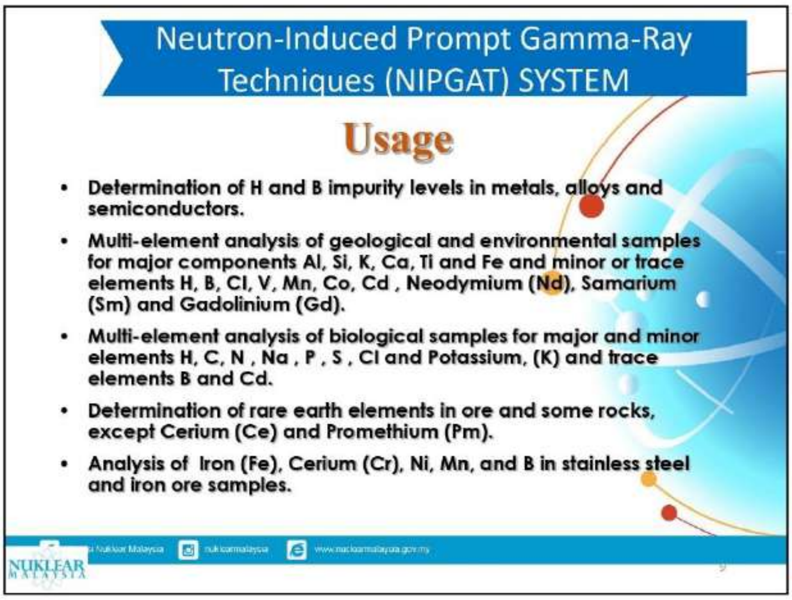
Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT) COMPONENTS

Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT) PRINCIPLE

- The neutron source emits neutrons and enters the target medium of the sample material.
- The penetrating power depends on the type of material in which neutrons can interact deeply with the nuclei of the elements present.
- This interaction will produce gamma rays through two fast neutron reactions.


Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT) PRINCIPLE
Sumber Neutron
Sampel
Pengesan HPGE
Komputer


Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT)
Advantages
• Non-destructive Techniques
• Easy sample preparation
Mobile
In- situ and online measurement
CAUTION


Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT) SYSTEM
Usage
• Determination of H and B impurity levels in metals, alloys and semiconductors.
• Multi-element analysis of geological and environmental samples for major components Al, Si, K, Ca, Ti and Fe and minor or trace elements H, B, Cl, V, Mn, Co, Cd , Neodymium (Nd), Samarium (Sm) and Gadolinium (Gd).
• Multi-element analysis of biological samples for major and minor elements H, C, N , Na , P , S , Cl and Potassium, (K) and trace elements B and Cd.
• Determination of rare earth elements in ore and some rocks, except Cerium (Ce) and Promethium (Pm).
• Analysis of Iron (Fe), Cerium (Cr), Ni, Mn, and B in stainless steel and iron ore samples.
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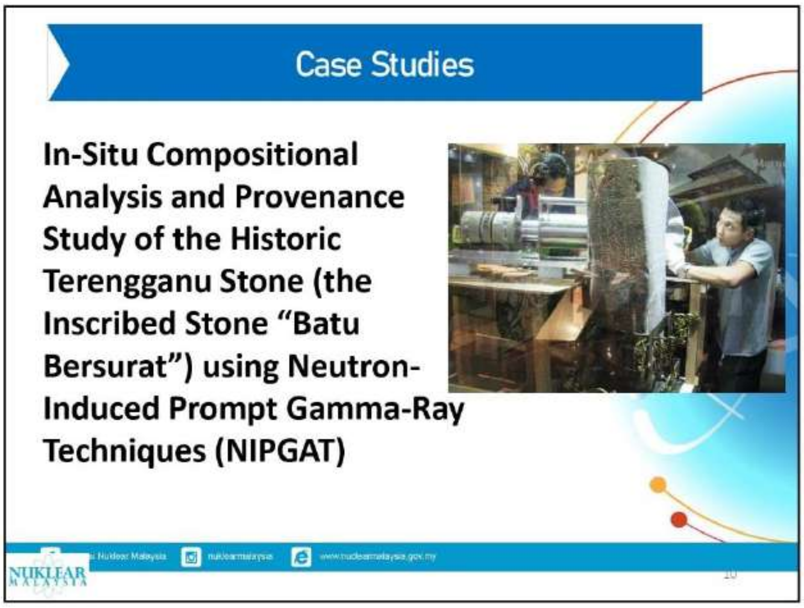
Case Studies
In-Situ Compositional Analysis and Provenance Study of the Historic Terengganu Stone (the Inscribed Stone "Batu Bersurat") using Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT)
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Case Studies
IAEA/COORDINATED RESEARCH PROJECT
NUKLEAR MALAYSIA
IAEA
NAMES AND AFFILIATION OF PROJECT MEMBERS:
Jaafar Abdullah[1], Lahasen@Normanshah Dahing[1], Roslan Yahya[1], Mohamad Rabaie Shaari[1], Airwan Affandi Mahmood[1] and Hearie Hassan[1].
[1]Malaysian Nuclear Agency, Malaysia.
Tajul Anuar Jamaluddin[2]
[2]National University of Malaysia
Mohd Yusof Abdullah[3], Nor Ainah Mahmud[3]
[3]Terengganu State Museum, Malaysia.
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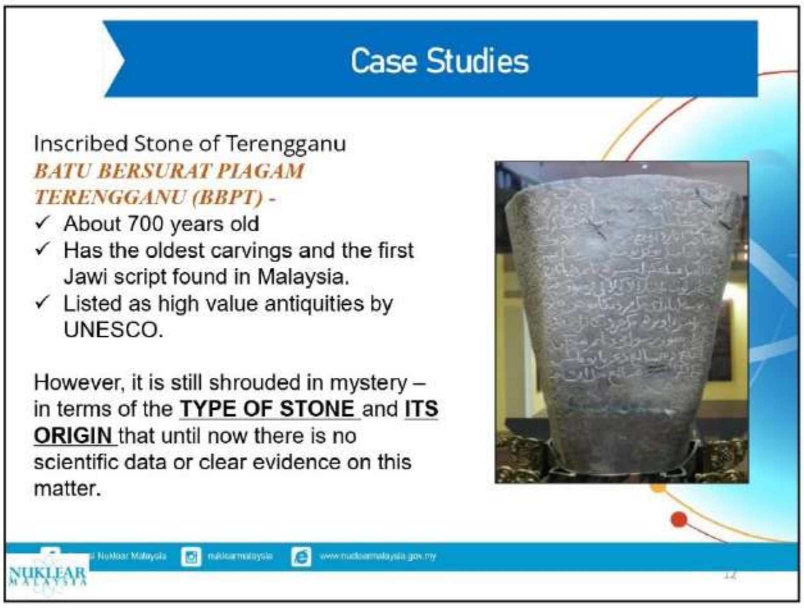
Case Studies
Inscribed Stone of Terengganu
BATU BERSURAT PIAGAM TERENGGANU (BBPT) -
✓ About 700 years old
✓ Has the oldest carvings and the first Jawi script found in Malaysia.
✓ Listed as high value antiquities by UNESCO.
However, it is still shrouded in mystery – in terms of the TYPE OF STONE and ITS ORIGIN that until now there is no scientific data or clear evidence on this matter.
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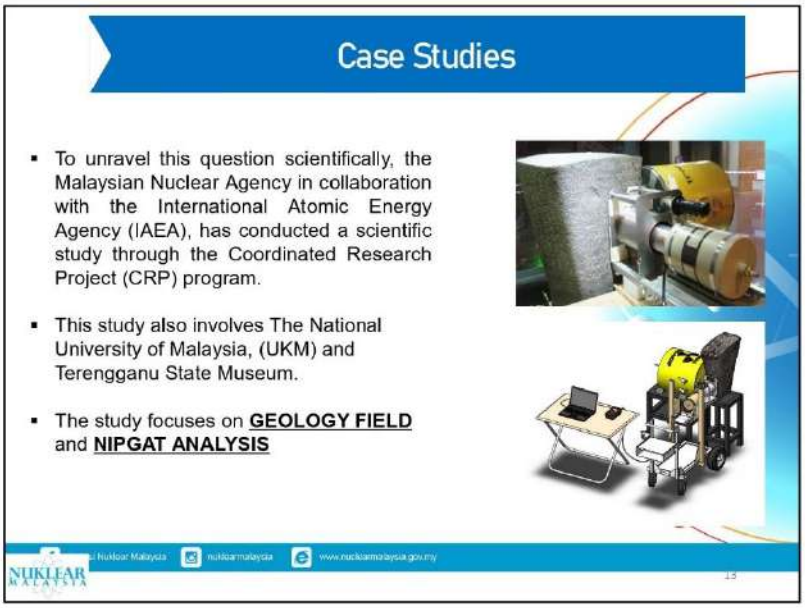
Case Studies
To unravel this question scientifically, the Malaysian Nuclear Agency in collaboration with the International Atomic Energy Agency (IAEA), has conducted a scientific study through the Coordinated Research Project (CRP) program.
This study also involves The National University of Malaysia, (UKM) and Terengganu State Museum.
The study focuses on GEOLOGY FIELD and NIPGAT ANALYSIS
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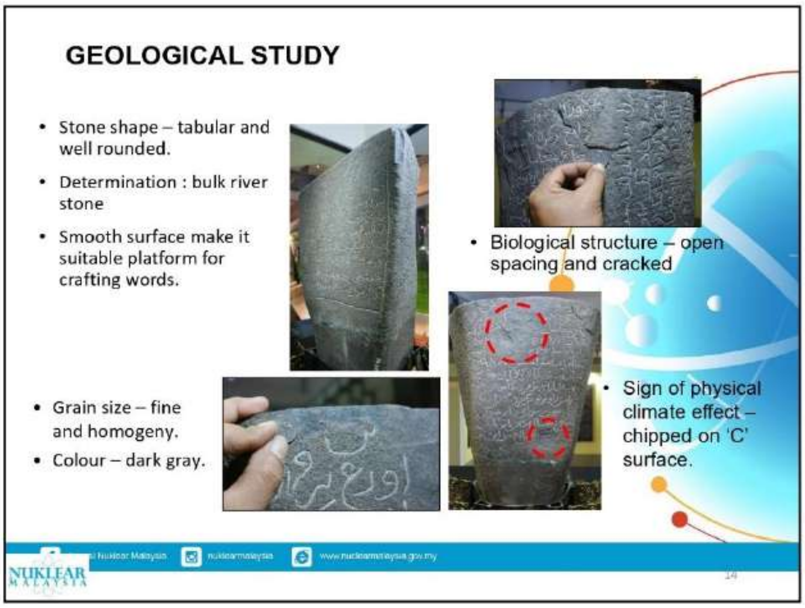
GEOLOGICAL STUDY
Stone shape – tabular and well rounded.
Determination : bulk river stone
Smooth surface make it suitable platform for crafting words.
Biological structure – open spacing and cracked
Grain size – fine and homogeny.
Colour – dark gray.
Sign of physical climate effect – chipped on 'C' surface.
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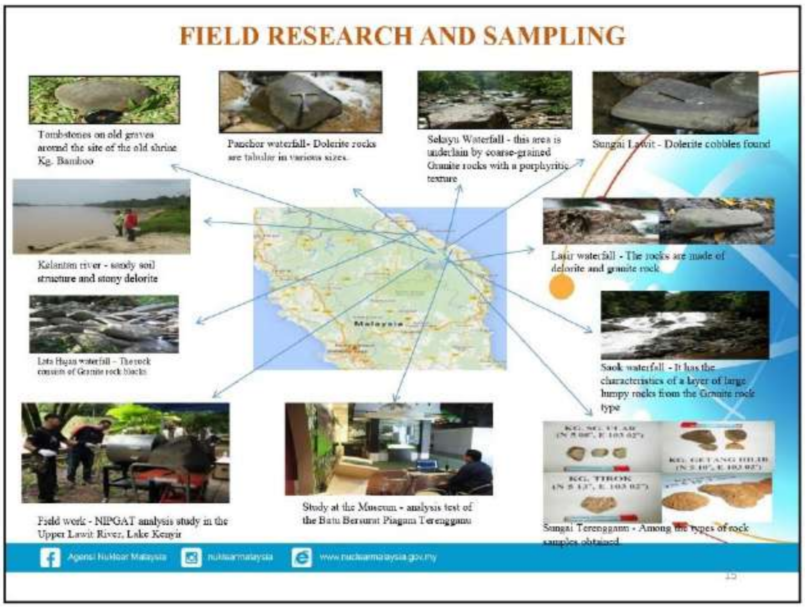
FIELD RESEARCH AND SAMPLING
Tombstones on old graves around the site of the old shrine Kg. Bamboo
Panchor waterfall- Dolerite rocks are tabular in various sizes.
Selayu Waterfall - this area is underlain by coarse-grained Granite rocks with a porphyritic texture
Sungai Lawit - Dolerite cobbles found
Kelantan river - sandy soil structure and stony delorite
Lasir waterfall - The rocks are made of delorite and granite rock
Lata Hujan waterfall – The rock consists of Granite rock blocks
Malaysia
Saok waterfall - It has the characteristics of a layer of large lumpy rocks from the Granite rock type
Field work - NIPGAT analysis study in the Upper Lawit River, Lake Kenyir
Study at the Museum - analysis test of the Batu Bersurat Piagam Terengganu
KG. TIROK
Sungai Terengganu - Among the types of rock samples obtained.
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GEOLOGICAL STUDY

Observations on location of the Inscribed Stone discovery – Tara River, Terengganu.

- Buluh village is an island sandbar left by the Terengganu River rejuvenation activities.
- In the east, the island is bordered by the River Tersat flowing from the south-west.
- The estimated topography height is less than 20m above sea level.

- Settlements are generally concentrated in the highlands and the shoulder of the island shelf. Terengganu River meander groove that has left the ground is now characterized by low alluvial river flat and is currently used as agricultural land.

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GEOLOGICAL STUDY

Observation at Sekayu River and Panchor River.

- Dolerite found in various structure – fine grain and coarse grain with dark and light in colour.
- Various size and shape of stone blocks.
- Sekayu river is shallow with narrow and fast stream. Deny the possibility of inscribed stone taken from this place due to difficulties to transport via raft or boat.

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Malaysian Nuclear Agency

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GEOLOGICAL STUDY

Early finding: high possibility of source location is upstream of Panchor River.

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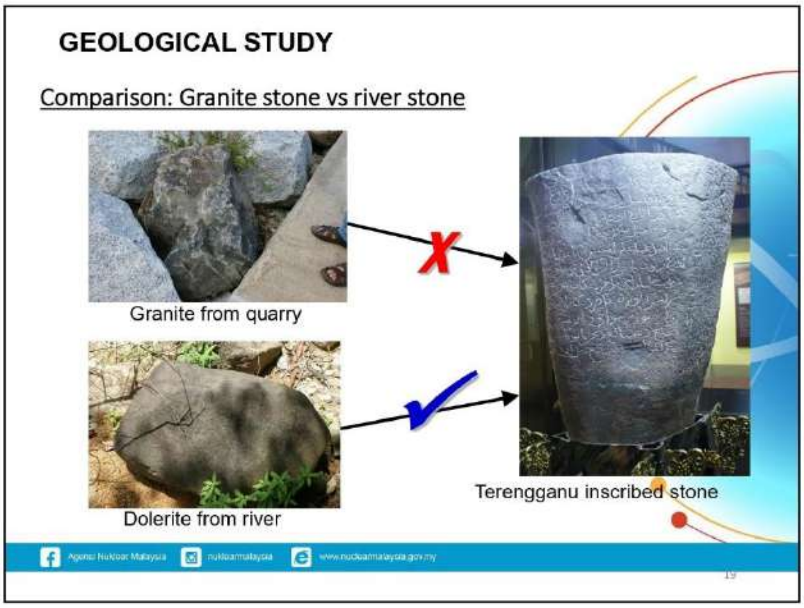
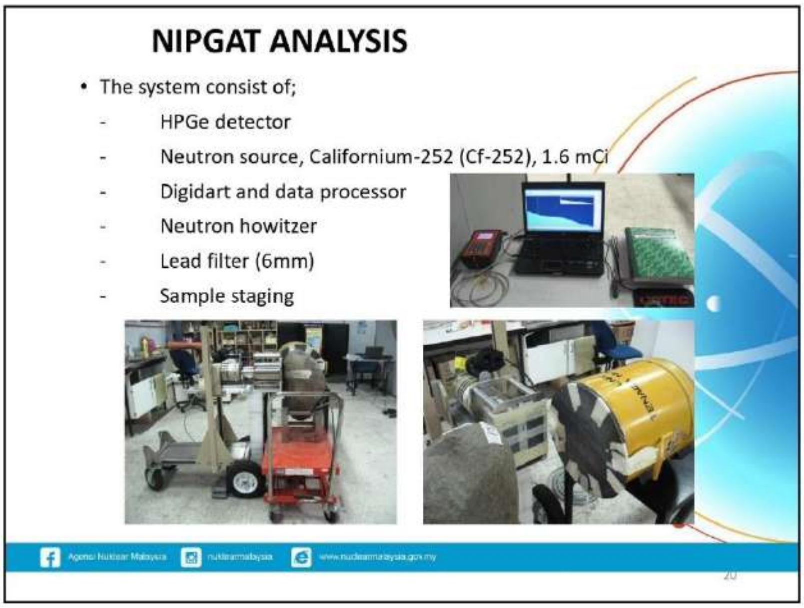
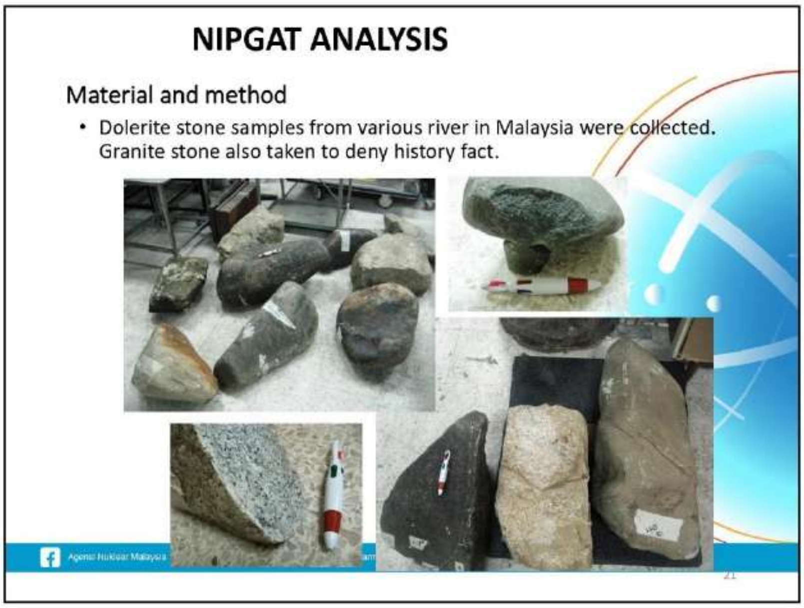
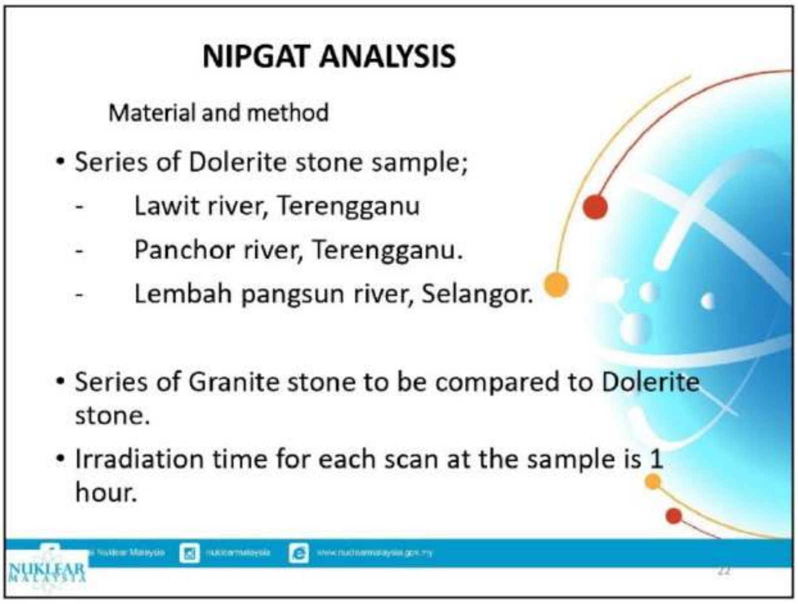

GEOLOGICAL STUDY
Comparison: Granite stone vs river stone
Granite from quarry
Dolerite from river
Terengganu inscribed stone


NIPGAT ANALYSIS
• The system consist of;
- HPGe detector
- Neutron source, Californium-252 (Cf-252), 1.6 mCi
- Digidart and data processor
- Neutron howitzer
- Lead filter (6mm)
- Sample staging


NIPGAT ANALYSIS
Material and method
• Dolerite stone samples from various river in Malaysia were collected. Granite stone also taken to deny history fact.


NIPGAT ANALYSIS
Material and method
• Series of Dolerite stone sample;
- Lawit river, Terengganu
- Panchor river, Terengganu.
- Lembah pangsun river, Selangor.
• Series of Granite stone to be compared to Dolerite stone.
• Irradiation time for each scan at the sample is 1 hour.
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NIPGAT ANALYSIS
Material and method
• Weathered surfaces were cleaned with no special treatment, to represent original feature of Inscribed stone.
• Sample is set between the NIPGAT system.
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NIPGAT ANALYSIS
In-situ Scanning, Terengganu's State Museum
• Scanning at original Batu Bersurat Piagam Terengganu
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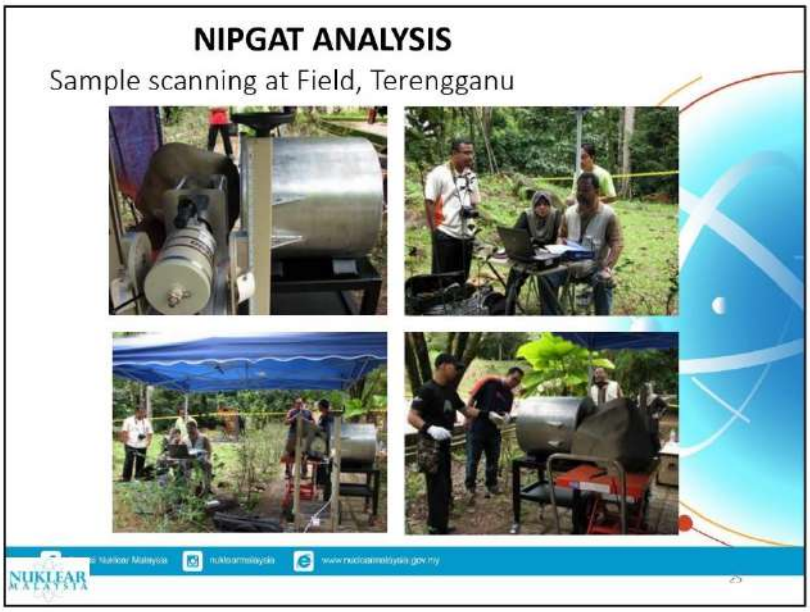
NIPGAT ANALYSIS
Sample scanning at Field, Terengganu
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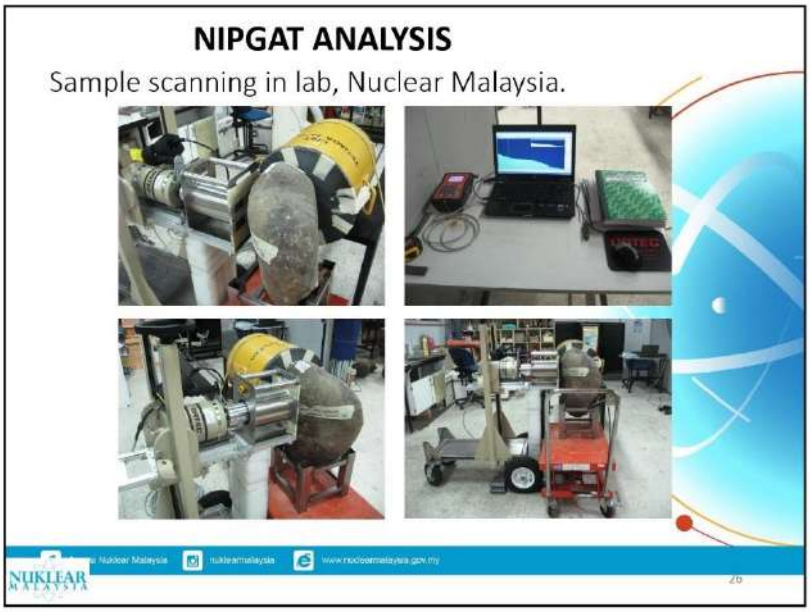
NIPGAT ANALYSIS
Sample scanning in lab, Nuclear Malaysia.
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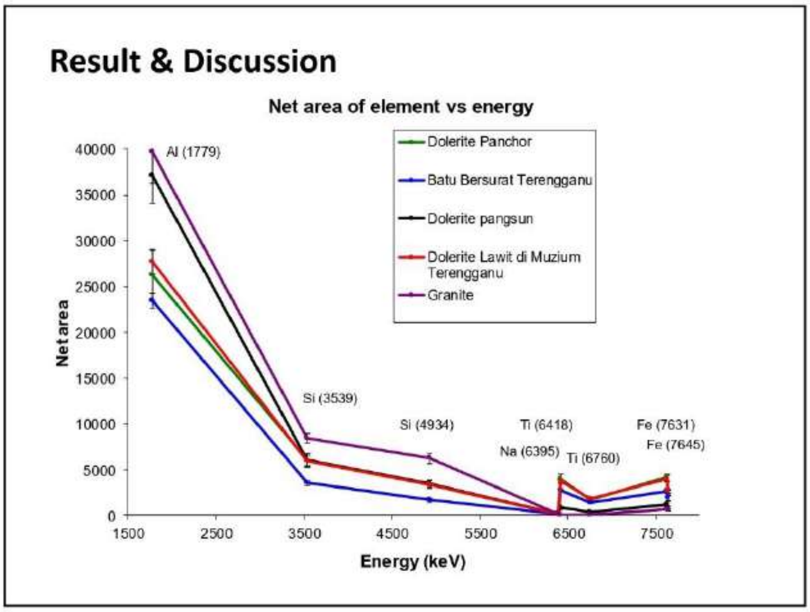
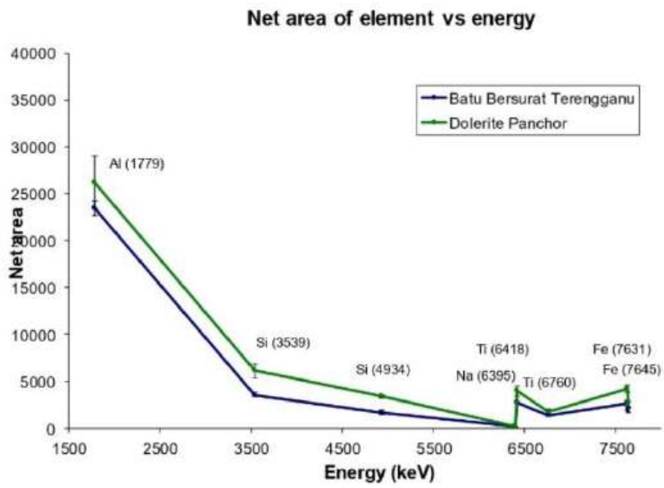

Result & Discussion
Net area of element vs energy
Dolerite Panchor
Batu Bersurat Terengganu
Dolerite pangsun
Dolerite Lawit di Muzium Terengganu
Granite
Al (1779)
Si (3539)
Si (4934)
Ti (6418)
Na (6395)
Ti (6760)
Fe (7631)
Fe (7645)
Net area
40000
35000
30000
25000
20000
15000
10000
5000
0
1500
2500
3500
4500
5500
6500
7500
Energy (keV)

Result & Discussion

- Large different of net area for Al can be seen on graph.
- Area of Al for Dolerite Pangsun is extremely higher than Dolerite from Panchor, Lawit and inscribed stone.
- Al for Dolerite Pangsun is similar to Granite.
- Net area of Si is for inscribed stone is low compared to Dolerite from other places. The different is extremely large to Net area of Si in Granite.
- For Ti, inscribed stone seems similar to Dolerite from Lawit and Panchor. Net area for Ti in Granite and Dolerite Pangsun is very low to be compared to inscribed stone.

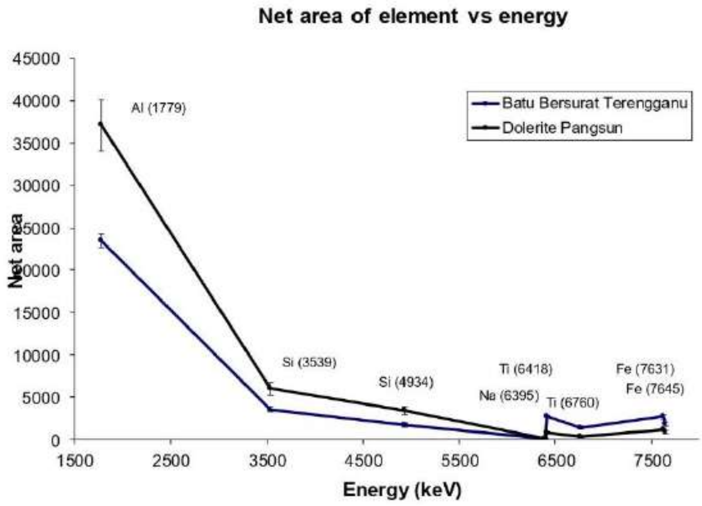
Result & Discussion



Result & Discussion

- Dolerite Panchor pattern seems similar to the inscribed stone.
- However, the area for Al, Si, Ti and Fe is slightly higher for Dolerite Panchor compared to inscribed stone.

Result & Discussion

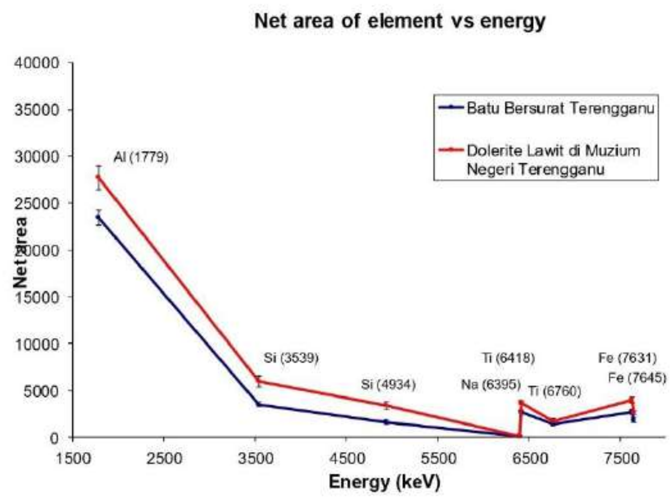


Result & Discussion

- Dolerite Pangsun has extremely higher net are of Al compared to the inscribed stone.
- Net area for Ti is low compared to inscribed stone.

Agensi Nuklear Malaysia nuklearmalaysia www.nuclearmalaysia.gov.my

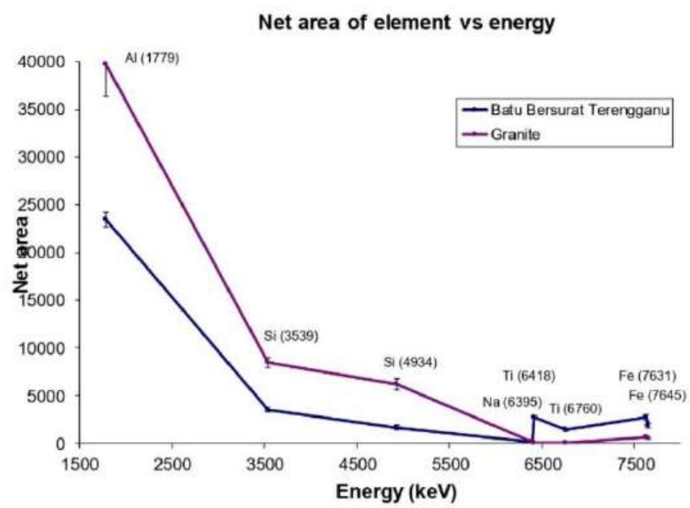
Result & Discussion



Result & Discussion

- Dolerite Lawit pattern seems similar to the inscribed stone.
- However, the area for Al, Si, Ti and Fe is slightly higher for Dolerite Lawit compared to inscribed stone.

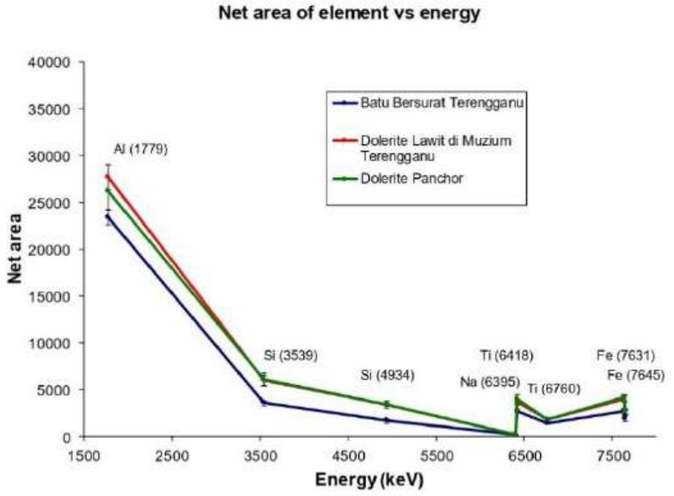
Result & Discussion



Result & Discussion

- Pattern of inscribed stone is exactly different from Granite stone.
- Different of Al net area is extremely large.
- Si pattern also at far and Ti for granite is very low to be compared to Dolerite from another place.

Result & Discussion



Result & Discussion

- Dolerite Lawit in Nuclear Malaysia shows different pattern from Dolerite Lawit in Muzium Negeri Terengganu and Dolerite Panchor.
- Al peak is very low compared to the others.

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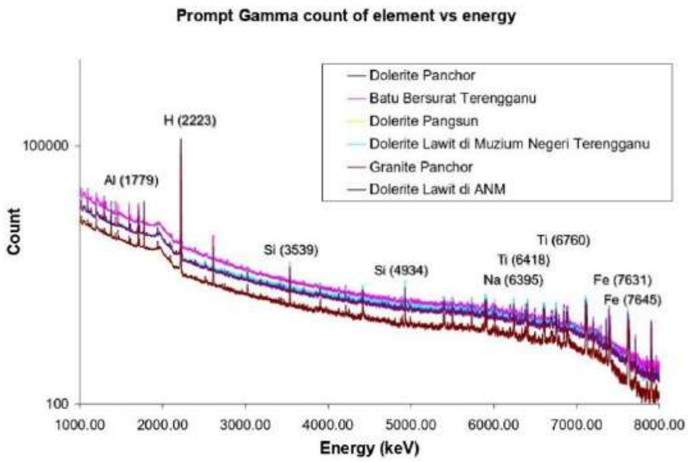
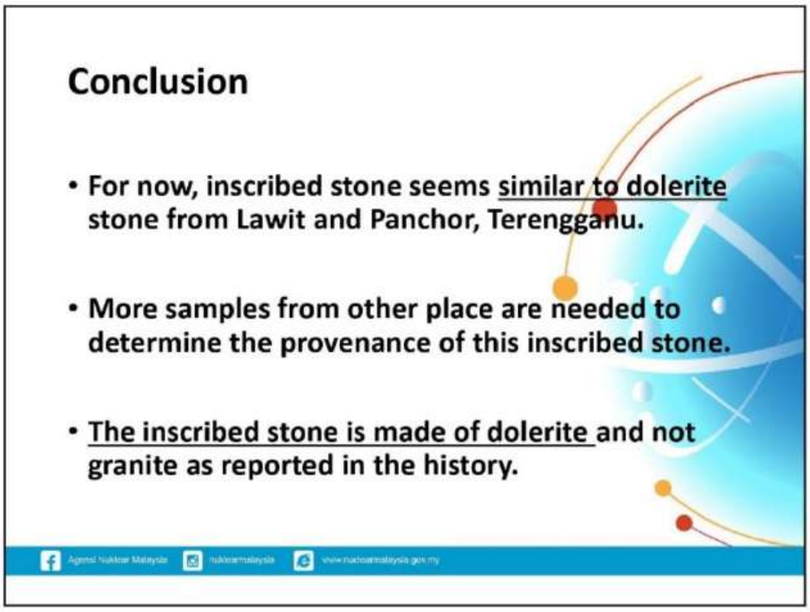
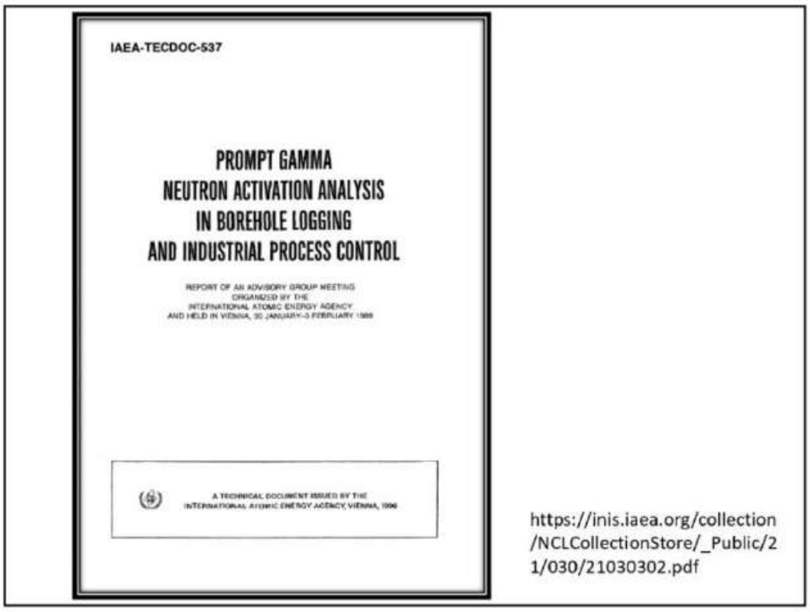
Result & Discussion

Energy peak spectrum for activated elements.




Conclusion
• For now, inscribed stone seems similar to dolerite stone from Lawit and Panchor, Terengganu.
• More samples from other place are needed to determine the provenance of this inscribed stone.
• The inscribed stone is made of dolerite and not granite as reported in the history.


IAEA-TECDOC-537
PROMPT GAMMA
NEUTRON ACTIVATION ANALYSIS
IN BOREHOLE LOGGING
AND INDUSTRIAL PROCESS CONTROL
https://inis.iaea.org/collection/NCLCollectionStore/_Public/21/030/21030302.pdf


Technical data on nucleonic gauges
IAEA

TECHNICAL ASPECT FOR OPERATING PORTABLE PROMPT GAMMA NEUTRON ACTIVATION ANALYSIS (PGNAA) ON TERENGGANU INSCRIBED STONE

ABSTRACTS

ABSTRACK

INTRODUCTION

Prompt Gamma Neutron Activation analysis (PGNAA) was first introduced around 30 years ago. Since then, the use of this technique in many areas has been growing as one of the non-destructive analytical methods based on nuclear techniques [1]-[3]. Along with the times and the needs of more complex

https://inis.iaea.org/collection/NCLCollectionStore/_Public/47/111/47111925.pdf

43

Quiz 1

PGNAA is a non-destructive analytical technique. What does this mean in the context of cultural heritage analysis?

A. It does not require specialized equipment
B. It is quick and easy to perform
C. It does not harm or damage the analysed objects
D. It can be conducted without trained personnel

44

Quiz 2

What type of information can be obtained through PGNAA in the analysis of cultural heritage?

A. DNA sequences of artifacts
B. Chemical composition of materials
C. Fossil dating
D. Social history of a civilization

45

Quiz 3

Which atomic particles are typically used to induce nuclear reactions in PGNAA for cultural heritage analysis?

A. Protons
B. Electrons
C. Neutrons
D. Photons

46

2.5 Application of Science and Technology in Marine Archaeological Studies

Name: Hasrizal Shaari
Date of Presentation: 24th October 2023
Email: riz@umt.gov.my

In marine archaeology, the confluence of science and technology has unveiled a significant chapter of history by excavating shipwrecks along the East Coast of Peninsular Malaysia. This region, historically a pivotal maritime route influenced by monsoonal winds, has witnessed the emergence of a unique underwater heritage site known as the Bidong shipwreck.

The discovery of the shipwreck, an incidental find by a local fisherman in 2012, sparked a series of scientific inquiries and archaeological pursuits helmed by Assoc. Prof. Dr. Hasrizal Bin Shaari from the Universiti Malaysia Terengganu (UMT). The site, now a gazetted National Heritage Zone, underwent its first excavation phase in November 2017. This pioneering endeavour was not merely about uncovering relics from the past but also about protecting Malaysia's rich underwater cultural heritage.

The excavation team, comprising around 25 divers contributing a cumulative 2760 man-hours, meticulously documented and rescued 306 ceramic artifacts during the initial phase. These items provided valuable insights into the trade activities that thrived in the region centuries ago. The ceramics, consisting of earthenware, stoneware, celadon, and porcelain, originate from the 13th to 16th centuries, with links to the *Sawankhalok* kilns in north-central Thailand.

A sophisticated suite of technological tools aided the archaeological process. Multibeam echosounder systems, such as the Klein 4900 Side Scan Sonar (SSS), offered high-resolution acoustic seabed images, facilitating the identification and mapping of potential shipwreck sites and artifacts. These images, captured by the sonar system towed by boat, revealed a detailed mosaic of the seabed, allowing for strategic planning of the excavation process.

The second phase of excavation, conducted in September 2022, advanced the research further by employing subsurface mapping techniques to reveal the wood remains of the ship, which had been buried due to sedimentation. This phase intensified the focus on the ship's structure and provided additional artifacts for study.

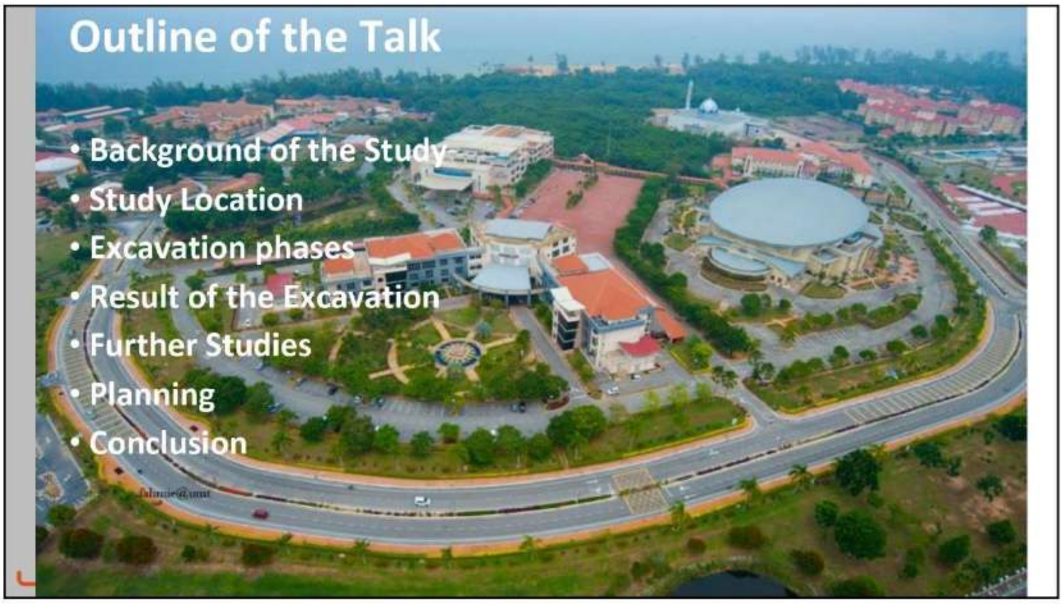
The artifacts recovered underwent rigorous recording, treatment, and preservation processes. The conservation approach balanced both destructive and non-destructive methods, ensuring the preservation of the artifacts' physical integrity while allowing for in-depth scientific analysis. This analysis entailed comparing similar artifacts in Southeast Asia, notably with collections in the Southeast Asia Ceramic Museum at Bangkok University and the National Maritime Museum in Chanthaburi, Thailand.

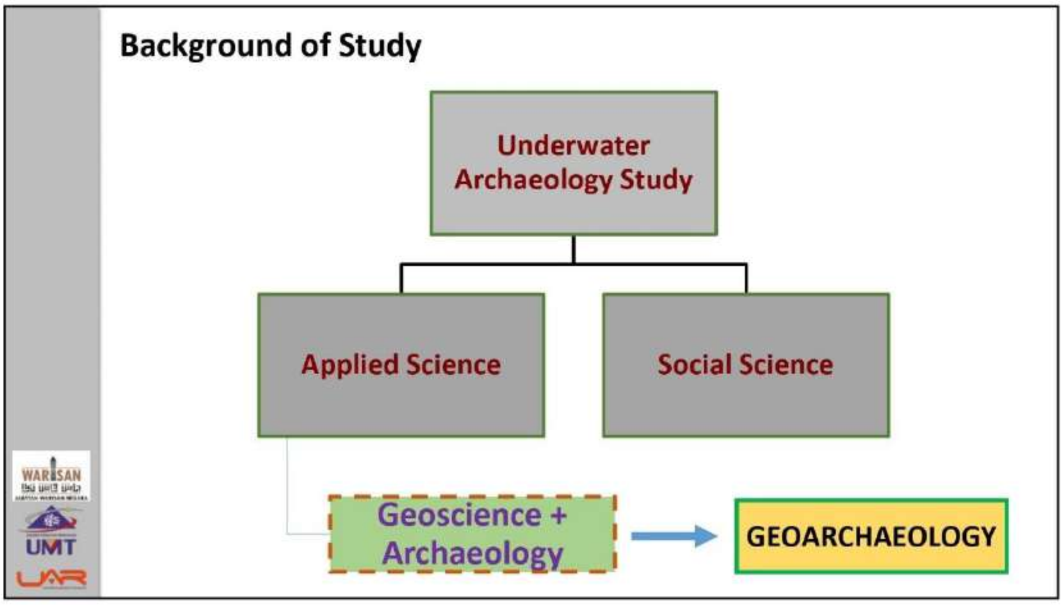
The scientific scrutiny extended beyond the ceramics, with wood fragments from the shipwreck undergoing analysis to determine the ship's age and origins. Species such as *Shorea Roxburghii* and *Hopea spp*., tropical trees from the region, were identified, offering clues to the ship's construction materials.

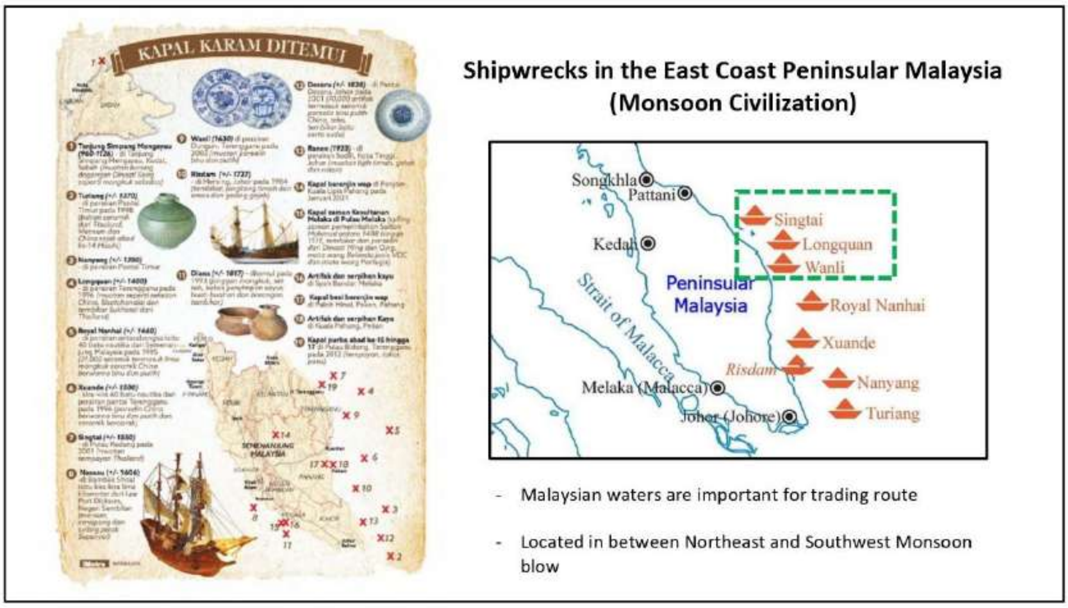
Future analytical plans include petrography studies of the ceramics and colour reflectance analyses, which will contribute to the body of knowledge concerning ceramic production and trade in historical Southeast Asia. Manuscripts detailing these findings are in various stages of preparation and review, promising to add a new narrative to the story of the Bidong shipwreck based on the latest excavations.

In conclusion, the Bidong shipwreck excavation exemplifies the fusion of geoscience and archaeology within the broader scope of social sciences. The application of nuclear techniques for characterising and preserving artifacts underscores the interdisciplinary nature of the contemporary archaeological practice. Through these scientific endeavours, a new understanding of the Monsoon Civilization's maritime history is emerging, painting a richer picture of the past for scholars and the public alike. The slides in the upcoming section detail the work done on this.

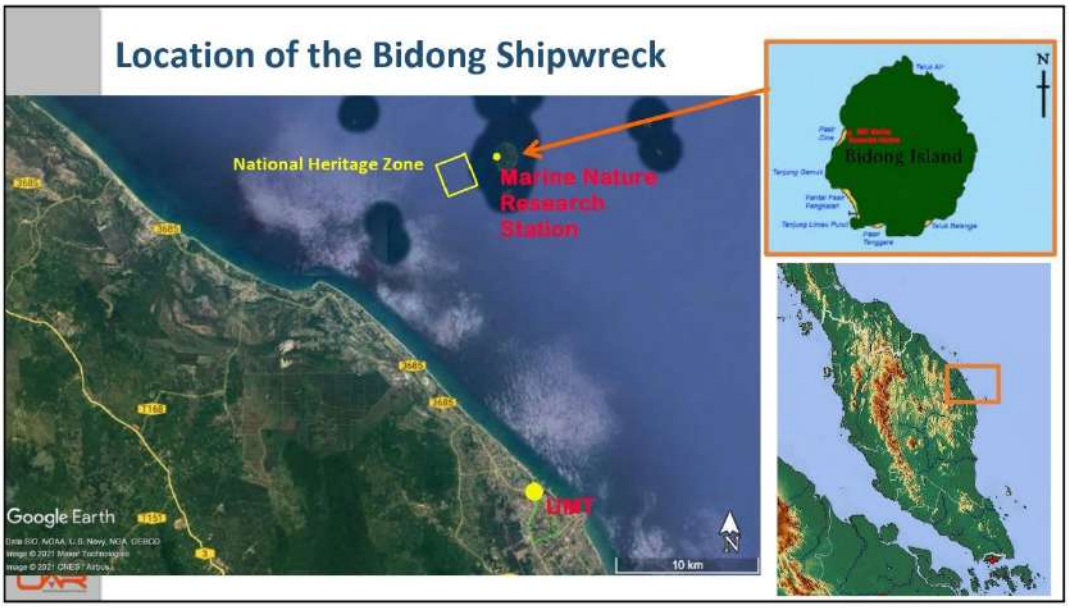

Regional Training Course on "THE APPLICATION OF NUCLEAR TECHNIQUES FOR CHARACTERIZATION AND PRESERVATION OF THE ARTIFACTS OBTAINED FROM THE SHIPWRECK"
UAR
Uzma Archaeological Research
Universiti Malaysia Terengganu
UMT
WARISAN
JABATAN WARISAN NEGARA
Application of Science and Technology in Marine Archaeological Studies
ASSOC. PROF. DR. HASRIZAL BIN SHAARI
Director
Centre of Research and Field Services (CRaFS),
Universiti Malaysia Terengganu (UMT)
Email: riz@umt.edu.my


Outline of the Talk
• Background of the Study
• Study Location
• Excavation phases
• Result of the Excavation
• Further Studies
• Planning
• Conclusion


Background of Study
Underwater Archaeology Study
Applied Science
Social Science
Geoscience + Archaeology
GEOARCHAEOLOGY
WARISAN
UMT
UAR

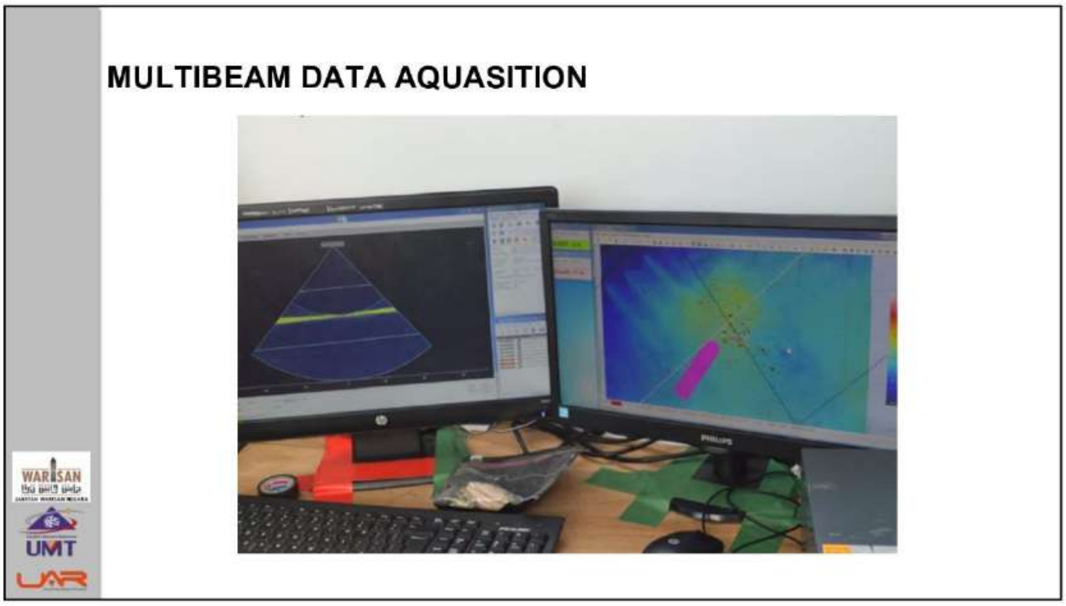

KAPAL KARAM DITEMUI
Shipwrecks in the East Coast Peninsular Malaysia
(Monsoon Civilization)
Songkhla
Pattani
Kedah
Strait of Malacca
Peninsular Malaysia
Singtai
Longquan
Wanli
Royal Nanhai
Xuande
Risdam
Nanyang
Turiang
Melaka (Malacca)
Johor (Johore)
- Malaysian waters are important for trading route
- Located in between Northeast and Southwest Monsoon blow

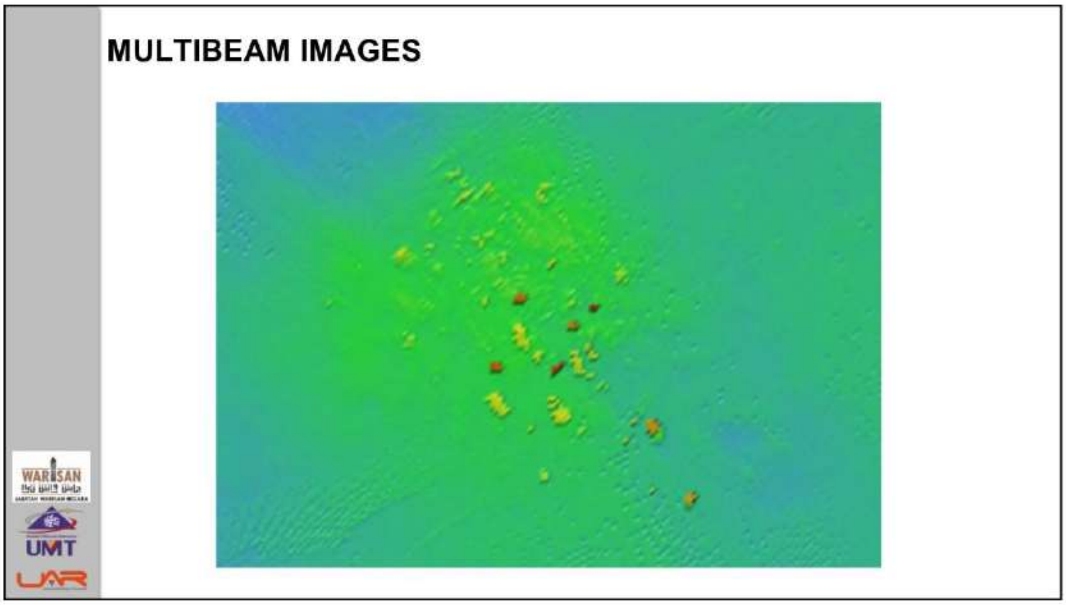

BACKGROUND
• Accidental meeting by local fisherman Encik Zazeri Ajang Yusof in 2012
• The registered excavation license code is T/BSW/S/17(1)
• 1st excavation November 2017 JWN.PP.600 / 3/3 (3)
• Gazetted of the site as a Heritage Protection Zone in 2018
• 2nd Excavation in September 2022
MOTIVATION
• This is the first shipwreck in shallow waters in Terengganu and close to the UMT research station.
• Conducting proper scientific excavations, protection and conservation of the artifacts found.
• Responsible for protecting the country's underwater cultural heritage.
WARISAN
UMT

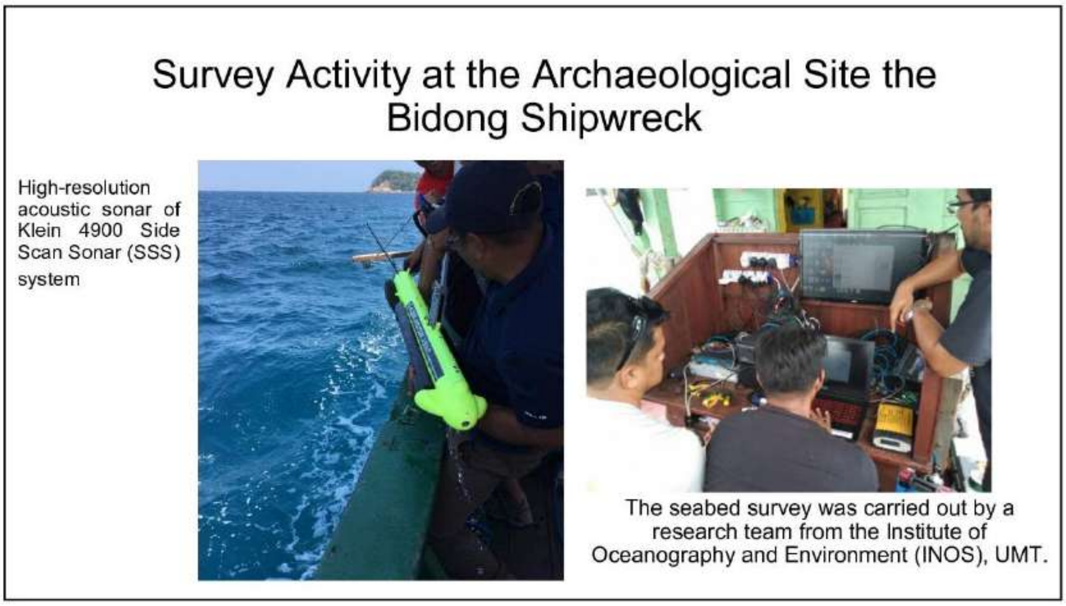

Location of the Bidong Shipwreck
National Heritage Zone
Marine Nature Research Station
UMT
Google Earth
10 km
N
Bidong Island

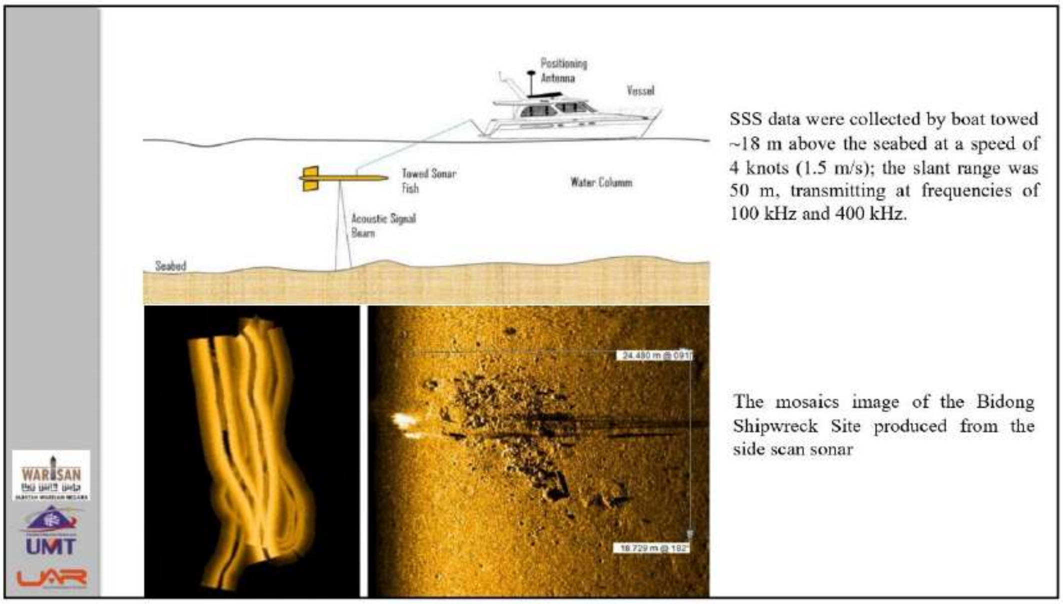

Bidong Island
UMT Marine Nature Research Station

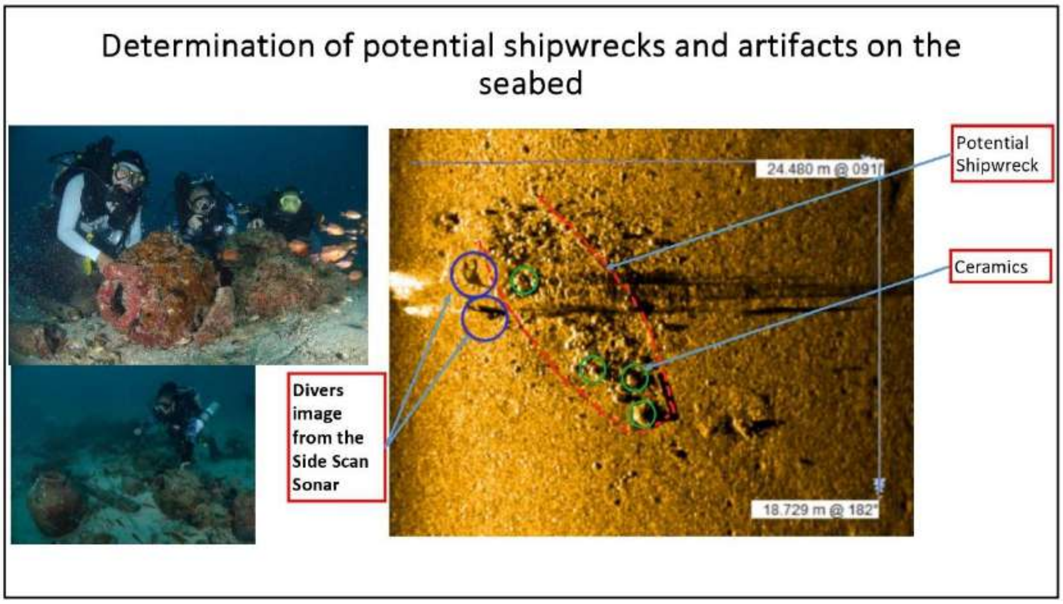

1st Phase Excavation - 2017

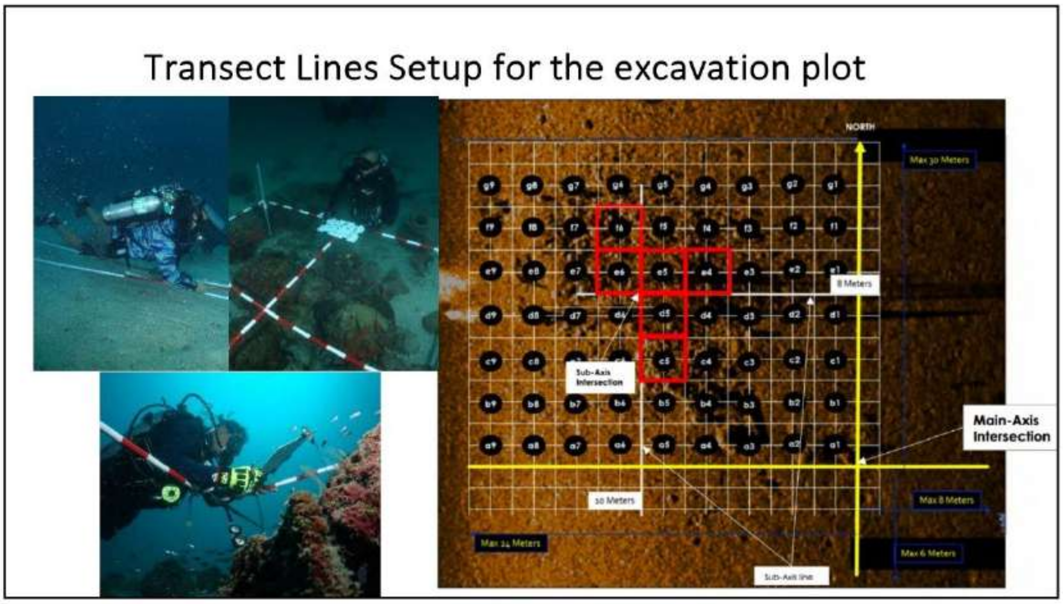

MULTIBEAM DATA AQUASITION


MULTIBEAM IMAGES


Survey Activity at the Archaeological Site the Bidong Shipwreck
High-resolution acoustic sonar of Klein 4900 Side Scan Sonar (SSS) system
The seabed survey was carried out by a research team from the Institute of Oceanography and Environment (INOS), UMT.


Positioning Antenna
Vessel
Towed Sonar Fish
Water Column
Acoustic Signal Beam
Seabed
SSS data were collected by boat towed ~18 m above the seabed at a speed of 4 knots (1.5 m/s); the slant range was 50 m, transmitting at frequencies of 100 kHz and 400 kHz.
24.480 m @ 091
18.729 m @ 182
The mosaics image of the Bidong Shipwreck Site produced from the side scan sonar
UMT


Determination of potential shipwrecks and artifacts on the seabed
Potential Shipwreck
Ceramics
24.480 m @ 091
18.729 m @ 182
Divers image from the Side Scan Sonar

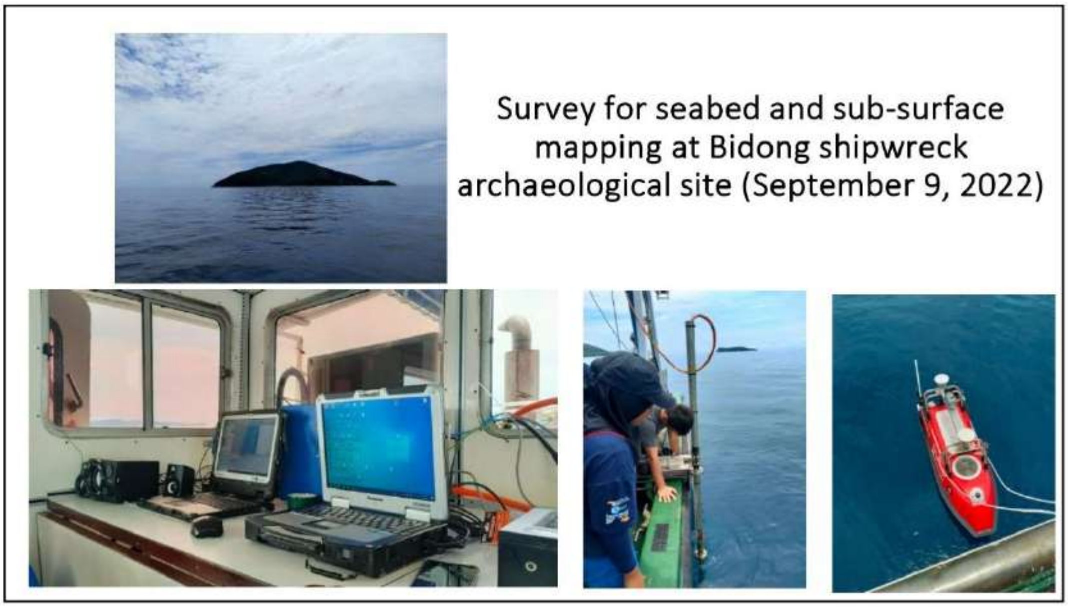

Transect Lines Setup for the excavation plot
NORTH
8 Meters
Sub-Axis Intersection
Main-Axis Intersection
Sub-Axis line

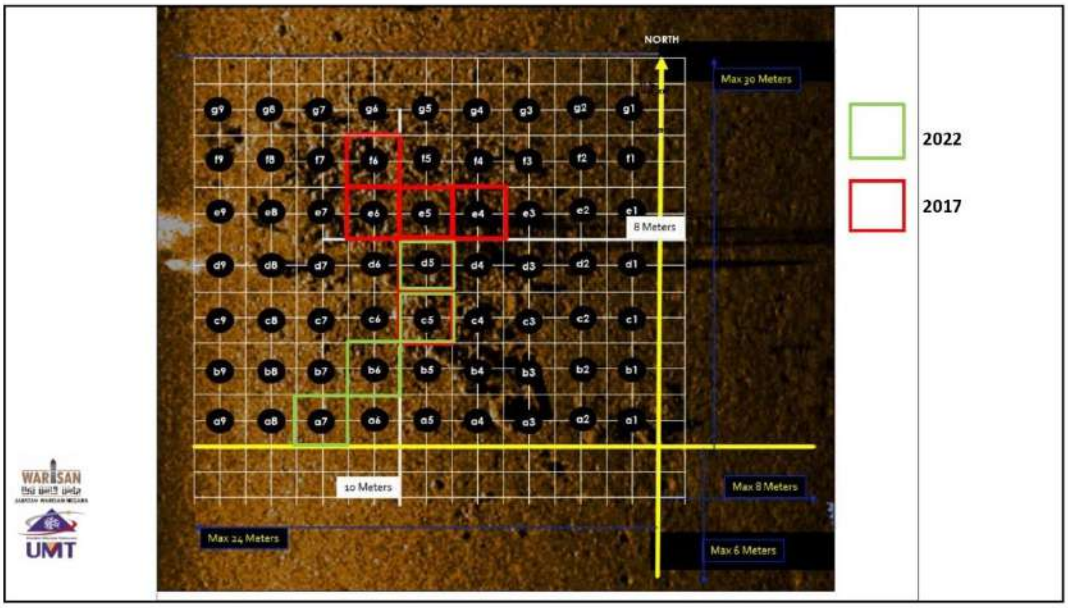

Penyelamatan &
Perekodan
WARISAN
UMT

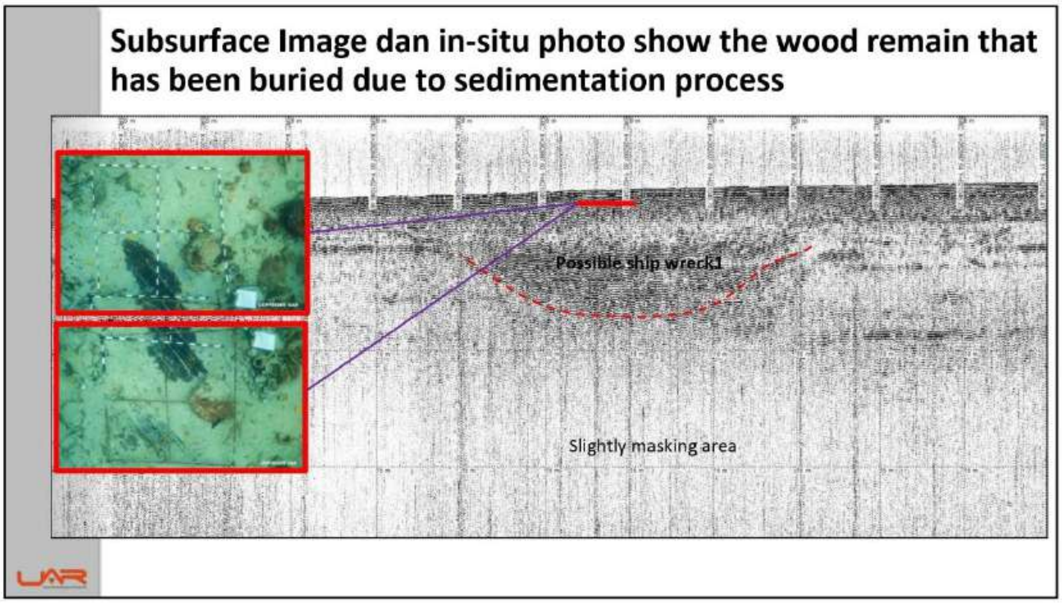

Rescuing &
Recording
Massive Operation
• Involved ~25 Divers
• 2760 Man-hours
WARISAN
UMT


Among the Artifacts
Discovered during the
1st phase excavation
306 Discovered
Ceramics
WARISAN
UMT


2nd Phase Excavation - 2022

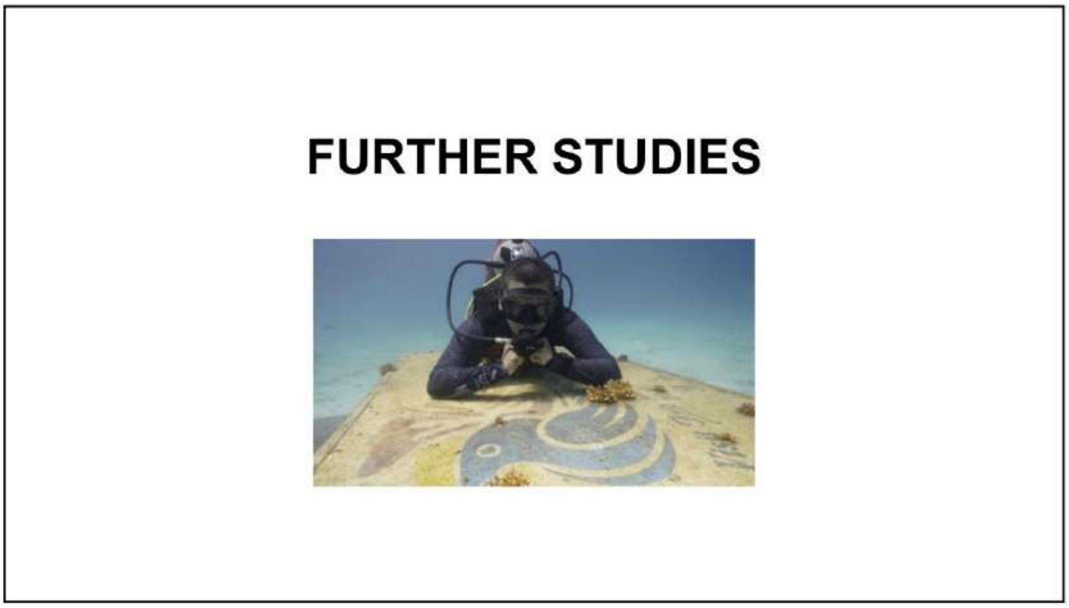

Survey for seabed and sub-surface
mapping at Bidong shipwreck
archaeological site (September 9, 2022)


NORTH
Max 30 Meters
8 Meters
10 Meters
Max 8 Meters
Max 24 Meters
Max 6 Meters
2022
2017
WARISAN
UMT


Subsurface Image dan in-situ photo show the wood remain that has been buried due to sedimentation process
Possible ship wreck1
Slightly masking area

ARTIFACTS RECORDING, TREATMENT AND STORING

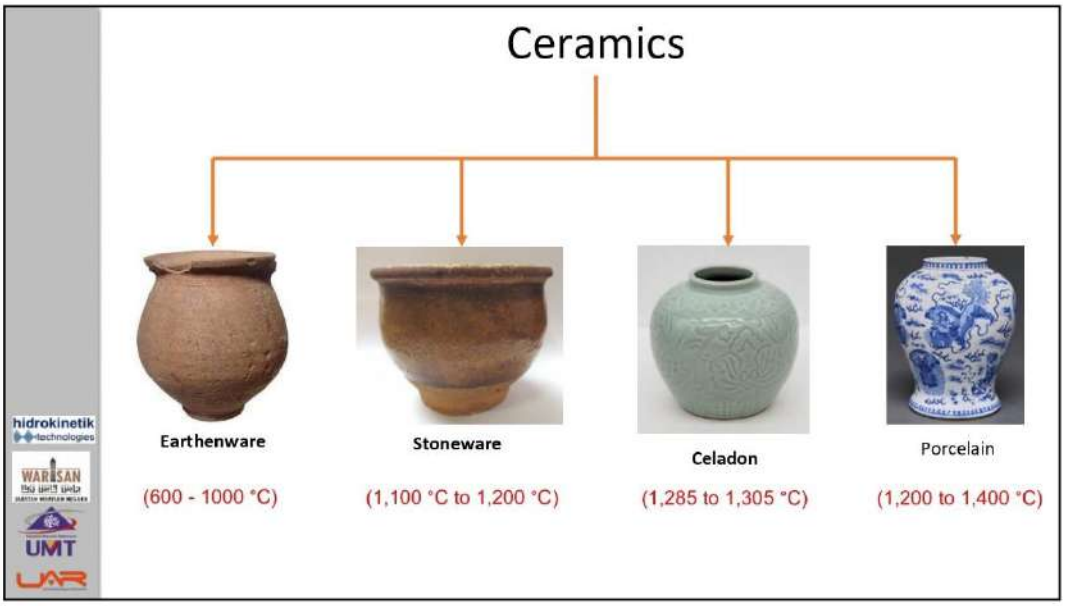

Preservation & Storage
WARISAN
UMT

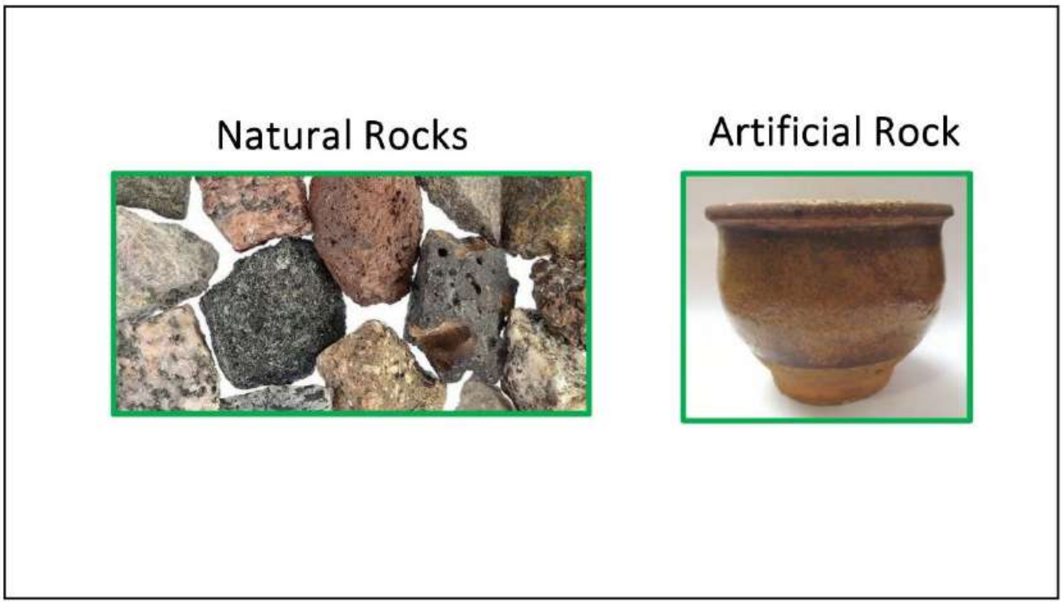

FURTHER STUDIES

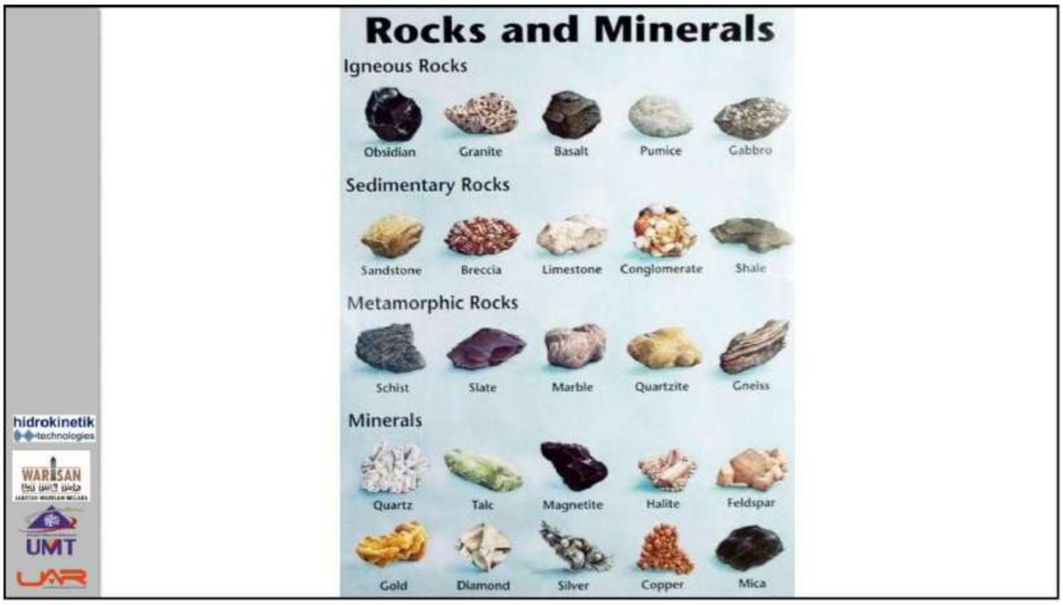

Physical evidence on the pattern and shape of artefacts showed the probable type of Si Satchanalai and Maenam Noi, Thailand from the 1st phase excavation
Relative Comparison
WARISAN
UMT

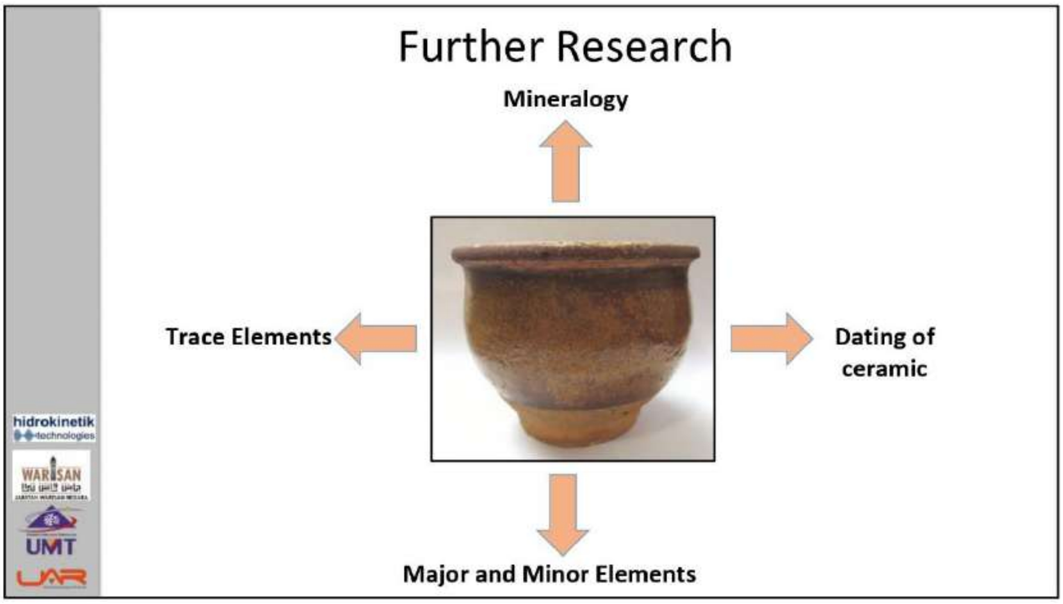

Relative Comparison - Southeast Asia Ceramic Museum Bangkok University, Thailand

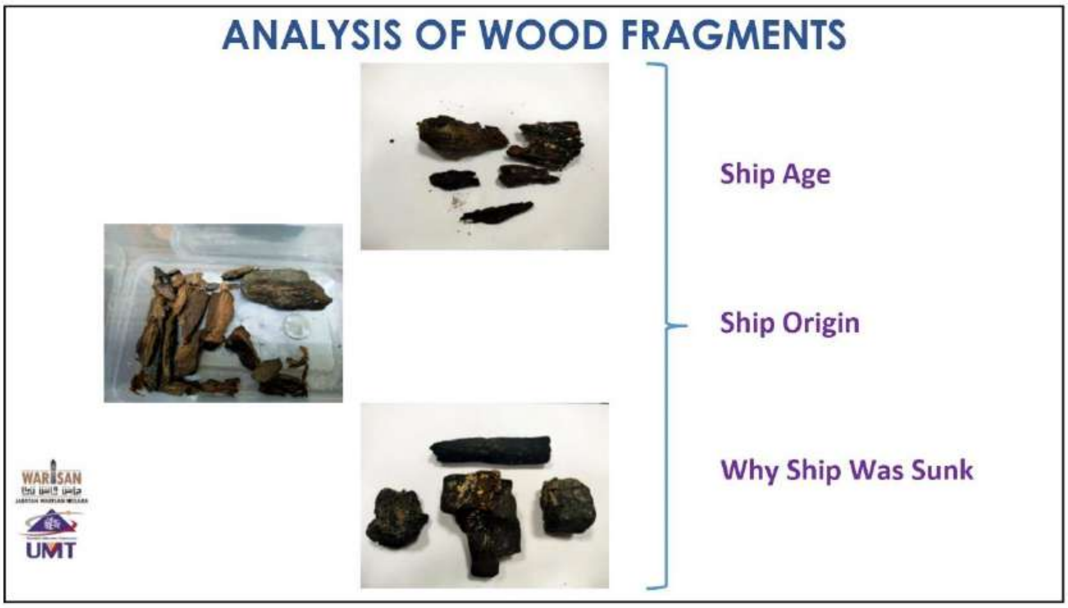

Relative Comparison - National Maritim Museum Chanthaburi, Thailand

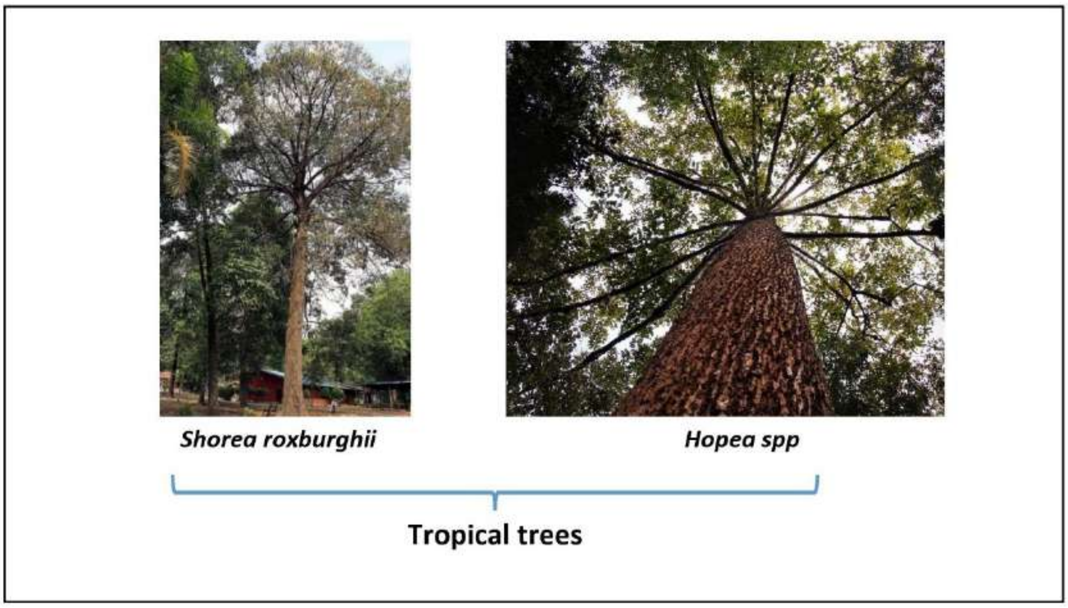

Ceramics
Earthenware
(600 - 1000 °C)
Stoneware
(1,100 °C to 1,200 °C)
Celadon
(1,285 to 1,305 °C)
Porcelain
(1,200 to 1,400 °C)
hidrokinetik
technologies
UMT

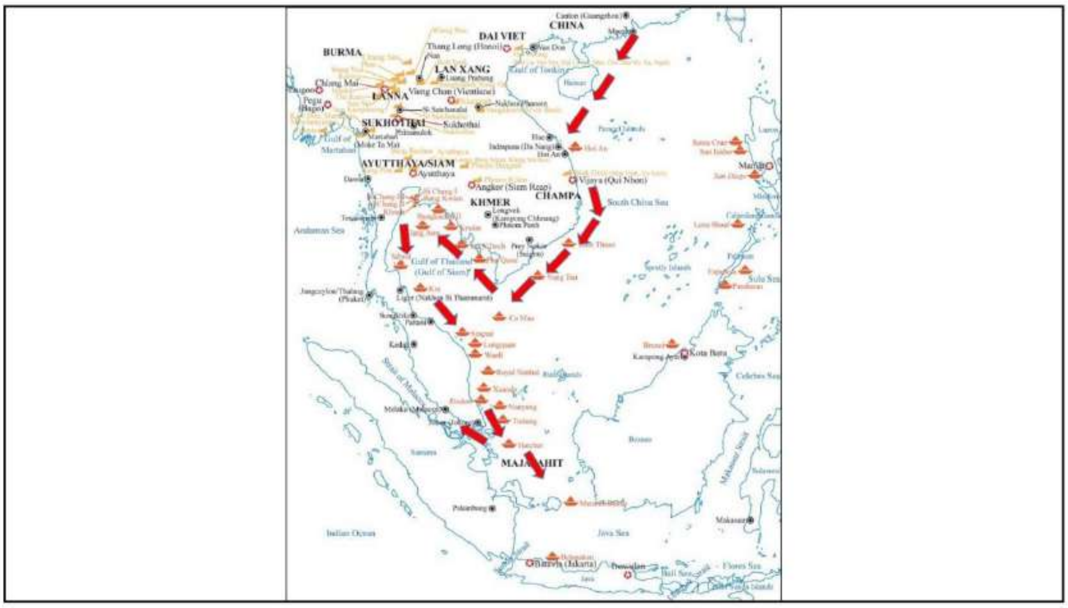

Natural Rocks
Artificial Rock

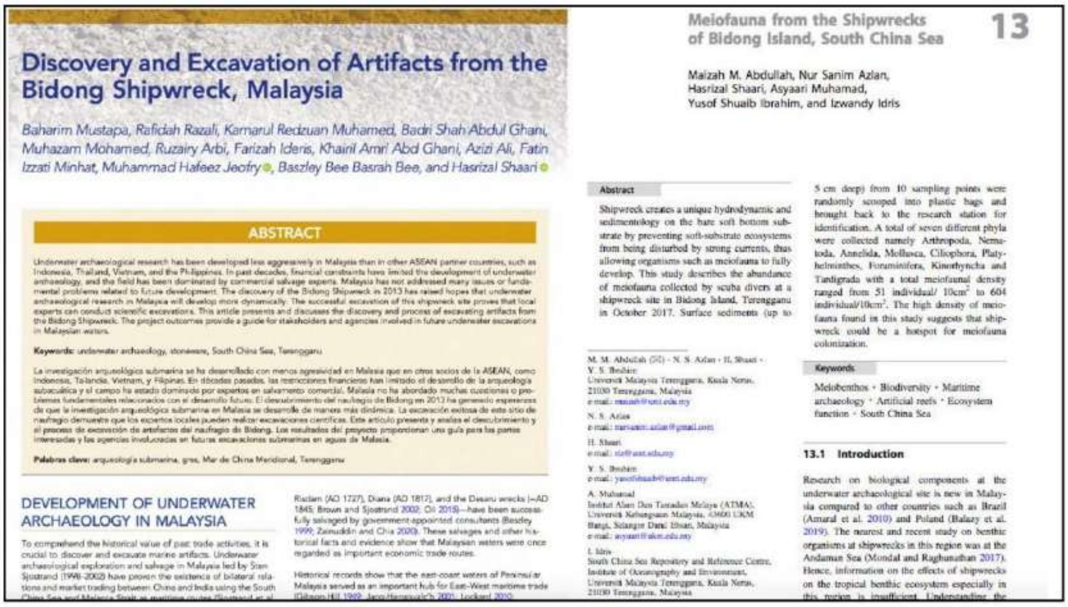

Rocks and Minerals
Igneous Rocks
Obsidian
Granite
Basalt
Pumice
Gabbro
Sedimentary Rocks
Sandstone
Breccia
Limestone
Conglomerate
Shale
Metamorphic Rocks
Schist
Slate
Marble
Quartzite
Gneiss
Minerals
Quartz
Talc
Magnetite
Halite
Feldspar
Gold
Diamond
Silver
Copper
Mica
hidrokinetik
technologies
WARISAN
UMT


Further Research
Mineralogy
Trace Elements
Dating of ceramic
Major and Minor Elements
hidrokinetik
technologies
WARISAN
UMT


ANALYSIS OF WOOD FRAGMENTS
Ship Age
Ship Origin
Why Ship Was Sunk
WARISAN
UMT


Shorea roxburghii
Hopea spp
Tropical trees


CHINA
DAI VIET
BURMA
LAN XANG
LANNA
SUKHOTHAI
AYUTTHAYA/SIAM
KHMER
CHAMPA
MAJAPAHIT



Discovery and Excavation of Artifacts from the Bidong Shipwreck, Malaysia

Baharim Mustapa, Rafidah Razali, Kamarul Redzuan Muhamed, Badri Shah Abdul Ghani, Muhazam Mohamed, Ruzairy Arbi, Farizah Ideris, Khairil Amri Abd Ghani, Azizi Ali, Fatin Izzati Minhat, Muhammad Hafeez Jeofry, Baszley Bee Basrah Bee, and Hasrizal Shaari

ABSTRACT

Underwater archaeological research has been developed less aggressively in Malaysia than in other ASEAN partner countries, such as Indonesia, Thailand, Vietnam, and the Philippines. In past decades, financial constraints have limited the development of underwater archaeology, and the field has been dominated by commercial salvage experts. Malaysia has not addressed many issues or fundamental problems related to future development. The discovery of the Bidong Shipwreck in 2013 has raised hopes that underwater archaeological research in Malaysia will develop more dynamically. The successful excavation of this shipwreck site proves that local experts can conduct scientific excavations. This article presents and discusses the discovery and process of excavating artifacts from the Bidong Shipwreck. The project outcomes provide a guide for stakeholders and agencies involved in future underwater excavations in Malaysian waters.

Keywords: underwater archaeology, stoneware, South China Sea, Terengganu

DEVELOPMENT OF UNDERWATER ARCHAEOLOGY IN MALAYSIA

To comprehend the historical value of past trade activities, it is crucial to discover and excavate marine artifacts. Underwater archaeological exploration and salvage in Malaysia led by Sten Sjostrand (1998–2002) have proven the existence of bilateral relations and market trading between China and India using the South China Sea and Malacca Strait as maritime routes ...

Risdam (AD 1727), Diana (AD 1817), and the Desaru wrecks (~AD 1845; Brown and Sjostrand 2002; Oii 2015)—have been successfully salvaged by government-appointed consultants (Besdey 1999; Zainuddin and Chia 2020). These salvages and other historical facts and evidence show that Malaysian waters were once regarded as important economic trade routes.

Historical records show that the east-coast waters of Peninsular Malaysia served as an important hub for East-West maritime trade ...

13 Meiofauna from the Shipwrecks of Bidong Island, South China Sea

Maizah M. Abdullah, Nur Sanim Azlan, Hasrizal Shaari, Asyaari Muhamad, Yusof Shuaib Ibrahim, and Izwandy Idris

Abstract

Shipwreck creates a unique hydrodynamic and sedimentology on the bare soft bottom substrate by preventing soft-substrate ecosystems from being disturbed by strong currents, thus allowing organisms such as meiofauna to fully develop. This study describes the abundance of meiofauna collected by scuba divers at a shipwreck site in Bidong Island, Terengganu in October 2017. Surface sediments (up to 5 cm deep) from 10 sampling points were randomly scooped into plastic bags and brought back to the research station for identification. A total of seven different phyla were collected namely Arthropoda, Nematoda, Annelida, Mollusca, Ciliophora, Platyhelminthes, Foraminifera, Kinorhyncha and Tardigrada with a total meiofaunal density ranged from 51 individual/ $10cm^2$ to 604 individual/$10cm^2$. The high density of meiofauna found in this study suggests that shipwreck could be a hotspot for meiofauna colonization.

Keywords

Meiobenthos · Biodiversity · Maritime archaeology · Artificial reefs · Ecosystem function · South China Sea

13.1 Introduction

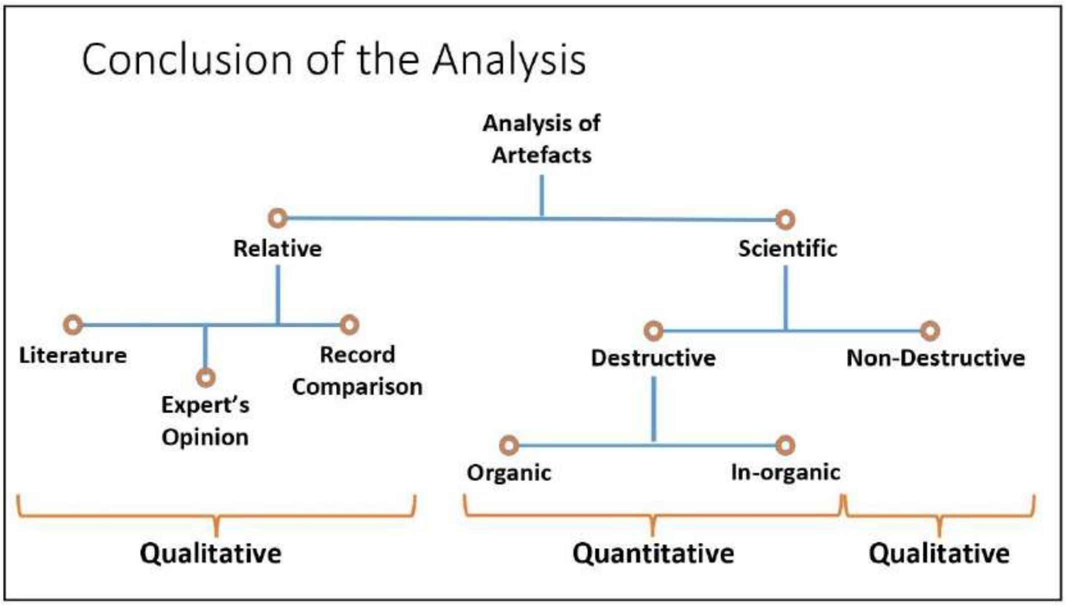
Research on biological components at the underwater archaeological site is new in Malaysia compared to other countries such as Brazil (Amaral et al. 2010) and Poland (Balazy et al. 2019). The nearest and recent study on benthic organisms at shipwrecks in this region was at the Andaman Sea (Mondal and Raghunathan 2017). Hence, information on the effects of shipwrecks on the tropical benthic ecosystem especially in this region is insufficient. ...

Future analytical planning:

- Petrography study of the ceramics
- Color reflectance of the ceramics

Manuscripts in pipeline

1. **Potential Application of Seabed Mapping in Underwater Archaeological Research in Malaysia: A Review (Under review)**
2. **The Preliminary Dating of the Bidong Shipwreck, Malaysia (Under review)**
3. **The Origin of The Bidong Shipwreck, Malaysia (draft and will be submitted soon)**
4. **New Narrative of the Bidong Shipwreck Based on the Second Phase Excavation (draft)**
5. **Mineral composition of ceramic from the Bidong Shipwreck (draft)**
6. **Microstructure of discovered ceramics from Bidong Shipwreck (draft)**


Conclusion of the Analysis
Analysis of Artefacts
Relative
Scientific
Literature
Expert's Opinion
Record Comparison
Destructive
Non-Destructive
Organic
In-organic
Qualitative
Quantitative
Qualitative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THANK YOU
www.umt.edu.my
ASSOC. PROF. DR. HASRIZAL SHAARI
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CENTRE OF RESEARCH AND FIELD SERVICE (CRaFS),
UNIVERSITI MALAYSIA TERENGGANU.
Email: riz@umt.edu.my

2.6 Application of Nuclear Techniques for Characterization and Preservation of Artifacts: Focus on Disinfestation and Disinfection: Biocidal Treatments of Collections

Name: Laurent Cortella
Date of Presentation: 24th October 2023
Email: laurent.cortella@cea.fr

Preserving our cultural heritage is paramount, and technological advancements have opened up new avenues for protecting artifacts from the ravages of time. One remarkable method that has gained prominence is the application of nuclear techniques in preserving and characterising artifacts. This article delves into the fascinating world of using nuclear technology to safeguard our precious historical treasures.

Artifacts, whether ancient manuscripts, sculptures, or delicate textiles, are susceptible to biodeterioration caused by insects, fungi, and other microorganisms. One of the groundbreaking solutions to combat this threat is gamma rays, a form of ionizing radiation. Controlled exposure to gamma radiation can effectively eradicate wood-boring insects, fungi, and other pests that compromise the integrity of artifacts.

The effectiveness of gamma rays in eradicating insects is a matter of dose. Through meticulous research, scientists have determined specific doses that cause the death of cells and, consequently, the affected organisms. Certain insects, such as eggs, are more sensitive to radiation, making them easier to eradicate. This precise control over the radiation dose ensures the preservation of artifacts while eliminating the threats posed by pests.

In addition to insects, fungi pose a significant threat to various artifacts, especially those made of organic materials like paper and wood. Gamma irradiation, coupled with concurrent treatments, has effectively controlled postharvest diseases like Botrytis cinerea in cut roses. The dose required for fungicidal treatment depends on the species and the initial biological load of the artifact. Striking the right balance is crucial to ensure the artifact remains intact while the fungi are eliminated.

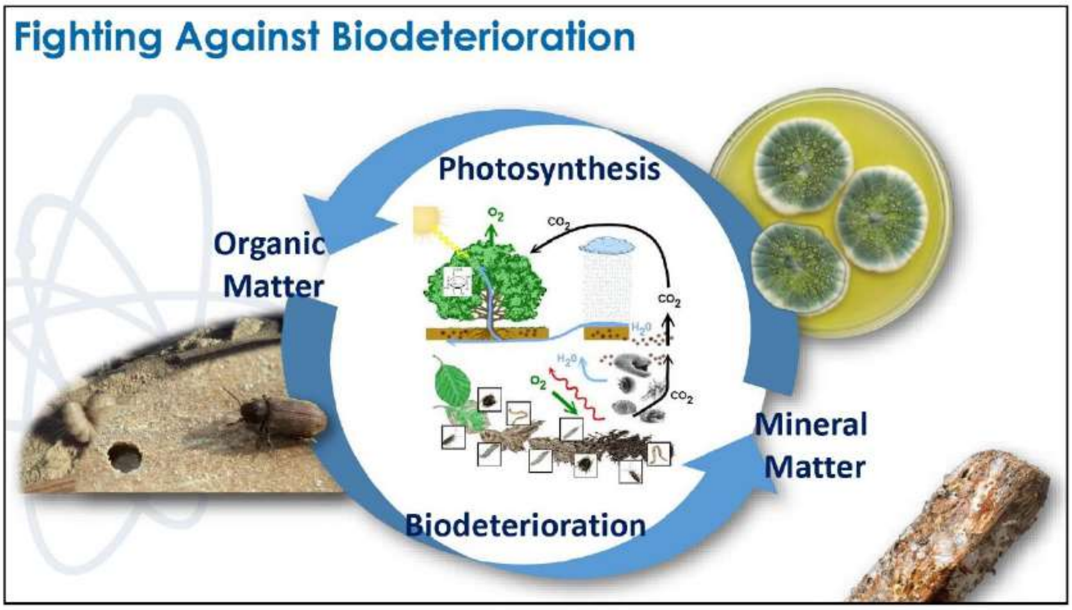
While the application of ionizing radiation is highly practical, it has challenges. Controlling the dose rate, considering factors such as distance to the radiation source and the object's thickness, is essential to avoid overexposure. Scientists meticulously monitor the artifacts' color, physical integrity, and molecular structure to guarantee they remain unchanged during the preservation process.

Preserving vast collections, such as those in the National Archives, presents unique challenges. The discovery of mold-contaminated documents necessitated a large-scale solution. Fumigation with ethylene oxide, while practical, raised safety concerns due to the dangerous nature of the chemical. To address this, scientists explored alternative methods, including irradiation, ensuring both the artifacts and the preservation experts remain safe.

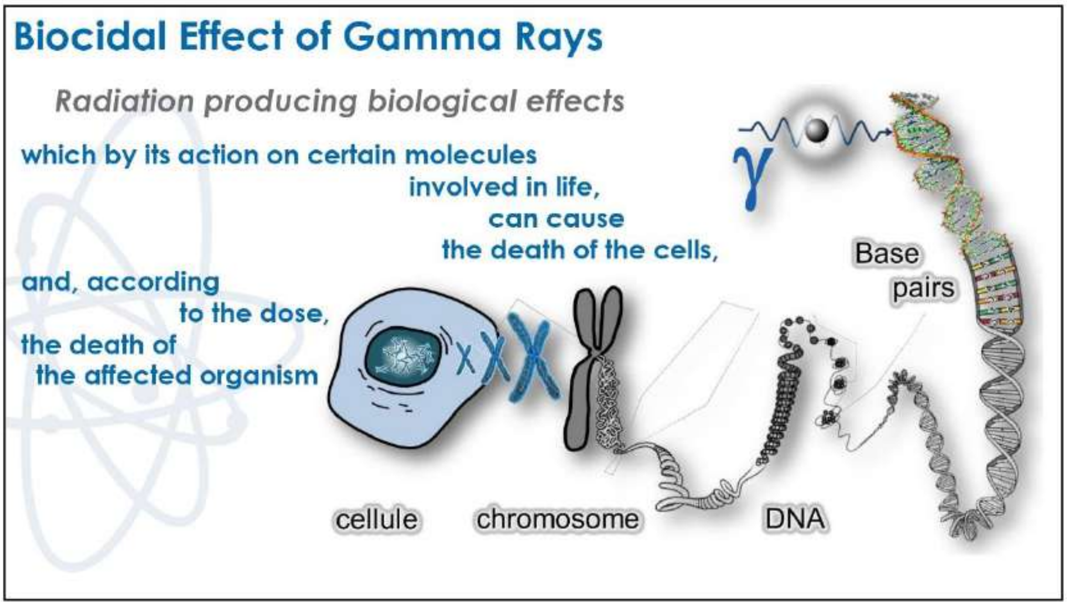
As technology evolves, so do preservation techniques. Innovations include disinfecting frozen artifacts, such as an Egyptian mummy after a flood, and addressing organic remains from medieval burials. On-site interventions, biocidal cleaning, and irradiation in airtight packaging are among the methods employed to mitigate the challenges posed by biodeterioration.

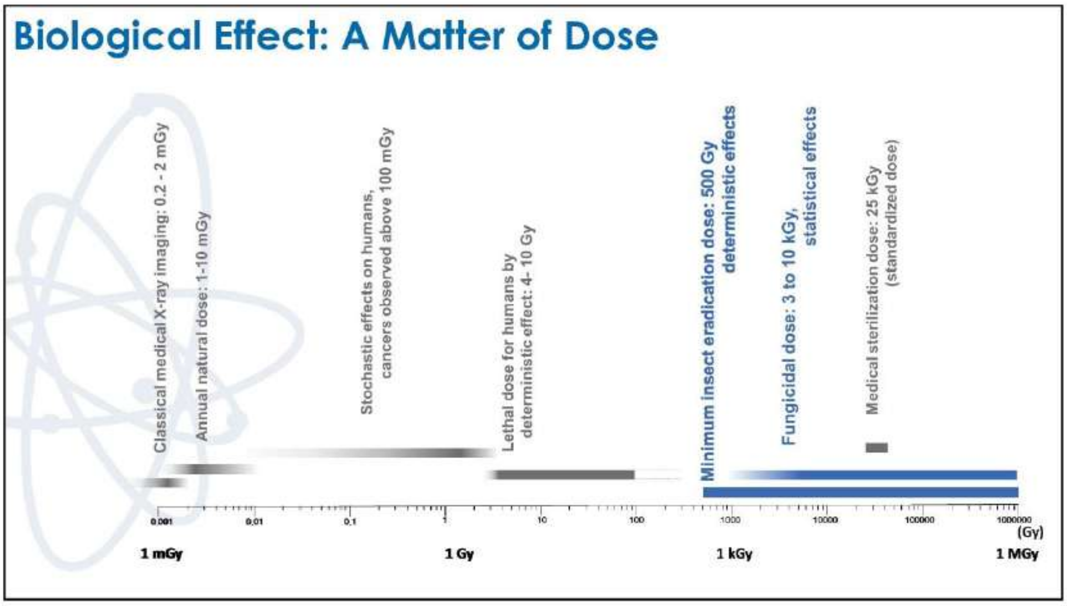
Applying nuclear techniques in artifact preservation represents a remarkable intersection of science, art, and history. By harnessing the power of controlled radiation, experts can safeguard our cultural heritage for future generations. As we continue to explore innovative methods, the legacy of our ancestors remains not only preserved but also celebrated, ensuring that the wonders of the past continue to inspire and captivate us in the years to come. The slides in the upcoming section detail the work done on this.

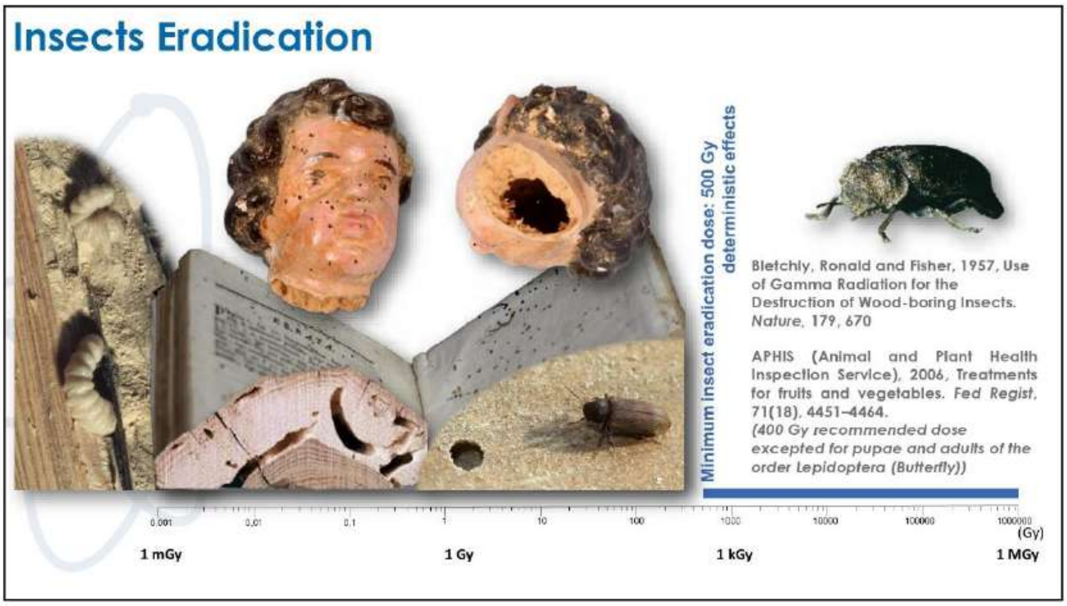

Application of Nuclear Techniques for
Characterization and Preservation of Artifacts
Focus on Disinfestation and Disinfection:
Biocidal Treatments of Collections
arc
nucle
art
Melaka, 2023 October 23th-27th
Laurent CORTELLA, from
for
IAEA

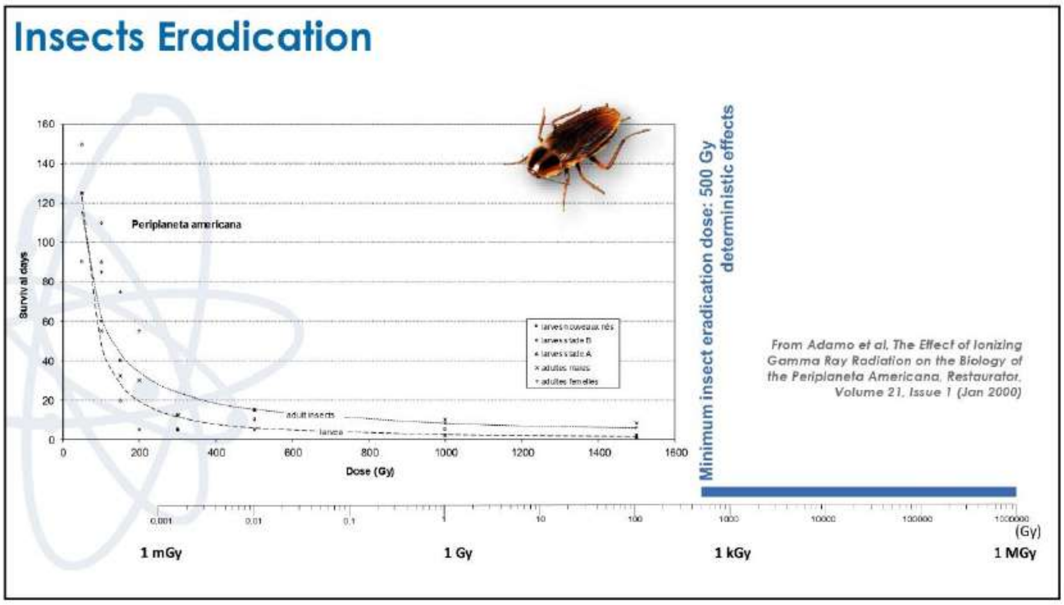

Fighting Against Biodeterioration
Photosynthesis
Organic
Matter
Mineral
Matter
Biodeterioration

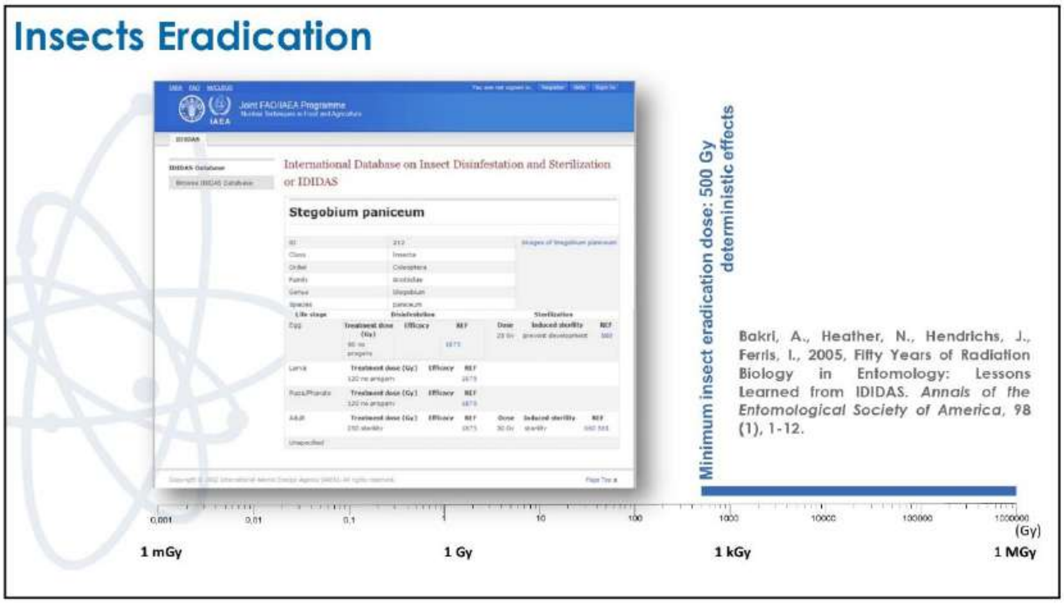

Biocidal treatment
by simple exposure to gamma rays

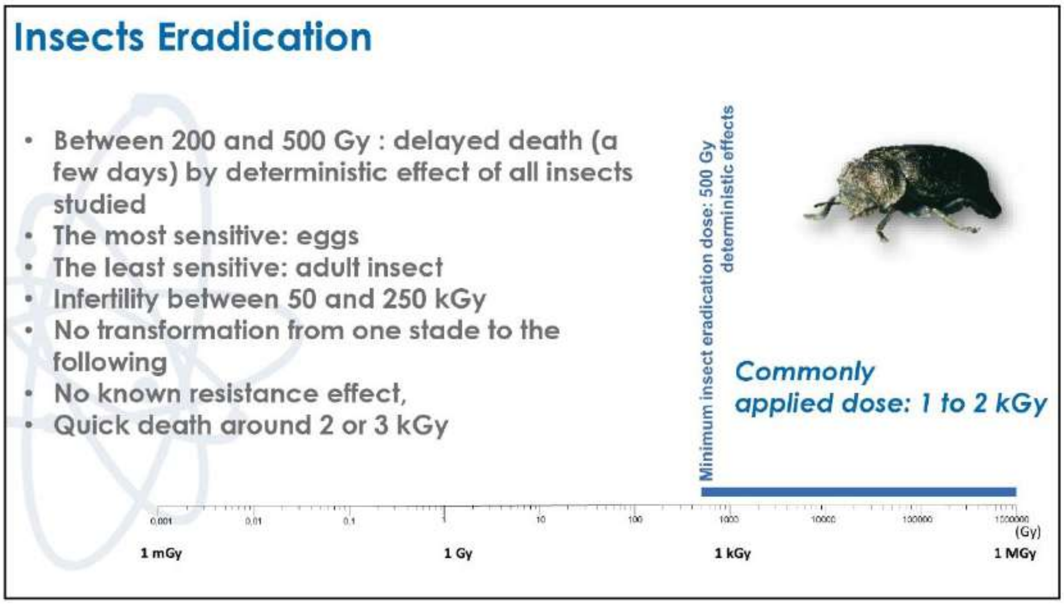

Biocidal Effect of Gamma Rays
Radiation producing biological effects
which by its action on certain molecules
involved in life,
can cause
the death of the cells,
and, according
to the dose,
the death of
the affected organism
γ
Base
pairs
cellule
chromosome
DNA

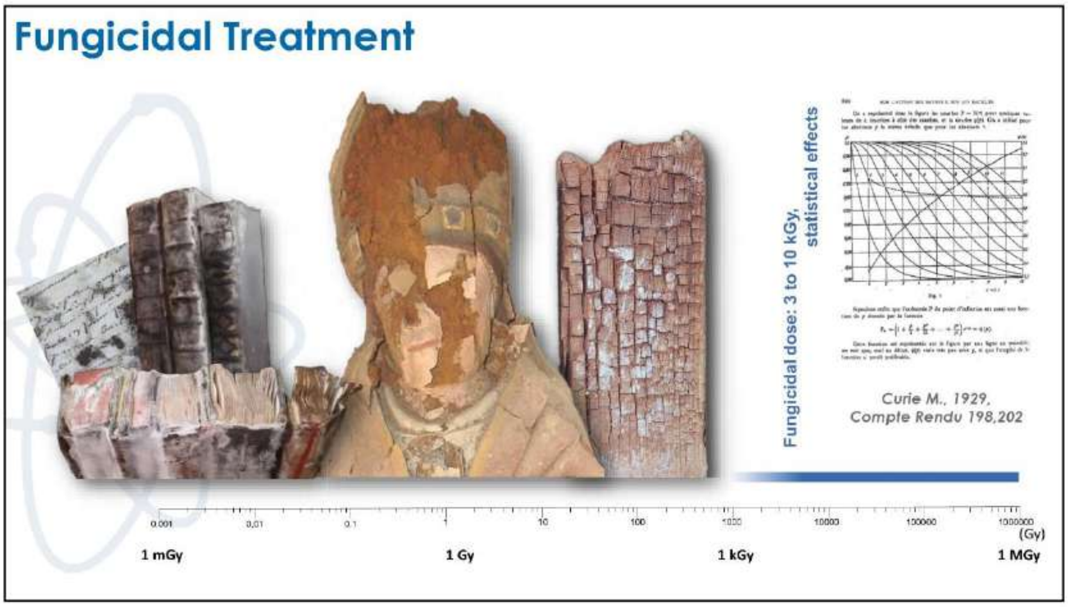

Biological Effect: A Matter of Dose
Classical medical X-ray imaging: 0.2 - 2 mGy
Annual natural dose: 1-10 mGy
Stochastic effects on humans, cancers observed above 100 mGy
Lethal dose for humans by deterministic effect: 4- 10 Gy
Minimum insect eradication dose: 500 Gy deterministic effects
Fungicidal dose: 3 to 10 kGy, statistical effects
Medical sterilization dose: 25 kGy (standardized dose)
0.001
0,01
0,1
1
10
100
1000
10000
100000
1000000
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy

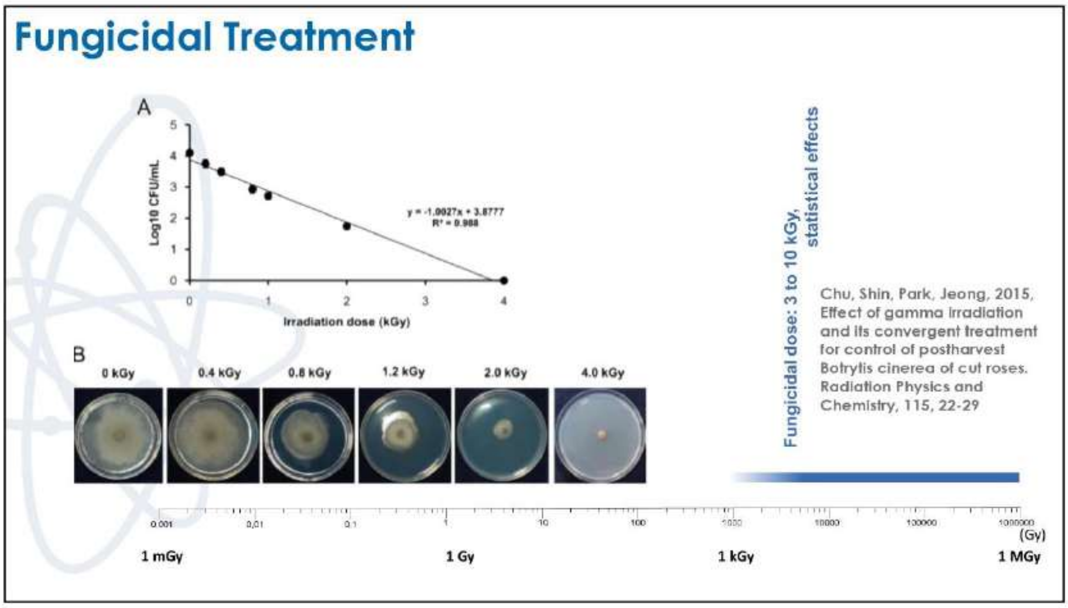

Insects Eradication
Minimum insect eradication dose: 500 Gy deterministic effects
Bletchly, Ronald and Fisher, 1957, Use of Gamma Radiation for the Destruction of Wood-boring Insects. Nature, 179, 670
APHIS (Animal and Plant Health Inspection Service), 2006, Treatments for fruits and vegetables. Fed Regist, 71(18), 4451–4464.
(400 Gy recommended dose excepted for pupae and adults of the order Lepidoptera (Butterfly))
0.001
0,01
0,1
1
10
100
1000
10000
100000
1000000
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy

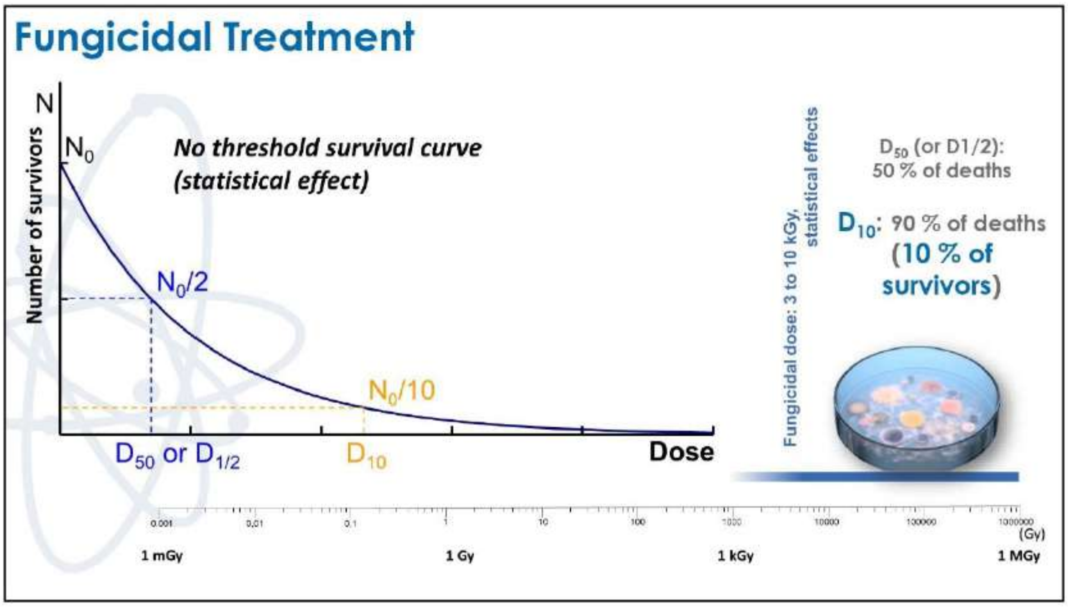

Insects Eradication
Periplaneta americana
Survival days
Dose (Gy)
adult insects
larvae
Minimum insect eradication dose: 500 Gy
deterministic effects
From Adamo et al, The Effect of Ionizing Gamma Ray Radiation on the Biology of the Periplaneta Americana, Restaurator, Volume 21, Issue 1 (Jan 2000)
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy

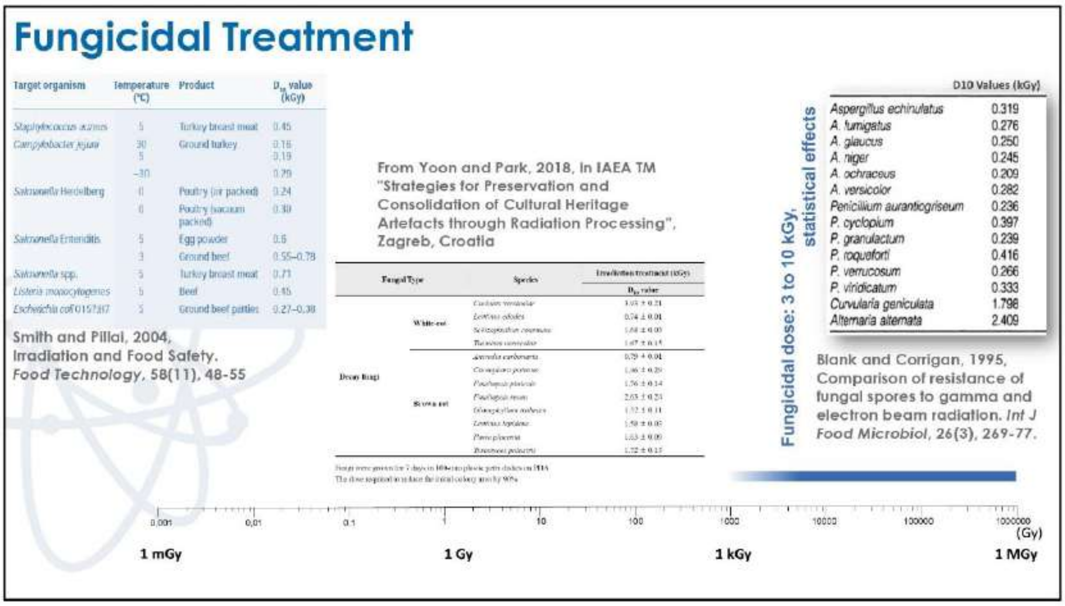

Insects Eradication
Joint FAO/IAEA Programme
International Database on Insect Disinfestation and Sterilization or IDIDAS
Stegobium paniceum
Minimum insect eradication dose: 500 Gy
deterministic effects
Bakri, A., Heather, N., Hendrichs, J., Ferris, I., 2005, Fifty Years of Radiation Biology in Entomology: Lessons Learned from IDIDAS. Annals of the Entomological Society of America, 98 (1), 1-12.
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy

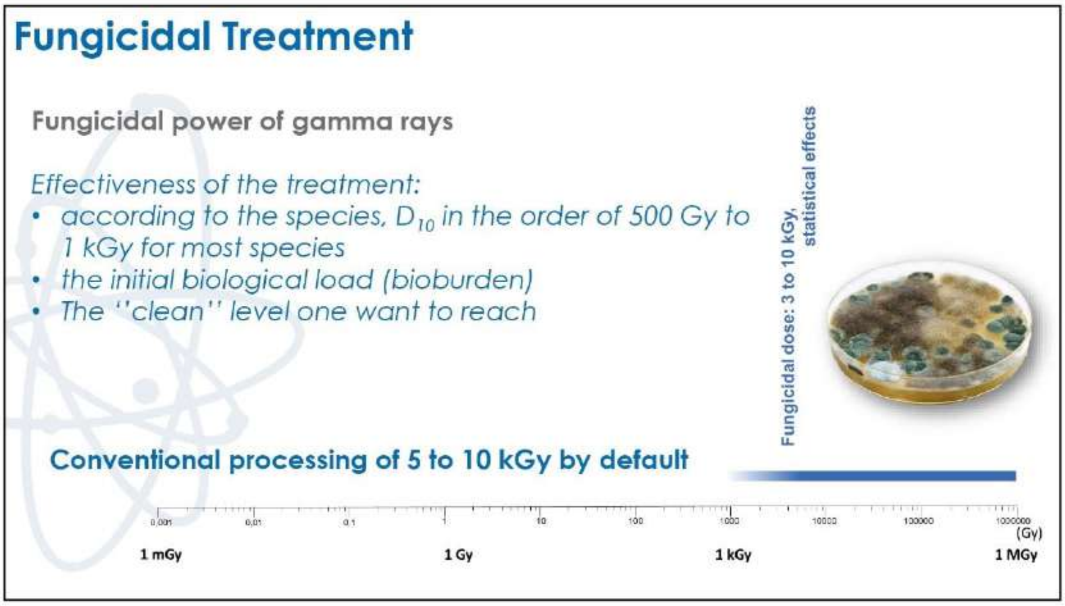

Insects Eradication
• Between 200 and 500 Gy : delayed death (a few days) by deterministic effect of all insects studied
• The most sensitive: eggs
• The least sensitive: adult insect
• Infertility between 50 and 250 kGy
• No transformation from one stade to the following
• No known resistance effect,
• Quick death around 2 or 3 kGy
Minimum insect eradication dose: 500 Gy
deterministic effects
Commonly applied dose: 1 to 2 kGy
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy

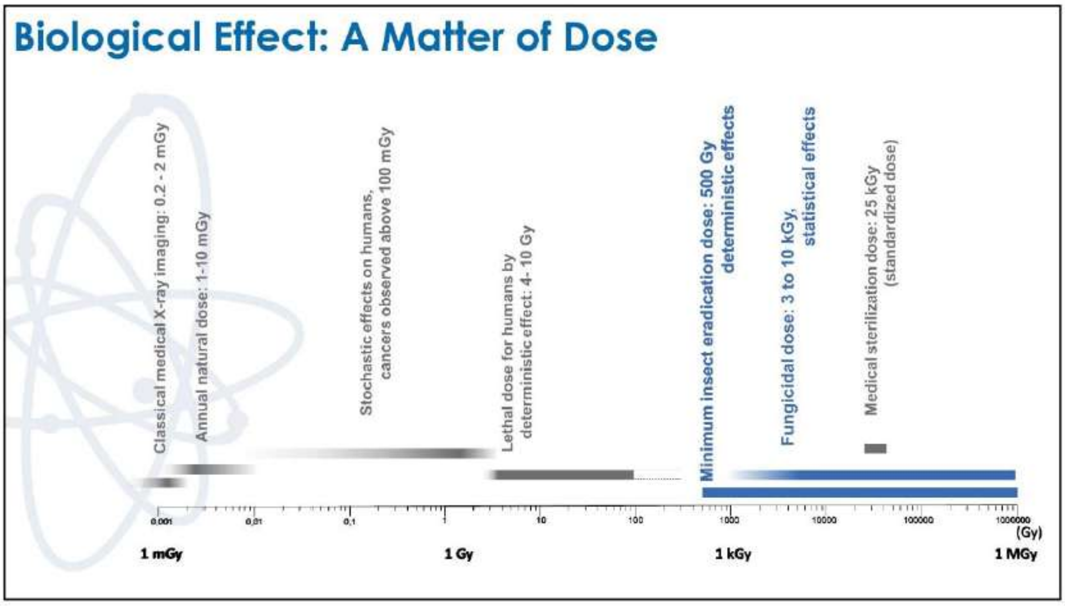

Fungicidal Treatment
Fungicidal dose: 3 to 10 kGy, statistical effects
Curie M., 1929, Compte Rendu 198,202
1 mGy
1 Gy
1 kGy
1 MGy
(Gy)

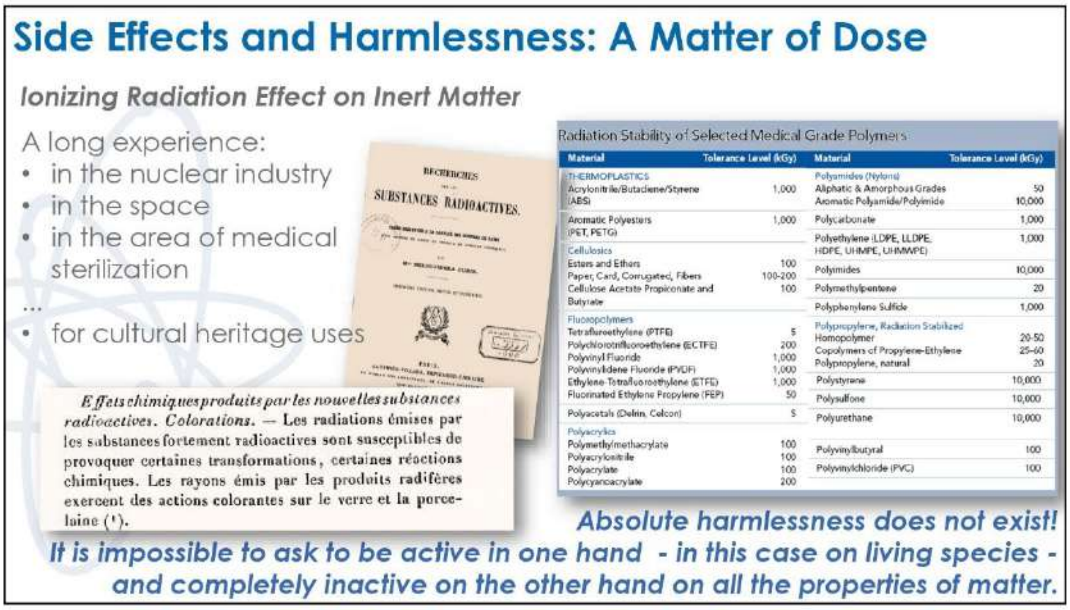

Fungicidal Treatment
A
Log10 CFU/mL
y = -1.0027x + 3.8777
R² = 0.988
Irradiation dose (kGy)
B
0 kGy
0.4 kGy
0.8 kGy
1.2 kGy
2.0 kGy
4.0 kGy
Fungicidal dose: 3 to 10 kGy, statistical effects
Chu, Shin, Park, Jeong, 2015, Effect of gamma irradiation and its convergent treatment for control of postharvest Botrytis cinerea of cut roses. Radiation Physics and Chemistry, 115, 22-29
1 mGy
1 Gy
1 kGy
1 MGy
(Gy)

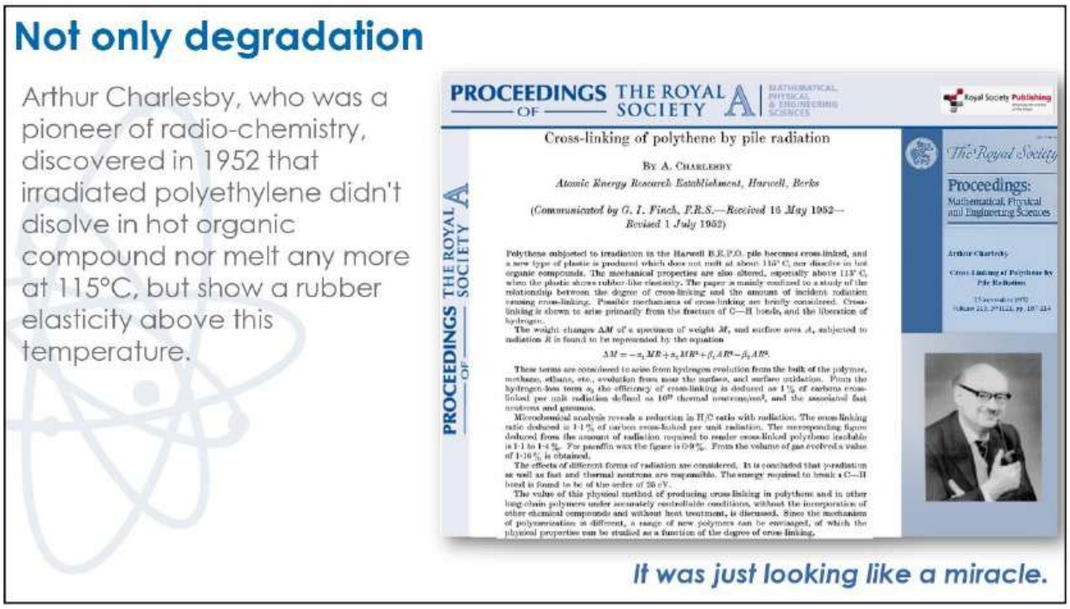

Fungicidal Treatment
N
Number of survivors
N0
No threshold survival curve (statistical effect)
N0/2
N0/10
D50 or D1/2
D10
Dose
Fungicidal dose: 3 to 10 kGy, statistical effects
D50 (or D1/2): 50 % of deaths
D10: 90 % of deaths (10 % of survivors)
1 mGy
1 Gy
1 kGy
1 MGy
(Gy)

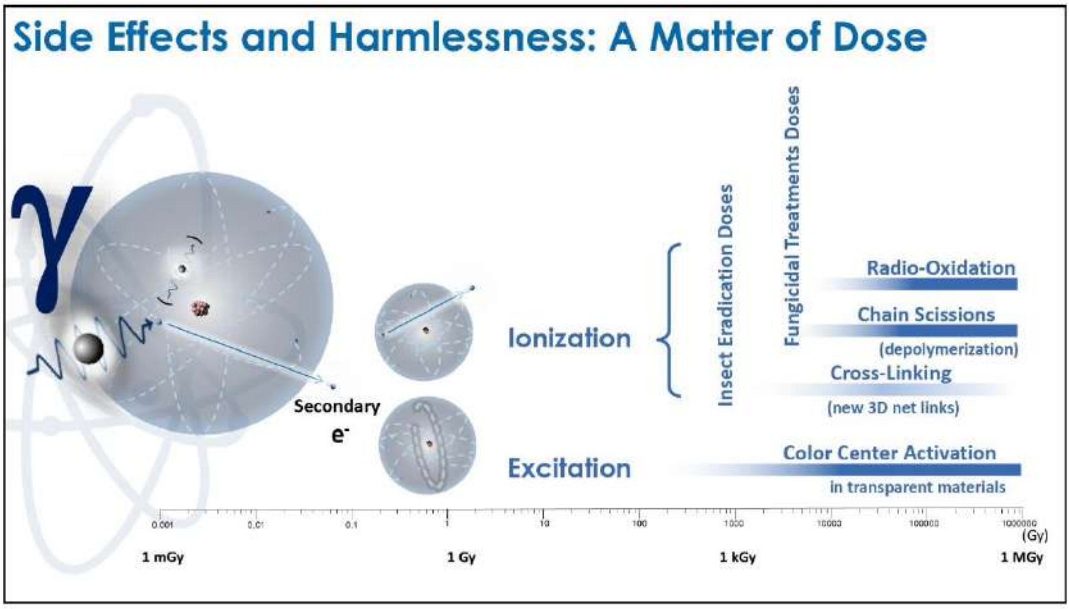

Fungicidal Treatment
Target organism | Temperature (°C) | Product | D10 value (kGy)
Staphylococcus aureus | 5 | Turkey breast meat | 0.45
Campylobacter jejuni | 30 | Ground turkey | 0.16
5 | 0.19
−30 | 0.29
Salmonella Heidelberg | 0 | Poultry (air packed) | 0.24
0 | Poultry (vacuum packed) | 0.30
Salmonella Enteritidis | 5 | Egg powder | 0.6
3 | Ground beef | 0.55–0.78
Salmonella spp. | 5 | Turkey breast meat | 0.71
Listeria monocytogenes | 5 | Beef | 0.45
Escherichia coli O157:H7 | 5 | Ground beef patties | 0.27–0.38
Smith and Pillai, 2004,
Irradiation and Food Safety.
Food Technology, 58(11), 48-55
From Yoon and Park, 2018, in IAEA TM "Strategies for Preservation and Consolidation of Cultural Heritage Artefacts through Radiation Processing", Zagreb, Croatia
D10 Values (kGy)
Aspergillus echinulatus 0.319
A. fumigatus 0.276
A. glaucus 0.250
A. niger 0.245
A. ochraceus 0.209
A. versicolor 0.282
Penicillium aurantiogriseum 0.236
P. cyclopium 0.397
P. granulactum 0.239
P. roquefort 0.416
P. verrucosum 0.266
P. viridicatum 0.333
Curvularia geniculata 1.798
Alternaria alternata 2.409
Blank and Corrigan, 1995, Comparison of resistance of fungal spores to gamma and electron beam radiation. Int J Food Microbiol, 26(3), 269-77.
Fungicidal dose: 3 to 10 kGy, statistical effects
0,001 0,01 0,1 1 10 100 1000 10000 100000 1000000 (Gy)
1 mGy 1 Gy 1 kGy 1 MGy

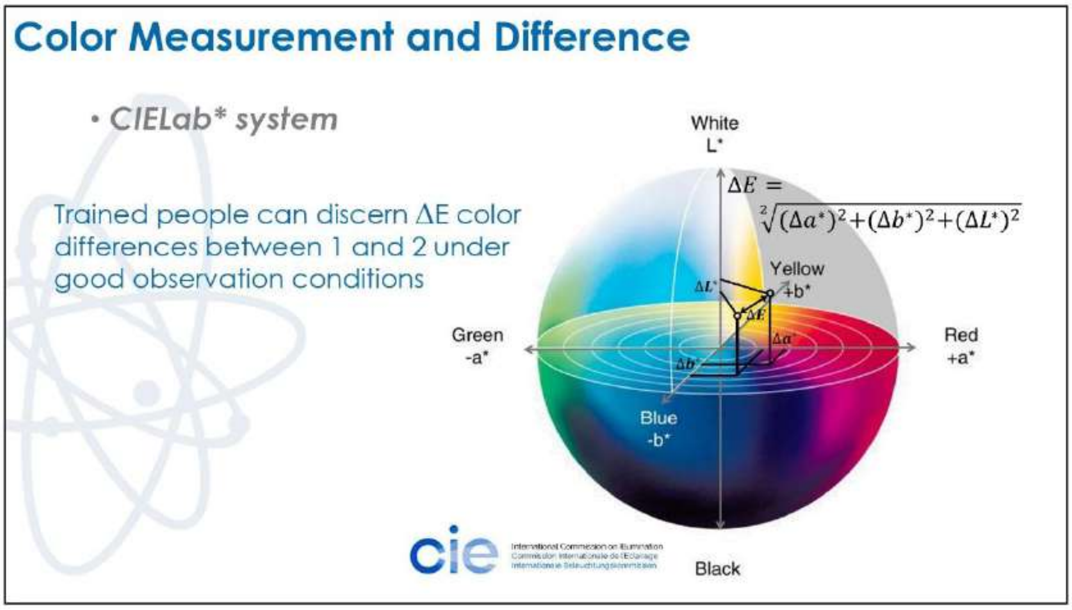

Fungicidal Treatment
Fungicidal power of gamma rays
Effectiveness of the treatment:
• according to the species, D10 in the order of 500 Gy to 1 kGy for most species
• the initial biological load (bioburden)
• The "clean" level one want to reach
Conventional processing of 5 to 10 kGy by default
Fungicidal dose: 3 to 10 kGy, statistical effects
0,001 0,01 0,1 1 10 100 1000 10000 100000 1000000 (Gy)
1 mGy 1 Gy 1 kGy 1 MGy

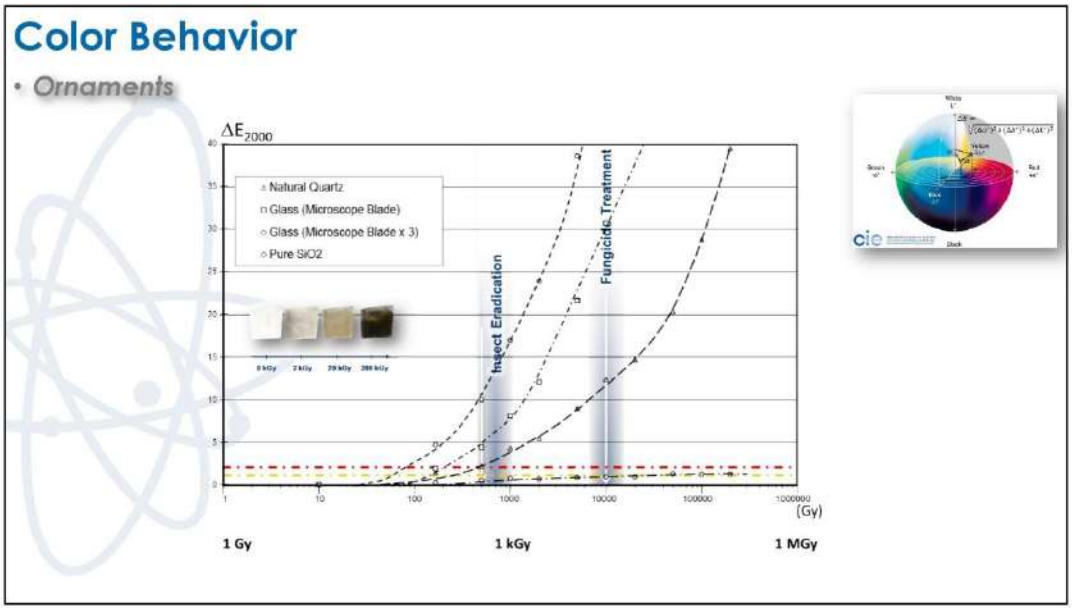

Biological Effect: A Matter of Dose
Classical medical X-ray imaging: 0.2 - 2 mGy
Annual natural dose: 1-10 mGy
Stochastic effects on humans, cancers observed above 100 mGy
Lethal dose for humans by deterministic effect: 4- 10 Gy
Minimum insect eradication dose: 500 Gy deterministic effects
Fungicidal dose: 3 to 10 kGy, statistical effects
Medical sterilization dose: 25 kGy (standardized dose)
0,001 0,01 0,1 1 10 100 1000 10000 100000 1000000 (Gy)
1 mGy 1 Gy 1 kGy 1 MGy

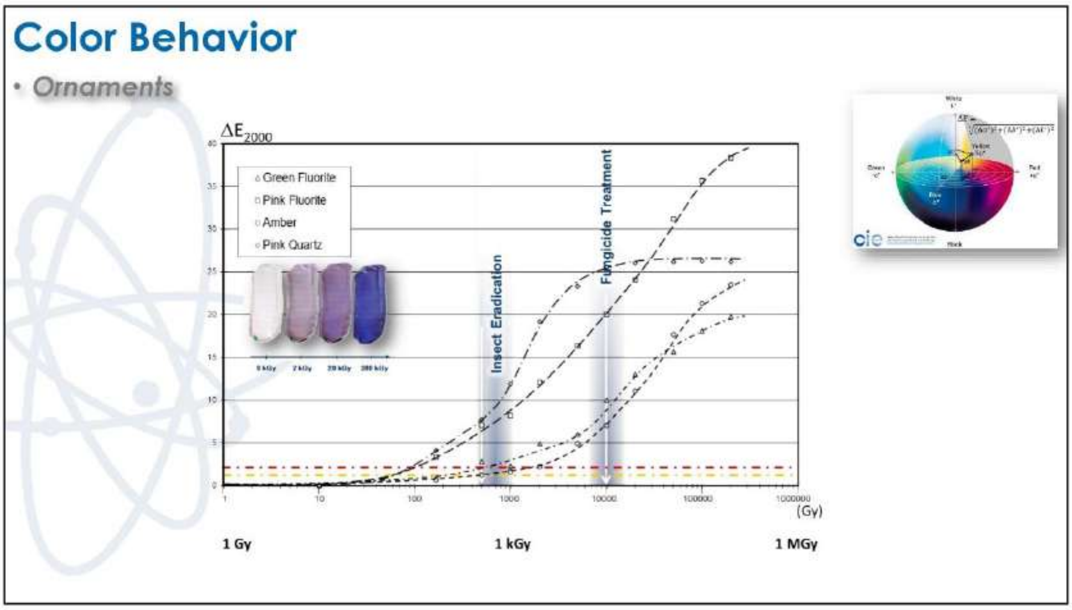

Side Effects and Harmlessness: A Matter of Dose
Ionizing Radiation Effect on Inert Matter
A long experience:
• in the nuclear industry
• in the space
• in the area of medical sterilization
...
• for cultural heritage uses
RECHERCHES
SUBSTANCES RADIOACTIVES.
Effets chimiques produits par les nouvelles substances radioactives. Colorations. — Les radiations émises par les substances fortement radioactives sont susceptibles de provoquer certaines transformations, certaines réactions chimiques. Les rayons émis par les produits radifères exercent des actions colorantes sur le verre et la porcelaine (¹).
Radiation Stability of Selected Medical Grade Polymers
Material | Tolerance Level (kGy) | Material | Tolerance Level (kGy)
THERMOPLASTICS
Acrylonitrile/Butadiene/Styrene (ABS) 1,000
Aromatic Polyesters (PET, PETG) 1,000
Cellulosics
Esters and Ethers 100
Paper, Card, Corrugated, Fibers 100-200
Cellulose Acetate Propiconate and Butyrate 100
Fluoropolymers
Tetrafluroethylene (PTFE) 5
Polychlorotrifluoroethylene (ECTFE) 200
Polyvinyl Fluoride 1,000
Polyvinylidene Fluoride (PVDF) 1,000
Ethylene-Tetrafluoroethylene (ETFE) 1,000
Fluorinated Ethylene Propylene (FEP) 50
Polyacetals (Delrin, Celcon) 5
Polyacrylics
Polymethylmethacrylate 100
Polyacrylonitrile 100
Polyacrylate 100
Polycyanoacrylate 200
Polyamides (Nylons)
Aliphatic & Amorphous Grades 50
Aromatic Polyamide/Polyimide 10,000
Polycarbonate 1,000
Polyethylene (LDPE, LLDPE, HDPE, UHMPE, UHMWPE) 1,000
Polyimides 10,000
Polymethylpentene 20
Polyphenylene Sulfide 1,000
Polypropylene, Radiation Stabilized
Homopolymer 20-50
Copolymers of Propylene-Ethylene 25-60
Polypropylene, natural 20
Polystyrene 10,000
Polysulfone 10,000
Polyurethane 10,000
Polyvinylbutyral 100
Polyvinylchloride (PVC) 100
Absolute harmlessness does not exist!
It is impossible to ask to be active in one hand - in this case on living species - and completely inactive on the other hand on all the properties of matter.

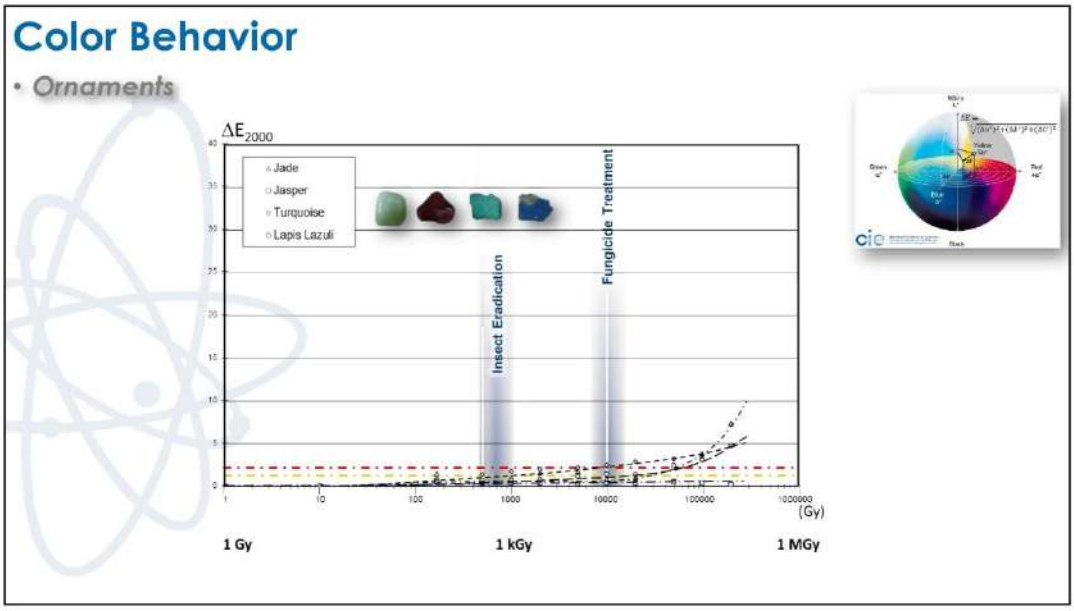

Not only degradation
Arthur Charlesby, who was a pioneer of radio-chemistry, discovered in 1952 that irradiated polyethylene didn't disolve in hot organic compound nor melt any more at 115°C, but show a rubber elasticity above this temperature.
PROCEEDINGS OF THE ROYAL SOCIETY A
Cross-linking of polythene by pile radiation
By A. Charlesby
Atomic Energy Research Establishment, Harwell, Berks
(Communicated by G. I. Finch, F.R.S.—Received 16 May 1952—Revised 1 July 1952)
The Royal Society
Proceedings: Mathematical, Physical and Engineering Sciences
It was just looking like a miracle.

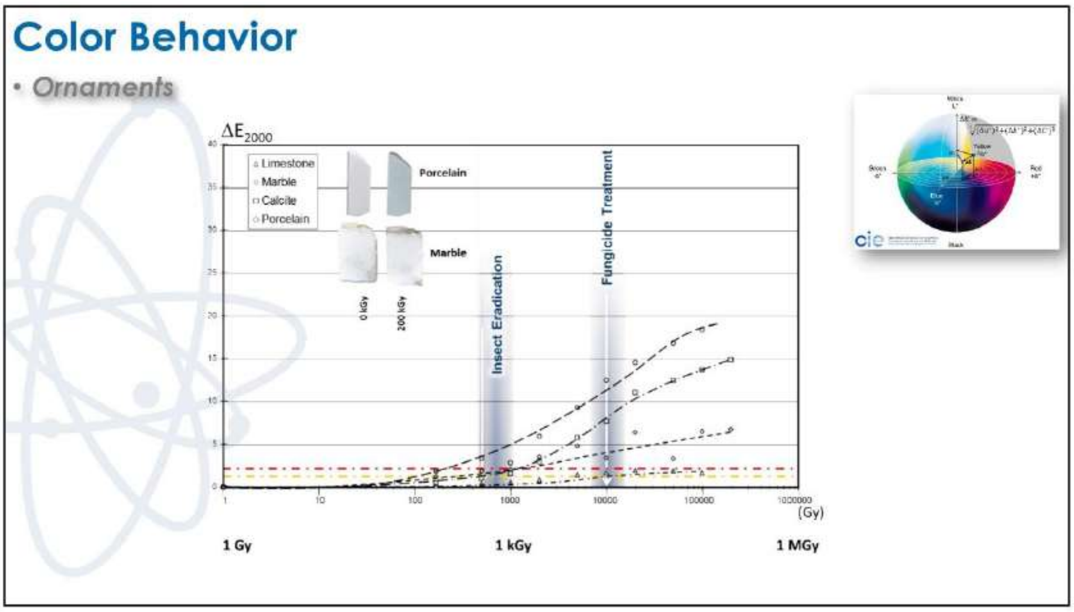

Side Effects and Harmlessness: A Matter of Dose
γ
Secondary e⁻
Ionization
Excitation
Insect Eradication Doses
Fungicidal Treatments Doses
Radio-Oxidation
Chain Scissions
(depolymerization)
Cross-Linking
(new 3D net links)
Color Center Activation
in transparent materials
0.001
0.01
0.1
1
10
100
1000
10000
100000
1000000
(Gy)
1 mGy
1 Gy
1 kGy
1 MGy

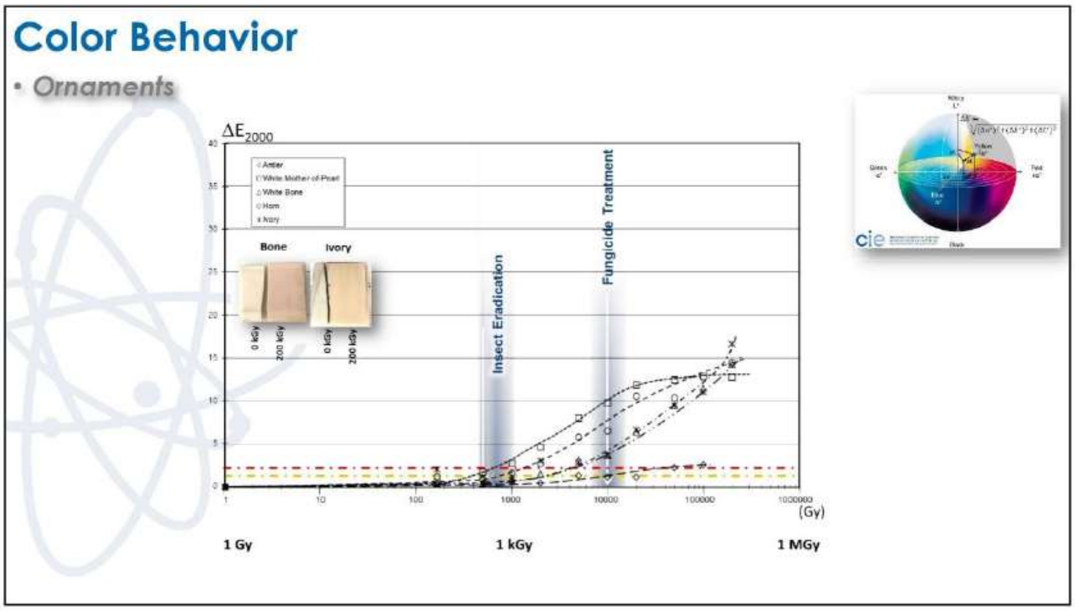

Color Measurement and Difference
• CIELab* system
Trained people can discern ΔE color differences between 1 and 2 under good observation conditions
White
L*
$\Delta E = \sqrt[2]{(\Delta a^*)^2+(\Delta b^*)^2+(\Delta L^*)^2}$
Yellow
+b*
Green
-a*
Red
+a*
Blue
-b*
Black
cie

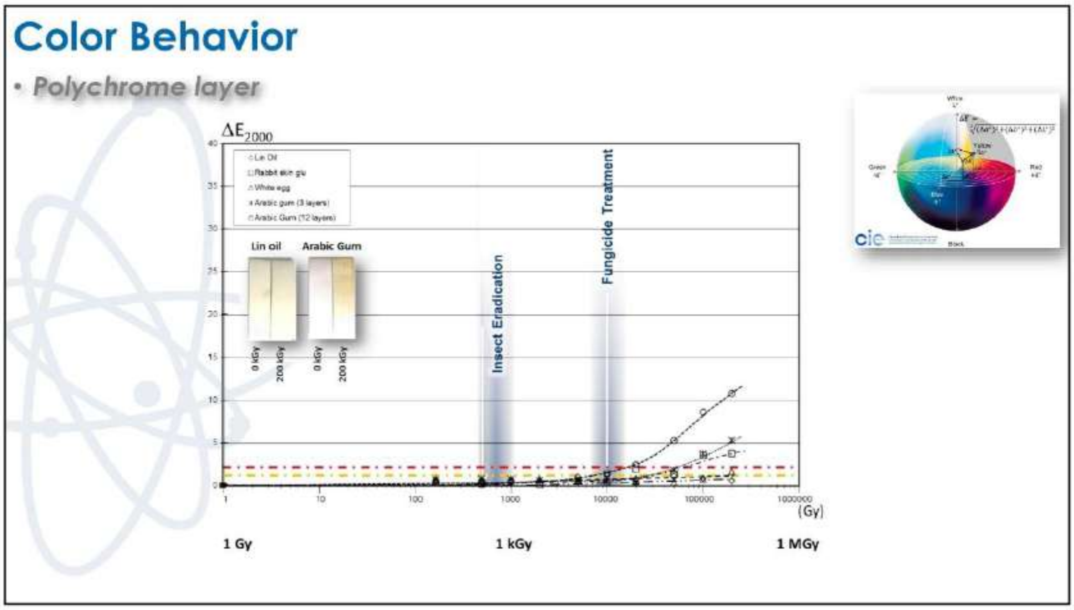

Color Behavior
• Ornaments
ΔE2000
Natural Quartz
Glass (Microscope Blade)
Glass (Microscope Blade x 3)
Pure SiO2
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

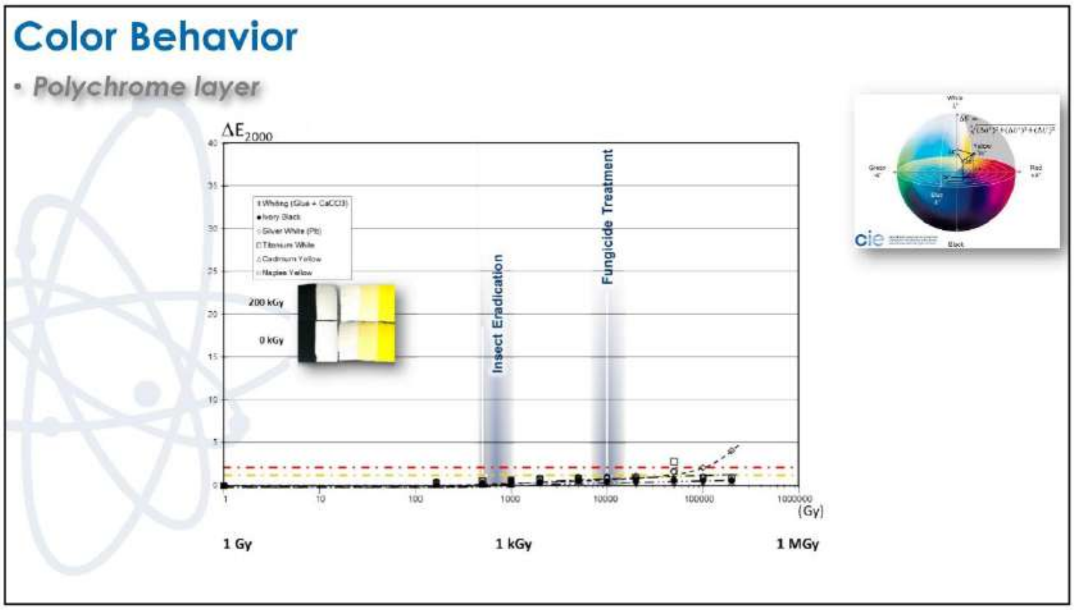

Color Behavior
• Ornaments
ΔE2000
Green Fluorite
Pink Fluorite
Amber
Pink Quartz
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

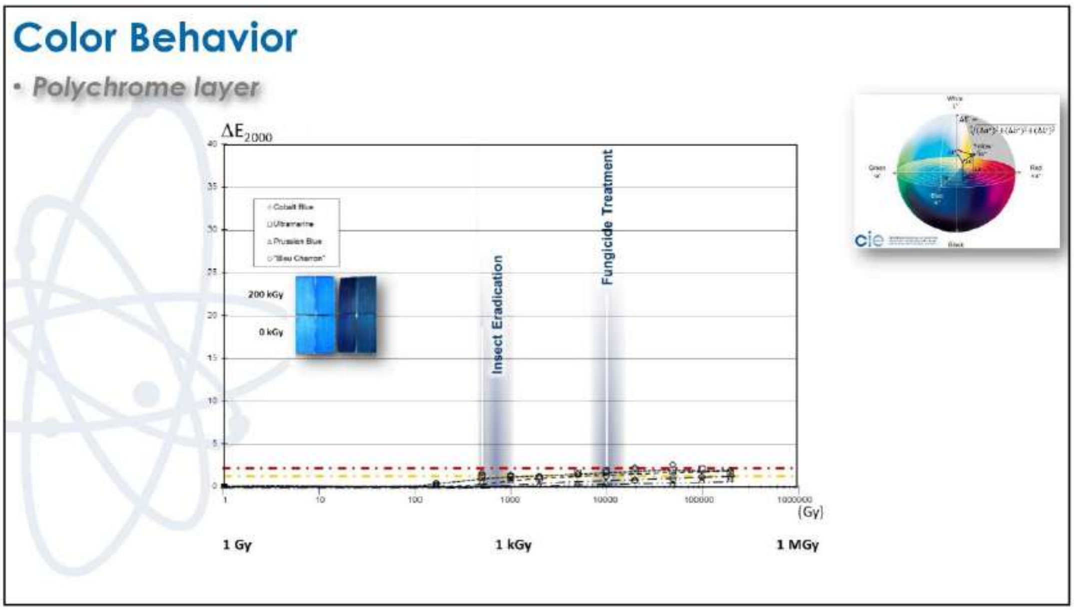

Color Behavior
• Ornaments
ΔE2000
Jade
Jasper
Turquoise
Lapis Lazuli
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

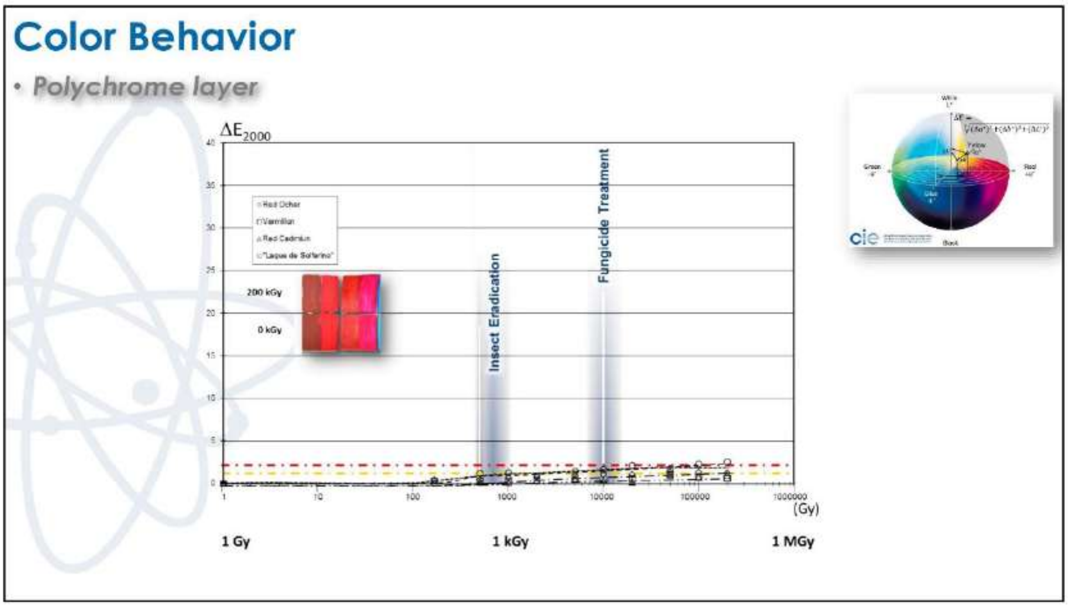

Color Behavior
• Ornaments
ΔE2000
Limestone
Marble
Calcite
Porcelain
Porcelain
Marble
0 kGy
200 kGy
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

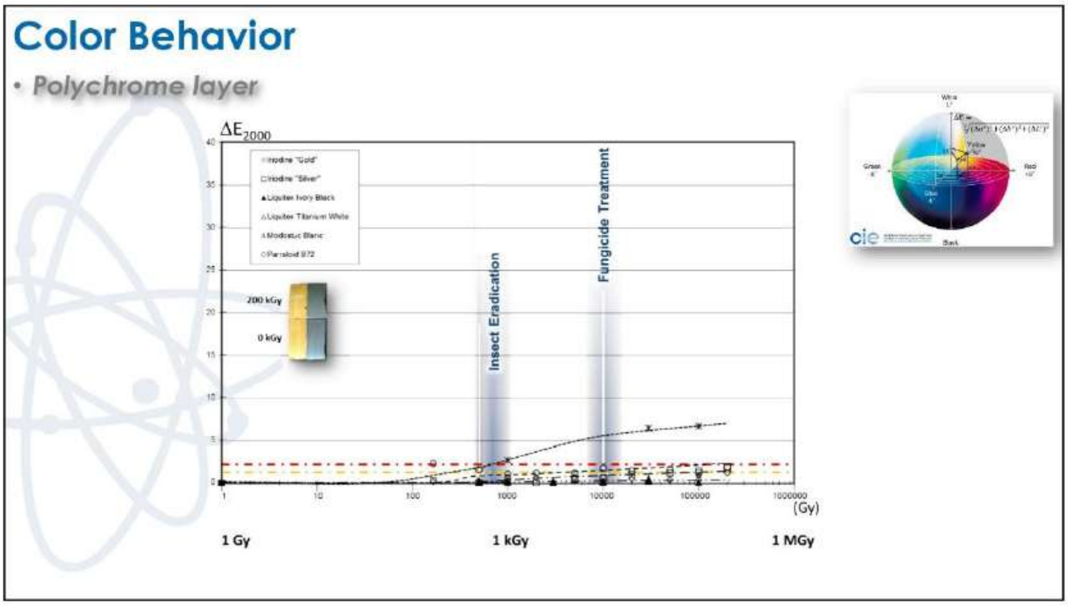

Color Behavior
• Ornaments
ΔE2000
Amber
White Mother-of-Pearl
White Bone
Horn
Ivory
Bone
Ivory
0 kGy
200 kGy
0 kGy
200 kGy
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

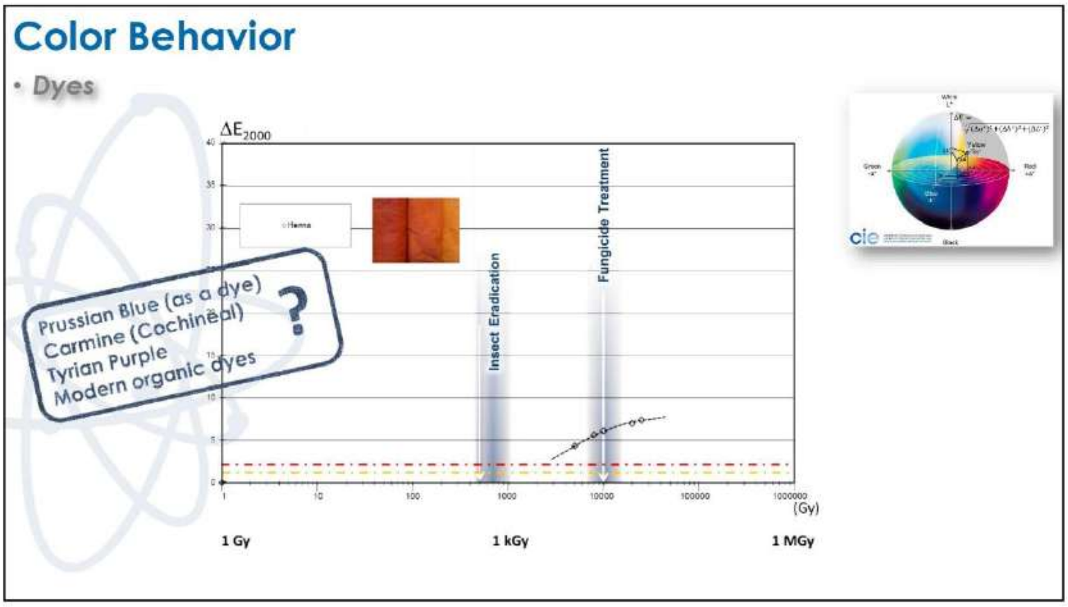

Color Behavior
• Polychrome layer
ΔE2000
Lin oil
Arabic Gum
0 kGy
200 kGy
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

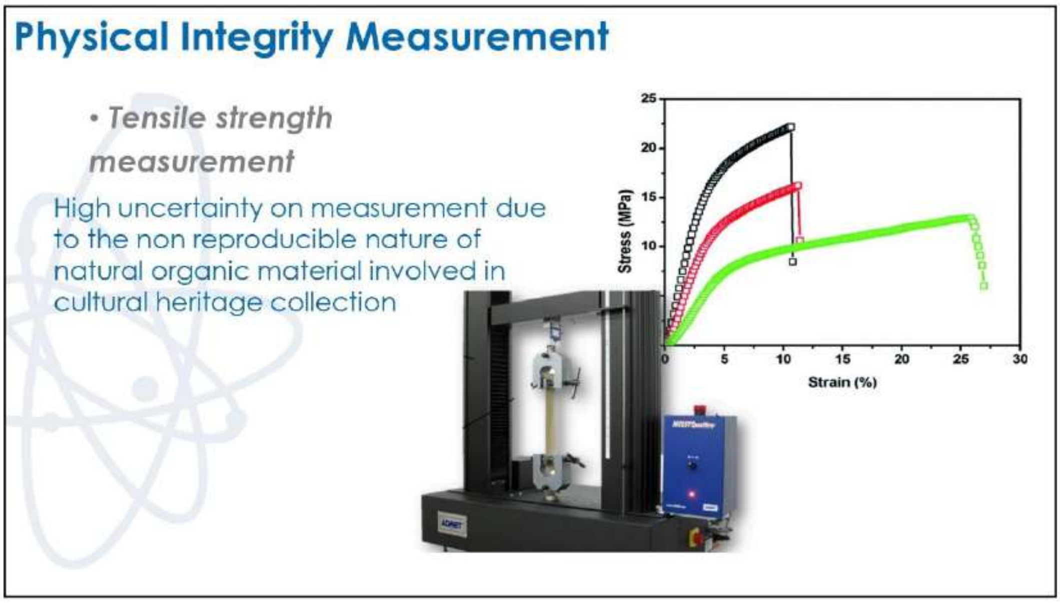

Color Behavior
• Polychrome layer
ΔE2000
200 kGy
0 kGy
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

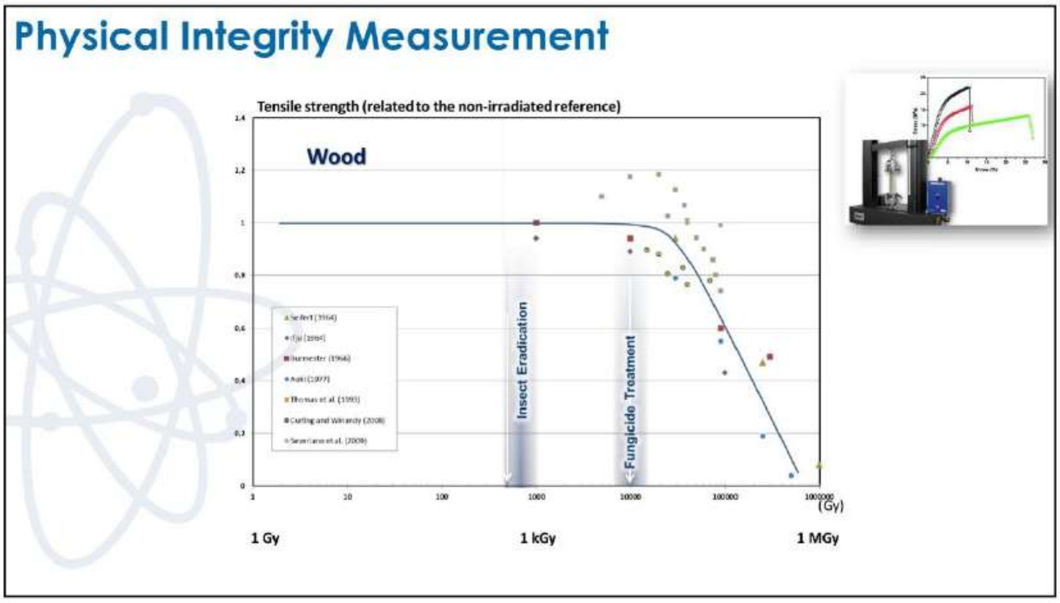

Color Behavior
• Polychrome layer
ΔE2000
200 kGy
0 kGy
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

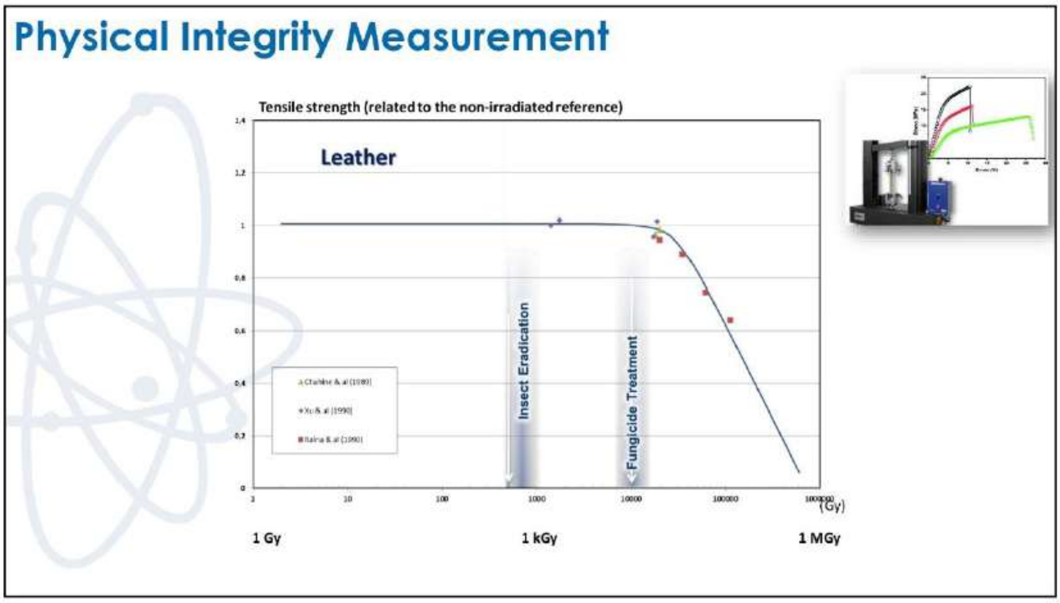

Color Behavior
• Polychrome layer
ΔE2000
200 kGy
0 kGy
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

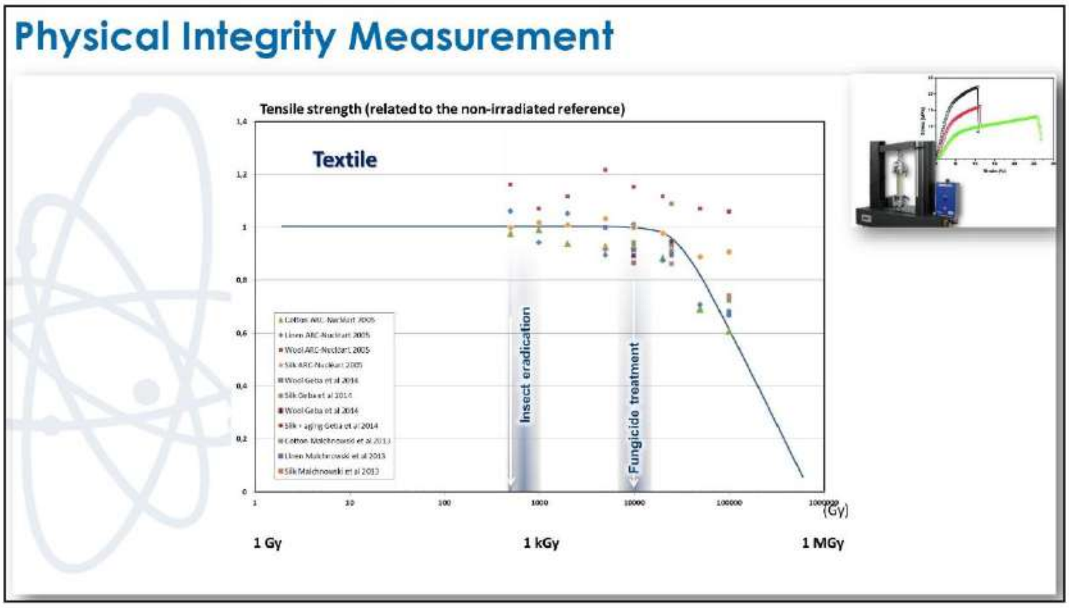

Color Behavior
• Polychrome layer
ΔE2000
200 kGy
0 kGy
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

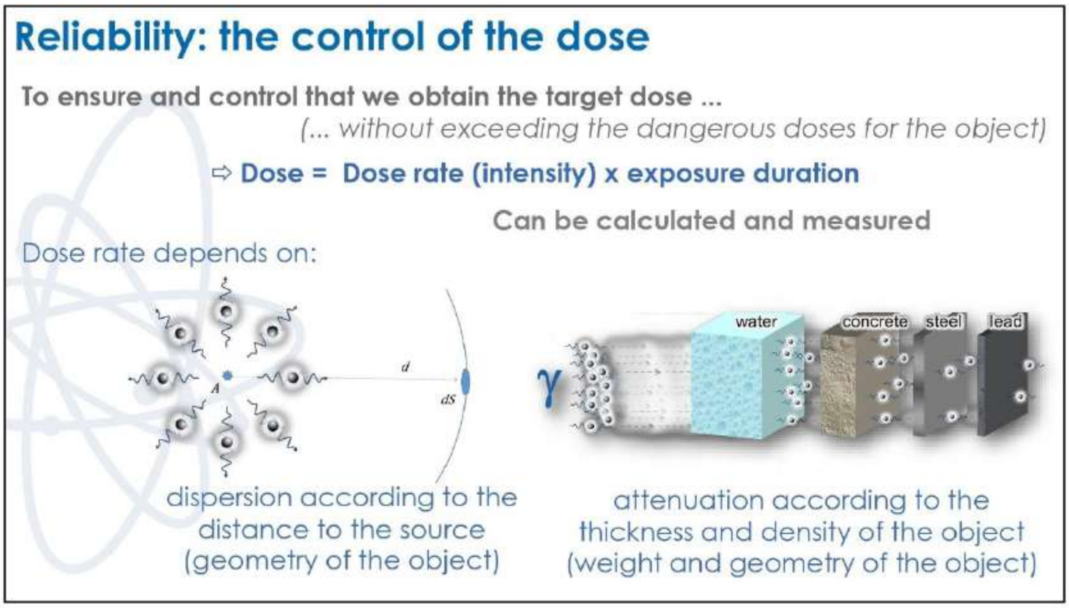

Color Behavior
• Dyes
ΔE2000
Henna
Prussian Blue (as a dye)
Carmine (Cochineal)
Tyrian Purple
Modern organic dyes
?
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy


Physical Integrity Measurement
• Tensile strength measurement
High uncertainty on measurement due to the non reproducible nature of natural organic material involved in cultural heritage collection
Stress (MPa)
Strain (%)

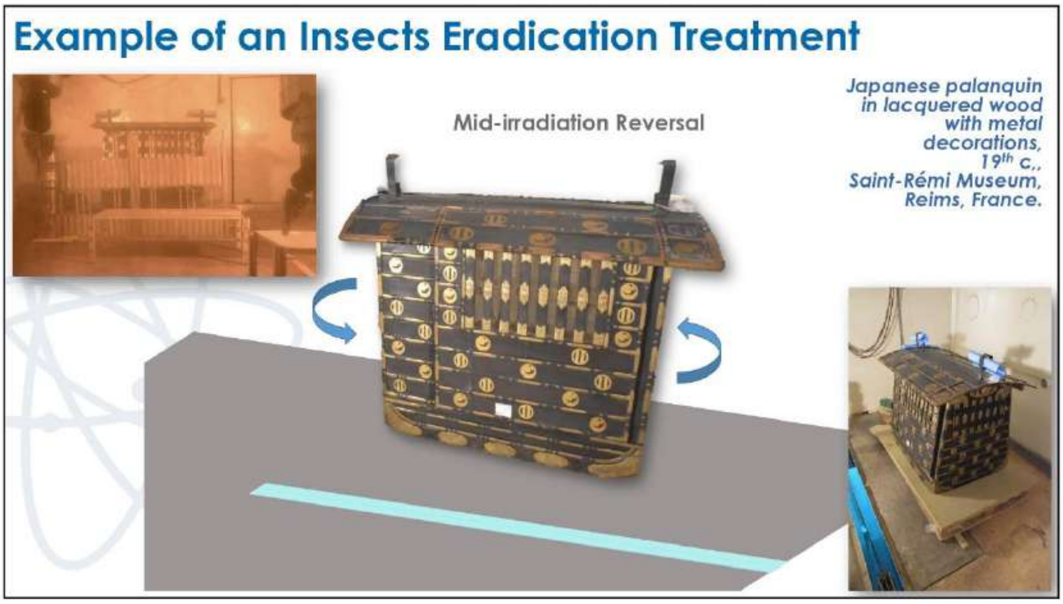

Physical Integrity Measurement
Tensile strength (related to the non-irradiated reference)
Wood
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

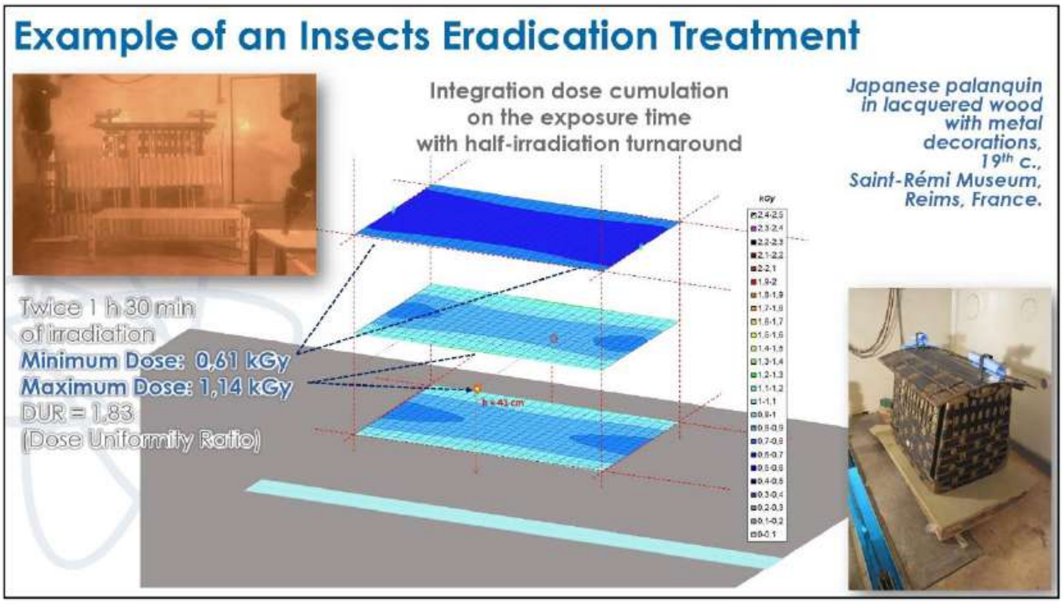

Physical Integrity Measurement
Tensile strength (related to the non-irradiated reference)
Leather
Insect Eradication
Fungicide Treatment
(Gy)
1 Gy
1 kGy
1 MGy

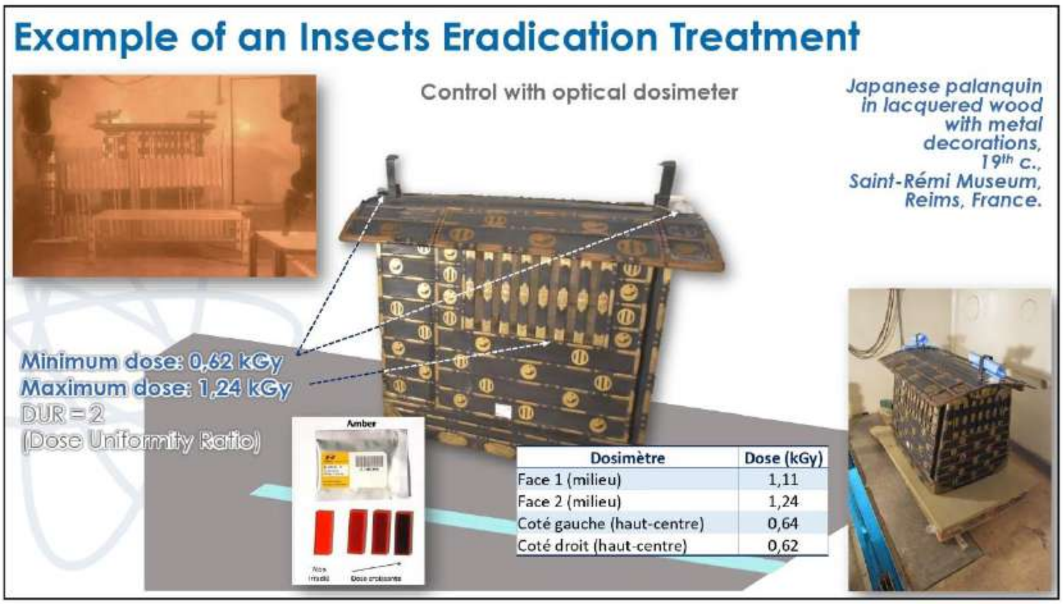

Physical Integrity Measurement
Tensile strength (related to the non-irradiated reference)
Textile
Insect eradication
Fungicide treatment
(Gy)
1 Gy
1 kGy
1 MGy


Reliability: the control of the dose
To ensure and control that we obtain the target dose ...
(... without exceeding the dangerous doses for the object)
⇨ Dose = Dose rate (intensity) x exposure duration
Can be calculated and measured
Dose rate depends on:
water
concrete
steel
lead
γ
dispersion according to the distance to the source (geometry of the object)
attenuation according to the thickness and density of the object (weight and geometry of the object)


Example of an Insects Eradication Treatment
Japanese palanquin in lacquered wood with metal decorations, 19th c., Saint-Rémi Museum, Reims, France.


Example of an Insects Eradication Treatment
Mid-irradiation Reversal
Japanese palanquin in lacquered wood with metal decorations, 19th c., Saint-Rémi Museum, Reims, France.


Example of an Insects Eradication Treatment
Integration dose cumulation on the exposure time with half-irradiation turnaround
Japanese palanquin in lacquered wood with metal decorations, 19th c., Saint-Rémi Museum, Reims, France.
Twice 1 h 30 min of irradiation
Minimum Dose: 0,61 kGy
Maximum Dose: 1,14 kGy
DUR = 1,83
(Dose Uniformity Ratio)
kGy

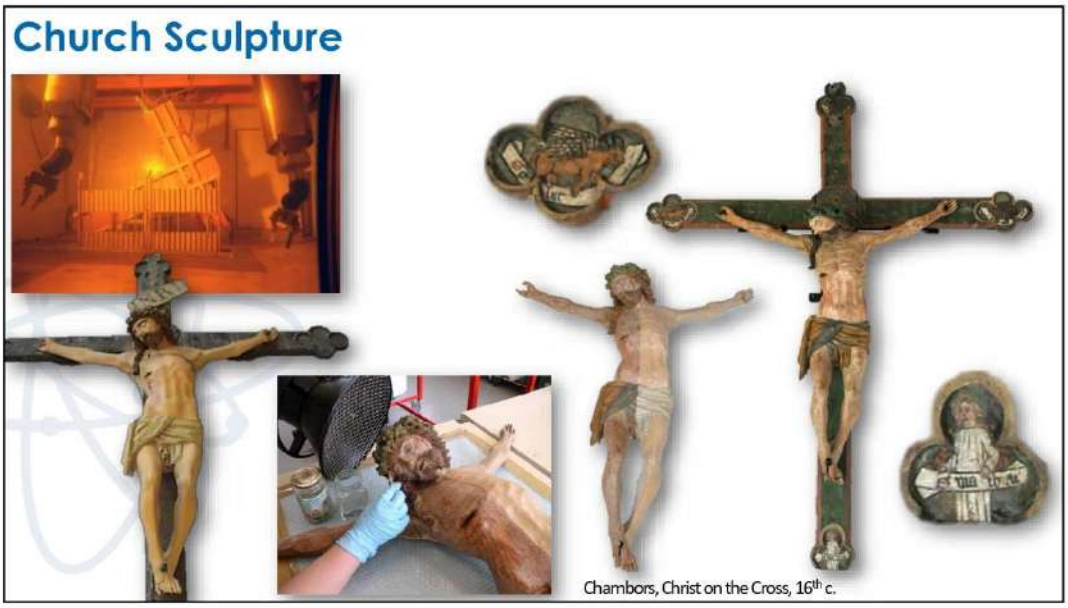

Example of an Insects Eradication Treatment
Control with optical dosimeter
Japanese palanquin in lacquered wood with metal decorations, 19th c., Saint-Rémi Museum, Reims, France.
Minimum dose: 0,62 kGy
Maximum dose: 1,24 kGy
DUR = 2
(Dose Uniformity Ratio)
Amber
Dosimètre | Dose (kGy)
Face 1 (milieu) | 1,11
Face 2 (milieu) | 1,24
Coté gauche (haut-centre) | 0,64
Coté droit (haut-centre) | 0,62


Thousands of Collections Treated for Disinfestation
• Furniture
• Wooden sculptures
• Archaeological wooden artifacts
• Painting
• Ethnological artefacts
• Books and archives
• Modern Art
• Musical instruments
• Natural history specimens


Private and Public Collections of Furniture


Church Sculpture
Yenne, Pietà, 15th – 16th c.

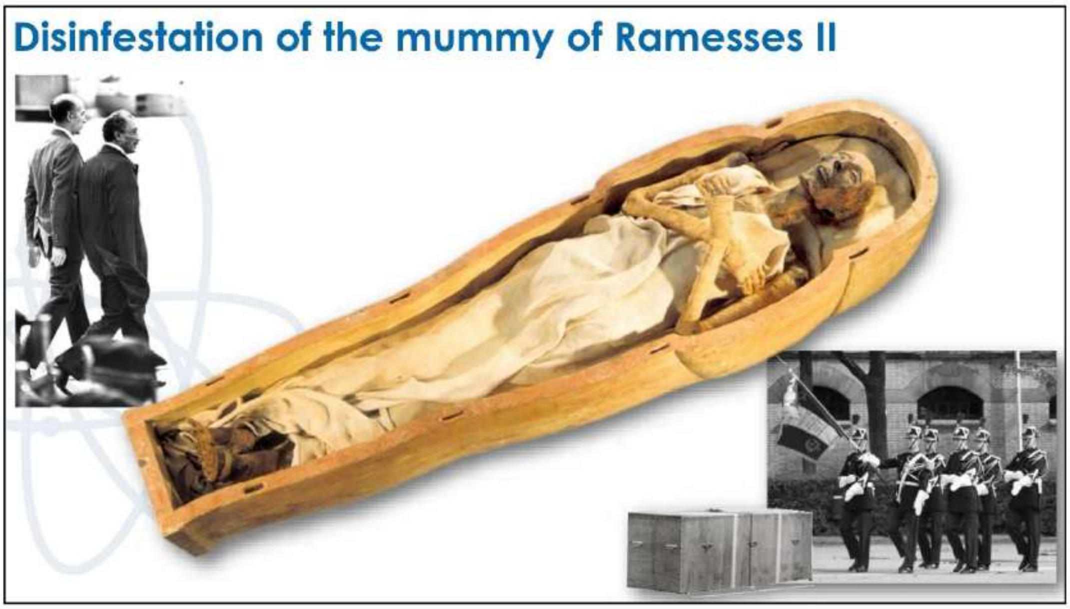

Church Sculpture

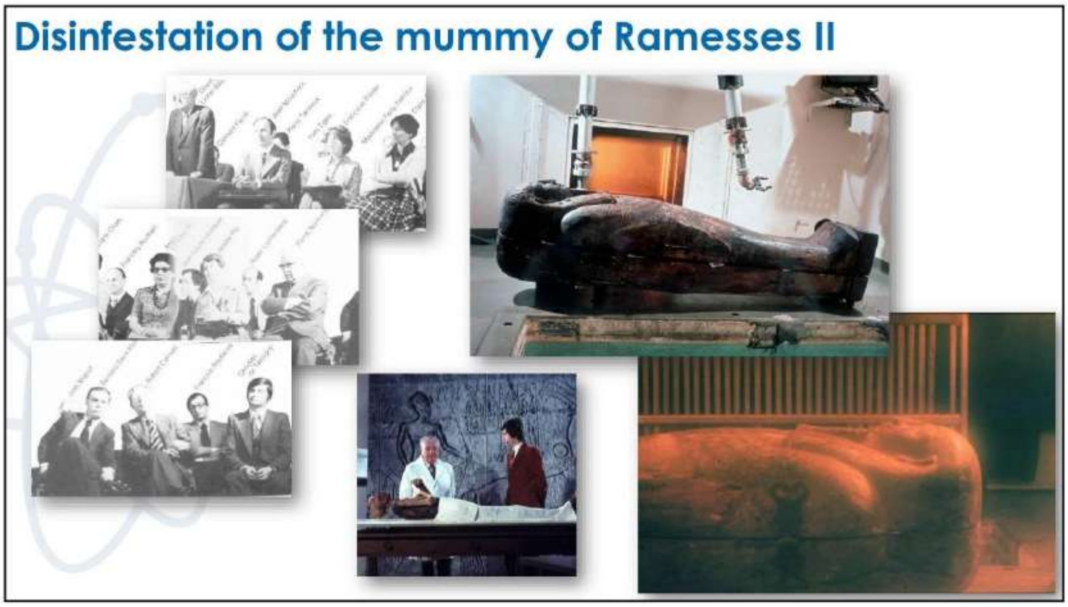

Church Sculpture
Chambors, Christ on the Cross, 16th c.

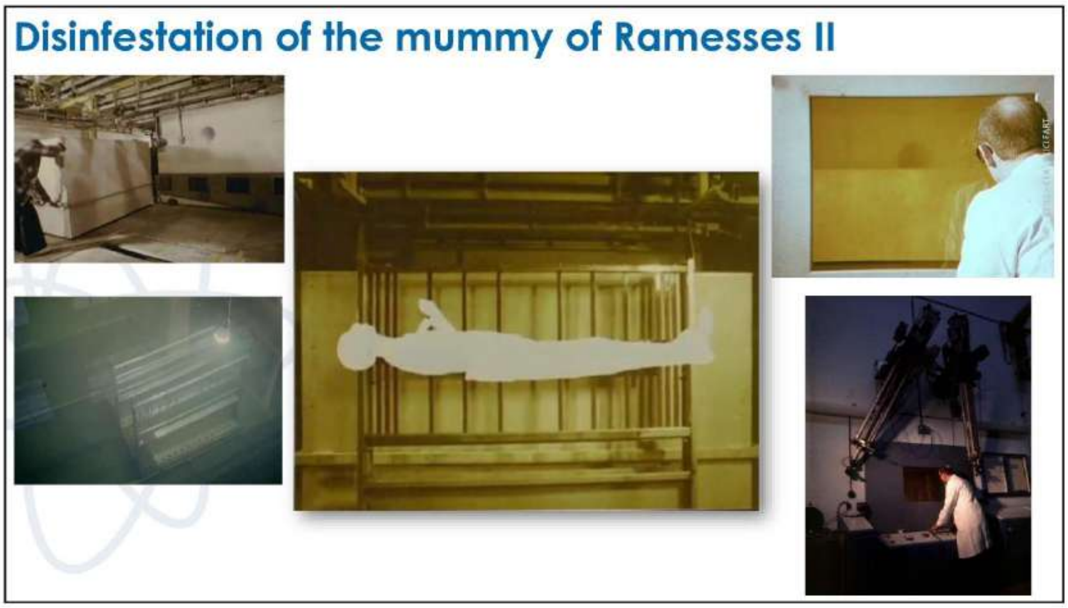

Ethnological Artefacts
Objets ethnographiques, Collection Lacroix, XXè s., Musée de Fessy
Bobsleigh, milieu du XXe s., Villard-de-Lans


Historical Artefact
Sedan Chair,
1752 Paul Pastre Museum,
Marsillargue


Archaeological Waterlogged Organic Material
• Treatment targeting the anaerobic flora of1500 Gallo-Roman votive offerings preserved in waterlogged state under water in small plastic bags (approximatively 20 m3).

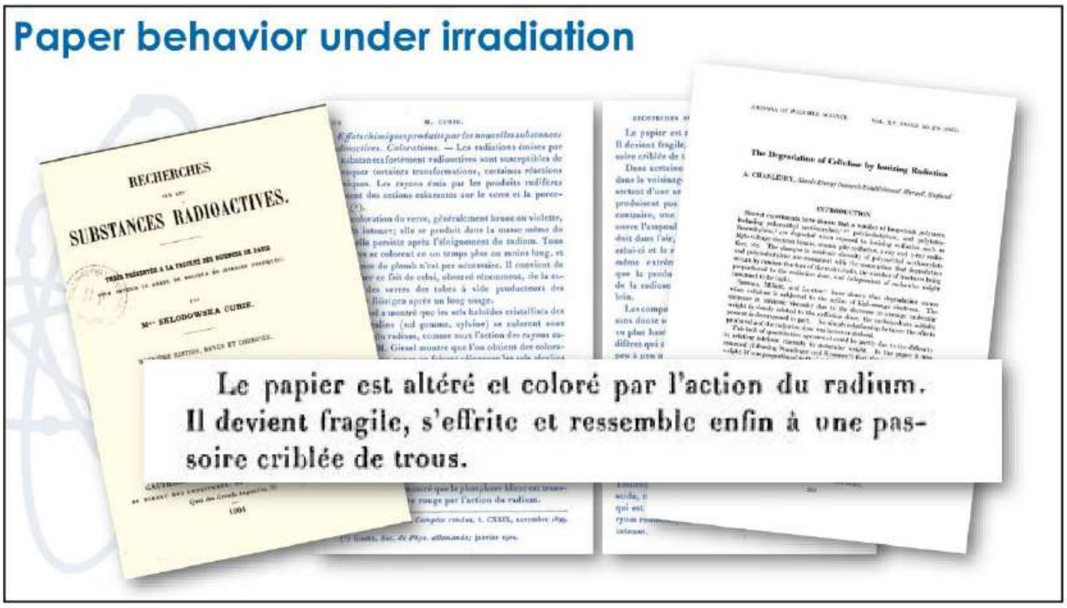

Disinfestation of the mummy of Ramesses II

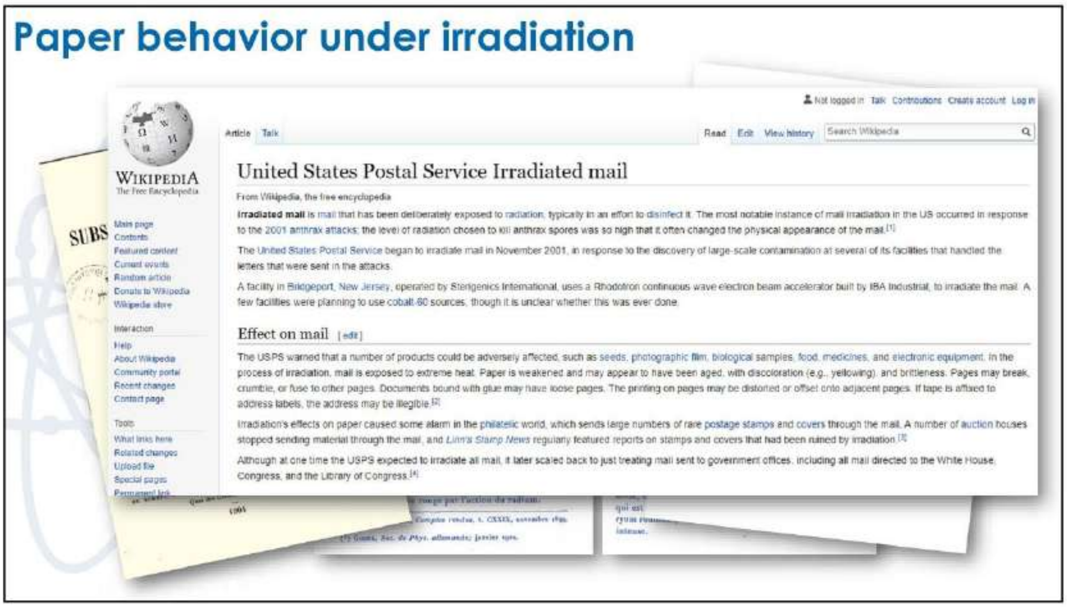

Disinfestation of the mummy of Ramesses II

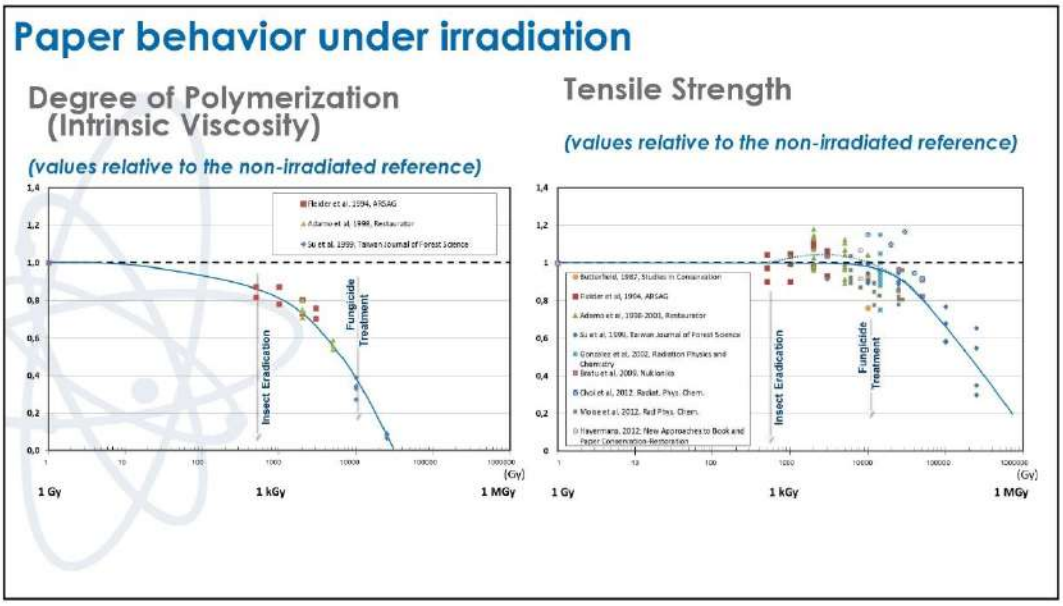

Disinfestation of the mummy of Ramesses II

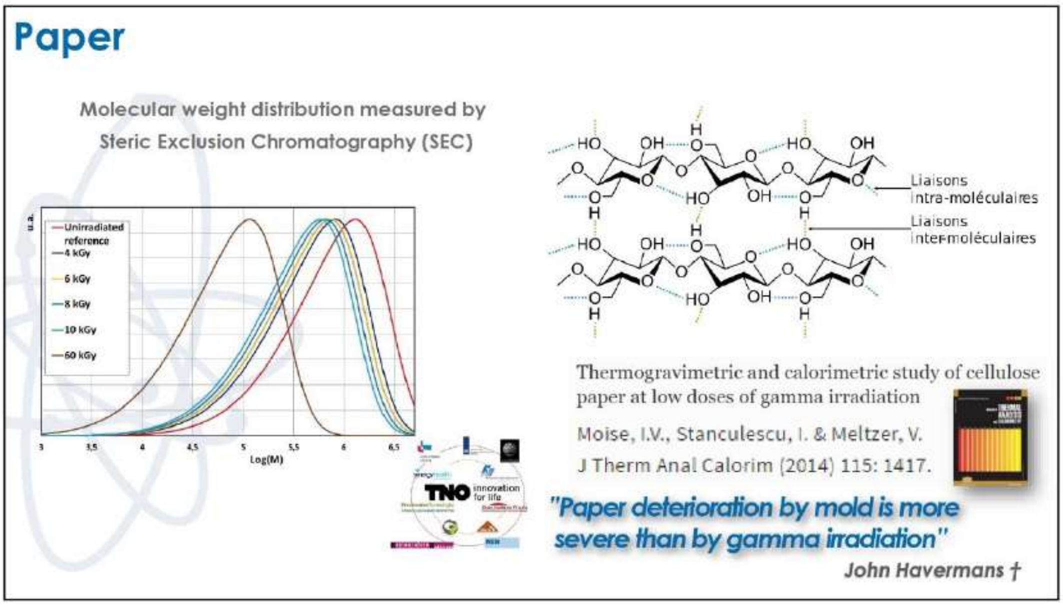

Khroma, the baby mammoth


Khroma, the baby mammoth
AU PUY-EN-VELAY RENCONTREZ LES MAMMOUTHS


Paper behavior under irradiation
RECHERCHES SUR LES SUBSTANCES RADIOACTIVES.
Le papier est altéré et coloré par l'action du radium. Il devient fragile, s'effrite et ressemble enfin à une passoire criblée de trous.

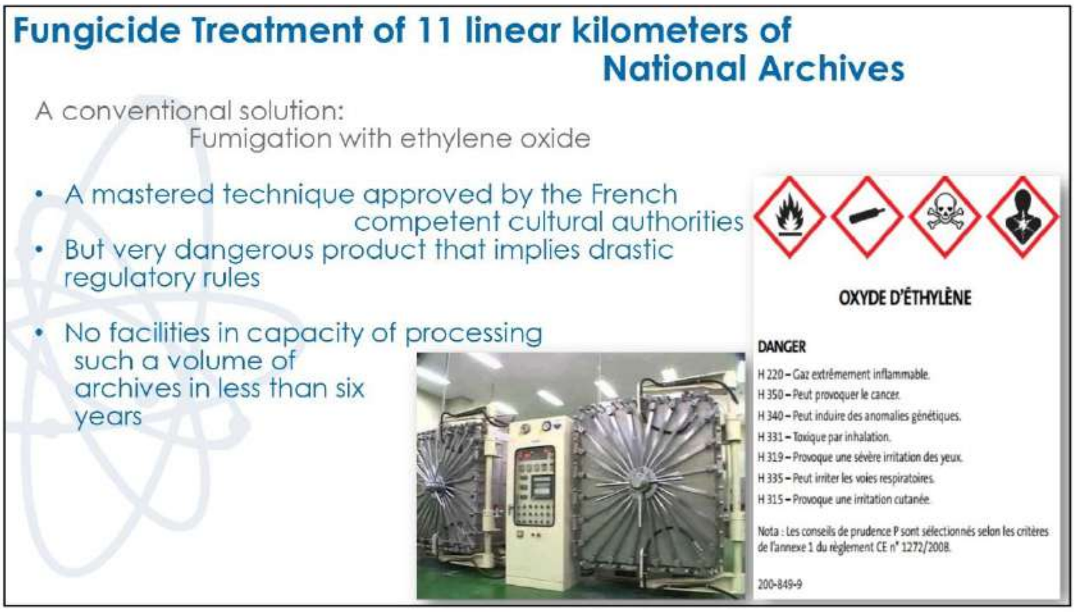

Paper behavior under irradiation
WIKIPEDIA
The Free Encyclopedia
Not logged in Talk Contributions Create account Log in
Article Talk
Read Edit View history
United States Postal Service Irradiated mail
From Wikipedia, the free encyclopedia
Irradiated mail is mail that has been deliberately exposed to radiation, typically in an effort to disinfect it. The most notable instance of mail irradiation in the US occurred in response to the 2001 anthrax attacks; the level of radiation chosen to kill anthrax spores was so high that it often changed the physical appearance of the mail.[1]
The United States Postal Service began to irradiate mail in November 2001, in response to the discovery of large-scale contamination at several of its facilities that handled the letters that were sent in the attacks.
A facility in Bridgeport, New Jersey, operated by Sterigenics International, uses a Rhodotron continuous wave electron beam accelerator built by IBA Industrial, to irradiate the mail. A few facilities were planning to use cobalt-60 sources, though it is unclear whether this was ever done.
Effect on mail [edit]
The USPS warned that a number of products could be adversely affected, such as seeds, photographic film, biological samples, food, medicines, and electronic equipment. In the process of irradiation, mail is exposed to extreme heat. Paper is weakened and may appear to have been aged, with discoloration (e.g., yellowing), and brittleness. Pages may break, crumble, or fuse to other pages. Documents bound with glue may have loose pages. The printing on pages may be distorted or offset onto adjacent pages. If tape is affixed to address labels, the address may be illegible.[2]
Irradiation's effects on paper caused some alarm in the philatelic world, which sends large numbers of rare postage stamps and covers through the mail. A number of auction houses stopped sending material through the mail, and Linn's Stamp News regularly featured reports on stamps and covers that had been ruined by irradiation.[3]
Although at one time the USPS expected to irradiate all mail, it later scaled back to just treating mail sent to government offices, including all mail directed to the White House, Congress, and the Library of Congress.[4]

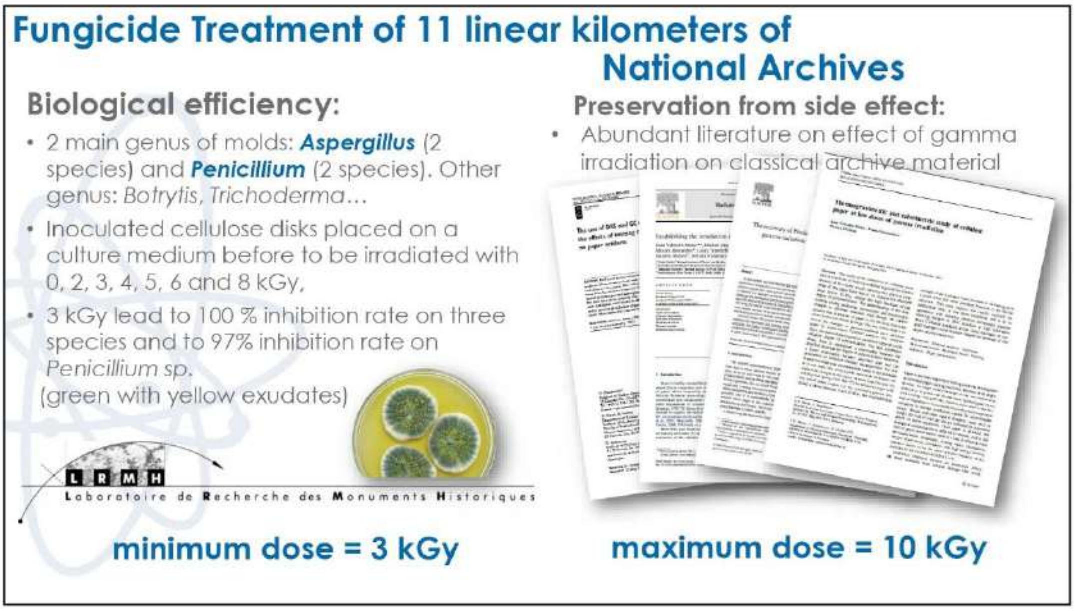

Paper behavior under irradiation
Degree of Polymerization (Intrinsic Viscosity)
(values relative to the non-irradiated reference)
Insect Eradication
Fungicide Treatment
1 Gy
1 kGy
1 MGy
Tensile Strength
(values relative to the non-irradiated reference)
Insect Eradication
Fungicide Treatment
1 Gy
1 kGy
1 MGy


Paper
Molecular weight distribution measured by Steric Exclusion Chromatography (SEC)
Unirradiated reference
4 kGy
6 kGy
8 kGy
10 kGy
60 kGy
Log(M)
Liaisons intra-moléculaires
Liaisons intermoléculaires
Thermogravimetric and calorimetric study of cellulose paper at low doses of gamma irradiation
Moise, I.V., Stanculescu, I. & Meltzer, V.
J Therm Anal Calorim (2014) 115: 1417.
"Paper deterioration by mold is more severe than by gamma irradiation"
John Havermans †

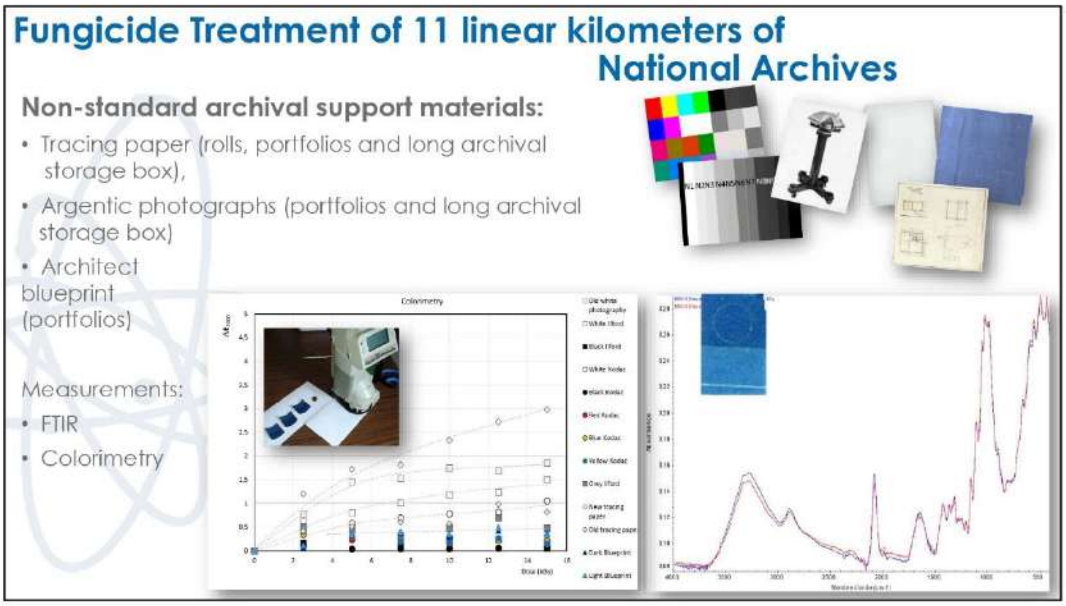

Paper
Use in many countries in the world
USA
• (1982) Alan Mason Chesney Medical Archives, Johns Hopkins Medical Institutions, Boston, MA
• (1997) The Morgan Library, Fort Collins, CO
The Netherlands
• (2006) Collections du Palais de la Paix de La Haye
Brasil, Germany, Poland, Romania, Argentina, …

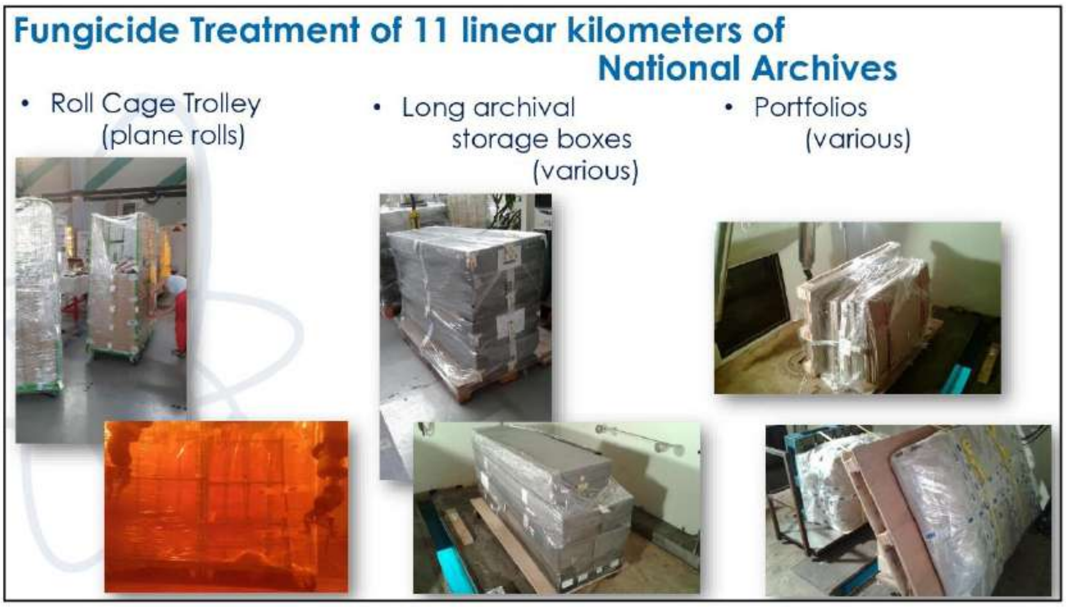

Fungicide Treatment of 11 linear kilometers of National Archives
A large scale disaster
• Discovery on the fifth basement floor: 5 cm of water covering 8 000 m² (July 2015, after the storage building closed for more than one year due to structural weaknesses)
• 56 000 standard folders boxes
• 1 482 rolls of planes, packaged or not
• 443 portfolios of planes …
ARCHIVES NATIONALES
55% of packaging contaminated with mold

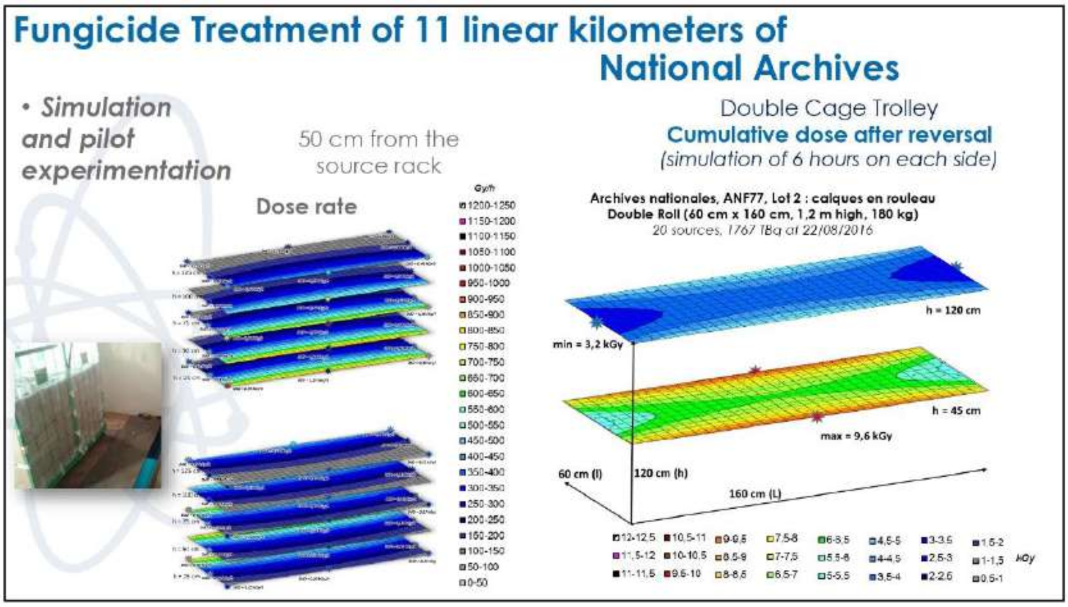

Fungicide Treatment of 11 linear kilometers of National Archives
A conventional solution:
Fumigation with ethylene oxide
• A mastered technique approved by the French competent cultural authorities
• But very dangerous product that implies drastic regulatory rules
• No facilities in capacity of processing such a volume of archives in less than six years
OXYDE D'ÉTHYLÈNE
DANGER
H 220 – Gaz extrêmement inflammable.
H 350 – Peut provoquer le cancer.
H 340 – Peut induire des anomalies génétiques.
H 331 – Toxique par inhalation.
H 319 – Provoque une sévère irritation des yeux.
H 335 – Peut irriter les voies respiratoires.
H 315 – Provoque une irritation cutanée.
Nota : Les conseils de prudence P sont sélectionnés selon les critères de l'annexe 1 du règlement CE n° 1272/2008.
200-849-9


Fungicide Treatment of 11 linear kilometers of National Archives
Biological efficiency:
• 2 main genus of molds: Aspergillus (2 species) and Penicillium (2 species). Other genus: Botrytis, Trichoderma…
• Inoculated cellulose disks placed on a culture medium before to be irradiated with 0, 2, 3, 4, 5, 6 and 8 kGy,
• 3 kGy lead to 100 % inhibition rate on three species and to 97% inhibition rate on Penicillium sp.
(green with yellow exudates)
LRMH
Laboratoire de Recherche des Monuments Historiques
minimum dose = 3 kGy
Preservation from side effect:
• Abundant literature on effect of gamma irradiation on classical archive material
maximum dose = 10 kGy


Fungicide Treatment of 11 linear kilometers of National Archives
Standard folders boxes: Industrial facilities
• High capacity (50 to 100 pallets per week)
• Good mastery of DUR even on large pallets
STERIS
Non standard format or material at ARC-Nucléart irradiator
• Complementary studies
• Non automated procedure
arc nucle art
1170 pallets
54 "processing units"


Fungicide Treatment of 11 linear kilometers of National Archives
Non-standard archival support materials:
• Tracing paper (rolls, portfolios and long archival storage box),
• Argentic photographs (portfolios and long archival storage box)
• Architect blueprint (portfolios)
Measurements:
• FTIR
• Colorimetry
Colorimetry


Fungicide Treatment of 11 linear kilometers of National Archives
• Roll Cage Trolley (plane rolls)
• Long archival storage boxes (various)
• Portfolios (various)


Fungicide Treatment of 11 linear kilometers of National Archives
• Simulation and pilot experimentation
50 cm from the source rack
Dose rate
Double Cage Trolley
Cumulative dose after reversal
(simulation of 6 hours on each side)
Archives nationales, ANF77, Lot 2 : calques en rouleau
Double Roll (60 cm x 160 cm, 1,2 m high, 180 kg)
20 sources, 1767 TBq at 22/08/2016
min = 3,2 kGy
h = 120 cm
h = 45 cm
max = 9,6 kGy
60 cm (l)
120 cm (h)
160 cm (L)
kGy


Fungicide Treatment of 11 linear kilometers of National Archives
Systematic Routine Dose Control
Statistical Biological Control
ATP Test (growing activity)
Laboratoire de Recherche des Monuments Historiques
Systematic dose measurement (Minimum and maximum dose)
Mean max : 7,9 kGy
Mean min : 3,9 kGy
Dose (kGy)
Min
Max
Classical culture on medium
(before dust removal)
Laure Méric for
A2C


Treatments Addressing New Issues
2020 – Rescue of a frozen Egyptian mummy after a flood
• Fungicidal treatments at frozen state before its freeze-drying

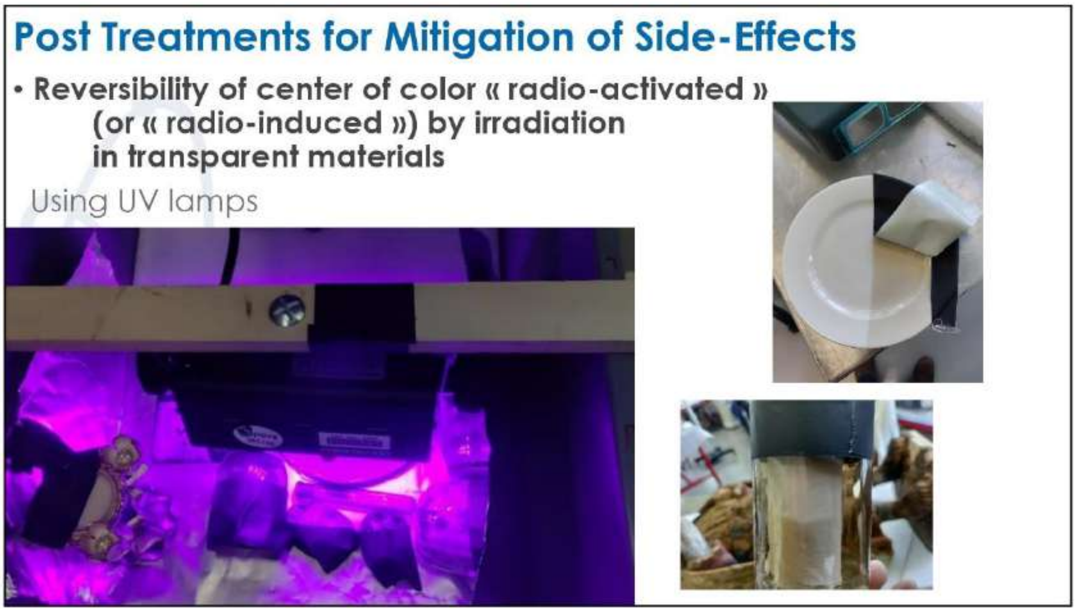

Treatments Addressing New Issues
2020 – Disinfection of humid organic remains from a medieval abbot burial awaiting "laboratory excavation"
• Sanitary and conservation bactericidal and fungicidal treatments
10 cm
Aubric de Braine remains – 13th c. – Soissons, France


Treatments Addressing New Issues
2021 – Disinfestation of a Gallo-Roman ex-voto released by a glacier
Gallo-Roman wooden ex-voto of Colerin
–1st or 2nd c. – Bessans, France


Treatments Addressing New Issues
2022 – Disinfection of paintings from two chapels infested by Serpula lacrymans
• On-site intervention for hermetic packaging
• Biocidal cleaning of the packaging before transport


Treatments Addressing New Issues
2022 – Disinfection of paintings from two chapels infested by Serpula lacrymans
• Irradiation in the airtight packaging


Treatments Addressing New Issues
2022 – Disinfection of paintings from two chapels infested by Serpula lacrymans
• Suction of the dead spores


Post Treatments for Mitigation of Side-Effects
• Reversibility of center of color « radio-activated » (or « radio-induced ») by irradiation in transparent materials
Using UV lamps


Thank you for your attention

2.7 Scanning Electron Microscopy and Energy Dispersive X-ray Analysis: Application in Artifact Characterization

Name: Nadira Kamarudin
Date of Presentation: 24th October 2023
Email: nadira@nm.gov.my

In a world where the past is continually interwoven with the present, preserving cultural heritage is a testament to human history and identity. As we move into the 21st century, our methods to conserve and understand these artifacts have become more sophisticated, blending the lines between science, technology, and art.

One of the most intriguing developments in this field is the use of gamma radiation in the conservation process. Traditionally, the thought of exposing ancient manuscripts and books to radiation has been met with concern, primarily due to the fear of potential damage to these delicate materials. However, recent studies have begun to shed a more positive light on this technique, suggesting that it could be a vital tool in the fight to preserve our cultural heritage.

The concern regarding gamma radiation stems from its powerful energy, which can alter the very structure of cellulose - the organic compound that forms the basis of paper. Yet, researchers are finding that controlled doses of gamma rays can effectively sterilise historical documents and books, eliminating biological contaminants such as mold and bacteria without harming the paper itself. This breakthrough presents a promising solution to the risks posed to human health by contaminated texts and halts the destruction of cultural artifacts in infested archives.

To thoroughly understand the impact of gamma irradiation on paper, scientists have conducted extensive studies comparing the effects of different radiation doses on cellulose. For instance, a sample of Whatman No.1 CHR paper, a standard reference material in filtration and laboratory processes, was subjected to high doses of gamma radiation. The results, examined under a Scanning Electron Microscope (SEM) at a magnification of 5000 times, provided crucial insights into the microscopic changes occurring within the paper's structure. These findings are invaluable, enabling conservators to determine the optimal radiation levels that can be applied safely to various materials.

Another aspect of cultural heritage that benefits from modern scientific methods is the analysis and characterization of textile-metal thread embroidery, a craft that adorns many historical artifacts. Over time, these metal threads can tarnish, losing their luster and making it challenging to appreciate the original beauty of the pieces. To address this, conservators turn to Energy-dispersive X-ray spectroscopy (EDX), a technique that allows for the elemental analysis of the threads.

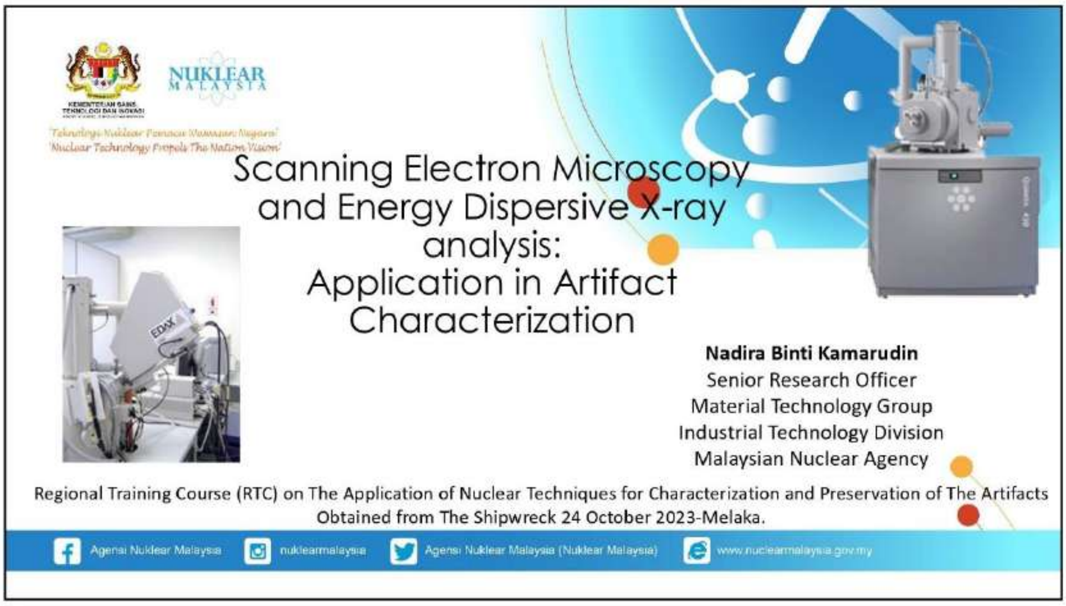
Through EDX, it is possible to identify the precise elements that compose the threads, providing percentages by weight. For instance, an analysis might reveal significant amounts of silver (Ag) and gold (Au) alongside other elements like carbon (C) and oxygen (O), offering clues to the item's age and the techniques used in its creation. The elemental composition can also help to verify the authenticity of the artifact, distinguishing between genuine antique pieces and more modern replicas.

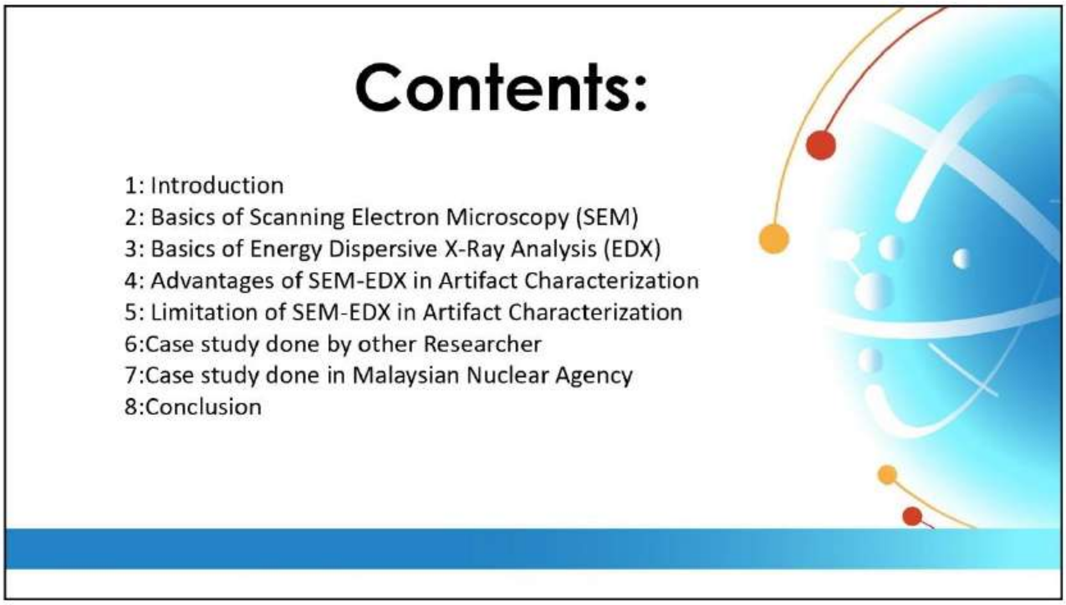
Further investigations into the microstructure of these threads are conducted using SEM micrographs, which offer a view into the morphology of samples at 400 times magnification. By examining these images, specialists can determine the manufacturing techniques employed in creating the threads. The presence or absence of mechanical strains or patterns, such as longitudinal striations, can indicate whether the threads were "beaten and cut" or produced using later techniques like "cast, drawn, and rolled." Such details not only help to authenticate the artifacts but also provide a window into the historical manufacturing practices.

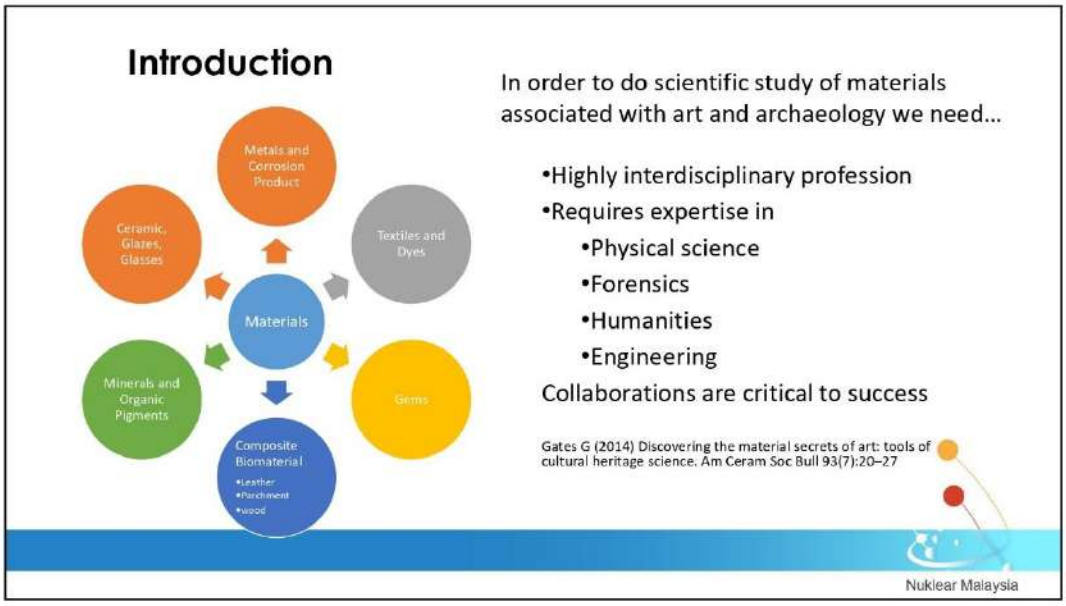
The significance of SEM and EDX in cultural heritage studies must be considered. These methods have become instrumental in solving archaeological puzzles and investigating various objects of art and culture. By correlating microchemistry with microstructure, scientists can uncover a wealth of information about an artifact. Beyond determining its composition and microstructure, these techniques can often trace the raw materials to their geographical origins, cross-referencing findings with extensive databases to confirm the artifact's authenticity.

Understanding the materials that make up cultural artifacts is crucial for their conservation. It allows conservators to create conditions that prevent further degradation and apply restoration techniques sympathetic to the original methods used to make these pieces. By using advanced scientific tools, conservators can ensure that the physical reminders of our collective past are preserved not just for current enjoyment but also for the benefit of future generations.

As we continue to develop and refine these technologies, the field of cultural heritage conservation is evolving into an interdisciplinary arena where history meets cutting-edge science. The melding of these disciplines is not just about preserving the physicality of artifacts but is also a commitment to maintaining a tangible connection to the narratives, knowledge, and aesthetics they carry. The ongoing advancements in conservation science are a beacon of hope, assuring that the stories and accomplishments of our ancestors will not be lost to the ravages of time. The slides in the upcoming section detail the work done on this.


NUKLEAR MALAYSIA
Scanning Electron Microscopy and Energy Dispersive X-ray analysis: Application in Artifact Characterization
EDAX
Nadira Binti Kamarudin
Senior Research Officer
Material Technology Group
Industrial Technology Division
Malaysian Nuclear Agency
Regional Training Course (RTC) on The Application of Nuclear Techniques for Characterization and Preservation of The Artifacts Obtained from The Shipwreck 24 October 2023-Melaka.
Agensi Nuklear Malaysia
nuklearmalaysia
Agensi Nuklear Malaysia (Nuklear Malaysia)
www.nuclearmalaysia.gov.my


Contents:
1: Introduction
2: Basics of Scanning Electron Microscopy (SEM)
3: Basics of Energy Dispersive X-Ray Analysis (EDX)
4: Advantages of SEM-EDX in Artifact Characterization
5: Limitation of SEM-EDX in Artifact Characterization
6:Case study done by other Researcher
7:Case study done in Malaysian Nuclear Agency
8:Conclusion


Introduction
Metals and Corrosion Product
Textiles and Dyes
Ceramic, Glazes, Glasses
Materials
Minerals and Organic Pigments
Gems
Composite Biomaterial
•Leather
•Parchment
•wood
In order to do scientific study of materials associated with art and archaeology we need...
•Highly interdisciplinary profession
•Requires expertise in
•Physical science
•Forensics
•Humanities
•Engineering
Collaborations are critical to success
Gates G (2014) Discovering the material secrets of art: tools of cultural heritage science. Am Ceram Soc Bull 93(7):20–27
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Scientific analytical tools for artifact characterization

- Stereomicroscope
- UV-Vis spectrometer
- Fluorescence Spectrometer
- Computer Tomography
- Radiography
- XRF
- SEM-EDX
- XRD
- FTIR
- PIXE
- And the list goes on expanding by time

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Scanning Electron Microscope (SEM)

A Scanning Electron Microscope (SEM) is an advanced microscopy technique that uses a focused beam of high-energy electrons to illuminate a specimen. Unlike traditional optical microscopes that use light, SEM relies on electron interactions with the sample's surface to produce detailed, high-resolution images.

Applications:

- Detailed imaging of surfaces at nanoscale resolution.
- Analysis of morphology, topography, and composition of various materials.
- Widely used in fields such as materials science, biology, geology, and archaeology.

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Sample-Electron Interaction

- The scanning electron microscope (SEM) produces images by scanning the sample with a high-energy beam of electrons.
- When the electron beam hits the surface of the sample, it penetrates the sample to a depth of a few microns, depending on the accelerating voltage and the density of the sample.
- As the electrons interact with the sample, they produce secondary electrons, backscattered electrons, and characteristic X-rays.
- These signals are collected by one or more detectors to form images which are then displayed on the computer screen.

https://myscope.training

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Energy Dispersive X-Ray Analysis (EDX)

Energy Dispersive X-Ray Analysis (EDX) is a technique often coupled with SEM to provide elemental analysis of a sample. When the electron beam interacts with the specimen, it causes the emission of characteristic X-rays from the atoms in the sample. EDX detects and analyzes these X-rays to determine the elemental composition of the material.

Applications:

- Elemental analysis of materials without the need for extensive sample preparation.
- Identification of trace elements and impurities.
- Characterization of chemical composition in a wide range of samples.

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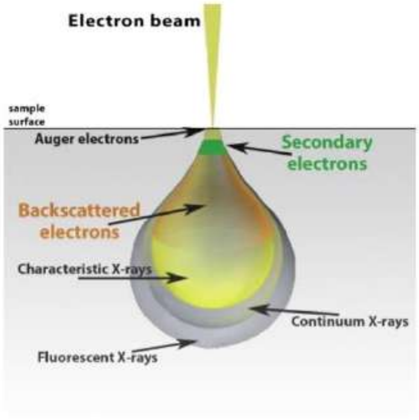
EDX



- Detection of the X-rays, which are generated from the electron-sample interaction, is also widely used to perform elemental analysis of the sample.
- Every material produces X-rays that have a specific energy; X-rays are the material's fingerprint. So, by detecting the energies of X-rays that come out of a sample with an unknown composition, it is possible to identify all the different elements that it contains.

https://www.nanoscience.com/techniques/scanning-electron-microscopy/

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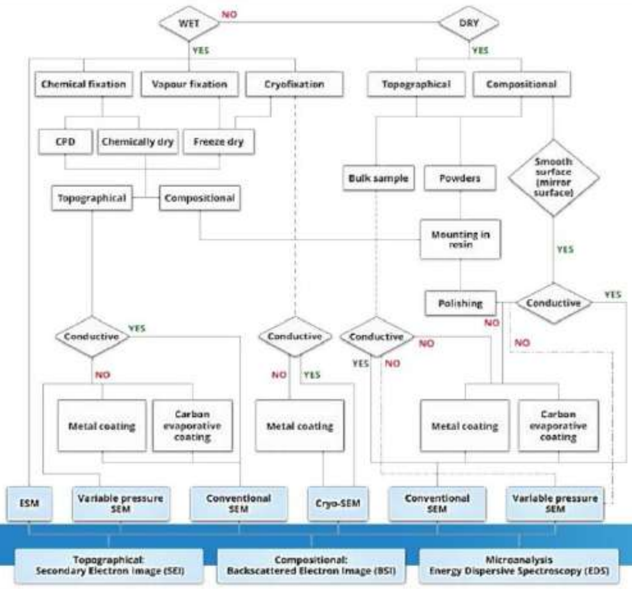
Sample Preparation



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Advantages of SEM-EDX in Artifact Characterization

The combination of Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Analysis (EDX) brings several advantages to the table, making them powerful tools for artifact characterization:

1.High-Resolution Imaging:
SEM provides exceptionally high-resolution images, allowing researchers to visualize and capture intricate details at the nanoscale.
Enables the examination of surface structures, textures, and fine features of artifacts with unprecedented clarity.

2. 3D Imaging Capability:
SEM's ability to generate three-dimensional images provides a comprehensive view of the topography and morphology of artifacts.
Essential for understanding the spatial relationships between different components of complex structures.

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Advantages of SEM-EDX in Artifact Characterization

3.Elemental Analysis with Energy Dispersive X-Ray Analysis (EDX):
SEM is often coupled with EDX, enabling simultaneous imaging and elemental analysis.
Facilitates the identification and quantification of elements within artifacts, contributing to a thorough characterization.

4. Non-Destructive Nature:
SEM allows for non-destructive imaging, preserving the integrity of delicate or valuable artifacts.
Ideal for examining artifacts that cannot undergo traditional destructive analytical techniques.

5. Versatility Across Materials:
From metals and ceramics to biological specimens, SEM accommodates a wide range of materials for analysis. Offers a versatile approach to studying artifacts from various disciplines.

6. Sample Surface Sensitivity:
SEM is particularly sensitive to the surface of samples, making it suitable for investigating surface modifications, coatings, or contamination on artifacts.

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Advantages of SEM-EDX in Artifact Characterization

7. Advancements in Sample Preparation Techniques:
Ongoing developments in sample preparation techniques have enhanced the compatibility of SEM with diverse artifact types. Reduced requirements for elaborate sample preparations, making the technique more accessible.

8. Educational and Outreach Value:
SEM's visually striking images have significant educational and outreach potential.
Captivating visuals generated by SEM contribute to public engagement and the communication of scientific discoveries.

SEM-EDX serves as a cornerstone in artifact characterization, offering researchers a powerful and versatile tool for exploring the minute details that shape our understanding of historical, cultural, and scientific contexts.

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Limitation of SEM-EDX in Artifact Characterization

SEM-EDX is a powerful tool for artifact characterization but it does have some limitations, especially when applied to characterizing valuable artifacts. Some of them are:

1. Sample Preparation Challenges:
The preparation of samples for SEM-EDX analysis can be time-consuming and may require special techniques. For delicate or valuable museum artifacts, the preparation process may be limited to non-destructive methods.

2. Surface Sensitivity:
SEM is primarily surface-sensitive. It may not penetrate deep into the material, limiting the analysis to surface features. This can be a drawback when studying the internal structure of artifacts.

3. Beam Damage:
The electron beam in SEM can cause damage to some materials over time. This is particularly relevant for sensitive artifacts with organic components or fragile surfaces.

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Limitation of SEM-EDX in Artifact Characterization

4. Charge Accumulation:
Insulating materials can accumulate charge during SEM analysis, leading to imaging artifacts and distortion. Conductive coatings or other measures are often required to mitigate this effect.

5. Limited Elemental Range:
While EDX is excellent for identifying and quantifying elements, it may have limitations in detecting light elements. Elements with low atomic numbers may not produce strong X-ray signals, making their analysis less reliable.

6. Quantitative Accuracy:
Achieving accurate quantitative results with EDX may be challenging, and calibration is necessary for precise elemental quantification. Environmental conditions can also affect results.

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Limitation of SEM-EDX in Artifact Characterization

7. Small Field of View:
SEM typically has a smaller field of view compared to other imaging techniques, limiting the amount of the artifact that can be examined in a single view.

8. Cost and Accessibility:
SEM-EDX equipment can be expensive to acquire and maintain. This may pose challenges for smaller museums or institutions with limited budgets.

9. Resolution vs. Depth of Field Trade-off:
Achieving high resolution in SEM images may come at the expense of depth of field. This trade-off can limit the simultaneous detailed imaging of both surface and subsurface features.

10. Artifact Size Constraints:
The size of the artifact may affect the feasibility of SEM-EDX analysis. Extremely large or irregularly shaped artifacts may be challenging to analyze effectively.

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Limitation of SEM-EDX in Artifact Characterization

11. Limited to Solid Samples:
SEM-EDX is primarily designed for solid samples. It may not be suitable for the analysis of certain types of artifacts, such as liquids or gases.

12. Complexity of Interpretation:
Interpreting SEM-EDX results requires expertise, and misinterpretations can occur. Collaboration with experts in SEM-EDX analysis is crucial for accurate artifact characterization.

Despite these limitations, when used judiciously and with proper consideration of these challenges, SEM-EDX remains an invaluable tool for studying museum artifacts, offering unique insights into their composition and structure.

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Case Studies done by other Researchers

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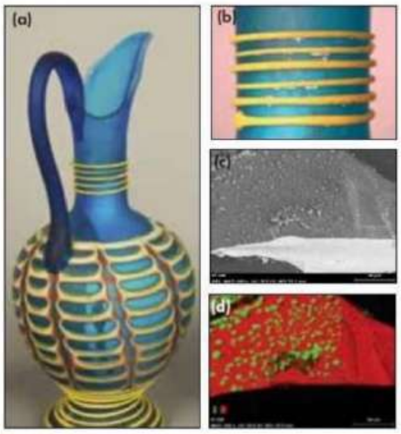
Venetian glass Ewer



- Conservators noticed the presence of a white crystalline material on the surface of the Venetian glass *Ewer (Figure(a) and (b)) while preparing* it for exhibition.
- Because this artwork was created in the late 19th or early 20th century with the intention of appearing ancient or antique, the question arose whether the accretion indicated an unstable glass composition or if it was evidence of the "antiquing" process used by the creator and, therefore, ought to be preserved as part of the object's history.
- Extracting a small sample that included the glass and the accretion for SEM-EDS analysis showed with certainty that the white material had been applied, because fluorine was detected only in the accretion, not in the underlying glass substrate (Figure (c) and (d)).
- In this case, material analysis informed the proper conservation of the object during its preparation for exhibition—the accretion was evidence of the maker's antiquing technique, thus it was preserved

Elliott and J. Giaccai, "The technical analysis of a glass Ewer by Salviati & Co.," *The Journal of the Walters Art Museum*, ***70–71***, 133–37 (2012–2013).

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Quran

R. Bahadori, F. Bahrololoomi, and N. M. Kashani, *Proc. 39 Int. Symp. on Archeometry, Leuven, Belgium, 2012, p. 324*

- Koran fragments dated to the 10th–11th centuries AD, parchment, and ink were investigated by the SEM–EDX methods.
- A microanalysis of the parchment revealed carbon and oxygen in its composition (and thus confirmed the organic nature of this object of study), as well as Si, Na, K, Ca, Mg, Cl, and S. The presence of some elements may be related to the parchment processing aimed at imparting it with a certain hue.
- The manuscript text was written in inks of three colors: black, red, and green. An analysis showed that part of the red ink contains mercury and that it was made based on vermilion or cinnabar (HgS). Possible cinnabar sources are the river rock near the town of Takab (western Iran) or the mines near Fergana.
- At the same time, a number of red paint samples exhibited the presence of iron and oxygen; i.e., part of red ink was made based on ochre (a mixture of iron oxide with clay). Another component of red ink was based on an organic pigment. Green ink contained copper salts and black ink contained mainly carbon, with a small amount of iron impurity, although a final conclusion on the composition of this pigment has not been drawn.
- Based on the EDX data and the established composition of the pigments, one can formulate suggestions about the sources of their origin.

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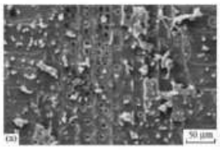
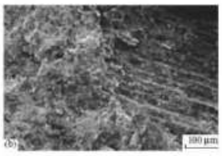
Possible factors wood degradation



It was found in that a thermal treatment at temperatures in the range of 190–240°C may cause formation of microcracks and structural decomposition, which manifests itself in a separation of lamellae. An increase in temperature in the presence of moisture and under pressure leads to the softening of lignin (a natural polymer formed on the walls of woody vegetable cells). This process may be accompanied by changes in cellular membranes and the formation of holes in pine wood



The metal corrosion products from the metal environment of an artifact, particularly iron ions, are catalysts for cellular-wall decomposition reactions. Metal ions can be accumulated in the intercellular space to form a replica of the original wood structure in the course of time

Vasiliev, A.L., Kovalchuk, M.V. & Yatsishina, E.B. Crystallogr. Rep. (2016) 61: 873.

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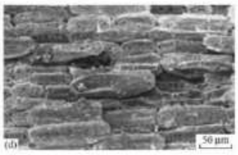
Possible factors wood degradation

Mechanical effects cause wood destruction, which begins in the direction parallel to fibers, at the boundaries between cells, independent of the load direction



The most hazardous and destructive damage of wooden articles is caused by fungi. Traces of fungus infection can be found after several days. Fungi, which grow in cracks and holes, may lead to a significant damage after several months.

Vasiliev, A.L., Kovalchuk, M.V. & Yatsishina, E.B. Crystallogr. Rep. (2016) 61: 873.

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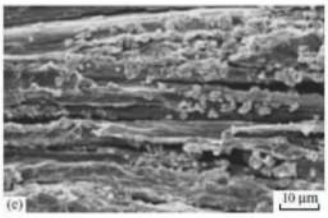
Possible factors wood degradation



Treatment procedures used in conservation and cleaning or gluing may also lead to the degradation of archaeological wooden objects.

Thus, gaining insight into the wood degradation processes helps one develop a protocol for reconstructing and preserving wooden artefacts.

Vasiliev, A.L., Kovalchuk, M.V. & Yatsishina, E.B. Crystallogr. Rep. (2016) 61: 873.

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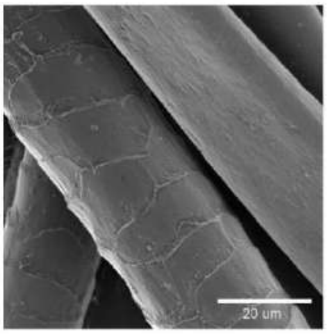
Authenticity (forgery)



The image shows human hair and nylon fibres.

- https://myscope.training

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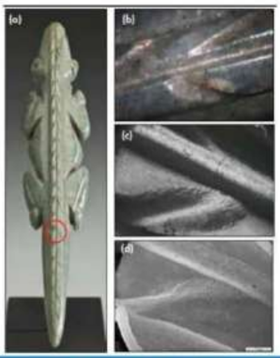
Authenticity (ancient or not?)

Jade Crocodile Effigy Pendant (15.7 cm high) carved in Atlantic Watershed-style and attributed to ancient Costa Rica



Tool marks from abrasives on carved jade, provide evidence that helps distinguish between ancient and modern techniques and can inform questions of authenticity.

(b) Toolmarks are difficult to discern on Crocodile's surface in this 10-mm long photomicrograph.

(d) SEM micrograph of silicone impression

SEM micrograph shown in Figure (d) clearly shows a surface prepared using loose abrasives.

Ancient American societies carved jade extensively using loose abrasives that created irregularly and variably sized marks.

Modern cottage industries also supply collectors with carved jade objects that imitate ancient production, although these techniques make use of fixed abrasives that leave marks appearing as fine, regularly spaced parallel lines.

J. Lauffenburger, "Approaches to authentication"; pp. 198–200 in *Exploring Art of the Ancient Americas. Giles, London, 2012*

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Conservation Of Metallic Embroidery Threads In Historic Textile Objects

Ahmed, Harby. (2014). A new approach to the conservation of metallic embroidery threads in historic textile objects from private collections. International Journal of Conservation Science. 5. 21-34.

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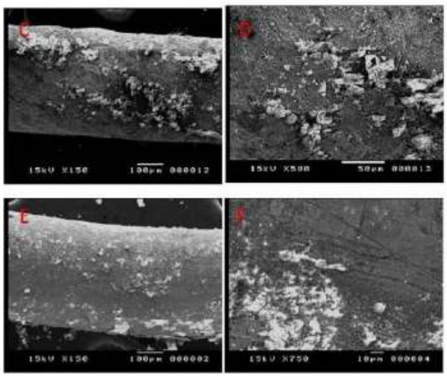

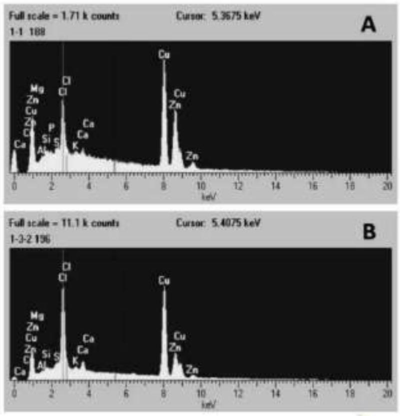

SEM images of the yellow metal threads (C and D)
and black metal threads (E and F), we can see the corrosion over the threads

Ahmed, Harby. (2014). A new approach to the conservation of metallic embroidery threads in historic textile objects from private collections. International Journal of Conservation Science. 5. 21-34.

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Studies done Nuclear Malaysia

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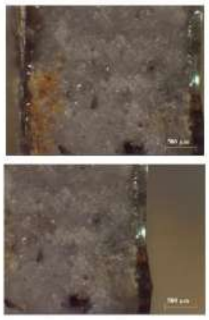
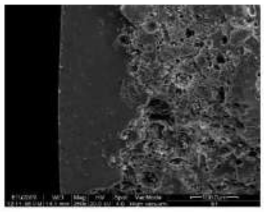
Ceramic (S1)- Nassau Ship Wreckage





SEM micrograph of S1 cross section at 250x magnification. The difference in density of glaze and base material of the sample can easily be distinguished.

Elements	Base (Wt%)
O	27.59
Al	11.80
Si	53.30
K	4.43
Ca	0.80
Fe	1.58

Elements	Glaze (Wt%)
C	39.86
O	8.48
Al	7.13
Si	27.42
K	1.75
Ca	12.18
Fe	3.19

EDX analysis result for base and glaze layer

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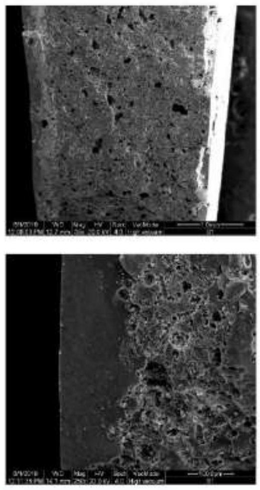
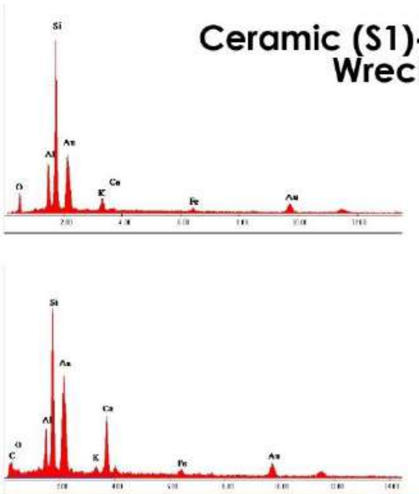
Ceramic (S1)- Nassau Ship Wreckage





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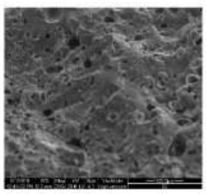
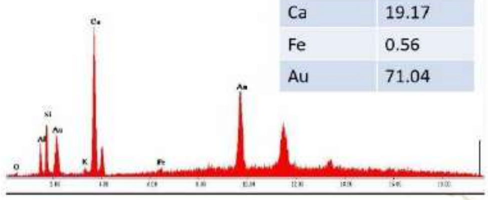
Seramik (S2)- Nassau Ship Wreackage





Element	Wt %
O	1.35
Al	2.58
Si	4.26
K	1.04
Ca	19.17
Fe	0.56
Au	71.04

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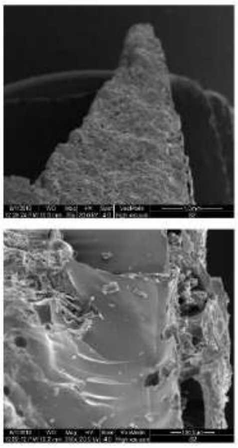
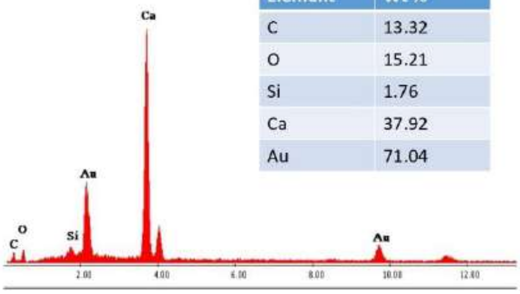
Seramik (S2)- Nassau Ship Wreackage





Element	Wt %
C	13.32
O	15.21
Si	1.76
Ca	37.92
Au	71.04

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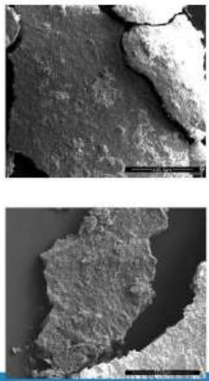
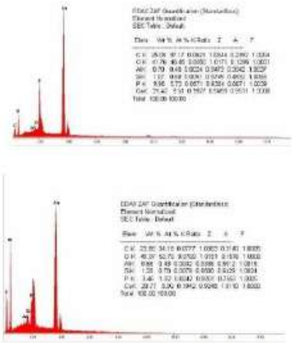
Degradation of Hoabinhian Skeleton Collection

Prehistoric human skeletons between 6,000-8,000 years old





The surface of the bone that has experienced deterioration that is likely from the effects of fungal growth.

The surface of the black fungus in figure 2 has dried and elemental analysis shows that there are bone elements that have been corroded similar to the fungus. This proves that fungi are also biodeterioration agents that contribute to the fragility of the skeleton collection.

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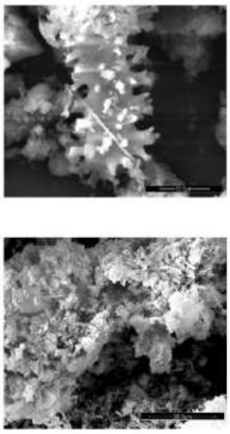

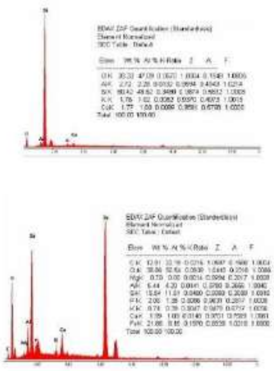

Crystal microstructure growth. These crystals are scattered throughout the bone fragments and are very fragile. Elemental analysis shows that the crystals formed are likely calcite crystals.

Precipitation of hydroxyapatite crystals when they react with moisture and also the sediment that is soil.

The results of elemental analysis show the complex elements of bone and also soil represented by high Si content

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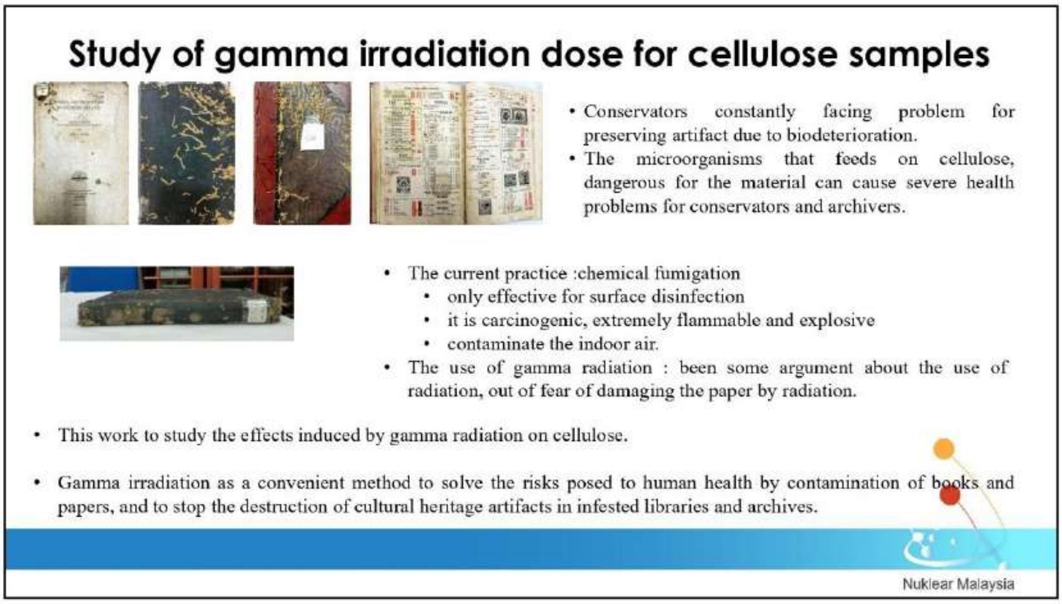
Study of gamma irradiation dose for cellulose samples
• Conservators constantly facing problem for preserving artifact due to biodeterioration.
• The microorganisms that feeds on cellulose, dangerous for the material can cause severe health problems for conservators and archivers.
• The current practice :chemical fumigation
• only effective for surface disinfection
• it is carcinogenic, extremely flammable and explosive
• contaminate the indoor air.
• The use of gamma radiation : been some argument about the use of radiation, out of fear of damaging the paper by radiation.
• This work to study the effects induced by gamma radiation on cellulose.
• Gamma irradiation as a convenient method to solve the risks posed to human health by contamination of books and papers, and to stop the destruction of cultural heritage artifacts in infested libraries and archives.
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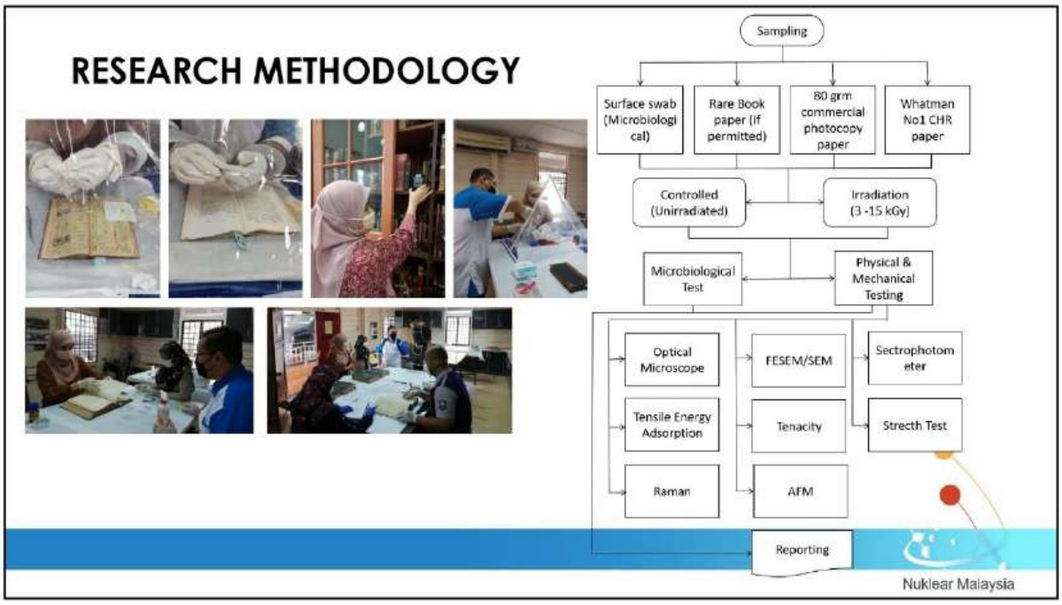
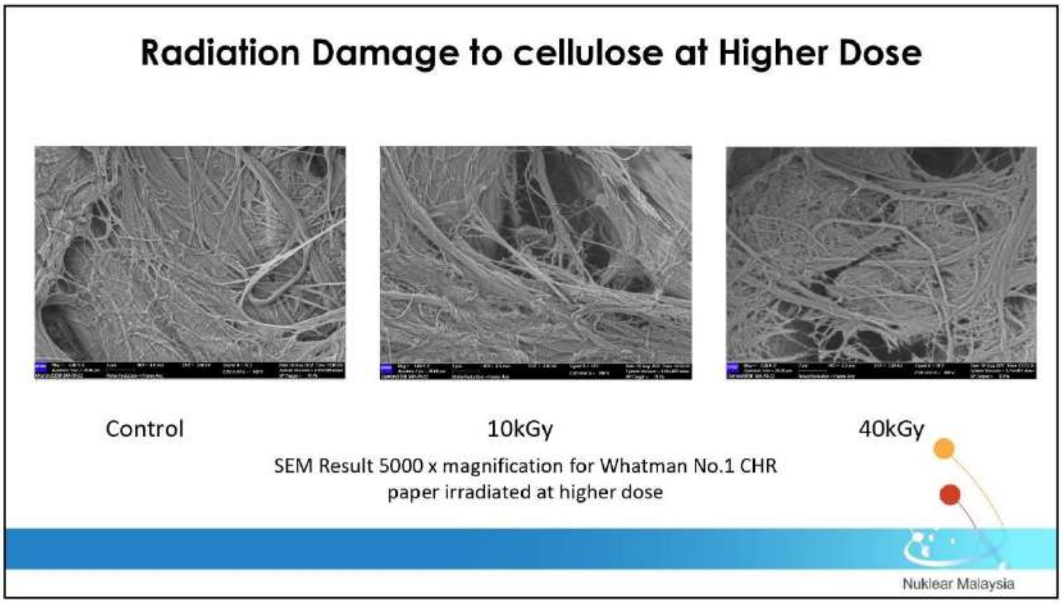

RESEARCH METHODOLOGY
Sampling
Surface swab (Microbiological)
Rare Book paper (if permitted)
80 grm commercial photocopy paper
Whatman No1 CHR paper
Controlled (Unirradiated)
Irradiation (3 -15 kGy)
Microbiological Test
Physical & Mechanical Testing
Optical Microscope
FESEM/SEM
Sectrophotometer
Tensile Energy Adsorption
Tenacity
Strecth Test
Raman
AFM
Reporting
Nuklear Malaysia


Radiation Damage to cellulose at Higher Dose
Control
10kGy
40kGy
SEM Result 5000 x magnification for Whatman No.1 CHR paper irradiated at higher dose
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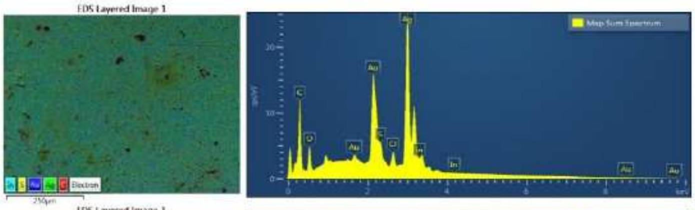
ANALYSES AND CHARACTERIZATION OF TEXTILE – METAL THREAD EMBROIDERY

The tarnished metal threads

Nuklear Malaysia

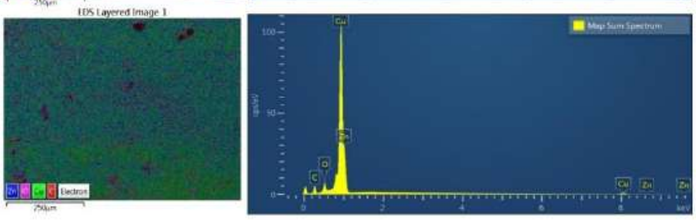
EDX elemental analysis

S1



Element	Wt%
C	6.96
O	3.77
S	2.14
Cl	1.12
Ag	60.45
In	0.46
Au	25.09
Total:	100.00

S2



Element	Wt%
C	6.02
O	2.18
Cu	64.72
Zn	27.07
Total:	100.00

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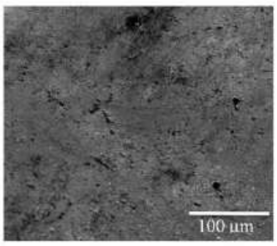
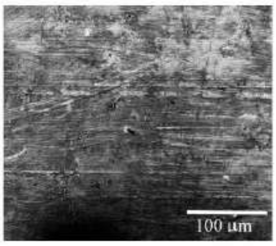
SEM Micrograph



S1



S2

Morphology of samples view by SEM micrograph at 400 times magnification

The surface of S1 shows no mechanical strains or longitudinal striations. It also shows no specific patterns. This indicate that "beaten and cut" manufacturing process was implemented in producing sample S1.

Sample S2 clearly shows longitudinal striations which prove that these two samples were produce using a latter technique, "cast, drawn and rolled". These findings proven that sample S1 has shown authentication by the way it is produce.

Nadira et al. Malaysia Museum Journal, Vol. 38, 2021

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Conclusion

- The ability of electron microscopy to make the correlation between microchemistry and micro structure is vital in cultural heritage studies.
- SEM and EDX is widely used to solve archaeological problems and investigate various objects of culture and art.
- Understanding of material is crucial to conserve artefact
- These method allow one not only to determined the microstructure of material and elemental composition of the artefact; but sometimes determined the raw material it was made of; establish the geographic region of the origin of this material and lots more compared to databases to ensure the authenticity of the artefact.

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2.8 X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) Technique: Application in Artifact Characterization

Name: Roshasnorlyza Hazan
Date of Presentation: 24th October 2023
Email: roshasnorlyza@nm.gov.my

In archaeology and cultural heritage preservation, scientists and researchers employ cutting-edge techniques to unravel the mysteries hidden within ancient artifacts. One such powerful method is X-ray technology, including X-ray Fluorescence (XRF) and X-ray Diffraction (XRD), which provides valuable insights into the composition, structure, and historical significance of these treasures.

X-ray Fluorescence (XRF) analysis, a non-destructive analytical technique, allows scientists to determine the chemical composition of various materials. By irradiating a sample with X-rays, this method induces fluorescence in its atoms, revealing the elements present and their concentrations. This technique has proven instrumental in studying artifacts like ancient coins, vases, and rare books.

XRF analysis operates on fluorescence intensity, where the emitted X-rays are analyzed to identify specific elements. This method offers several advantages, including non-destructiveness, ease of operation, and the ability to analyze solid, powder, and liquid samples. Despite its usefulness, XRF does have limitations, such as interferences between elements and limited depth of penetration into the sample.

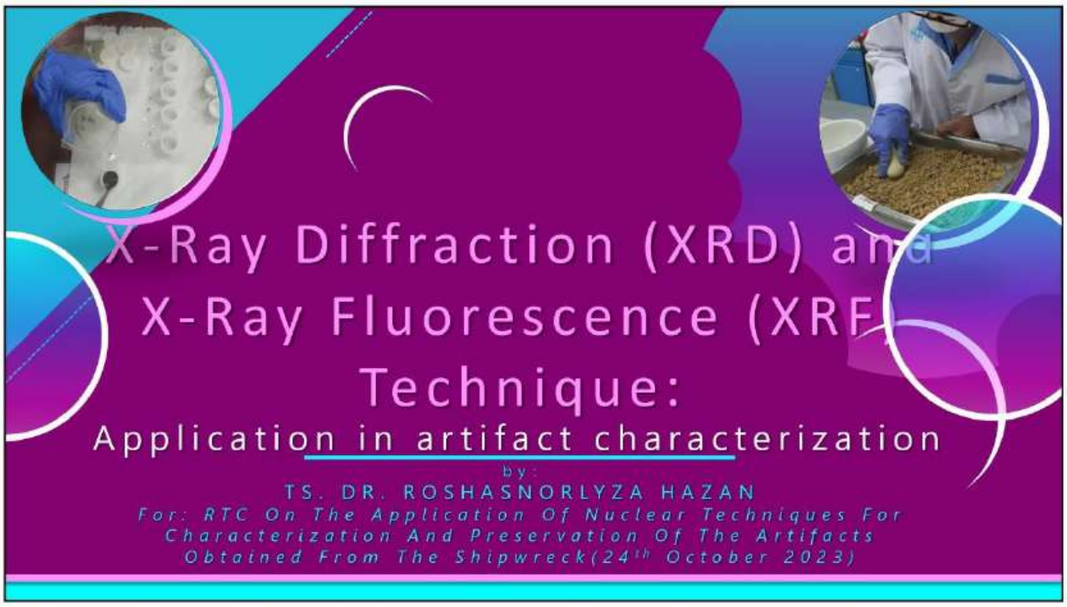
In conjunction with XRF, X-ray Diffraction (XRD) analysis provides detailed information about the crystallographic structure and physical properties of materials. By analyzing the diffraction patterns produced when X-rays interact with a crystalline sample, scientists can identify different crystalline phases and gain insights into the material's composition and structure. This method aids in the identification of authentic artifacts by comparing their XRD patterns with those in reference databases.

Researchers use these techniques to study various artifacts, each offering unique challenges and discoveries. For instance, in the case of ancient coins, XRF analysis helps identify the metal composition, allowing historians to trace the coin's origin and historical context. Similarly, ancient vases provide valuable insights into ancient civilizations, with XRD analysis revealing the techniques used in their production and authentication.

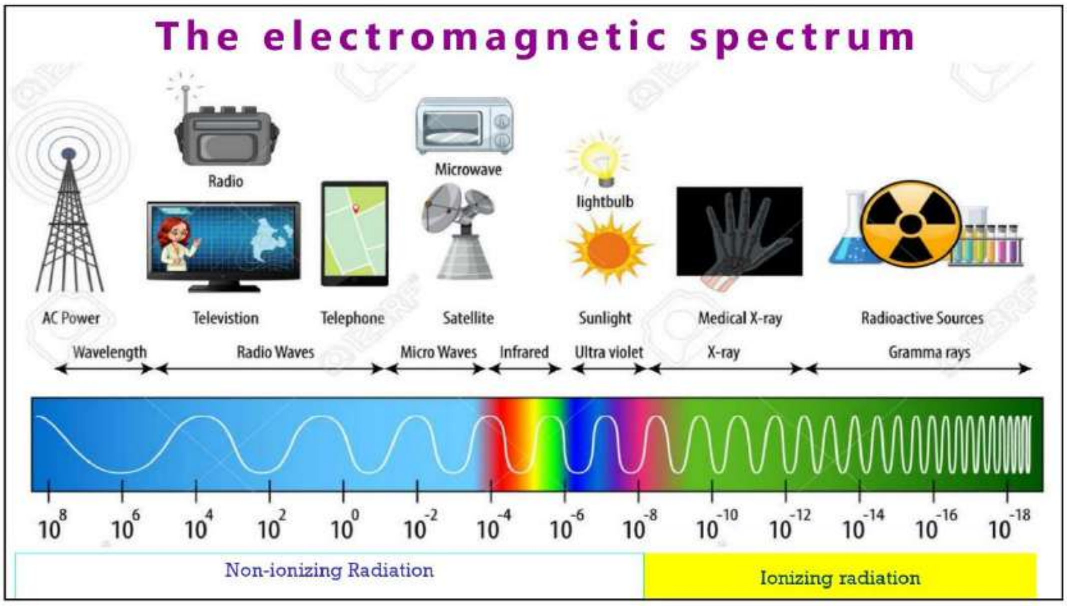
Rare books, often susceptible to degradation over time, benefit from X-ray analysis techniques to preserve their cultural heritage. XRF analysis can determine the composition of inks and pigments used in illustrations, shedding light on the book's origin and historical significance. Additionally, XRD analysis aids in understanding the paper's composition and response to environmental factors, guiding conservation efforts.

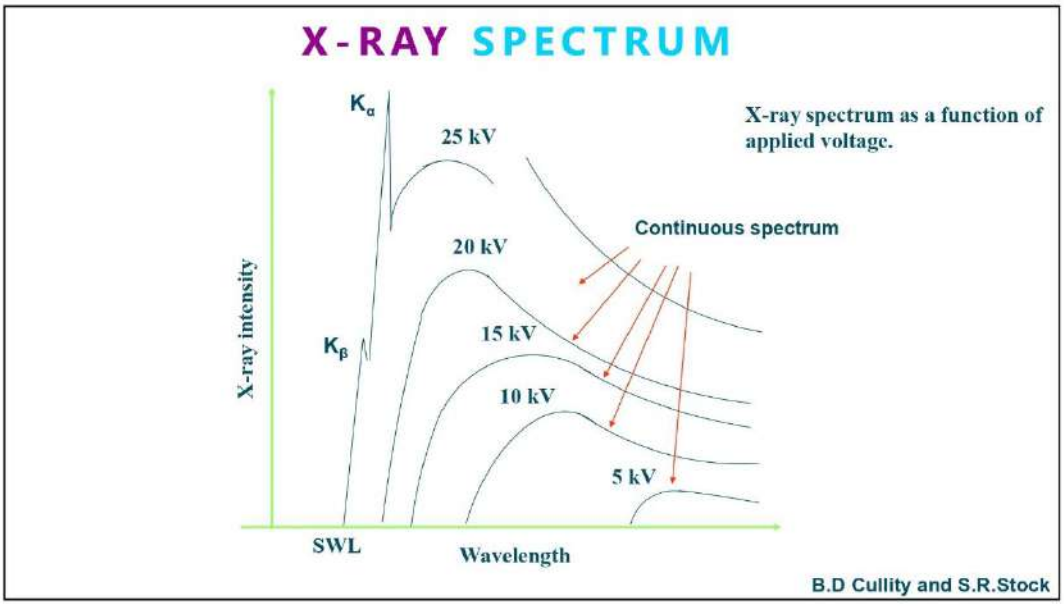
One of the significant advantages of these X-ray techniques lies in their ability to preserve the integrity of artifacts. Unlike traditional methods that might require destructive testing, XRF and XRD analyses ensure that the artifacts remain intact for future generations to study and appreciate. Furthermore, these techniques are fast, accurate, and minimize sample preparation, making them invaluable tools in archaeology.

In summary, the synergy between X-ray Fluorescence and X-ray Diffraction analyses has revolutionized the study of ancient artifacts, enabling researchers to delve deeper into history. By uncovering the secrets of ancient coins, vases, rare books, and various other artifacts, scientists continue to enrich our understanding of human civilization and preserve our cultural heritage for generations. The slides in the upcoming section detail the work done on this.

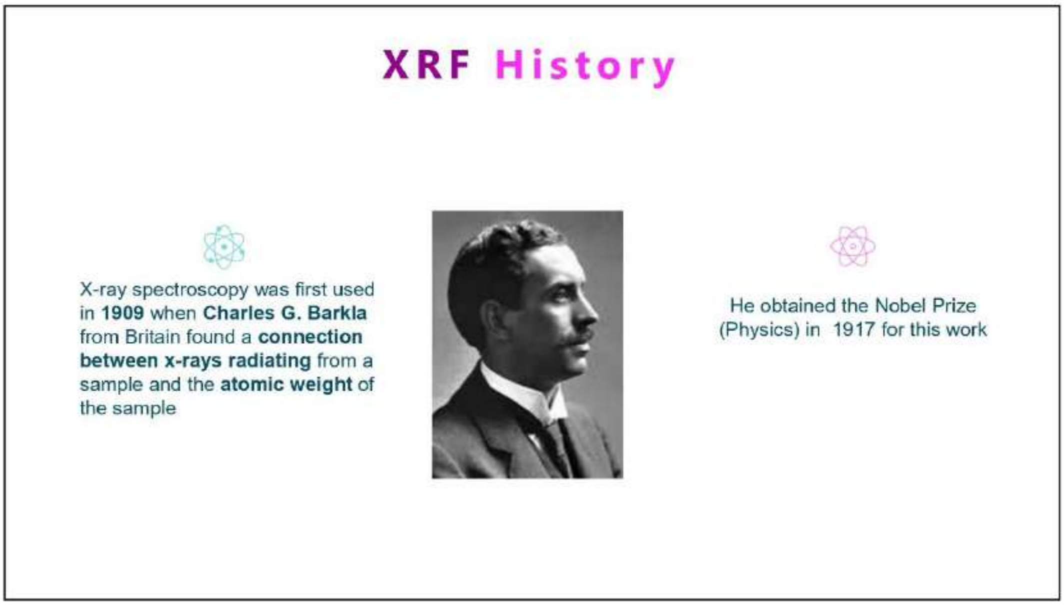

X-Ray Diffraction (XRD) and
X-Ray Fluorescence (XRF)
Technique:
Application in artifact characterization
by:
TS. DR. ROSHASNORLYZA HAZAN
For: RTC On The Application Of Nuclear Techniques For Characterization And Preservation Of The Artifacts Obtained From The Shipwreck(24th October 2023)

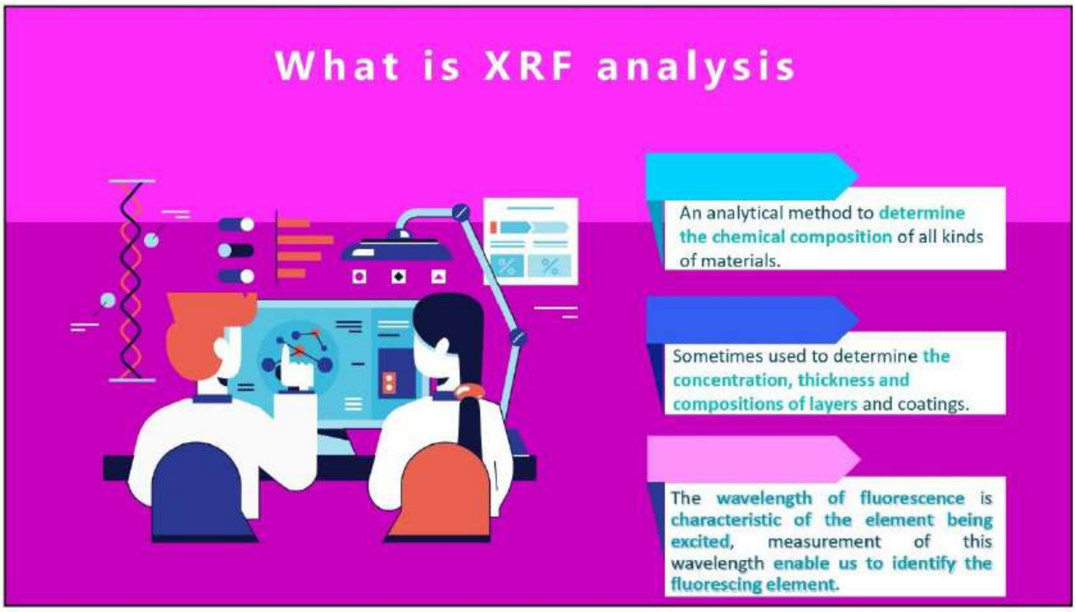

AGENDA
1. What is X-RAY?
2. X-Ray Fluorescence (XRF)
3. X-Ray Diffraction (XRD)
4. XRF and XRD application in artifact characterization
4a. Ancient Coin
4b. Ancient Vase
4c. Rare Book

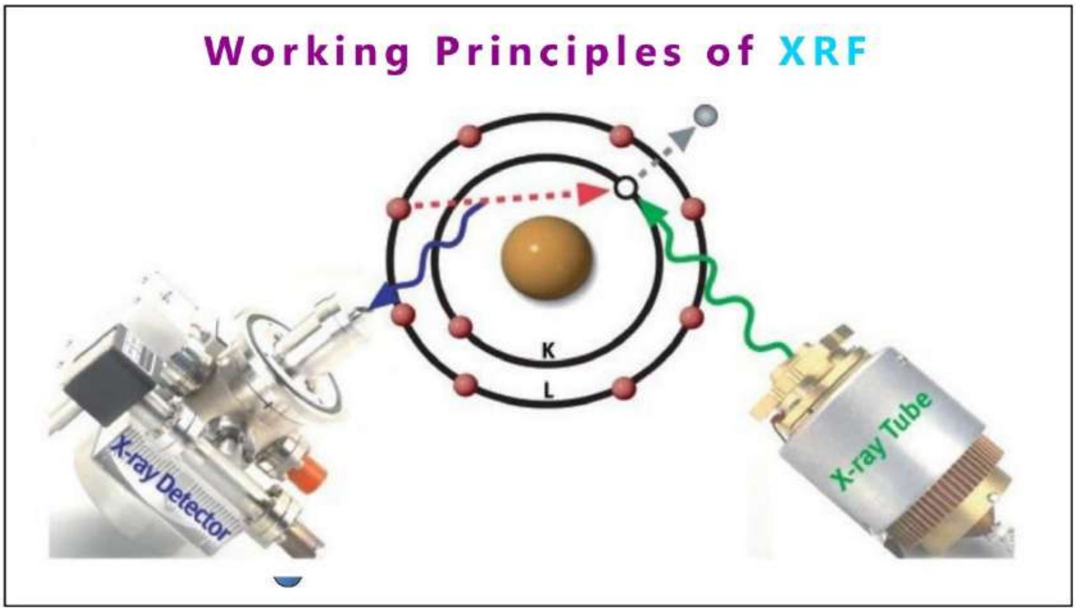

The electromagnetic spectrum
Radio
Microwave
lightbulb
AC Power
Televistion
Telephone
Satellite
Sunlight
Medical X-ray
Radioactive Sources
Wavelength
Radio Waves
Micro Waves
Infrared
Ultra violet
X-ray
Gramma rays
10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6 10^-8 10^-10 10^-12 10^-14 10^-16 10^-18
Non-ionizing Radiation
Ionizing radiation

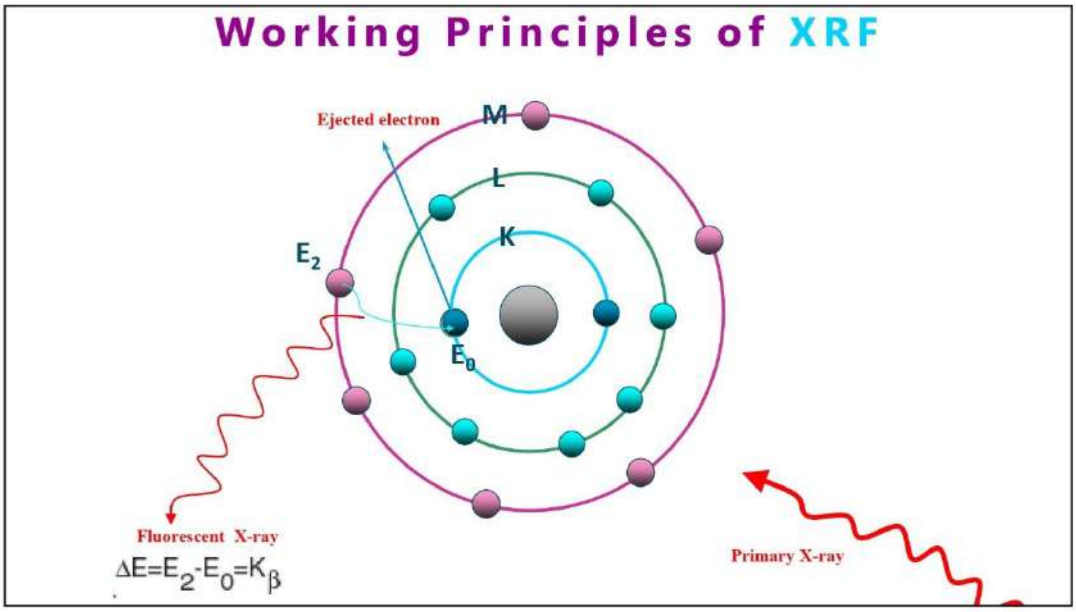

X-RAY SPECTRUM
X-ray spectrum as a function of applied voltage.
K_α
K_β
25 kV
20 kV
15 kV
10 kV
5 kV
Continuous spectrum
X-ray intensity
SWL
Wavelength
B.D Cullity and S.R.Stock


X-Ray Fluorescence (XRF)


XRF History
X-ray spectroscopy was first used in 1909 when Charles G. Barkla from Britain found a connection between x-rays radiating from a sample and the atomic weight of the sample
He obtained the Nobel Prize (Physics) in 1917 for this work


What is XRF analysis
An analytical method to determine the chemical composition of all kinds of materials.
Sometimes used to determine the concentration, thickness and compositions of layers and coatings.
The wavelength of fluorescence is characteristic of the element being excited, measurement of this wavelength enable us to identify the fluorescing element.


Working Principles of XRF
K
L
X-ray Detector
X-ray Tube

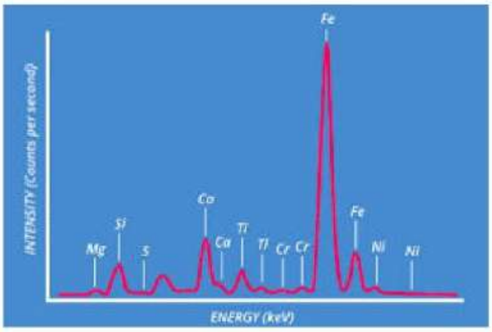

Working Principles of XRF
Ejected electron
M
L
K
E2
E0
Fluorescent X-ray
ΔE=E2-E0=Kβ
Primary X-ray

The **intensity of the fluorescence** depends on **how much of that element** is in x-ray beam.

Hence measurement of the fluorescence intensity makes possible the quantitative determination of an element.

The process of detecting and analyzing the emitted x-rays is called **"X-ray Fluorescence Analysis."**

In most cases the innermost K and L shells are involved in XRF detection. A typical x-ray spectrum from an irradiated sample will display multiple peaks of different intensities.



Elements That Can Generally Be Analyzed with XRF

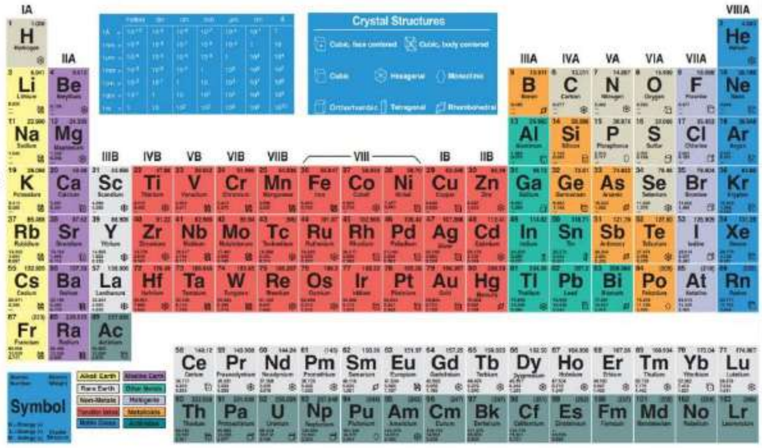
Energy Dispersive Type

$_{11}$Na to $_{92}$U

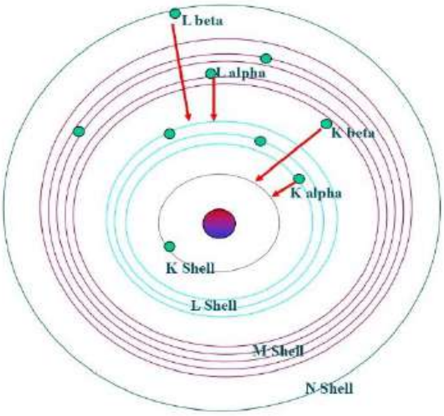
Wavelength Dispersive Type

$_{4}$Be to $_{92}$U

(With an analyzing crystal and detector combination)



K, L and M Spectral Lines



- **K - alpha lines:** L shell e- transition to fill vacancy in K shell. Most frequent transition, hence most intense peak.
- **K - beta lines:** M shell e- transitions to fill vacancy in K shell.
- **L - alpha lines:** M shell e- transition to fill vacancy in L shell.
- **L - beta lines:** N shell e- transition to fill vacancy in L shell.

Comparisons of Methods used for Elemental analysis

Techniques	Neutron activation analysis (NAA)	Atomic Absorption Spectrometer (AAS)	Inductive couple plasma (ICP)	**EDXRF**
Steps involved	Pack, irradiate, cooling, count	Dissolution, measure	Dissolution, measure	**Pack, measure**
Minimum time for analysis	6 hours	4 hours	4 hours	**4 min.**
Range of application	0.1ppm – 30%	ppb – 0.1%	ppt – 0.1%	**1 ppm upwards**
Nature of analysis	Non-destructive & simultaneous	Destructive & single element	Destructive & single element	**Non-destructive & simultaneous**

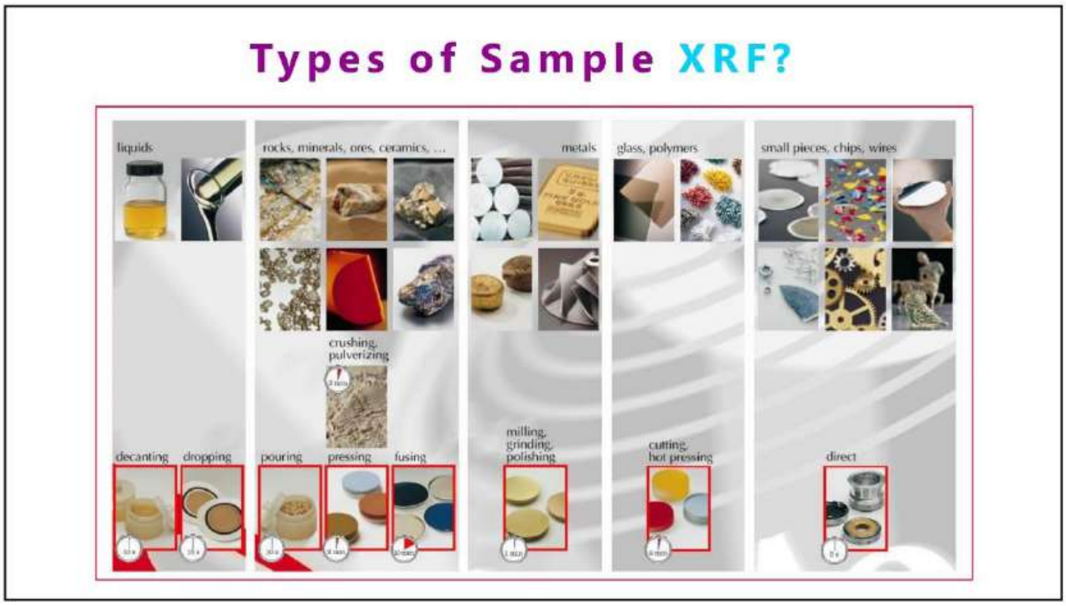
Why XRF?

- It is non destructive
- It is easy to operate and can handle variety of sample sizes.
- Good resolution, improved detection limit.
- Direct analysis on solid, powder, and liquid.
- Saves times analysis over conventional equipment.
- Fast and accurate.
- Minimum sample preparation.

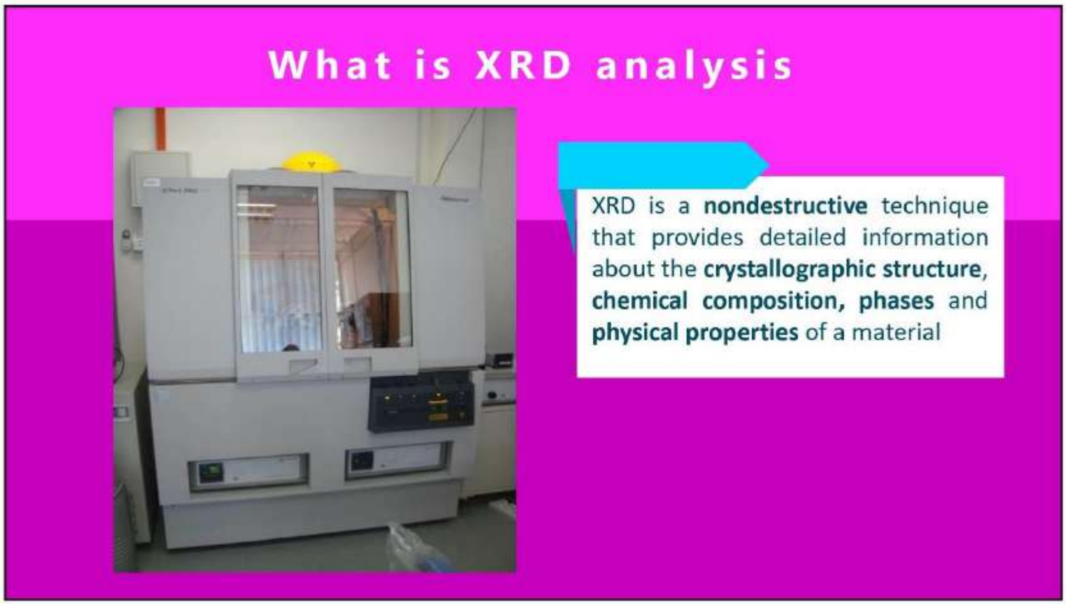
Limitation XRF?

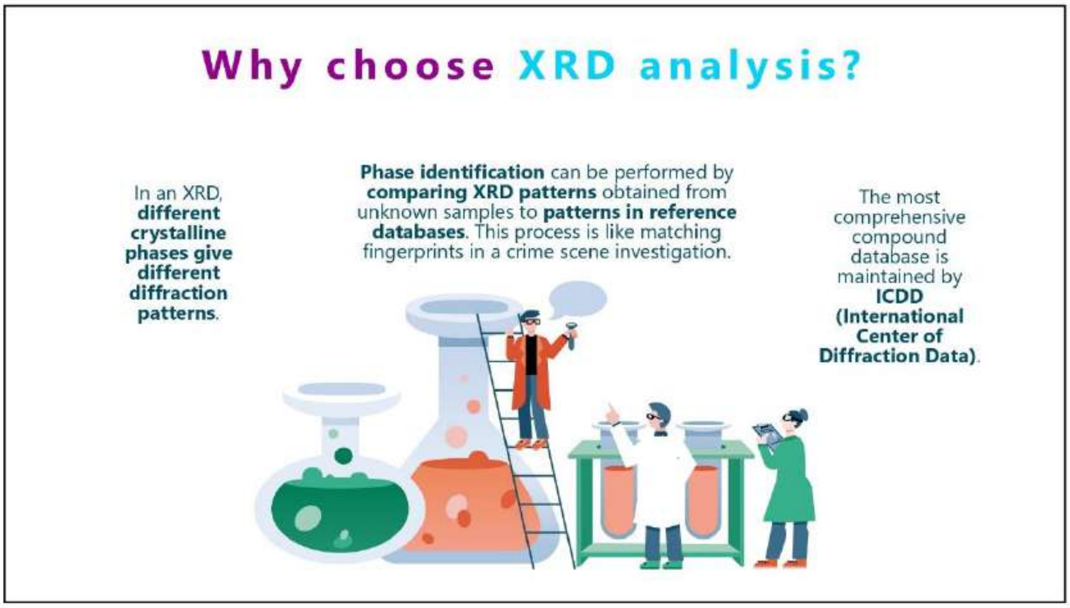
- Availability of commercial certified reference material. **Interferences between some elements** (high levels of one element may give a false positive for another due to overlapping emission lines and limited resolution of ~0.2 keV FWHM)
- Depth of penetration – 1 to 5 micron.
- Sizes of less than 1mm cannot be analyse alone.
- Generally detection limits for metals is not so good (20ppm – 50 ppm). **Must use alternate technique to measure sub-ppm levels**

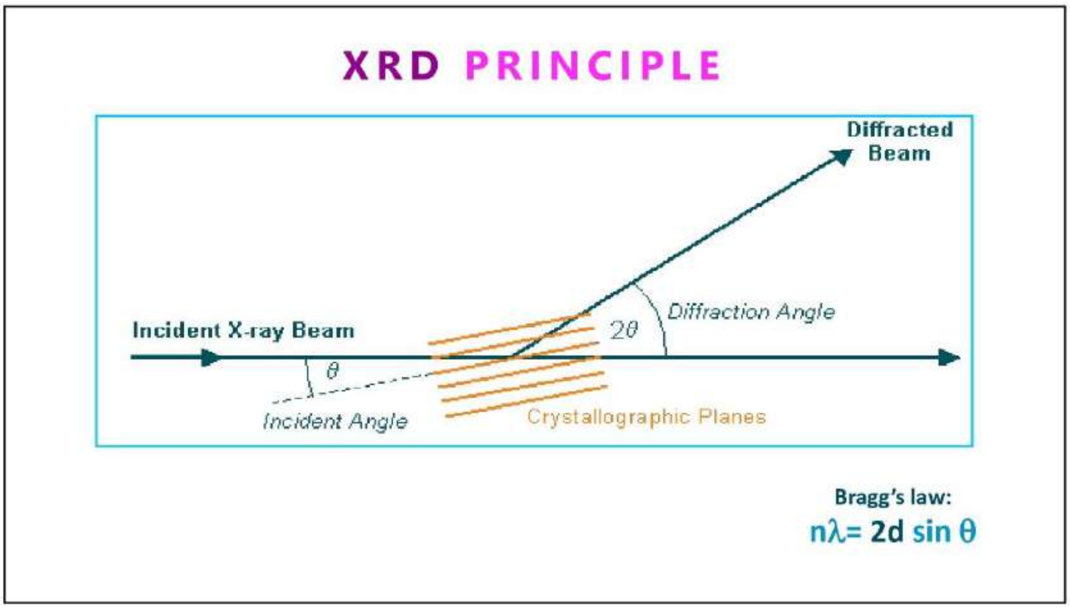
  (TXRF, GFAAS, ICP-AES, ICP-MS)
- **Accuracy**: **XRF is predominantly a surface analysis technique** (X-rays penetrate few mm into sample)
- **No info on chemical form of element** (alternate technique required for speciation)
- **To get more accurate results, one must homogenize the samples and calibrate instrument response using authentic standards**

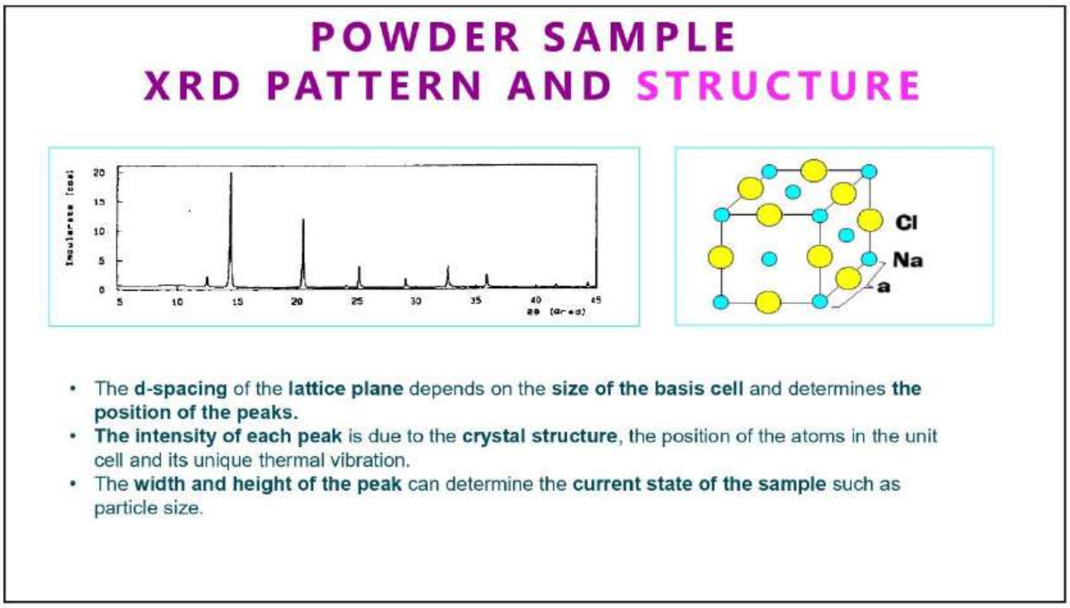

Types of Sample XRF?
liquids
rocks, minerals, ores, ceramics, ...
metals
glass, polymers
small pieces, chips, wires
crushing, pulverizing
milling, grinding, polishing
cutting, hot pressing
decanting
dropping
pouring
pressing
fusing
direct


X-Ray Diffraction (XRD)
PANalytical
X'Pert PRO


What is XRD analysis
XRD is a **nondestructive** technique that provides detailed information about the **crystallographic structure**, **chemical composition, phases** and **physical properties** of a material


Why choose XRD analysis?
In an XRD, different crystalline phases give different diffraction patterns.
Phase identification can be performed by comparing XRD patterns obtained from unknown samples to patterns in reference databases. This process is like matching fingerprints in a crime scene investigation.
The most comprehensive compound database is maintained by ICDD (International Center of Diffraction Data).


XRD PRINCIPLE
Diffracted Beam
Diffraction Angle
2θ
Incident X-ray Beam
θ
Incident Angle
Crystallographic Planes
Bragg's law:
nλ= 2d sin θ


POWDER SAMPLE
XRD PATTERN AND STRUCTURE
Cl
Na
a
The d-spacing of the lattice plane depends on the size of the basis cell and determines the position of the peaks.
The intensity of each peak is due to the crystal structure, the position of the atoms in the unit cell and its unique thermal vibration.
The width and height of the peak can determine the current state of the sample such as particle size.

Application XRF and XRD in artifact characterization

CASE STUDY 1 ANCIENT COIN

Results : Arab coin (Side 1)

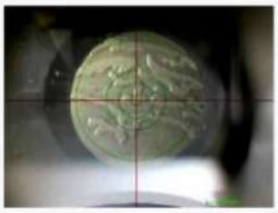
PCED

Analytical Results

Element	Result	Unit	3σ
Cu	58.103	%	0.079
Zn	36.410	%	0.056
Pb	1.838	%	0.025
Sn	1.134	%	0.030
Si	0.984	%	0.203
Fe	0.556	%	0.005
Ni	0.370	%	0.004
I	0.258	%	0.043
Tb	0.165	%	0.028
Ca	0.158	%	0.016
Mn	0.024	%	0.004

```
Matching
Candidate          Diff. Factor
C3604              0.65081
```

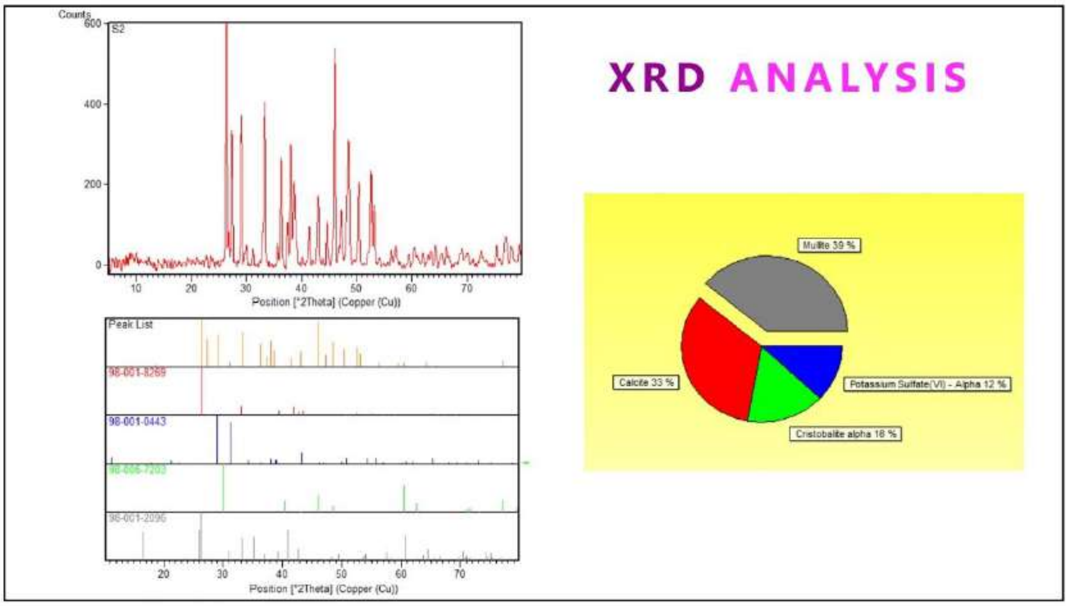
Sample Information

Sample Name :	Arab coin (Side 1)
Meas. Date :	2018-03-15 11:43:56
Group :	[Qual-Quant] easy-air
Comment:	Artifak
Operator :	
Sample Image :	

CASE STUDY 2 ANCIENT VASE

XRD ANALYSIS

Analyte	Calibration status	Compound formula	Measured (kcps)	Used (kcps)	Concentration	Unit	Calculation method	Status
Na	Calibrated	Na2O	0.176	0.212	0.195	%	Calculate	
Mg	Calibrated	MgO	1.418	1.710	0.426	%	Calculate	
Al	Calibrated	Al2O3	15.792	21.837	7.706	%	Calculate	
Si	Calibrated	SiO2	89.870	124.979	42.035	%	Calculate	
P	Calibrated	P2O5	10.872	15.408	3.288	%	Calculate	
S	Calibrated	SO3	3.021	3.962	1.045	%	Calculate	
Cl	Calibrated	Cl	1.438	1.331	0.302	%	Calculate	
K	Calibrated	K2O	13.381	15.645	4.151	%	Calculate	
Ca	Calibrated	CaO	88.696	104.599	34.206	%	Calculate	
Ti	Calibrated	TiO2	1.057	0.982	0.532	%	Calculate	
Cr	Calibrated	Cr2O3	0.190	0.079	502.5	ppm	Calculate	
Mn	Calibrated	MnO	0.401	0.261	0.115	%	Calculate	
Fe	Calibrated	Fe2O3	10.774	11.080	5.345	%	Calculate	
Ni	Calibrated	NiO	0.584	0.321	991.6	ppm	Calculate	
Cu	Calibrated	CuO	0.450	0.139	375.3	ppm	Calculate	
Zn	Calibrated	ZnO	1.047	0.915	0.117	%	Calculate	
Rb	Calibrated	Rb2O	5.241	2.862	577.8	ppm	Calculate	
Sr	Calibrated	SrO	6.677	5.532	0.167	%	Calculate	
Y	Calibrated	Y2O3	2.709	0.889	246.7	ppm	Calculate	
Zr	Calibrated	ZrO2	4.871	2.808	718.1	ppm	Calculate	
Pb	Calibrated	PbO	0.887	0.318	294.0	ppm	Calculate	


XRD ANALYSIS
Counts
600
400
200
0
S2
10
20
30
40
50
60
70
Position [°2Theta] (Copper (Cu))
Peak List
98-001-8269
98-001-0443
98-001-2096
Mullite 39 %
Calcite 33 %
Potassium Sulfate(VI) - Alpha 12 %
Cristobalite alpha 16 %


THANK
YOU
roshasnorlyza@nm.gov.my

2.9 Standard Operating Procedure Conservation & Restoration of Artifacts - Ceramics

Name: Muhamad Faiz Azizan
Date of Presentation: 24th October 2023
Email: faiz@jmm.gov.my

In the rich tapestry of human history, few objects tell the tales of past cultures like ceramics. From the intricate porcelain of ancient China to the rustic terracotta of the Mediterranean, ceramics are a tangible link to our ancestors. However, these artifacts, while they've survived centuries, are not impervious to the ravages of time. Conservation plays a critical role in preserving them for future generations. Here's an accessible guide to understanding and preserving these timeless treasures.

Ceramics are crafted from clay, shaped, and then hardened by heat. The process creates a material that can endure for millennia. But despite their seeming resilience, ceramics are vulnerable to many potential issues. Ceramics can suffer from glaze diseases, such as crazing, a network of fine lines on the glaze surface, or shivering, where the glaze peels off due to tension between the clay body and the glaze. Blisters and pitting can also occur during firing when gases fail to escape.

The process that gives ceramics their strength—the firing—can also make them vulnerable. Underfired objects are less durable and more porous, leading to problems like salt damage. Even well-fired ceramics aren't immune to trouble. Adhesives used in repairs can fail, and contaminants like soluble salts can wreak havoc if conditions aren't stable.

The key to ceramic conservation is maintaining a stable environment. Fluctuations in temperature and humidity can be particularly destructive. The ideal conditions for preserving ceramics are temperatures between 15-25°C and relative humidity levels of 40-60%. Keeping these conditions stable, with minimal variations, is crucial. Ceramics need a consistent climate because they expand and contract with temperature changes and absorb and release moisture with changes in humidity. Such movements can cause glazes to crack and salts to crystallize or redissolve, leading to damage.

When handling ceramics, one must be cautious. It is advisable to use disposable rubber gloves or clean hands. Objects should be carried one at a time, with support at the base and the sides, and a padded tray can be used to transport groups of objects. Storage is another vital consideration. Ceramics should be kept in a stable, dust-free environment without stacking, which can cause stress and breakage.

Before any cleaning or treatment begins, a thorough examination and documentation of the object are essential. This step helps in understanding the item's condition and in planning the appropriate conservation measures. Dry cleaning methods are preferred over wet or chemical treatments. If wet cleaning is necessary, it's important to test water, solvents, and any other chemicals on an inconspicuous part of the object to ensure they do not cause damage.

Desalination is a crucial step for objects recovered from burial or marine sites. It's essential to keep these objects from drying out before the process is complete, as the crystallization of salts within the ceramic pores can cause disintegration.

For repairs, selecting the suitable adhesive is critical. The chosen adhesive should be reversible—meaning it can be removed without damage to the original material—and have good aging properties. Repairing ceramics is a methodical process that requires patience and precision to restore the object while maintaining its historical integrity.

The conservation of ceramics is a meticulous and thoughtful process, requiring a deep understanding of the material, its environment, and its potential risks. By adhering to the guidelines of maintaining a stable climate, careful handling and storage, and appropriate cleaning and repair techniques, we can help preserve these precious links to our past. Through such dedicated efforts, we ensure that future generations can enjoy and learn from these historical objects, just as we do today. The responsibility lies with us to protect these cultural artifacts, not just as art pieces but as vessels of the human story. The slides in the upcoming section detail the work done on this.

REGIONAL TRAINING COURSE

The application of nuclear techniques for characterization and preservation of the artifacts obtained from the shipwreck

Standard Operating Procedure Conservation & Restoration of Artifacts - ceramics

23-27 OCTOBER, 2023
Melaka, MALAYSIA

Muhamad Faiz bin Azizan
Conservation Division
Department of Museums Malaysia

Content

- Terminology
- Conservation Division
- Ceramic Introduction
- Categories
- Examination
- Deterioration
- Curative Conservation
- Restoration
- Preventive Conservation
- Summary

Terminology for conservation

- **Terminology to characterize the conservation of tangible cultural heritage**
- At the 15th Triennial Conference held in New Delhi in September 2008, ICOM-CC adopted a resolution on a terminology for conservation to facilitate communication in the international professional and public fora and in the literature, since the same word may currently have different meanings in different places.
- ICOM-CC adopted the following terms: **"preventive conservation", "remedial conservation", and "restoration"** which together constitute **"conservation"** of the tangible cultural heritage. These terms are distinguished according to the aims of the measures and actions they encompass.
- #ICOM-CC – Committee of Conservation

ICOM-CC
Education and Training in Conservation

- **The definitions of the terms are as follows:**
- **Conservation** - all measures and actions aimed at safeguarding tangible cultural heritage while ensuring its accessibility to present and future generations. Conservation embraces preventive conservation, remedial conservation and restoration. All measures and actions should respect the significance and the physical properties of the cultural heritage item.
- **Preventive conservation** - all measures and actions aimed at avoiding and minimizing future deterioration or loss. They are carried out within the context or on the surroundings of an item, but more often a group of items, whatever their age and condition. These measures and actions are indirect – they do not interfere with the materials and structures of the items. They do not modify their appearance.

Conservation Division DMM

- The Conservation Division of the Department of Museums Malaysia is responsible for ensuring that the department's collections are in good condition and preserved. This objective is realized through research and conservation of artefacts.

Focus

- To conduct analysis, research, treatment and preservation of the museum collections for the purposes of exhibition, storage, education and documentation
- To carry out works to prevent damage and to repair artefacts
- To monitor the temperature control system, humidity, lighting and pests in the collection stores and museum galleries
- To provide training and advisory services on conservation to staff and relevant agencies

Activities

Preventive Conservation

- Action taken to prevent the natural deterioration of an object owing to environmental conditions such as temperature, humidity, lighting and pests such as insects, fungi and air pollution.

Curative Conservation

- Curative conservation is action taken to treat an object that is deteriorating. It is aimed at halting the deterioration process.

Restoration

- Treatment procedure that is undertaken with the aim of restoring cultural artefacts to their natural state by using materials similar to their original materials.

CERAMICS

Introduction

The term ceramic is used to describe a variety of fired clay objects. The transformation of an earthy substance by fire produces a durable material, examples of which have survived from ancient times until the present.

Ceramics became an important trade item and produced according to the needs of trade in ancient times. This fact is proven by the discovery of ceramic fragments that have various colors, shapes, decorative patterns and sizes found in archaeological sites and also underwater excavations.

The major ceramic categories are **earthenware, stoneware** and **porcelain.**

CATEGORIES

Earthenware bodies are derived from naturally occurring secondary clays. Earthenware consists of clay that is fired and polished. The manufacturing is more to traditional production process. Firing process at temperature of 950 °C - 1200 °C. The color after firing process is yellowish brown or reddish. The characteristics of clay pottery are waterproof, porous, easy to break, soft and non-acidic.

Stoneware bodies are composed of modified secondary clays, fired to high temperatures of 1200 °C to 1300 °C to produce a vitrified, hard and durable ceramic. The porosity of stoneware is < 3 % and colours include white, buff, grey and black.

Porcelain body is made from 50 % kaolinite, 25 % feldspar and 25 % quartz or flint. It is fired to a high temperature of 1400 °C to produce a vitreous, white, non-porous ceramic with a glassy fracture surface. Porcelain is defined as a high-quality ceramic because of its unique characteristics of decoration and physical strength. The content materials and manufacturing techniques are clearly different from the production of clay pottery.

Many further distinctions may be made within these groups according to the type of body, decoration, style or function of the object.

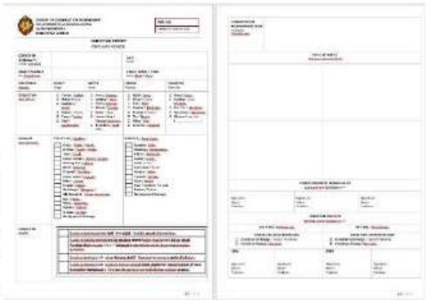
It is important to assess ceramic objects before treatment, as the type of ceramic obviously affects the treatment options.

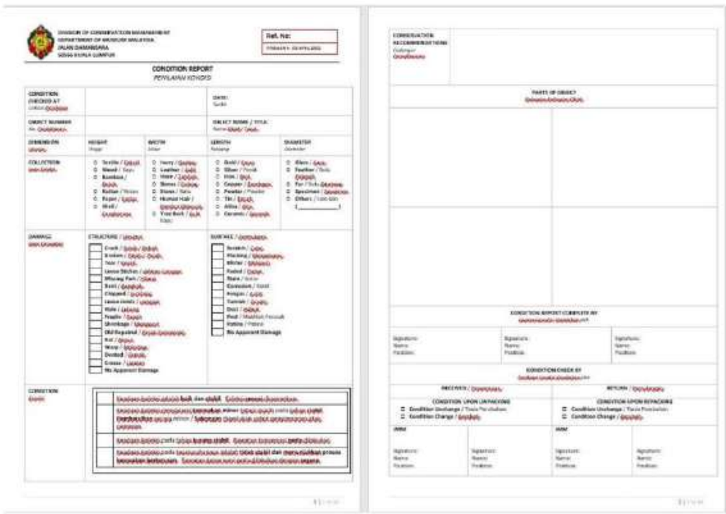
Examination

Condition Report

Before any treatment, examine the ceramic:

- the condition of the ceramic structure;
- the extent of previous repairs;
- any unfired decoration or blistering, weak and flaking glaze
- the presence of stains and residues.
- Pay particular attention to any unfired decoration or weak and flaking glaze, because if these are undetected they could be damaged during treatment. Note the presence of any stains and residues as these indicate the history and use of an object and, depending on their significance, it may be appropriate to retain them. Use notes, drawings and photographs to document the condition of the ceramic before it is treated. Record all observations and pertinent investigations.





Deterioration

Although ceramics are in the inorganic category that are usually less affected by environmental factors, there are also factors that can affect the condition of the ceramics.

(a) Surface damage due to salt contamination on a small ceramic jar.
(b) A ceramic that also has surface damage due to contamination from salt.

Deterioration

The most common ceramic conservation problems include:

- breakage;
- deterioration of previous repairs;
- flaking painted decoration or glaze;
- soiling or staining;
- loss and cracking
- damage from salt efflorescence.

Deterioration

Breakage

Careless handling

Stacking

Support

Previous repairs

Weak Joint

Inappropriate material

Mismatching

Irreversible material

Flaking painted decoration or glaze

Submerged

Environmental factors

Deterioration

Breakage

Careless handling - Most ceramics break due to careless handling. Example, ceramics that have a stem must be handled carefully by avoiding lifting from the stem.

Stacking - Ceramics are moved stacking in one container without any barriers can also cause the break due to physical force during movement.

Support - Improper support can also cause damage to the ceramic.

Previous repairs

Weak Joint - Ceramics that have been repaired have a weak point on the joint part.

Inappropriate material - The mistake of using an inappropriate material can change the color in a certain period of time.

Mismatching - of ceramic implants is also cause a problem.

Irreversible material – Not using adhesives recommended in ceramic conservation

Flaking painted decoration or glaze

Submerged - Ceramics that have been submerged for a long time at the bottom of the sea will have barnacles and shells attached to the ceramic area. This effect will cause motifs and glazed areas to come off.

Environmental factors - RH is a greater concern for ceramics contaminated with salts. When the RH rises above a certain critical RH, the salts deliquesce (they absorb enough moisture to form a solution) and later will crystallize when the RH falls below this critical RH. During the drying and crystallizing stage, the salt solution moves towards the zone of evaporation and crystals grow to the point of exploding the pore structure. The resultant flaking of the ceramic is called spalling.

Deterioration

Soiling or staining

Pollutants.

inappropriate cleaning agent

Loss and cracking

Fragile

Incorrect relative humidity

Damage from salt efflorescence

Deterioration

Soiling or staining

Pollutants - In a dusty or polluted environment, ceramics will become dirty if not protected from particulates. If dirt is left on the surfaces of objects, particularly porous, low-fired or unglazed ceramics, staining can develop. Dirt can also lodge in cracks and areas of repair, resulting in unsightly discolouration.

inappropriate cleaning agent - Using an inappropriate cleaning agent can leave dust on the ceramic.

Loss and cracking

Fragile - Archaeological material may be more fragile due to the leaching of components during burial.

Incorrect relative humidity - High RH (above 65%), mould can occur on ceramic surfaces if there are even small amounts of soiling, oils and food residues. Earthenware objects are more likely to be affected due to their porosity.

Damage from salt efflorescence

Damage from salt contamination may occur in unwashed objects recovered from buried or underwater sites. As the object dries, chloride and sulphate salts form crystals which expand and break up the ceramic. Signs of salt damage are white crystals on the surface, shallow pits on the ceramic body or missing spots of glaze.

Curative Conservation

Cleaning

As cleaning removes dirt which could otherwise be embedded further during subsequent treatment stages, it is usually the first stage of a conservation treatment. Cleaning techniques which may be applied to ceramics include:

- brushing;
- vacuuming;
- wiping with damp swabs
- Chipping
- Wipes

The use of this equipment needs to be handled with more care to prevent the ceramic surface from being scratched, worn and chipped

Curative Conservation

Brushing

- A soft brush method on the ceramic surface to remove dust and dirt that sticks to the collection. However, before this method is carried out, the conservator needs to first identify the type of dirt to be cleaned. which results from the deterioration process such as peeling of the glaze. cleaning must be thorough to avoid damage to the surface.

Curative Conservation

Vacuuming

- Taking into account the fragile physical factor of ceramic and may experience peeling of the glaze, the suction power must be adjusted to the minimum level. In addition, the vacuum nozzle part must be connected to a flexible rubber part and lined with gauze at the end. This is to prevent ceramic fragments from sticking.

Curative Conservation

wiping with damp swabs

- Always test potential solvents on an inconspicuous part of the ceramic to ensure that they have no adverse effects. Try solvents such as **methylated spirits**, **alcohol** and **acetone** on stubborn stains. Apply these with **cotton swabs**. If using acetone, take care, avoid contact with skin, wear eye protection and do not inhale the vapours

Curative Conservation

Chipping

- The chipping method is used when the sweep technique is unsuccessful in removing dirt. The effect of prior conservation such as excessive adhesive material and the effect of restoration among the examples. Likewise if there is growth of salt that harms ceramics. The use of scalpel blade are among the appropriate methods to use. The adhesive part must be moistened first so that it is easier to scrape.

Curative Conservation

Wipes

- The process of wiping ceramics using a damp cloth to remove dirt is the safest method that can be applied and also the most economical step without using any equipment and materials. However, the physical condition of the ceramics must be taken into account for fear that the cloth will get stuck on the shell.

Curative Conservation

Joining

- The **Paraloid B-72** can be directly applied to one of the break edges and the pieces immediately joined together. They should be then set down in a stable position while the adhesive sets. Setting time can vary with the thickness of the fragments and the ambient temperature and humidity, and can be anywhere from several minutes to several hours. Low-fired earthenware, terracotta, and pottery require that the edges be sealed or "primed" prior to any adhesive application so that the solvent is retained in the adhesive long enough for the adhesive to set.

Restoration

Restoration

- The restoration of cultural property involves using what exists, and is known of, an artifact to produce a representation of the complete object as it would have been in its earlier form. Ceramic vessels, having a large representation in the archaeological record and being a nice object for display purposes, are often chosen to be restored to their original state.
- The restoration of a ceramic, can only be attempted, if a full profile of the pot exists, the rim, body, base and handle(s) exist, then the missing areas can be filled to match the original shape. **Dental wax** and **Plaster of Paris** is often used as a fill material because it can be easily carved and is reversible.

Preventive Conservation

Storage and Display

- Protect ceramic objects against dust, harmful vapours and physical damage in storage. Achieve these aims by:
- storing ceramic objects in boxes, closed cupboards or on shelves that are not subject to vibration, jarring or shock;
- keeping objects clearly visible and accessible so that handling is minimised;
- using metal cabinets in preference to unsealed wooden cupboards or display cases. These latter units may emit organic acid vapours which are harmful to low-fired, unglazed ceramic objects;

Preventive Conservation

Storage and Display

- padding objects in boxes with bubble wrap or acid-free tissue paper;
- lining shelves with inert polyethylene foam sheet or acid-free paper and leaving enough space around each object for easy access; and
- not stacking objects. If stacking is unavoidable, as in the case of plates, separate objects with acid-free paper that has been cut to size and limit the height of the stack.

Preventive Conservation

Handling

- Take care when handling ceramic materials as they are often fragile and easily broken. Observe the following guidelines when handling ceramics:
- avoid unnecessary handling;
- use clean, bare hands or disposable rubber gloves;
- check for any breakages, cracks or old repairs;
- remove any loose parts such as lids before moving;
- do not pick up objects by handles or protruding parts;
- carry only one object at a time. Place one hand underneath the base and use the other hand to support the side of the object; and
- if a quantity of objects need to be moved, use a tray lined with bubble wrap, a thick, clean towel, cottonwool or crumpled tissue paper and pad between each object.

Preventive Conservation

Environment

- Ceramics are generally less sensitive to extremes or fluctuations in environmental conditions than materials like paper, wood and ivory. As this applies only to objects in good condition however, it is wise to protect all ceramics by storing or displaying them in a stable environment, with **temperatures in the range 15 - 25 °C** and within a **relative humidity range of 40 - 60 %. Limit temperature and relative humidity fluctuations to 4 °C and 5 % respectively within any 24 hour period.**
- Extremes, or sudden changes in temperature and relative humidity levels may cause susceptible ceramics and glazes to crack. If an object has been contaminated by soluble salts, fluctuations in relative humidity may cause disruption to the clay and glaze as the salts either crystallise or redissolve.
- Avoid heat build-up from lighting sources. For display, place lighting outside showcases and if possible direct light onto ceramic objects by reflection rather than direct illumination.

Summary

- Maintain ceramics in a stable environment with temperatures in the range 15 - 25 °C, within a relative humidity range of 40 - 60 % and with maximum variations of 4 °C and 5 % respectively within any 24 hour period.
- Avoid extremes or sudden changes in temperature and relative humidity to minimise damage to glaze, ceramic or adhesives.
- Store in a stable dust-free environment. Avoid stacking.
- Handle carefully, with disposable rubber gloves or clean, bare hands.
- Carry objects one at a time, with support provided at the base and side. Use a padded tray to carry a group of objects.
- Examine and document objects thoroughly before beginning cleaning or other treatment.
- Use dry cleaning methods before wet or chemical treatments. Test water, solvents and any other chemicals which come into contact with ceramic materials, on an inconspicuous part of the object.
- Desalinate objects recovered from burial or marine sites. Do not allow objects to dry before desalination is complete.
- For repairs, choose adhesives that are reversible and have good ageing properties. Methodically plan and execute the joining of broken ceramics.


Thank you

2.10 Application of Nuclear Techniques for Characterization and Preservation of Artifacts: Focus on Consolidation Using Radio-Curable Resin

Name: Laurent Cortella
Date of Presentation: 24th October 2023
Email: laurent.cortella@cea.fr

Preserving artworks is an intricate process that combines artistry with scientific innovation. In the realm of art conservation, one method has emerged as a ground-breaking technique: the use of radio-curable resin. This revolutionary approach, championed by experts like Laurent Cortella, harnesses nuclear techniques to characterize and preserve artifacts, ensuring their longevity for generations.

Radio-curable resin consolidation involves impregnating wooden artifacts with a specialized resin that solidifies under controlled irradiation. This method, developed in the 20th century, has become a pivotal tool in art restoration. The process begins by selecting an appropriate artifact, often suffering from severe damage or decay due to factors like xylophagous attacks.

The first application of radio-curable resin in cultural heritage took place at ARC-Nucléart. In this instance, intricate parquet flooring by Hache cabinetmakers, dating back to the 18th century, underwent innovative treatment. The chosen resin, MMA (Methyl Methacrylate), was ideal due to its low solvent properties, ensuring minimal risk to the existing glues.

The impregnation process is a meticulous endeavor. The wooden artifact is first subjected to a vacuum, ensuring it is air-free. Subsequently, the resin is incorporated, filling the microporosity of the wood. Under controlled pressure and nitrogen atmosphere, the resin permeates the entire volume of the artifact, ensuring its complete impregnation.

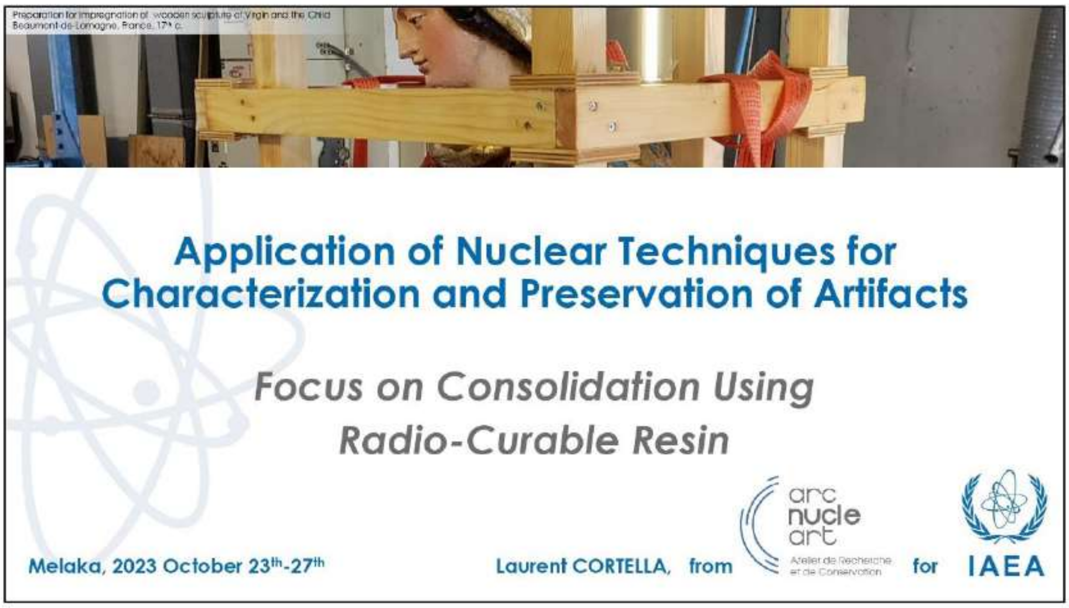
Radio-curable resin consolidation offers numerous advantages. It significantly enhances mechanical strength, ensuring the artifact's structural integrity. The homogeneous polymerization achieved through gamma radiation penetration is unmatched, even for substantial pieces. Additionally, the resin's chemical stability, coupled with its hydrophobic nature, protects against fungi, bacteria, and insects.

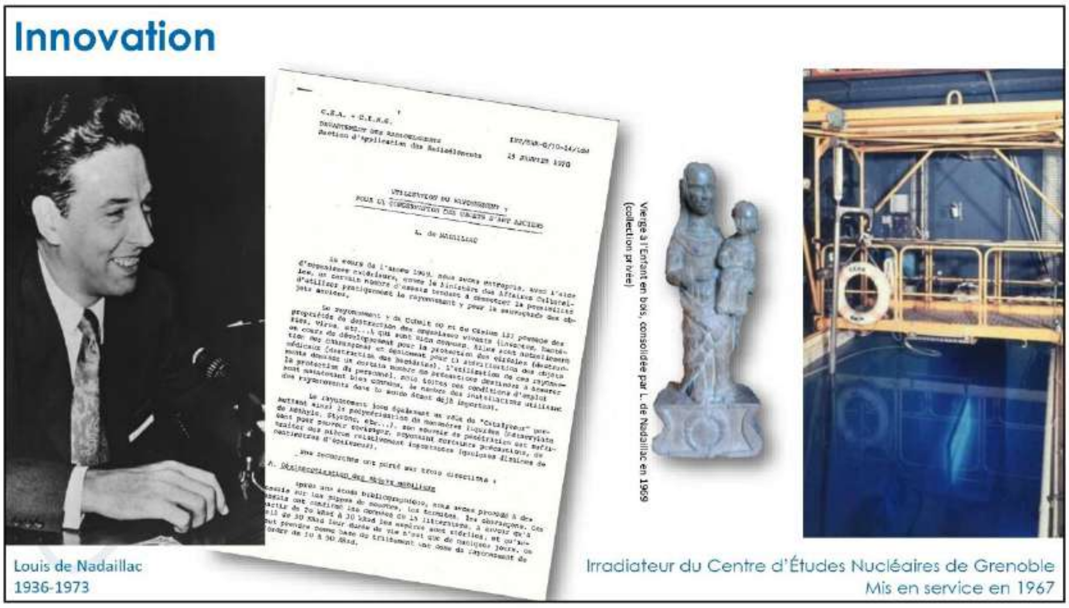
However, the technique has limitations. The artifact's weight increases, sometimes exceeding that of the original wood. Moreover, wood tends to darken, albeit more prominently on raw surfaces. Despite these drawbacks, the irreversible process remains invaluable, especially in conserving archaeological waterlogged wood and artifacts facing their last chance at restoration.

Conserving polychromed wooden sculptures presents unique challenges. The styrene in the resin can potentially dissolve certain polychromed layers. Thorough testing is imperative to prevent any damage. Additionally, unexpected uplifts of polychromed layers have been observed, a phenomenon attributed to resin shrinkage during radio-curing.

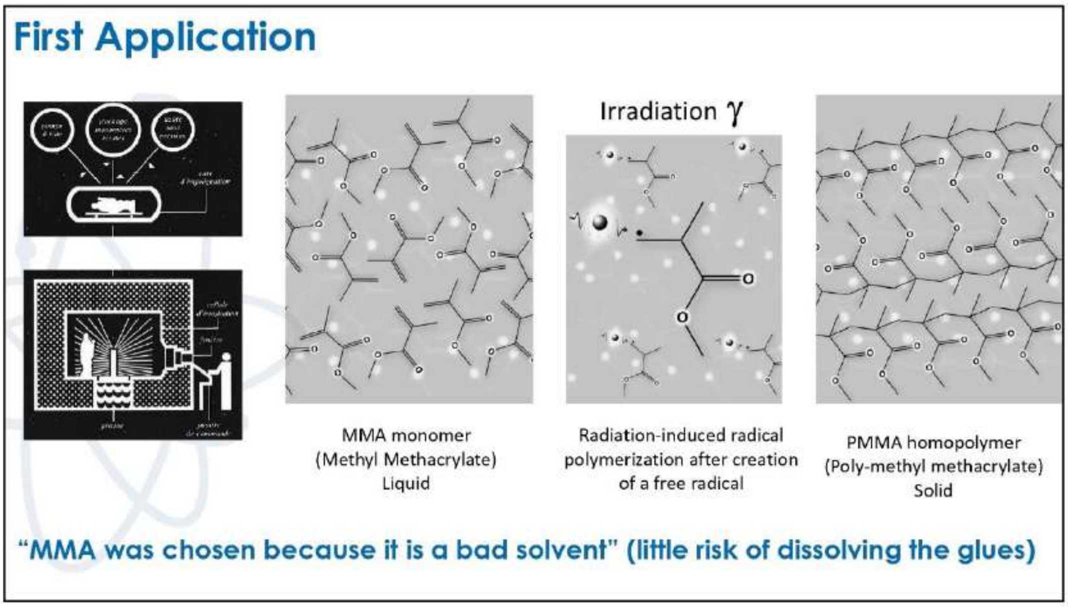
In response to these challenges, ongoing research aims to improve the treatment. Scientists are formulating new, styrene-free radio-curable resins that are reversible and safer. Innovations like the use of well-known substances such as Paraloid B72® in acrylate monomer base have shown promise, indicating a continuous evolution in art conservation.

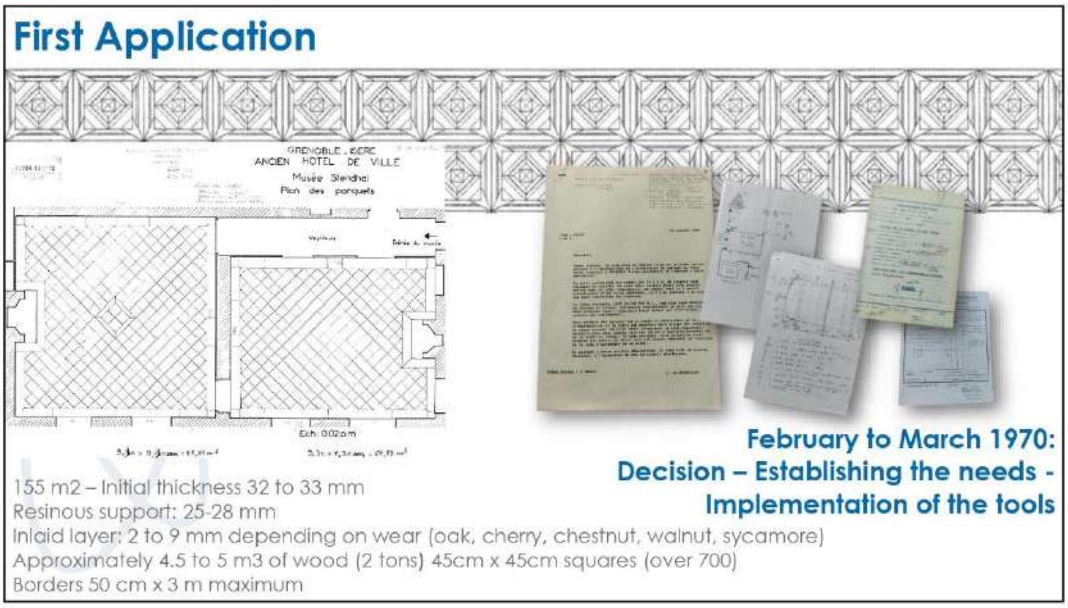
The marriage of art and science in conserving cultural heritage is awe-inspiring. Radio-curable resin consolidation is a testament to human ingenuity, enabling the restoration of artworks that might otherwise be lost to time. The preservation of our artistic heritage continues to advance, ensuring that the beauty of the past remains a beacon of inspiration for future generations. The slides in the upcoming section detail the work done on this.

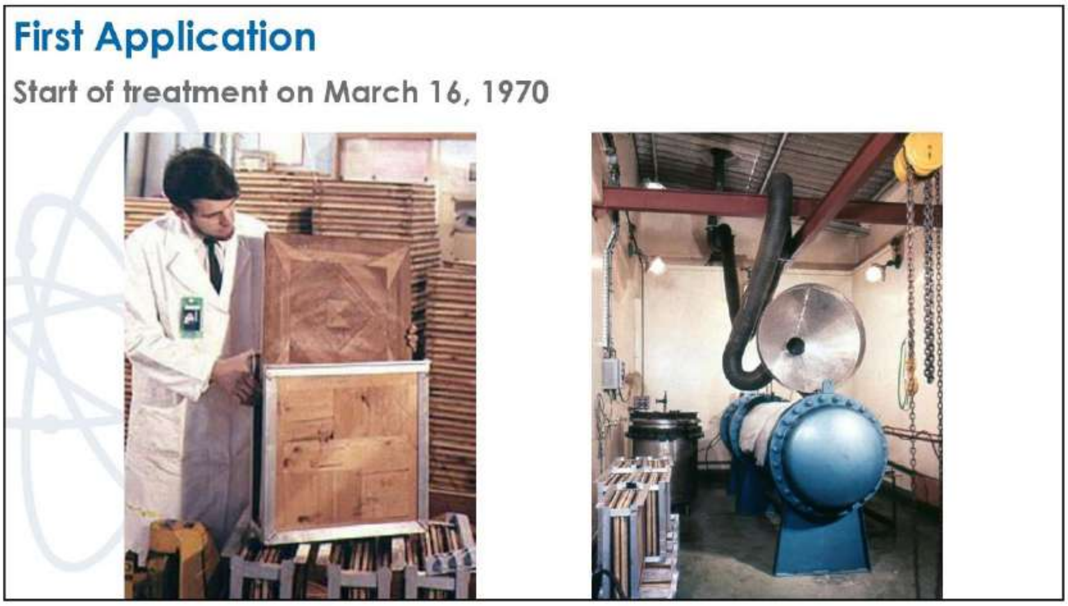

Preparation for impregnation of wooden sculpture of Virgin and the Child
Beaumont-de-Lomagne, France, 17th c.
Application of Nuclear Techniques for Characterization and Preservation of Artifacts
Focus on Consolidation Using Radio-Curable Resin
arc nucle art
Atelier de Recherche et de Conservation
IAEA
Melaka, 2023 October 23th-27th
Laurent CORTELLA, from
for


Innovation
Vierge à l'Enfant en bois, consolidée par L. de Nadaillac en 1969
(collection privée)
Louis de Nadaillac
1936-1973
Irradiateur du Centre d'Études Nucléaires de Grenoble
Mis en service en 1967


First Application
• Historically, the first application for cultural heritage in ARC-Nucléart
Inlaid parquet flooring by Hache cabinetmakers (18th c.) in the lounges of the Hôtel du Connétable de Lesdiguières, having served as wedding rooms when the building was used as Grenoble City Hall between 1867 and 1967


First Application
Irradiation γ
MMA monomer
(Methyl Methacrylate)
Liquid
Radiation-induced radical
polymerization after creation
of a free radical
PMMA homopolymer
(Poly-methyl methacrylate)
Solid
"MMA was chosen because it is a bad solvent" (little risk of dissolving the glues)


First Application
GRENOBLE . ISERE
ANCIEN HOTEL DE VILLE
Musée Stendhal
Plan des parquets
February to March 1970:
Decision – Establishing the needs -
Implementation of the tools
155 m2 – Initial thickness 32 to 33 mm
Resinous support: 25-28 mm
Inlaid layer: 2 to 9 mm depending on wear (oak, cherry, chestnut, walnut, sycamore)
Approximately 4.5 to 5 m3 of wood (2 tons) 45cm x 45cm squares (over 700)
Borders 50 cm x 3 m maximum


First Application
Start of treatment on March 16, 1970

First Application

End of treatment on April 13th, 1970

First Application

- Average impregnation rate of 93% (weight approximately doubles to reach 4.5 tones after treatment)
- Some deformation: "113 squares (out of more than 700) had to be pressed with heating in order to facilitate replacement"

In link with constraint imposed by the shrinkage during polymerization of MMA resins of the order of 20% by volume ?

The « Nucléart » Consolidation

After this first feedback, a new styrene-polyester resin was chosen with less shrinkage (around 10% by volume)

Consolidation by Radiation-Curing Resin

"Nucléart" method: Consolidation by densification in two steps

Impregnation

⇨

Radio-curing

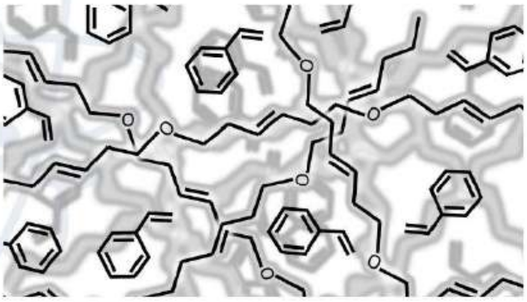
First Step: Impregnation

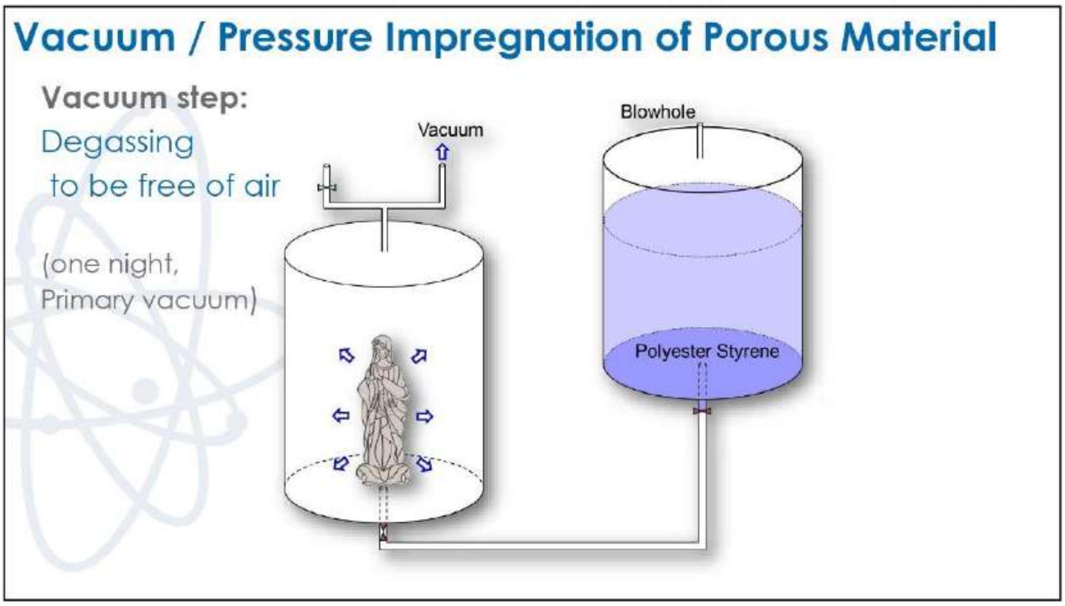
Microporosity have to be filled with radio-curing resin by this impregnation process.

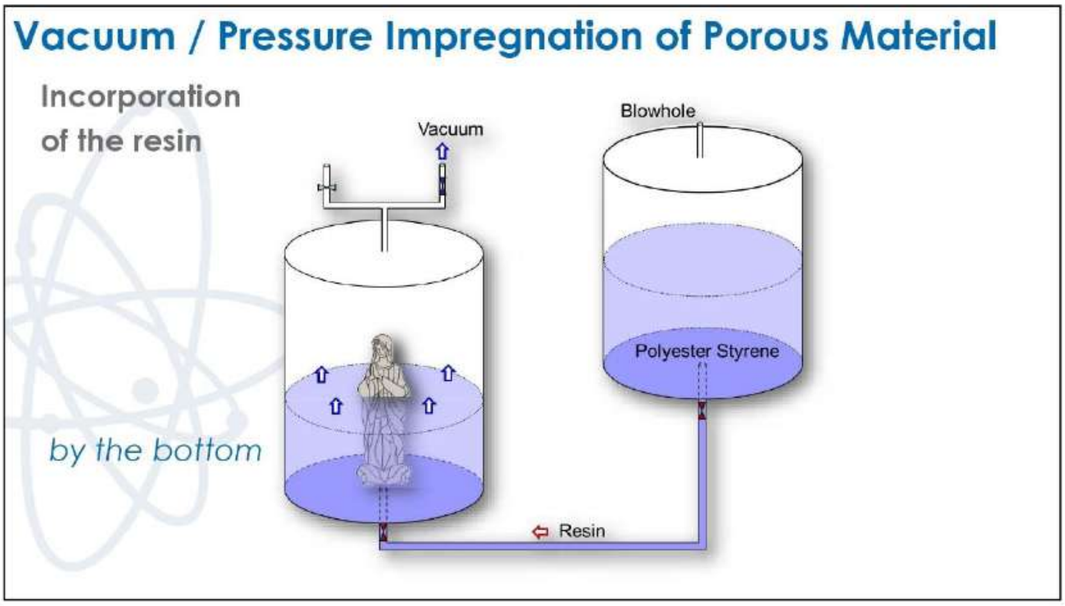
Styrene / Unsaturated Polyester Resin

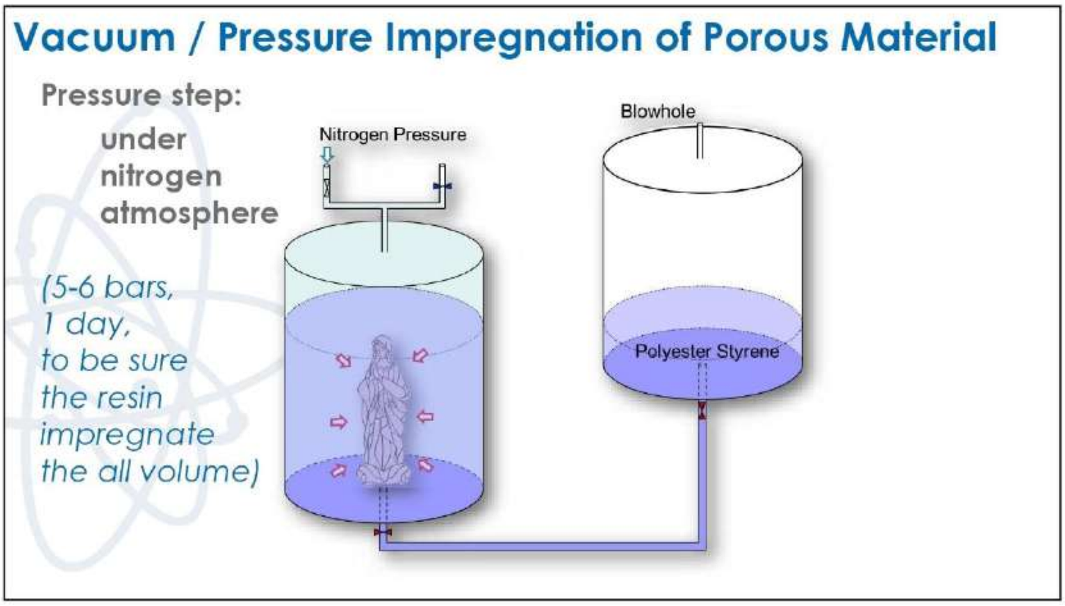
Unsaturated polyester prepolymer, in solution in an unsaturated monomer (styrene)

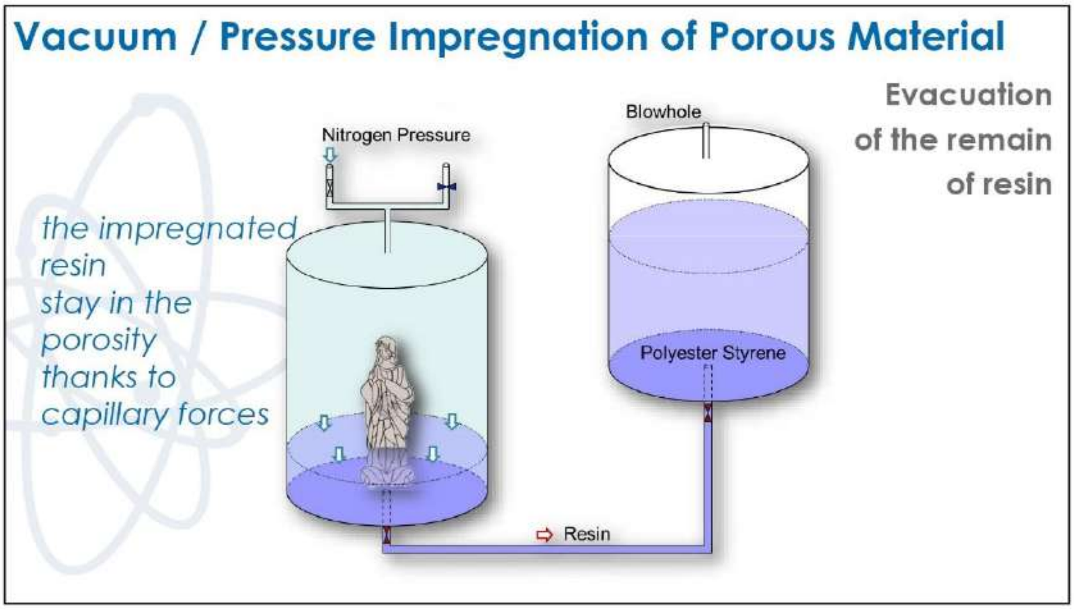
- 48% styrene and 52 % polyester (in mass) in order to obtain a viscosity around 100 centipoises (mPas) at 25°C (viscous liquid like olive oil)

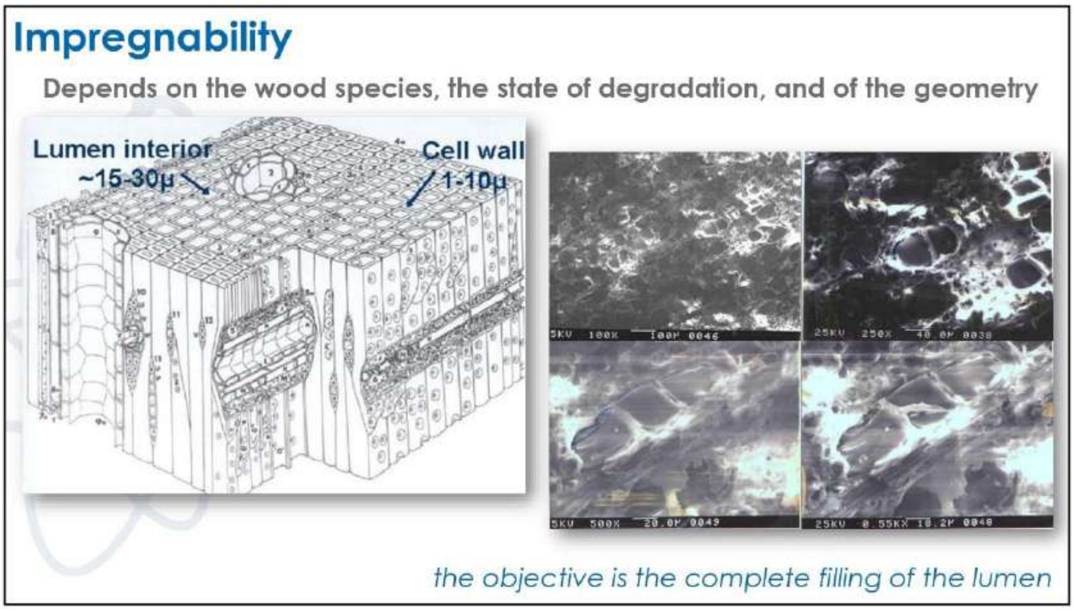



Vacuum / Pressure Impregnation of Porous Material
Vacuum step:
Degassing
to be free of air
(one night,
Primary vacuum)
Vacuum
Blowhole
Polyester Styrene

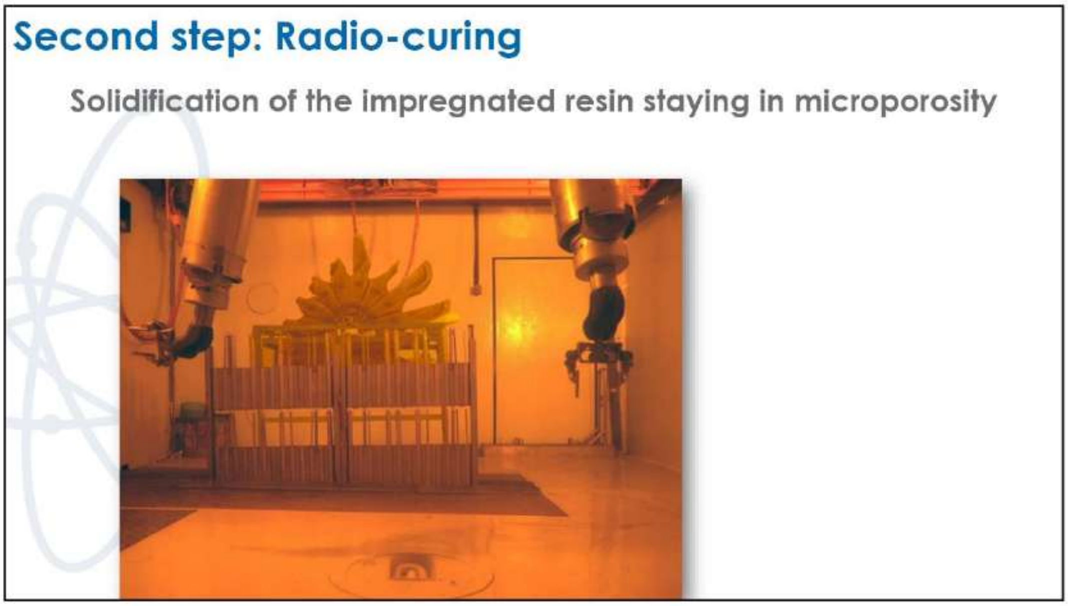

Vacuum / Pressure Impregnation of Porous Material
Incorporation
of the resin
by the bottom
Vacuum
Blowhole
Polyester Styrene
Resin

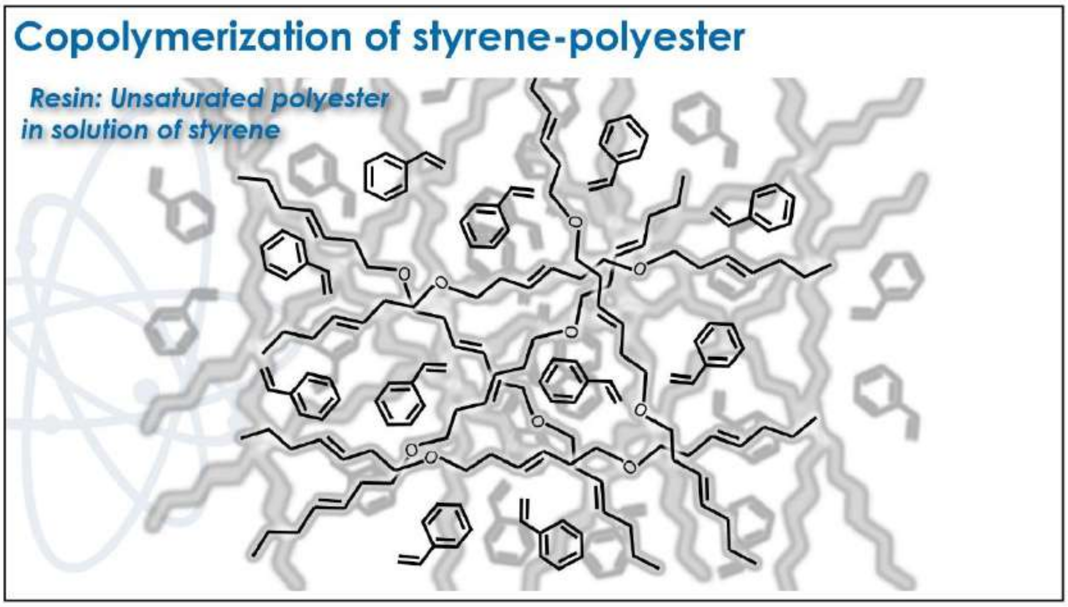

Vacuum / Pressure Impregnation of Porous Material
Pressure step:
under
nitrogen
atmosphere
(5-6 bars,
1 day,
to be sure
the resin
impregnate
the all volume)
Nitrogen Pressure
Blowhole
Polyester Styrene

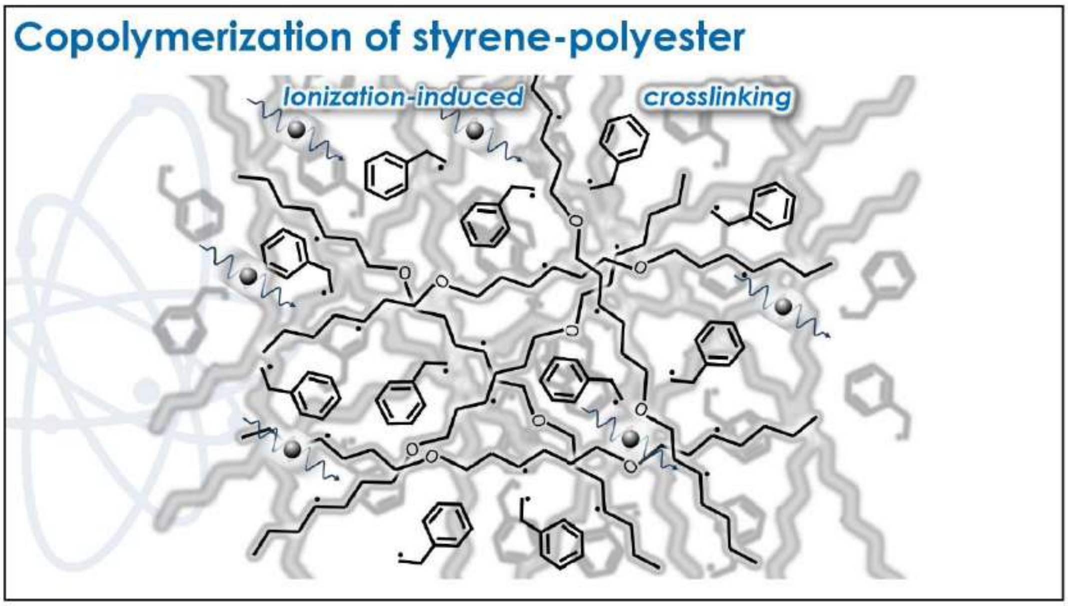

Vacuum / Pressure Impregnation of Porous Material
Evacuation
of the remain
of resin
Blowhole
Nitrogen Pressure
the impregnated
resin
stay in the
porosity
thanks to
capillary forces
Polyester Styrene
Resin

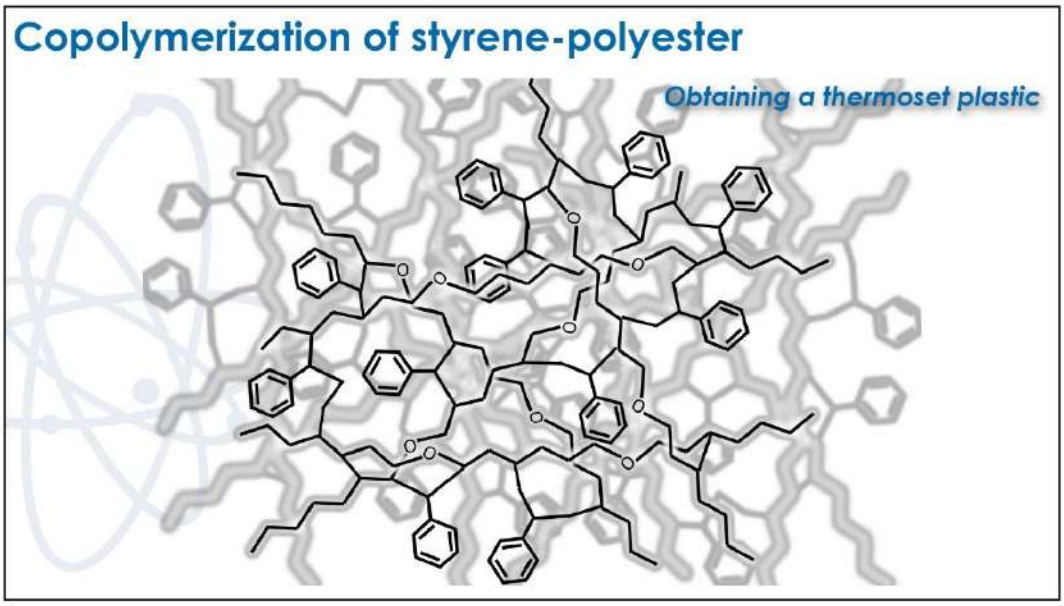

Impregnability
Depends on the wood species, the state of degradation, and of the geometry
Lumen interior
~15-30µ
Cell wall
1-10µ
the objective is the complete filling of the lumen

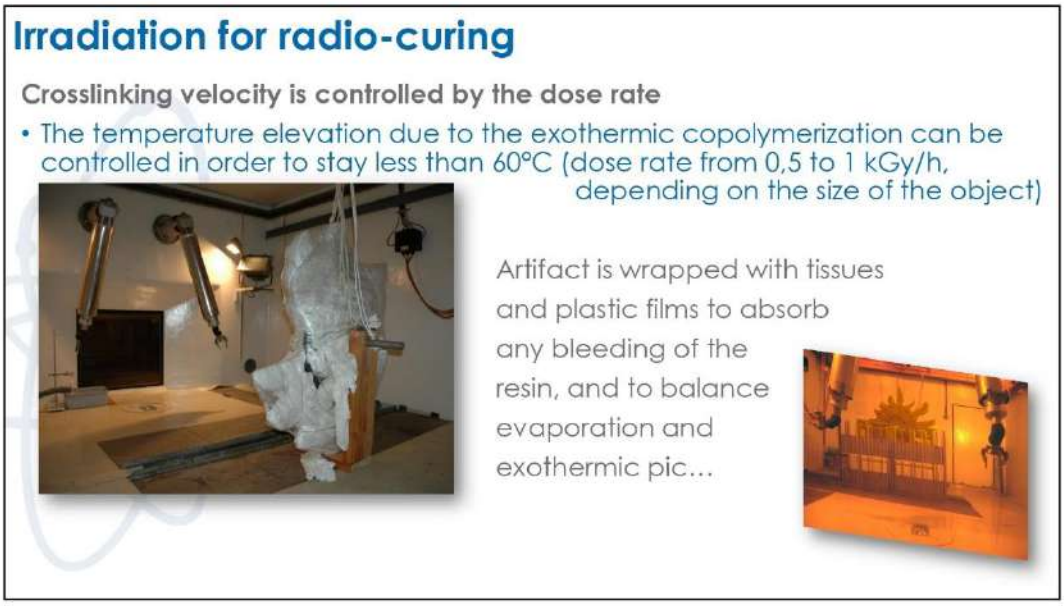

An intermediate step
Cleaning: A key step !!
But there is time to do it, carefully…

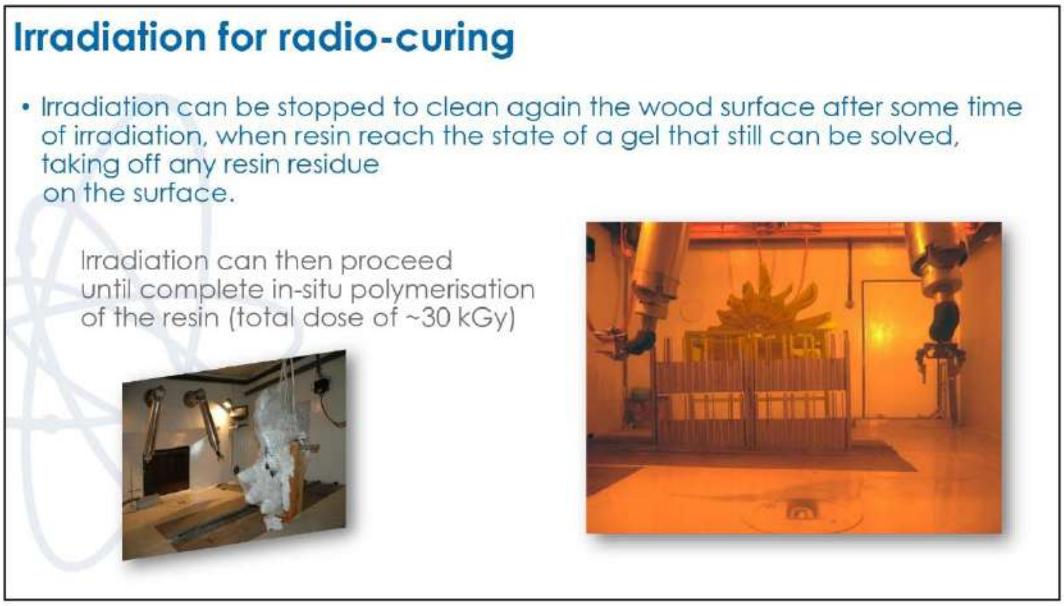

Second step: Radio-curing
Solidification of the impregnated resin staying in microporosity


Copolymerization of styrene-polyester
Resin: Unsaturated polyester in solution of styrene


Copolymerization of styrene-polyester
Ionization-induced
crosslinking


Copolymerization of styrene-polyester
Obtaining a thermoset plastic


Irradiation for radio-curing
Crosslinking velocity is controlled by the dose rate
• The temperature elevation due to the exothermic copolymerization can be controlled in order to stay less than 60°C (dose rate from 0,5 to 1 kGy/h, depending on the size of the object)
Artifact is wrapped with tissues and plastic films to absorb any bleeding of the resin, and to balance evaporation and exothermic pic…


Irradiation for radio-curing
• Irradiation can be stopped to clean again the wood surface after some time of irradiation, when resin reach the state of a gel that still can be solved, taking off any resin residue on the surface.
Irradiation can then proceed until complete in-situ polymerisation of the resin (total dose of ~30 kGy)

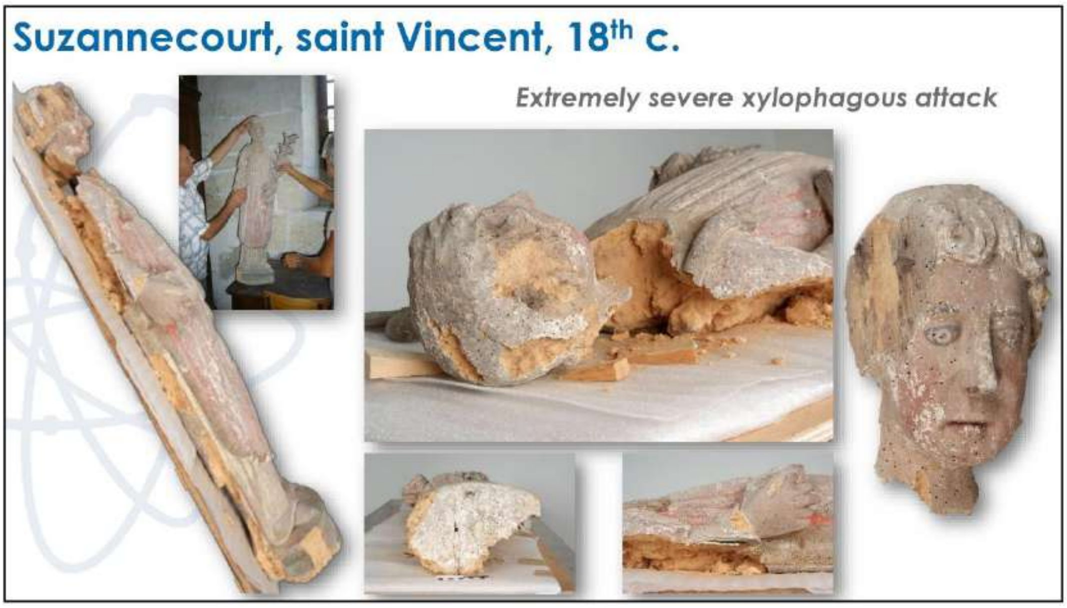
Benefits and drawbacks

A (very) limited practice:

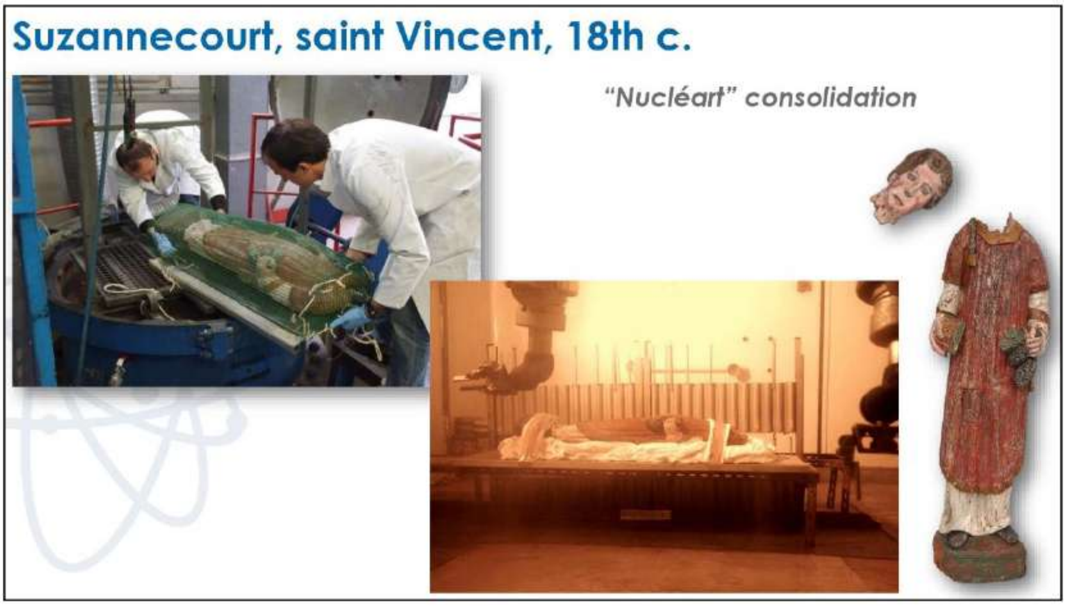
- Artifact take weight (it can double, meaning that sometimes there is more resin than wood !)
- Wood tends to darken more or less, as if it were wet (colors are enhanced), but this effect is more noticeable on the raw wood, and became less marked on patinated wood or low on polychromic layers
- It is absolutely irreversible

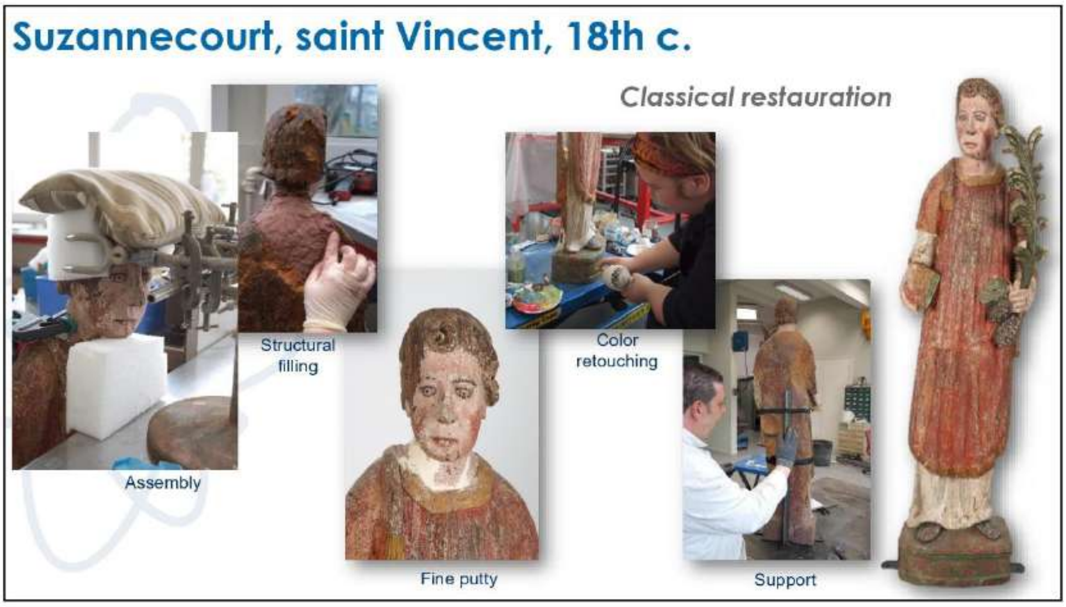
On balance

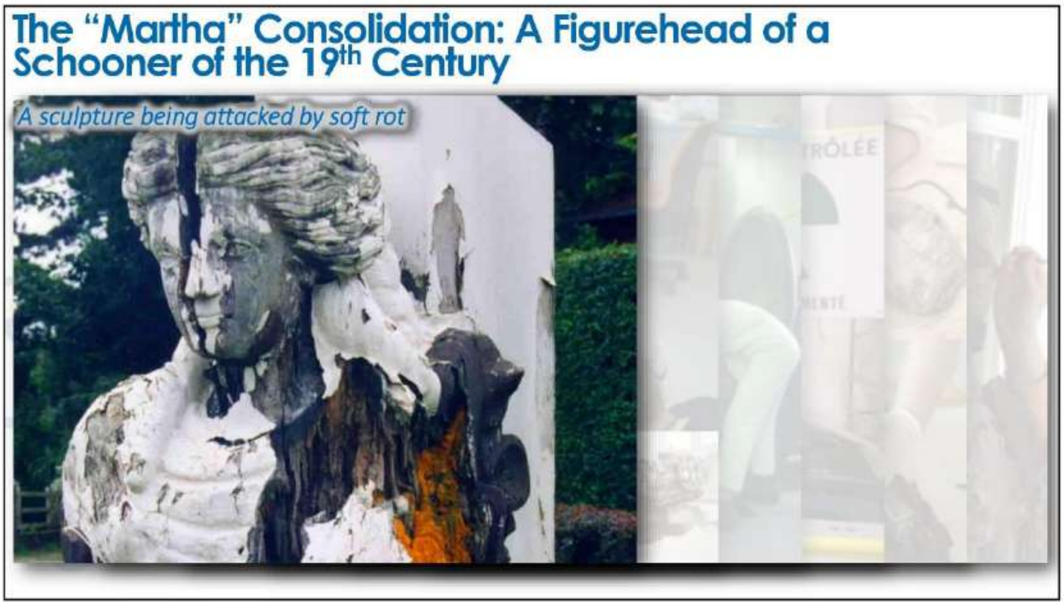
- It is very efficient to recover high-quality mechanical strength,
- Thanks to the penetrating power of gamma radiation, polymerization is extremely homogeneous, even on large piece of wood,
- It has very good chemical stability and low interaction with original organic material, given the hydrophobic nature of the resin.
  - It offer a kind of long-lasting protection against fungi, bacteria and insects, and protection against the exchange of moisture of the ambient atmosphere (but it isn't the aim of the treatment, and it isn't absolute protection).




Suzannecourt, saint Vincent, 18th c.
First intervention before consolidation


Suzannecourt, saint Vincent, 18th c.
"Nucléart" consolidation


Suzannecourt, saint Vincent, 18th c.
Classical restauration
Structural filling
Color retouching
Assembly
Fine putty
Support


The "Martha" Consolidation: A Figurehead of a Schooner of the 19th Century
A sculpture being attacked by soft rot


The "Martha" Consolidation: A Figurehead of a Schooner of the 19th Century
Dismantling


The "Martha" Consolidation: A Figurehead of a Schooner of the 19th Century
Impregnation

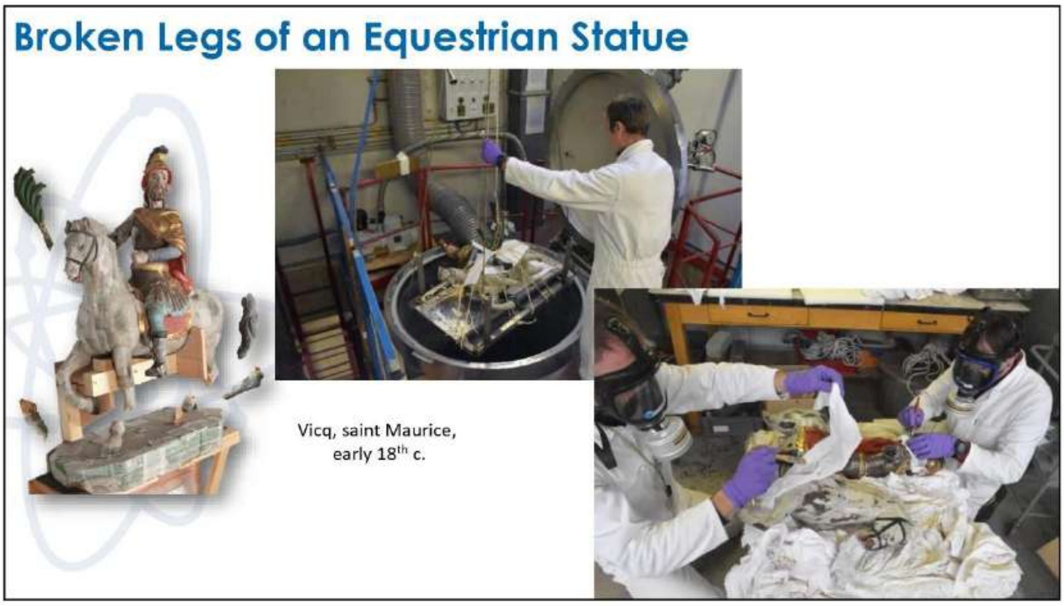

The "Martha" Consolidation: A Figurehead of a Schooner of the 19th Century
Irradiation (radio-curing)
ZONE CONTRÔLÉE
ACCÈS RÉGLEMENTÉ


The "Martha" Consolidation: A Figurehead of a Schooner of the 19th Century
Restauration: the puzzle


The "Martha" Consolidation: A Figurehead of a Schooner of the 19th Century
Restauration: last collage and retouch

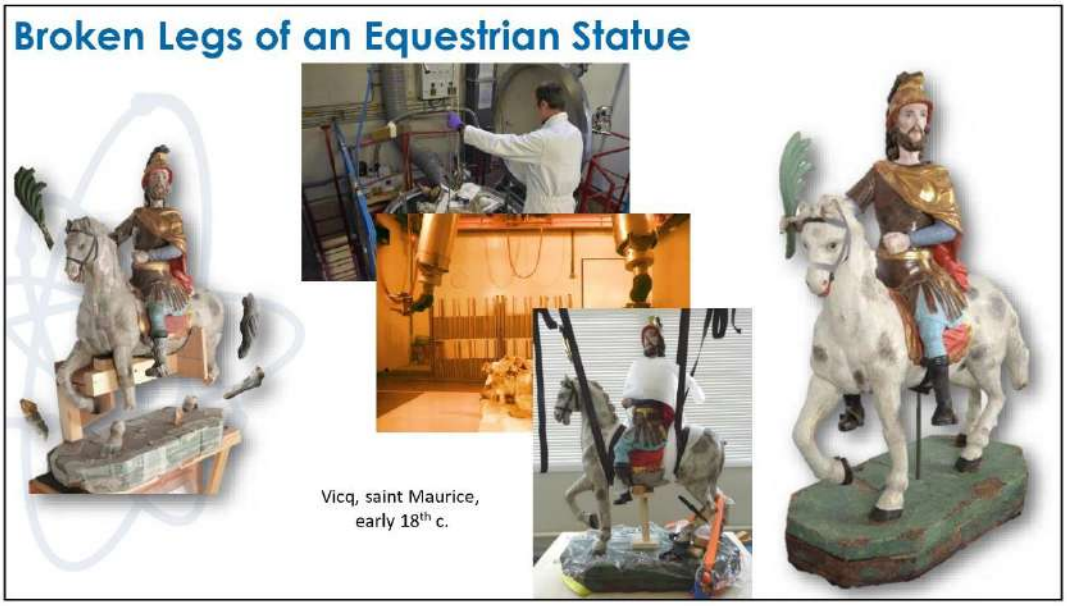

The "Martha" Consolidation: A Figurehead of a Schooner of the 19th Century
Before
After


Broken Legs of an Equestrian Statue
Vicq, saint Maurice, early 18th c.

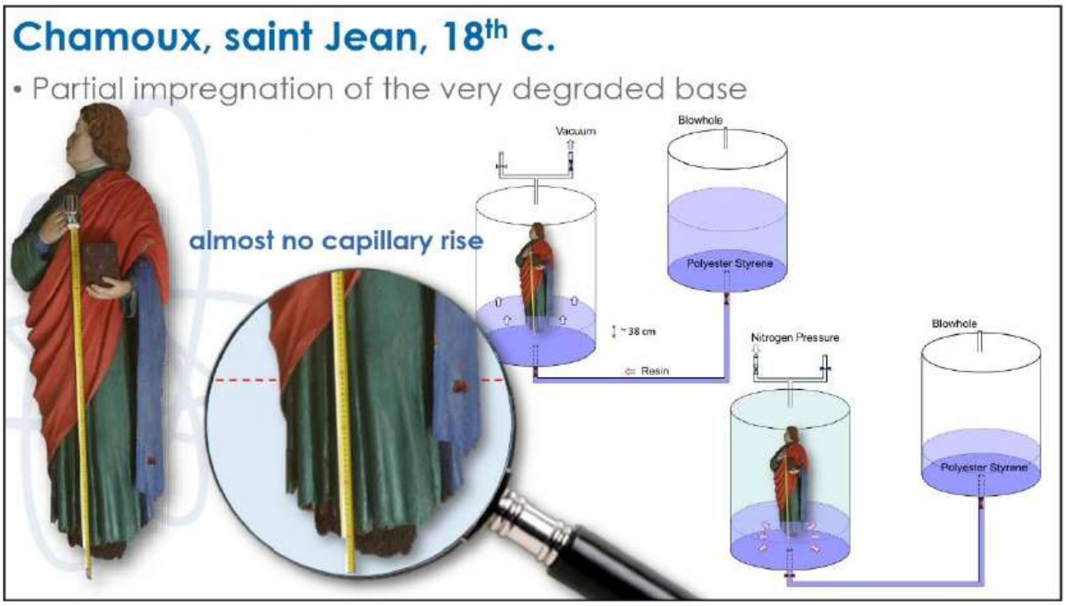

Broken Legs of an Equestrian Statue
Vicq, saint Maurice, early 18th c.

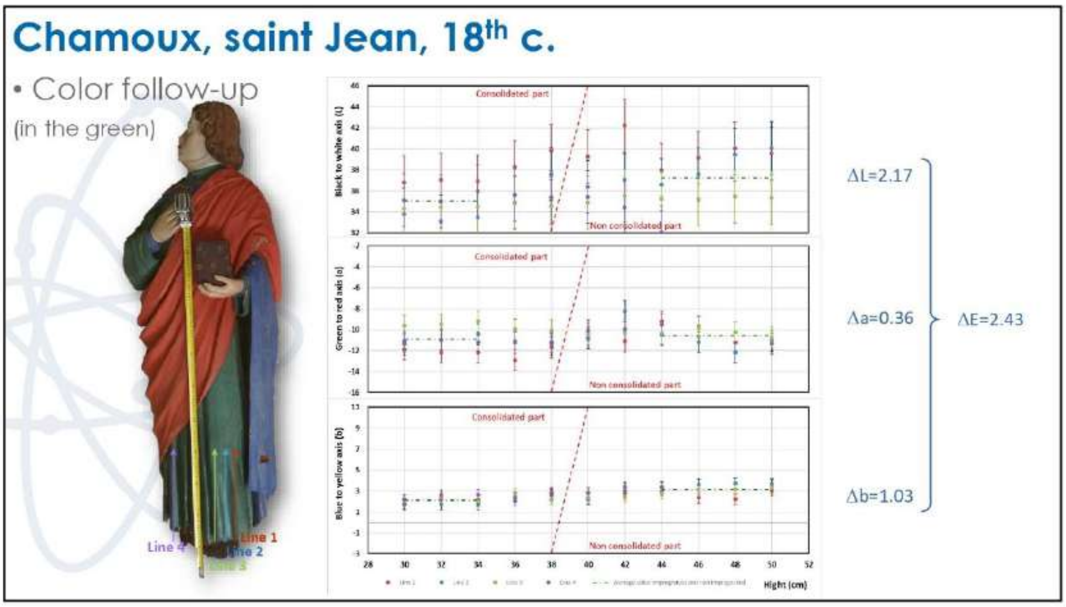

Broken Legs of an Equestrian Statue
Vicq, saint Maurice,
early 18th c.

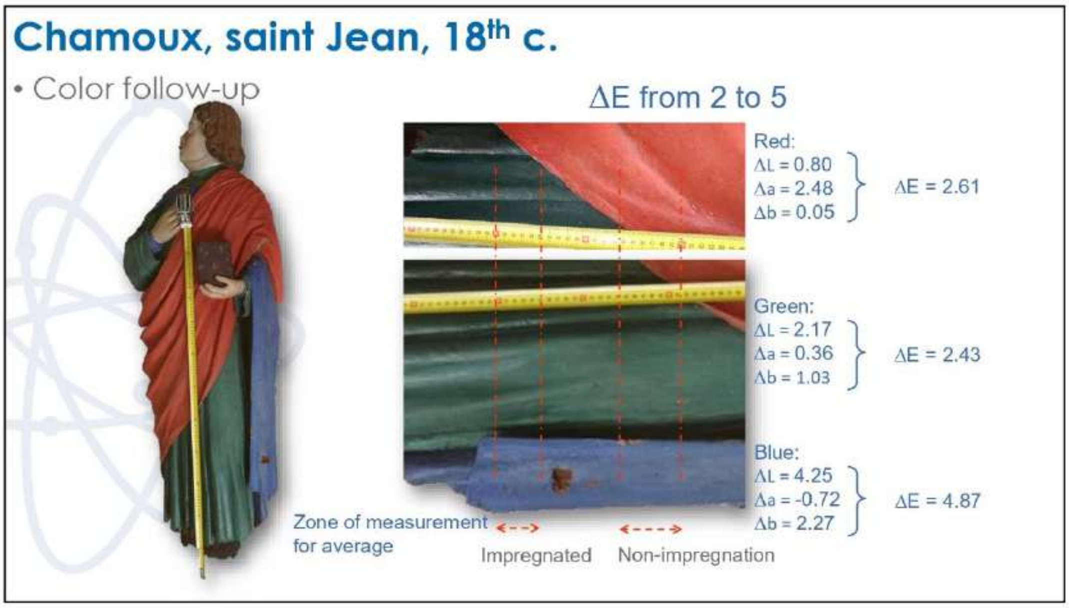

Broken Legs of an Equestrian Statue
Vicq, saint Maurice,
early 18th c.


Broken Legs of an Equestrian Statue
Vicq, saint Maurice,
early 18th c.

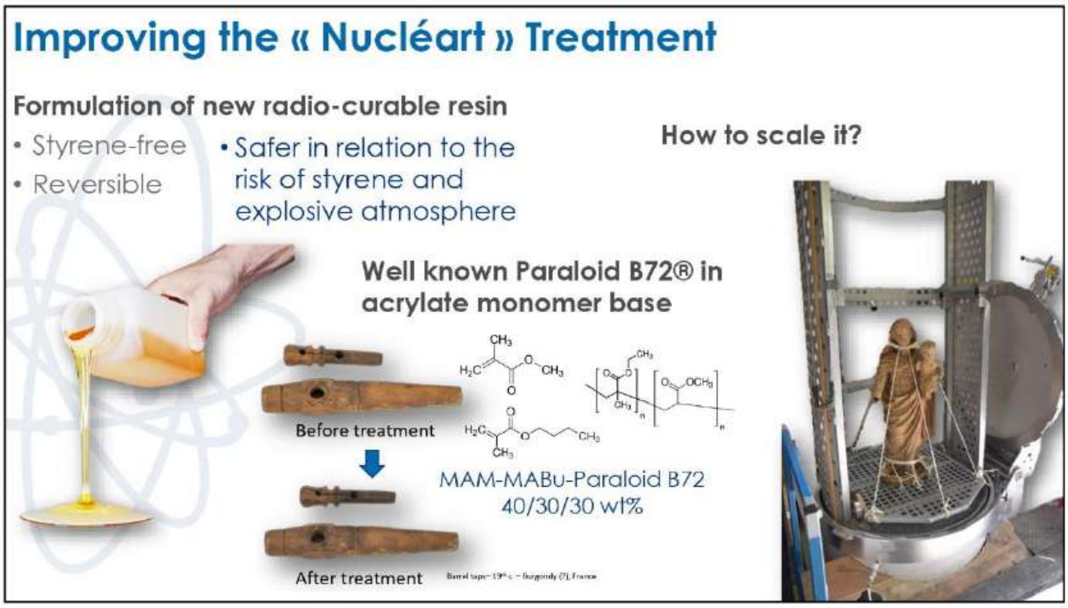

Risk with polychromed wooden sculpture
• Styrene can be solvent of some polychromed layers
• Unexpected uplift of polychromed layers have been observed on some rare cases, surely generated by shrinkage of resin during radio-curing
Some tests must be performed before impregnation


Chamoux, saint Jean, 18th c.
• Partial impregnation of the very degraded base
almost no capillary rise
Vacuum
Blowhole
Polyester Styrene
~38 cm
Resin
Nitrogen Pressure
Blowhole
Polyester Styrene


Chamoux, saint Jean, 18th c.
• Color follow-up
(in the green)
Line 1
Line 2
Line 3
Line 4
Consolidated part
Non consolidated part
ΔL=2.17
Δa=0.36
ΔE=2.43
Δb=1.03


Chamoux, saint Jean, 18th c.
• Color follow-up
ΔE from 2 to 5
Red:
ΔL = 0.80
Δa = 2.48
Δb = 0.05
ΔE = 2.61
Green:
ΔL = 2.17
Δa = 0.36
Δb = 1.03
ΔE = 2.43
Blue:
ΔL = 4.25
Δa = -0.72
Δb = 2.27
ΔE = 4.87
Zone of measurement for average
Impregnated
Non-impregnation


Styrene Risk
• Flammable liquid
• Explosive vapor
EX
• Nervous system hazard and earing loss
at very high concentrations
• Listed as "reasonably anticipated to be a human carcinogen"
by the American Department of Health and Human Services, 2011.
• Classified as "probably carcinogenic to humans"
by International Agency for Research on Cancer (IARC), in prep.


Improving the « Nucléart » Treatment
Formulation of new radio-curable resin
• Styrene-free
• Reversible
• Safer in relation to the risk of styrene and explosive atmosphere
How to scale it?
Well known Paraloid B72® in acrylate monomer base
Before treatment
MAM-MABu-Paraloid B72
40/30/30 wt%
After treatment


Thank you for your attention

2.11 Application of Nuclear Techniques for Characterization and Preservation of Artifacts: Focus on Treatments of Archaeological Waterlogged Wood

Name: Laurent Cortella
Date of Presentation: 24th October 2023
Email: laurent.cortella@cea.fr

In the heart of Arles, France, a remarkable piece of history was unearthed: a Roman chariot wheel, a silent witness to the grandeur of the first century. However, such artifacts, especially those crafted from wood, face the relentless threat of degradation over time. The challenge for conservators is not just to halt this decay but to reverse it, ensuring that these historical treasures endure for future generations.

Waterlogged archaeological wood in historical sites, often laden with iron and sulfur, presents a unique dilemma. When these elements combine, they form pyrite, also known as fool's gold, which, when exposed to air, can acidify and accelerate the deterioration of the wood. The conservation community recognizes this as a formidable foe, and experts have been crafting innovative solutions to this problem.

The methodology advocated here is both meticulous and ground-breaking. It begins with a poultice—a soft, moist mass of material—comprising 10% sodium carbonate and 5% disodium sebacate, with the balance being water. This concoction is applied to the affected wood, serving a dual purpose. The sodium carbonate works to neutralize the acidic environment that promotes pyrite formation, while disodium sebacate acts as a chelating agent, binding to iron ions and hindering their ability to react with sulfur.

This preventive treatment is critical in safeguarding artifacts like the Roman chariot wheel discovered in Arles, as well as the more massive Gallo-Roman Barges found in the same region. These barges, once a common sight along the waterways of Roman Gaul, today offer an invaluable glimpse into the engineering and daily life of ancient times. Preserving them is not just about maintaining the physical structure but also about protecting the historical narrative they carry.

The conservation process for these ancient relics is comprehensive. After the initial application of the poultice, the wood undergoes a pre-treatment phase before being treated with radio-curable styrene-polyester resins. This innovative treatment involves using resins that harden when exposed to radiation, providing sturdy support to the waterlogged wood without air drying, which can cause shrinking, warping, or cracking.

This process, however, has its challenges. The high consumption of polyethylene glycol (PEG), a polymer used in the conservation process, is notably expensive. PEG plays a crucial role in replacing the water within the wood's cellular structure, helping to maintain its shape and integrity. The financial implications of using such materials highlight the balance that must be struck between effectiveness and practicality in the field of conservation.

Despite these challenges, the commitment to preserving history is unwavering. As we venture into an era where the past is more tangible than ever, thanks to these conservation efforts, the focus shifts to sustainability. The conservation community is continually seeking ways to optimize these treatments, reducing costs without compromising efficacy.

The work being done in Arles serves as a testament to the dedication of conservators around the world. It's a delicate dance between science and art, where each step is carefully choreographed to ensure that the stories etched in wood and stone are not lost to time. Preserving the Gallo-Roman Barges and the Roman chariot wheel is not just a triumph of conservation technology; it is an ode to the past, an acknowledgment of the ingenuity and craftsmanship of our ancestors.

In essence, the conservation of waterlogged archaeological wood is a narrative. It speaks of the resilience of human heritage against the ravages of time. It tells a tale of modern-day guardians who wield science as their sword and dedication as their shield. The endeavors in Arles resonate with a clear message: our past is a mosaic of memories worth preserving, and through innovation and care, we ensure that this mosaic continues to inspire awe and wonder for generations to come.

As we advance, the conservation community's efforts will remain crucial in the fight against time and decay. It's a battle fought in the quiet corridors of history, a labor of love that demands our utmost respect and support. For in preserving these fragments of our past, we uphold the very essence of our civilization, ensuring that the wheels of history continue to turn unimpeded and everlasting. The slides in the upcoming section detail the work done on this.

Application of Nuclear Techniques for Characterization and Preservation of Artifacts

Focus on Treatments of Archaeological Waterlogged Wood

Malacca, 2023 October 23th-27th

Laurent CORTELLA, from arc nucle art (Atelier de Recherche et de Conservation) for IAEA

Preservation of archaeological organic material in natural environment

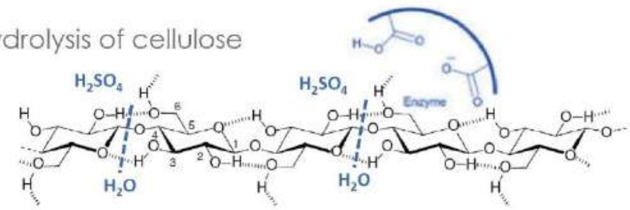
Where main pests (insects and fungi) don't « eat » the wood or organic material

- because there is no life (desert)
- because it is too cold (permafrost)
- because there is no oxygen
  - immersed in water
  - or buried in sediment saturated with water

Shape is conserved, wood is waterlogged

Degradation in water

- Macroscopic damages
  - Mechanical degradation: Erosion by courant, Mechanical stress due to the Archimedean thrust
  - Biological degradation: Perforation by roots (reeds), growth of algae
- Microscopic damages
  - Biological degradation: Anaerobic bacteria (enzymatic action, sulfate reducing bacteria)
  - Chemical degradation: Hydrolysis of cellulose



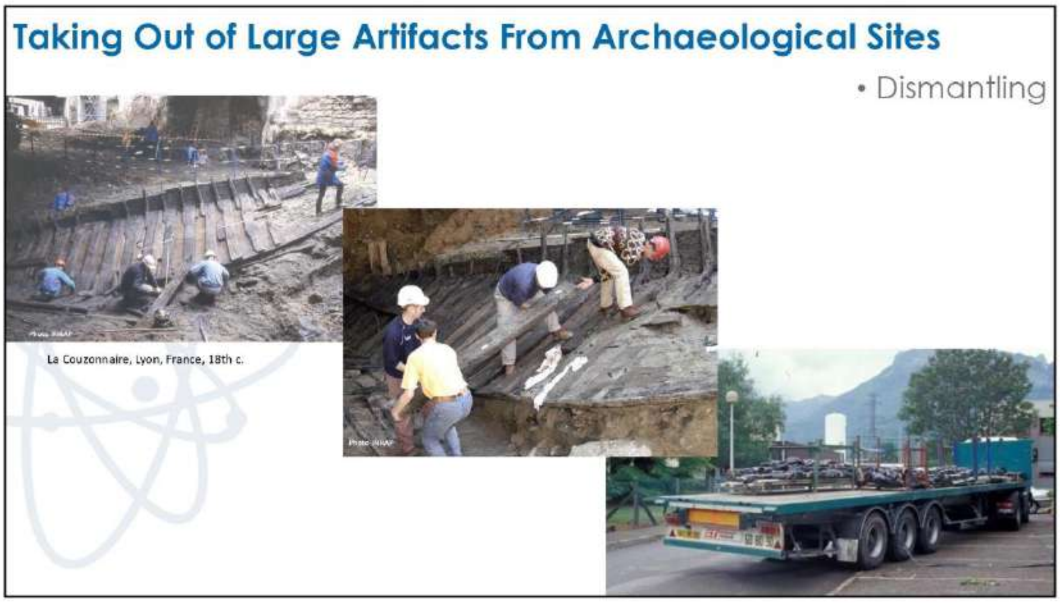
Solubilization and leaching of cellulose

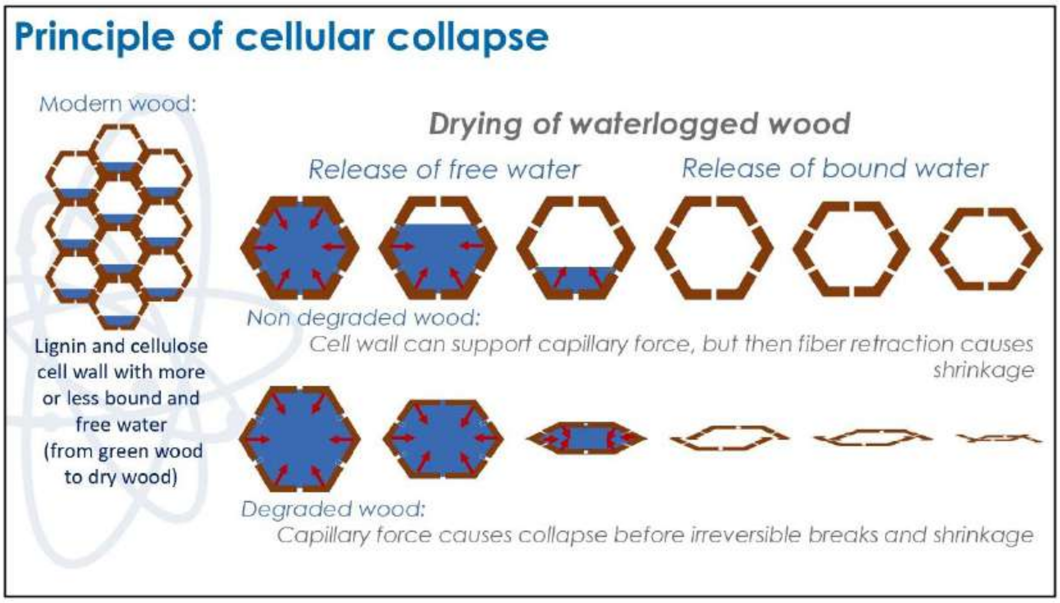
Loss of mechanical strength of the cell wall


Handling
• Archaeological objects often appear more stable and resistant than they actually are.
• The sediment provides support for fragile artifacts. Removing them directly may cause them to support their own weight.
Gallo-Roman fish-trap, Pont-sur-Seine, France, 1st c.


Taking Out of Large Artifacts From Archaeological Sites
• on clod
Gallic burial, Besançon, France, 1st century BC
Neolithic canoe, Paris-Bercy, France, 4500 BC

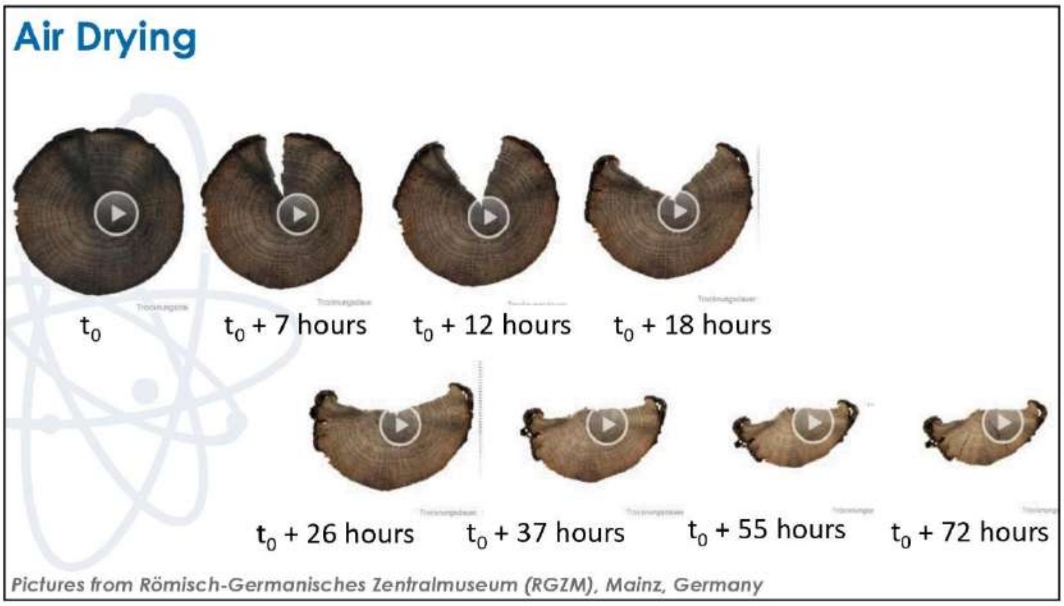

Taking Out of Large Artifacts From Archaeological Sites
• Substitution of sedimentary support
Canoe, Lac du Bourget, France, 9th c.
Livewell barque, Lyon, France, 16th c.

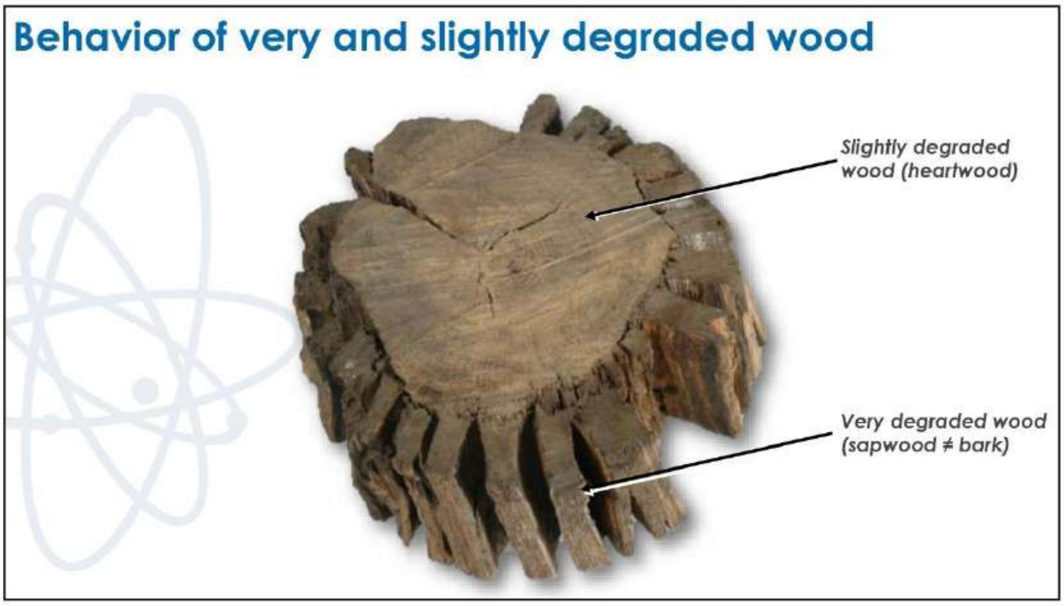

Taking Out of Large Artifacts From Archaeological Sites
• Dismantling
La Couzonnaire, Lyon, France, 18th c.


Principle of cellular collapse
Modern wood:
Lignin and cellulose cell wall with more or less bound and free water (from green wood to dry wood)
Drying of waterlogged wood
Release of free water
Release of bound water
Non degraded wood:
Cell wall can support capillary force, but then fiber retraction causes shrinkage
Degraded wood:
Capillary force causes collapse before irreversible breaks and shrinkage


First priority: Collapse MUST be avoided
Drying in air without treatment is forbidden
Always maintain archaeological wood in a wet state before to be treated
Watering, conditioning in a waterproof film, or keeping immersed in water


Irreversible collapse
• Volume loss > 50%


Air Drying
t_0
t_0 + 7 hours
t_0 + 12 hours
t_0 + 18 hours
t_0 + 26 hours
t_0 + 37 hours
t_0 + 55 hours
t_0 + 72 hours
Pictures from Römisch-Germanisches Zentralmuseum (RGZM), Mainz, Germany


Behavior of very and slightly degraded wood
Slightly degraded wood (heartwood)
Very degraded wood (sapwood ≠ bark)

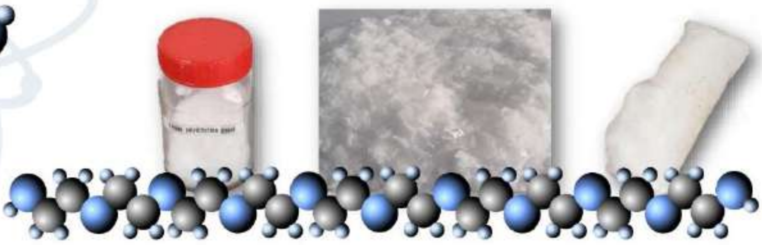
2 types of deformation during drying

	Modern wood	Archaeological wood
Type of deformation	Shrinkage	Shrinkage + collapse
Volume loss	<10 %	>50 %
Reversibility	Yes	No

Impregnation of Polyethylene Glycol

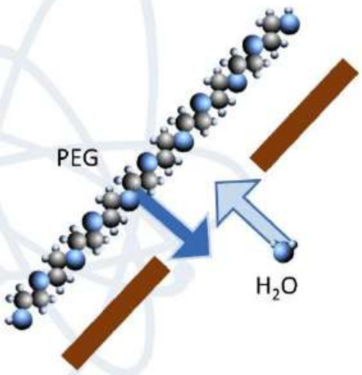
- To reinforce the cell wall : PEG of high molecular weight, a solid but soluble polymer

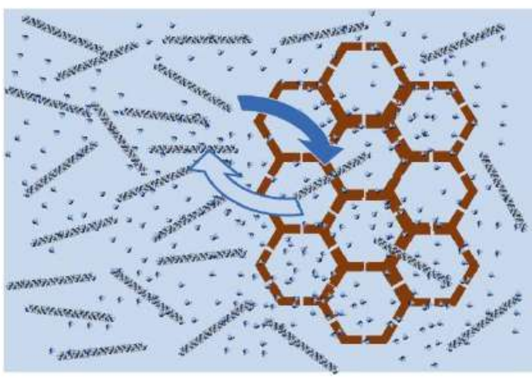
	Molecular Weight (kg.mol^{-1})	Fusion Temperature Range	Solubility in Water à 20°C (%Weigth)
PEG 2000	2000	48-52 °C	60
PEG 4000	4000	53-57 °C	50



Impregnation by osmotic exchange

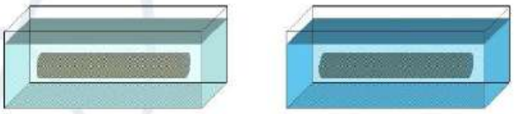
- Liquid diffusion of polyethylene glycol into the wood, tending towards an balance of concentrations on both sides





Classical impregnation at ARC-Nucléart

- Impregnation in 2 successive baths to avoid osmotic shock that could lead to dehydration ... and collapse



15-20 % PEG
4 to 6 month

35-40 % PEG
4 to 6 month

- No way to predict the time necessary to reach equilibrium, that depends on many parameters (surface condition, surface to ratio volume, state of degradation...)
  - By default, it is necessary to "oversize the durations"

Quality of the bath

Extraneous material

- Suspended matter:
  - Mineral or inert organic matter coming from the archaeological material
  - Dead or alive microorganism
- Dissolved substances:
  - Dissolved gases (bad smells)
  - Chemicals (e.g. biocides)
  - Salts, dyes ...

Filtration and U.V. biocide treatment

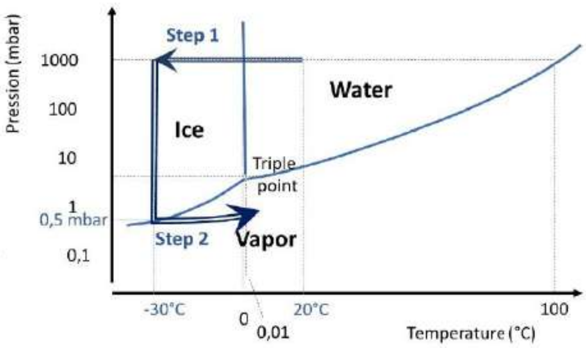
Freeze-Drying

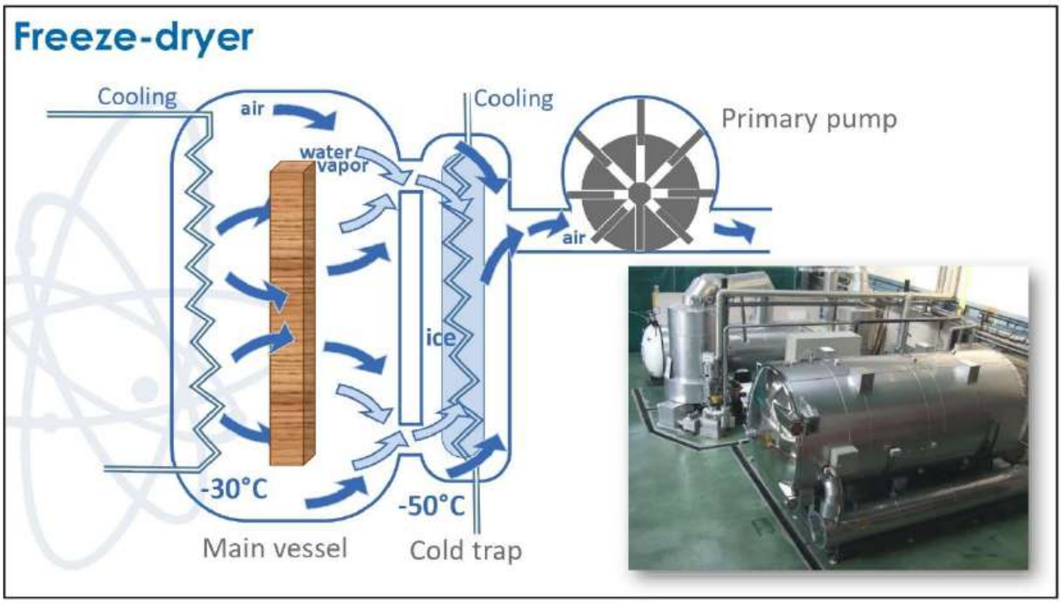
Wood is still filled with liquid

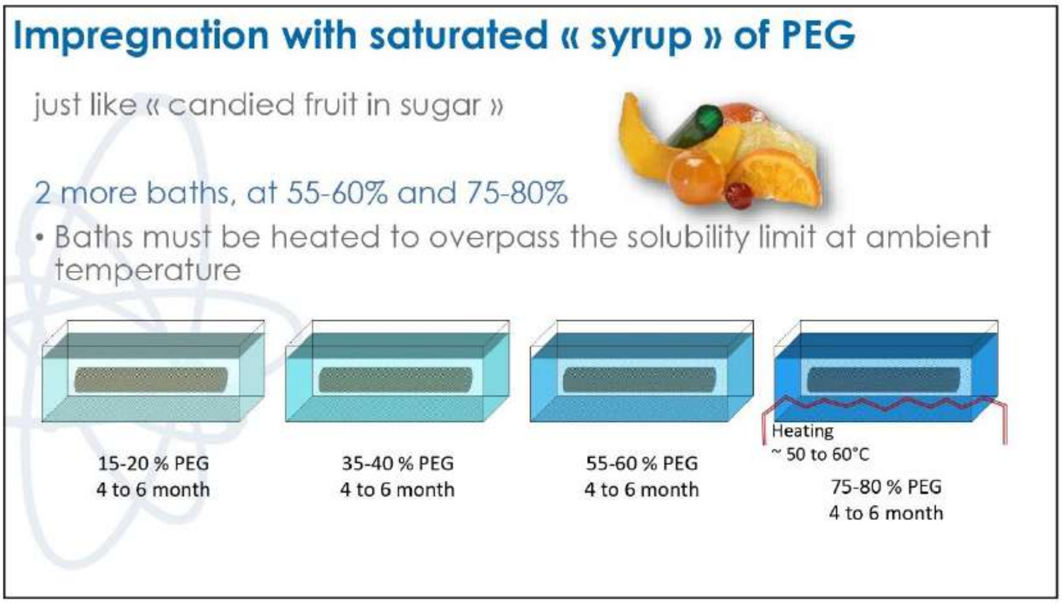
Release of water must be done in solid to gas phases to avoid capillarity forces

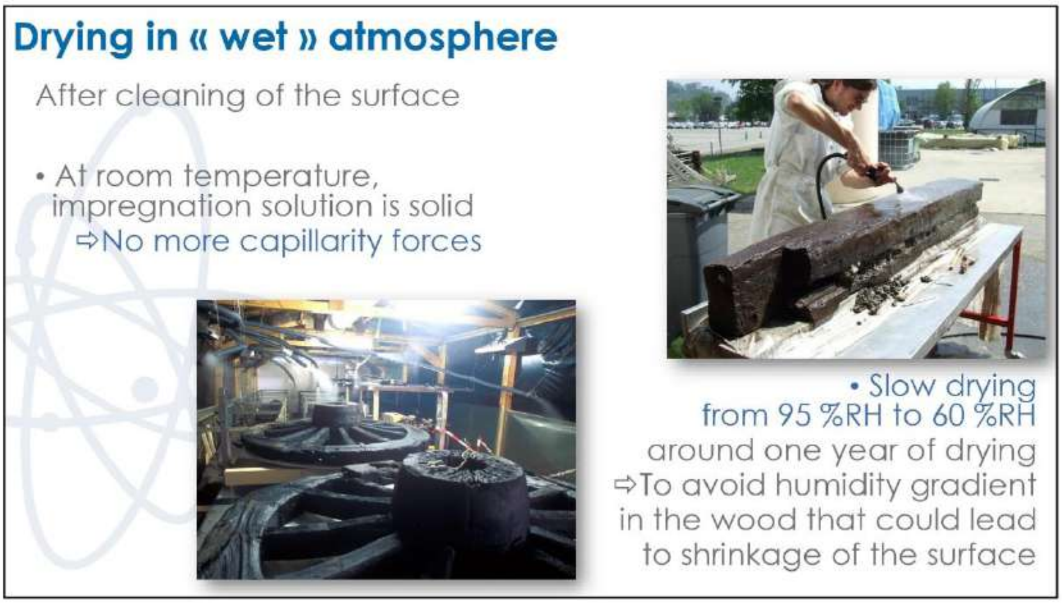
- Step 1: Freezing of water + PEG solution at -30 °C (in the wood) – 2-3 days

- Step 2: Vacuum, to trigger the sublimation of water 2-3 weeks

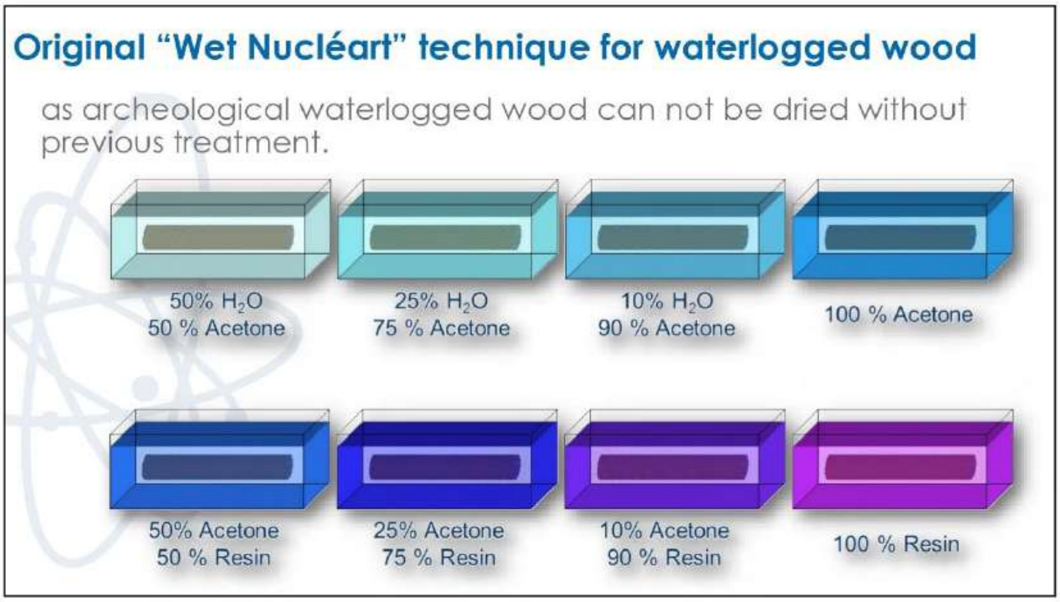



Freeze-dryer
Cooling
air
water vapor
Cooling
Primary pump
air
ice
-30°C
-50°C
Main vessel
Cold trap


Impregnation with saturated « syrup » of PEG
just like « candied fruit in sugar »
2 more baths, at 55-60% and 75-80%
• Baths must be heated to overpass the solubility limit at ambient temperature
15-20 % PEG
4 to 6 month
35-40 % PEG
4 to 6 month
55-60 % PEG
4 to 6 month
Heating
~ 50 to 60°C
75-80 % PEG
4 to 6 month


Drying in « wet » atmosphere
After cleaning of the surface
• At room temperature, impregnation solution is solid
⇨No more capillarity forces
• Slow drying
from 95 %RH to 60 %RH
around one year of drying
⇨To avoid humidity gradient in the wood that could lead to shrinkage of the surface


Lake Paladru: The Peasant Knights of the One Thousand Year
Thousands of artifacts treated since the 70's


Original "Wet Nucléart" technique for waterlogged wood
as archeological waterlogged wood can not be dried without previous treatment.
50% H_2O 50 % Acetone
25% H_2O 75 % Acetone
10% H_2O 90 % Acetone
100 % Acetone
50% Acetone 50 % Resin
25% Acetone 75 % Resin
10% Acetone 90 % Resin
100 % Resin


Archaeological Wood Treated with Nucléart Technique
To improve mechanical strength, or to insure stability in humid conditions and to avoid corrosion
thanks to the use of hydrophobic resin
Tromblon, XVIIe s., Cap d'Agde
Matériel d'accastillage, XVIIe s. , Saint-Malo
Patte d'animal (élément de sculpture), Époque gallo-romaine – Aix-en-Provence
Seau gaulois, Ie s. av J.C., Agen


« Tirez les premiers, messieurs les anglais ! »
("English Gentlemen, Please Fire First!")
To limit the acidification of wood and the formation of pyrite in the presence of sulfur and iron elements
Impregnation by successive baths at atmospheric pressure (double osmotic exchange)
Gun carriage from HMS Stirling Castle, 17th c.


« Tirez les premiers, messieurs les anglais ! »
("English Gentlemen, Please Fire First!")
To limit the acidification of wood and the formation of pyrite in the presence of sulfur and iron elements
Wrapping before irradiation to adsorb resin in excess
Gun carriage from HMS Stirling Castle, 17th c.


« Tirez les premiers, messieurs les anglais ! »
("English Gentlemen, Please Fire First!")
To limit the acidification of wood and the formation of pyrite in the presence of sulfur and iron elements
First part of irradiation before it jellified
Gun carriage from HMS Stirling Castle, 17th c.

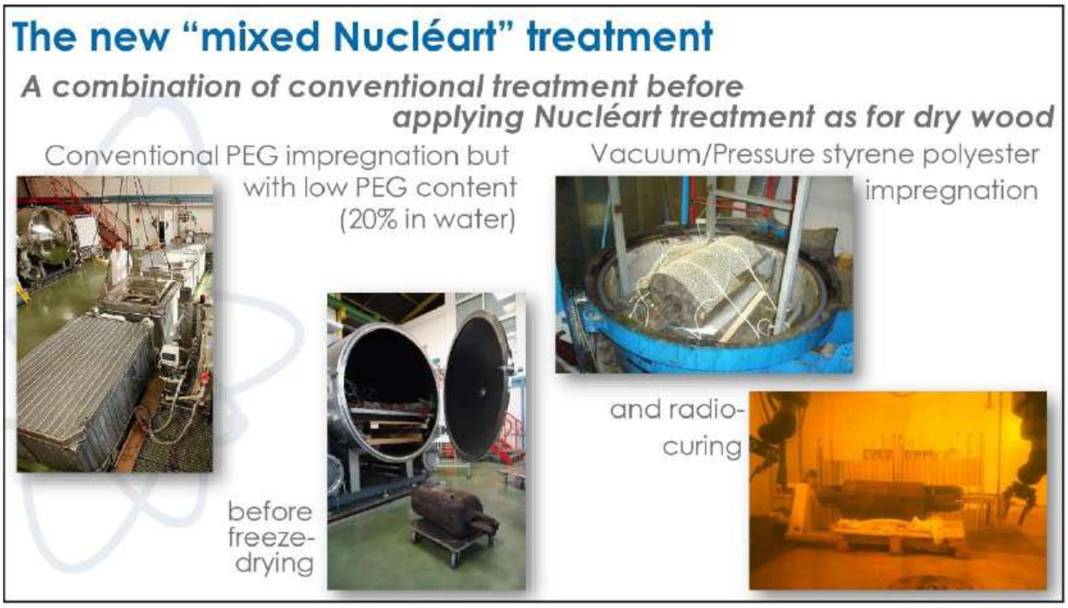

« Tirez les premiers, messieurs les anglais ! »
("English Gentlemen, Please Fire First!")
To limit the acidification of wood and the formation of pyrite in the presence of sulfur and iron elements
Cleaning the bright traces as resin is still in gel form
Gun carriage from HMS Stirling Castle, 17th c.


« Tirez les premiers, messieurs les anglais ! »
("English Gentlemen, Please Fire First!")
To limit the acidification of wood and the formation of pyrite in the presence of sulfur and iron elements
Second part of irradiation until complete curing
Gun carriage from HMS Stirling Castle, 17th c.


« Tirez les premiers, messieurs les anglais ! »
("English Gentlemen, Please Fire First!")
To limit the acidification of wood and the formation of pyrite in the presence of sulfur and iron elements
Gun carriage from HMS Stirling Castle, 17th c.


« La réponse française » (The French response)
Waterlogged before treatment
Afer treatment
"Pierrier", Le Havre, France, 16th c.

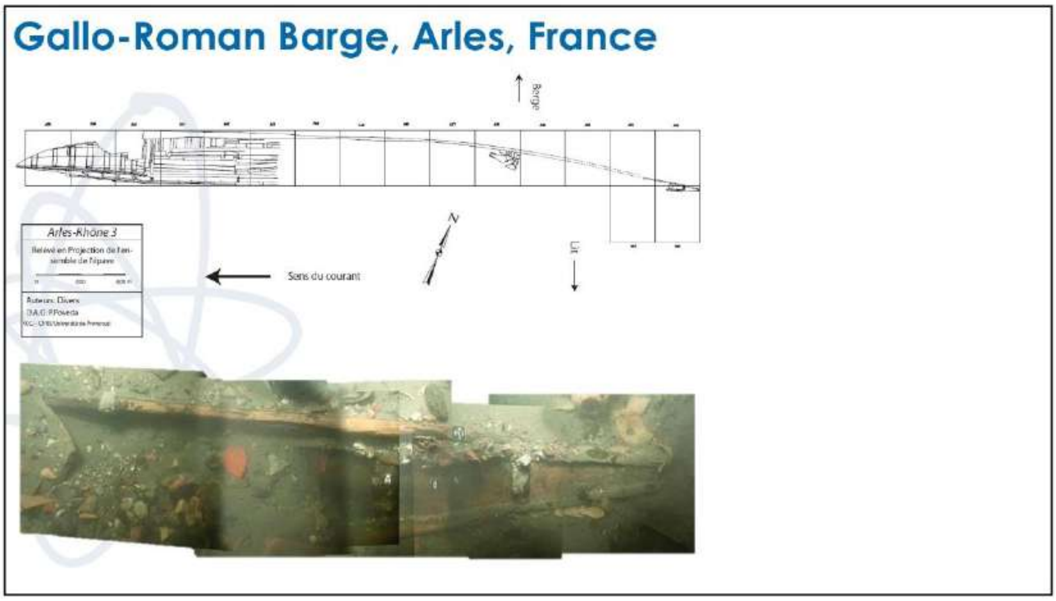

A long and complex technique
• 1 to 2 years of impregnation,
• a lot of handling to change the bath
• explosive risk using bath with lot of acetone and styrene at atmospheric pressure,
• lot of waste,
• expensive.
• still the best in terms of conservation of the initial volume of waterlogged wood
• very efficient to avoid corrosion when metal is present near the wood,
• A technique that provide encouraging results in the presence of sulfide compounds

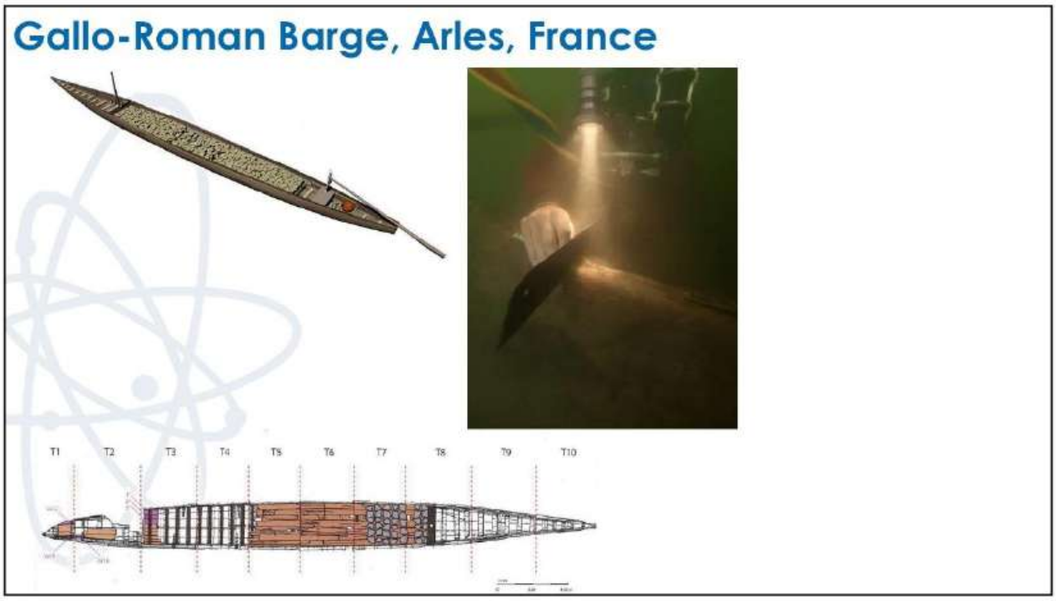

The new "mixed Nucléart" treatment
A combination of conventional treatment before applying Nucléart treatment as for dry wood
Conventional PEG impregnation but with low PEG content (20% in water)
before freeze-drying
Vacuum/Pressure styrene polyester impregnation
and radio-curing


Toward the best compromise
Pro
PEG + Freeze-drying
• Universal technique
• Wood looks like wood
PEG Saturation
• Less technical
• Don't need very special facility
• Good consolidation
• Can adapt easily even for big dimension
« Nucléart » technic
• Very good consolidation
• Very stable
• The shortest time of treatment (6-8 months)


Toward the best compromise
Cons
PEG + Freeze-drying
• Poor consolidation
• Unstable with humidity
• Promote corrosion of associated metals and apparition of pyrite in presence of sulfur
PEG Saturation
• Very long (up to 3 years)
• Difficult to manage plastic deformation
• High consumption of PEG (more expensive)
« Nucléart » technic
• Irreversible
• Heavy
• Need an irradiator and vapor pressure vessel
• Double process
• Expensive


Prevention of Pyrite Formation and Acidification
Pyrite formation on waterlogged archaeological wood in presence of iron and sulfur is one of most important problems that the conservation community is facing
Pretreatment before treatment with radio-curable styrene-polyester resins
Poultice of (10%Na_2CO_3+) 5% Disodium Sebacate+ 85%H_2O


Gallo-Roman Barge, Arles, France
Arles-Rhône 3
Sens du courant


Gallo-Roman Barge, Arles, France


Gallo-Roman Barge, Arles, France
© R. Benali / Studio Atlantis / CG13 / Mdaa


Gallo-Roman Barge, Arles, France
01


Gallo-Roman Barge, Arles, France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Gallo-Roman Barge, Arles, France
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Gallo-Roman Barge, Arles, France
iconcept
© R. Benali / Studio Atlantis / CG13 / Mdaa


Gallo-Roman Barge, Arles, France


Gallo-Roman Barge, Arles, France


Gallo-Roman Barge, Arles, France


Thank you for your attention

2.12 Nuclear as Scientific Approach in Characterization and Preservation of Cultural Heritage Artifact

Name: Muhammad Rawi Mohamed Zin
Date of Presentation: 27th October 2023
Email: muhammad_rawi @nm.gov.my

The mysteries of historical artifacts, sunken for centuries in shipwrecks or buried under layers of earth, have long captivated the human imagination. How do we uncover their secrets without causing damage? This is where the power of nuclear science comes into play, offering a non-destructive peek into the past.

At the intersection of high technology and archaeology, nuclear techniques have revolutionized our approach to characterizing and preserving cultural heritage artifacts. This presentation highlights the use of these techniques, focused on artifacts recovered from shipwrecks.

To understand how nuclear techniques aid in artifact analysis, one must first grasp how radiation interacts with different materials. When radiation encounters any substance, it can be absorbed or scattered by the atoms within. This interaction is pivotal to the characterization of materials.

Each material has a unique ability to attenuate or weaken, radiation, which can be measured. By examining how much radiation passes through an artifact, scientists can infer its composition and structure. This is particularly useful for reviewing objects that have corroded over time, such as ancient metal weapons and tools.

Neutrons and gamma rays are powerful probes that can penetrate deeply into materials without destroying them. By directing these rays at artifacts and analyzing how they are altered upon exit, researchers can identify different elements and compounds within the object.

The magic of the process lies in the emitted radiation spectrum, which acts as a unique identifier, almost like a fingerprint, of the material being tested. This 'prompt gamma spectrum' can reveal the elemental composition of an artifact, while 'neutron tomographic images' offer a glimpse into its internal structure.

Neutron tomography is akin to a highly sophisticated X-ray that can distinguish between light and heavy elements, a task beyond the capability of conventional X-rays. This makes it ideal for inspecting the intricate metalwork of ancient firearms or the delicate, fossilized remains of biological specimens.

The process involves taking two-dimensional projections of an object from various angles using neutron radiation. These projections are then mathematically reconstructed to form a 3D image. Known as the Radon transform, this technique allows for the visualization of the internal features of an artifact without any physical intrusion.

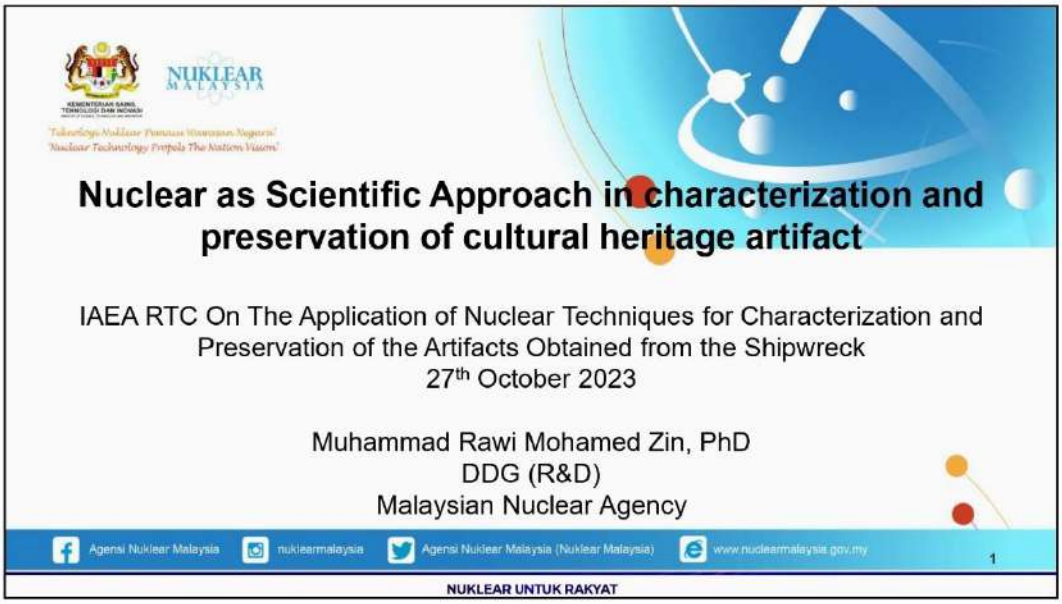
3D CT further enhances our ability to visualize the internal structure of cultural relics. By compiling multiple tomographic images taken around an object, it's possible to create a three-dimensional volume image. Such detailed views can reveal secrets locked within the artifacts, like the internal mechanisms of a corroded lock or the hidden layers of a mummified relic.

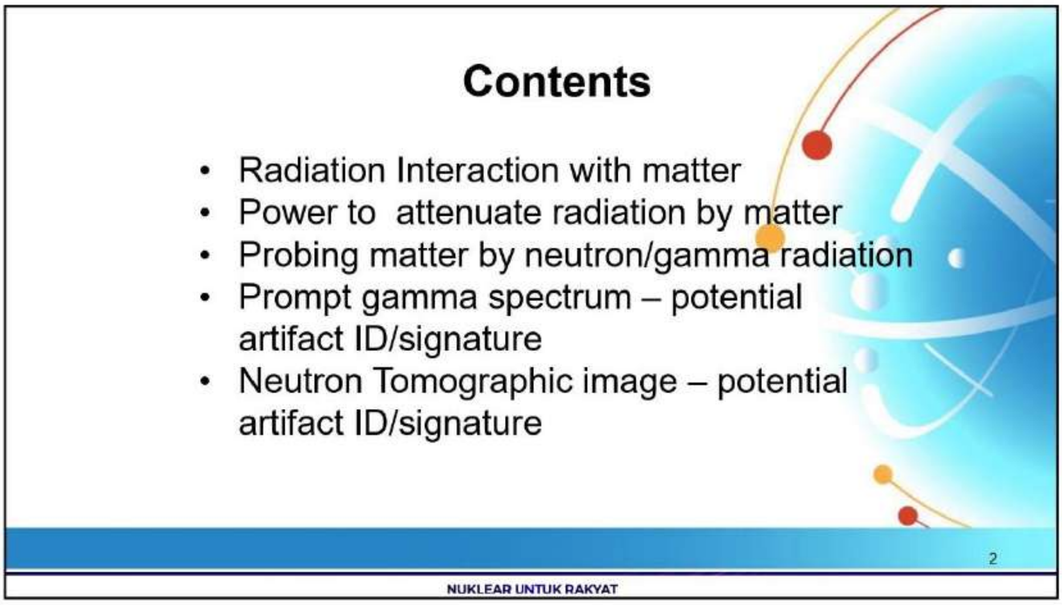
These nuclear techniques have been applied to various artifacts with astounding results. For instance, gamma and neutron radiography have been used to examine corroded rifles from shipwrecks, revealing details that the corrosive effects of seawater had been concealed for ages.

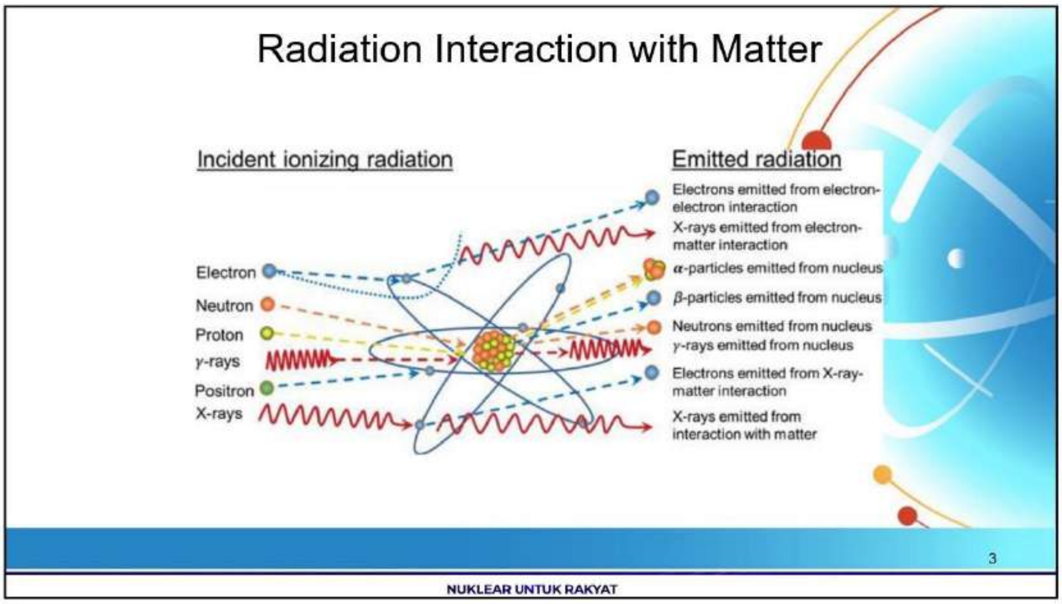
Another fascinating application is the study of fossilized specimens, such as spiders, where neutron radiographs can discern the fine details of their leg structures or the delicate intricacies of their heads. Such insights are invaluable to paleontologists and archaeologists who strive to understand the biological and cultural aspects of ancient life.

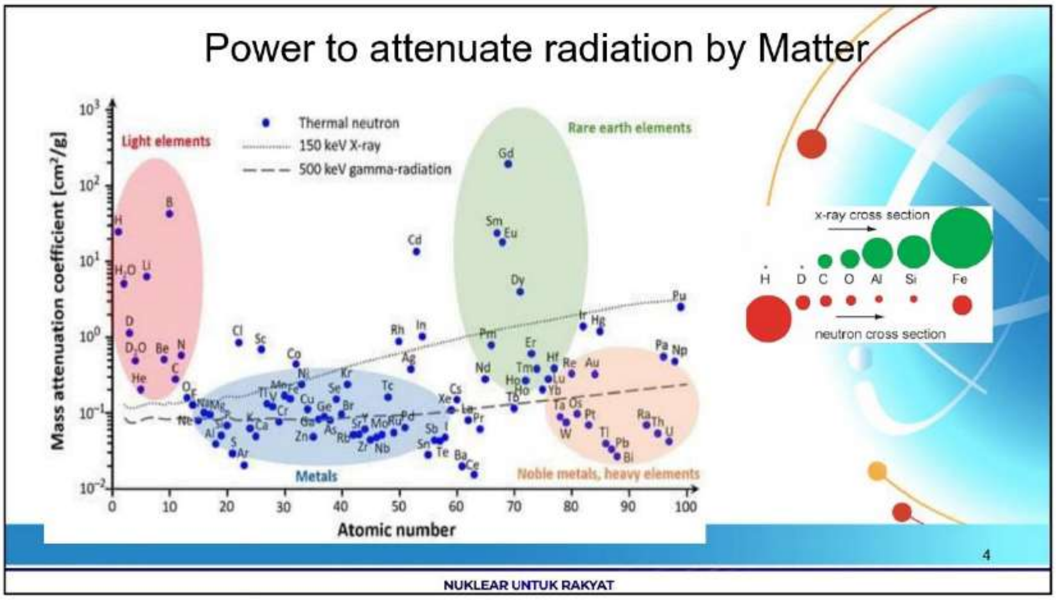
To harness these advanced techniques, professionals in the field must receive specialized training. The IAEA, through its training centres, equips researchers and conservationists with the knowledge to apply these nuclear methods effectively. This training ensures that cultural heritage artifacts are not only studied with great precision but also conserved for future generations.

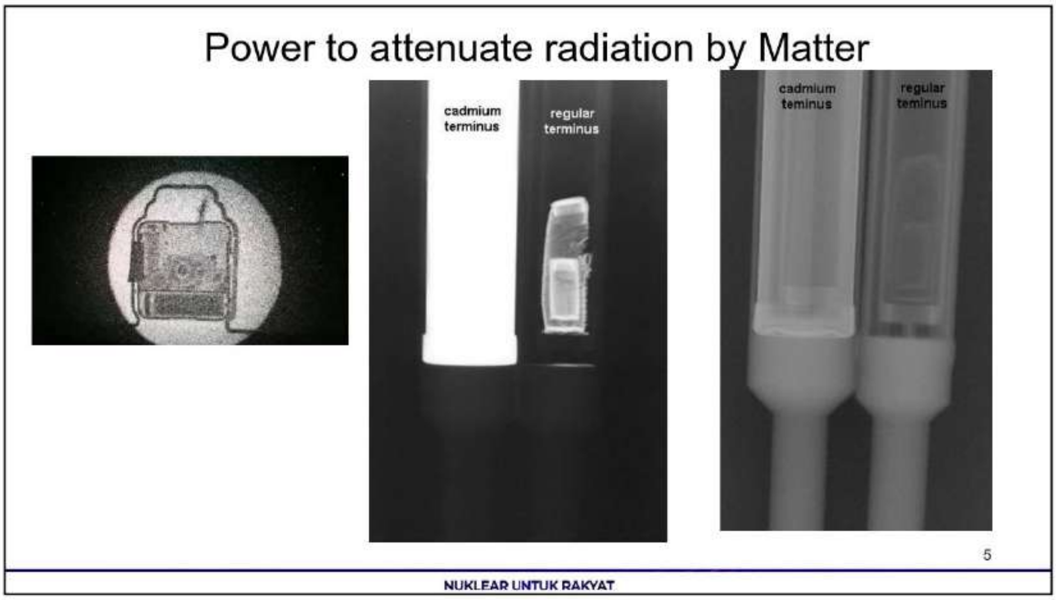
Integrating nuclear science into cultural heritage preservation represents a profound leap forward. It allows us to unravel the past with an accuracy and care that was once unimaginable. As we continue to refine these methods, the stories of human history, long silent, can now be told with the vivid detail they deserve, thanks to the innovative use of nuclear technology. The slides in the upcoming section detail the work done on this.

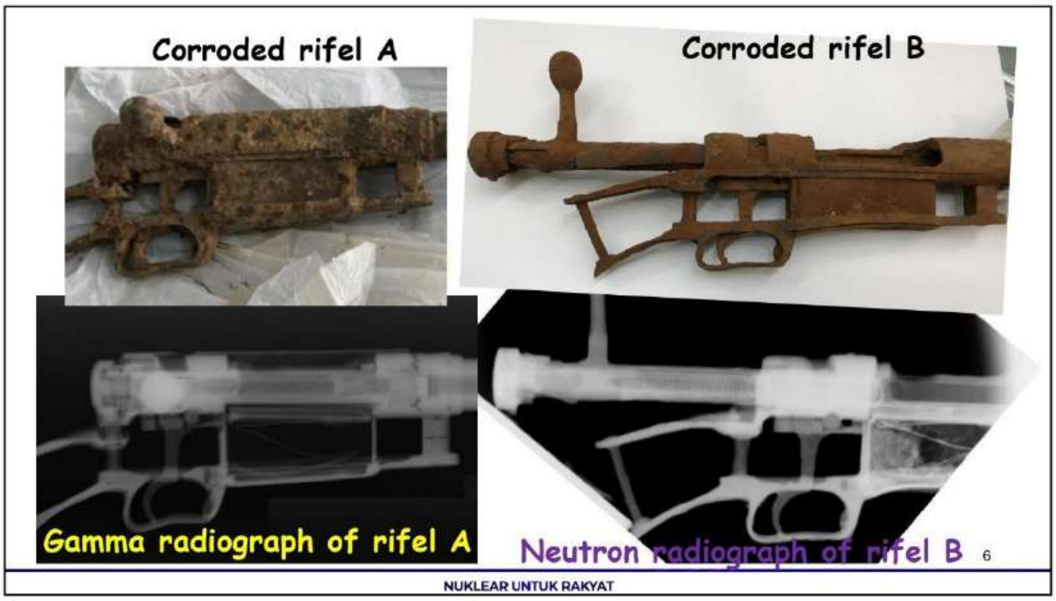

NUKLEAR MALAYSIA
Nuclear as Scientific Approach in characterization and preservation of cultural heritage artifact
IAEA RTC On The Application of Nuclear Techniques for Characterization and Preservation of the Artifacts Obtained from the Shipwreck
27th October 2023
Muhammad Rawi Mohamed Zin, PhD
DDG (R&D)
Malaysian Nuclear Agency
Agensi Nuklear Malaysia
nuklearmalaysia
Agensi Nuklear Malaysia (Nuklear Malaysia)
www.nuclearmalaysia.gov.my
1
NUKLEAR UNTUK RAKYAT

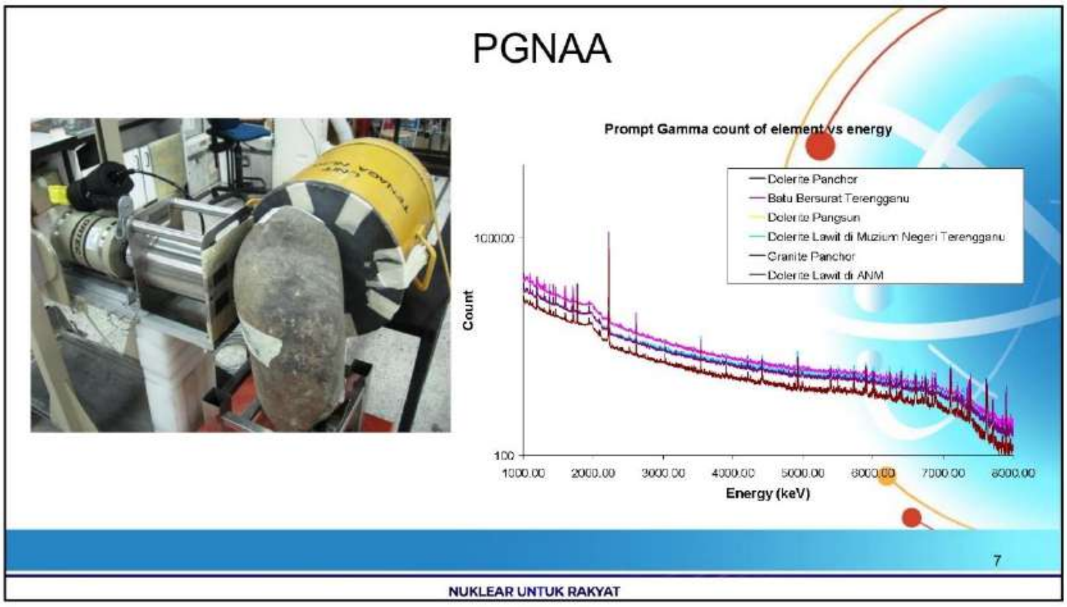

Contents
• Radiation Interaction with matter
• Power to attenuate radiation by matter
• Probing matter by neutron/gamma radiation
• Prompt gamma spectrum – potential artifact ID/signature
• Neutron Tomographic image – potential artifact ID/signature
2
NUKLEAR UNTUK RAKYAT

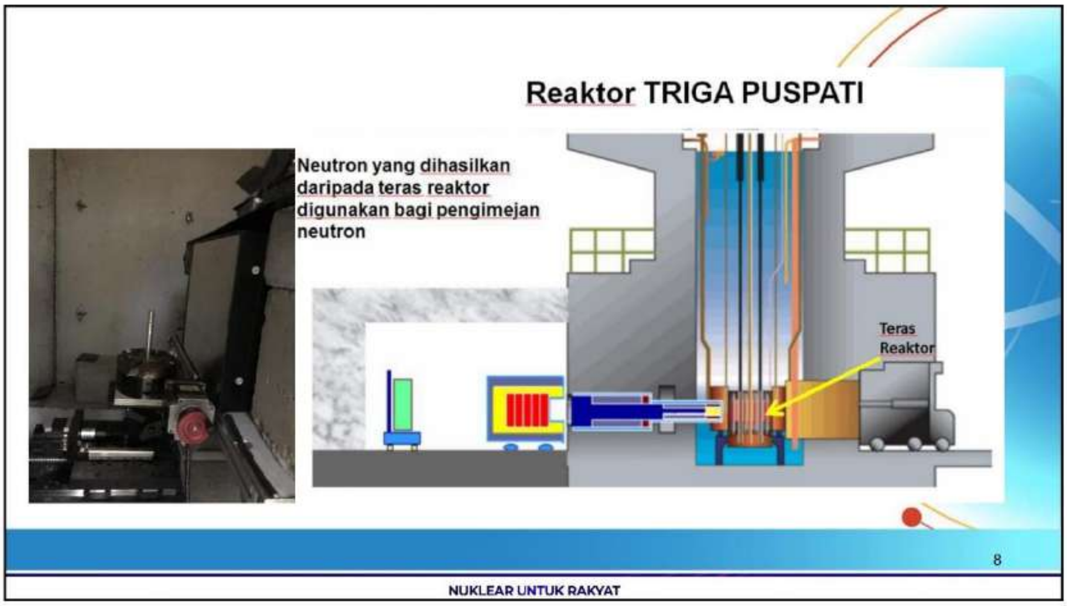

Radiation Interaction with Matter
Incident ionizing radiation
Electron
Neutron
Proton
γ-rays
Positron
X-rays
Emitted radiation
Electrons emitted from electron-electron interaction
X-rays emitted from electron-matter interaction
α-particles emitted from nucleus
β-particles emitted from nucleus
Neutrons emitted from nucleus
γ-rays emitted from nucleus
Electrons emitted from X-ray-matter interaction
X-rays emitted from interaction with matter
3
NUKLEAR UNTUK RAKYAT

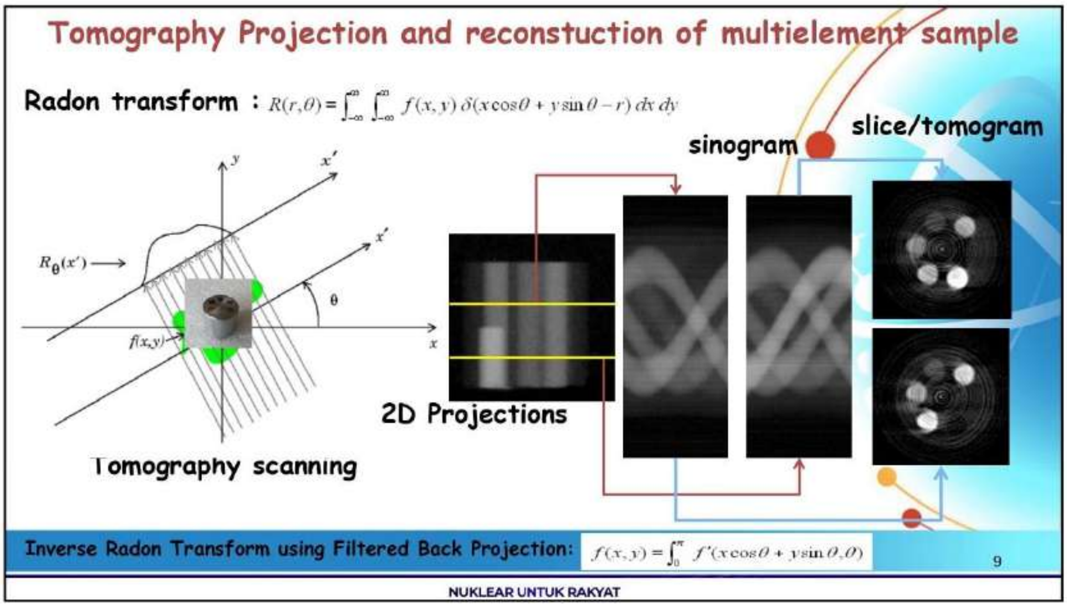

Power to attenuate radiation by Matter
Thermal neutron
150 keV X-ray
500 keV gamma-radiation
Light elements
Rare earth elements
Metals
Noble metals, heavy elements
Mass attenuation coefficient [cm²/g]
Atomic number
x-ray cross section
neutron cross section
4
NUKLEAR UNTUK RAKYAT

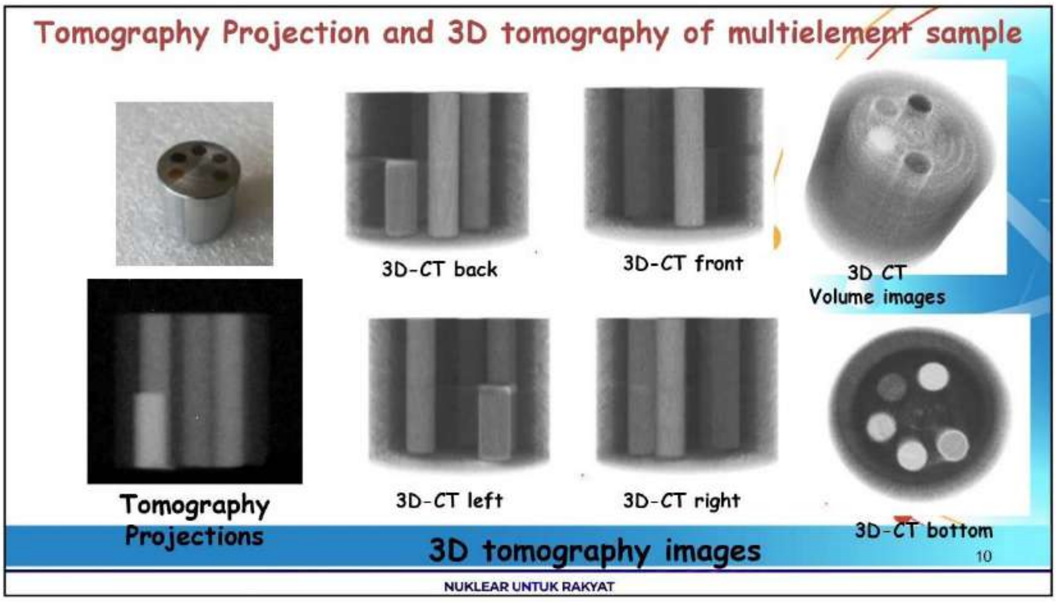

Power to attenuate radiation by Matter
cadmium terminus
regular terminus
cadmium teminus
regular teminus
5
NUKLEAR UNTUK RAKYAT

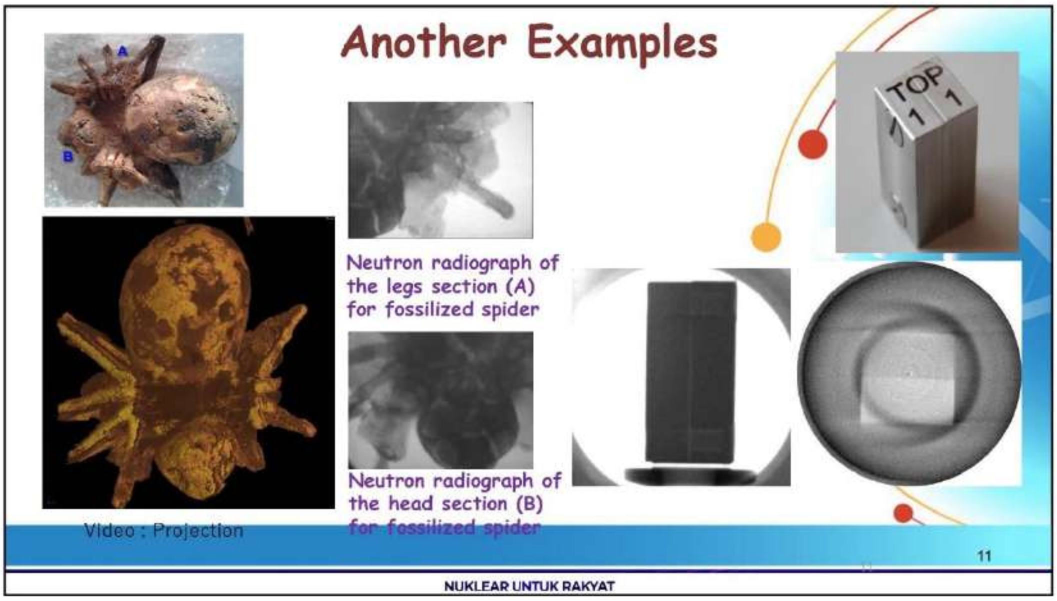

Corroded rifel A
Corroded rifel B
Gamma radiograph of rifel A
Neutron radiograph of rifel B
6
NUKLEAR UNTUK RAKYAT


PGNAA
Prompt Gamma count of element vs energy
Dolerite Panchor
Batu Bersurat Terengganu
Dolerite Pangsun
Dolerite Lawit di Muzium Negeri Terengganu
Granite Panchor
Dolerite Lawit di ANM
Count
Energy (keV)
7
NUKLEAR UNTUK RAKYAT


Reaktor TRIGA PUSPATI
Neutron yang dihasilkan daripada teras reaktor digunakan bagi pengimejan neutron
Teras Reaktor
8
NUKLEAR UNTUK RAKYAT


Tomography Projection and reconstuction of multielement sample
Radon transform : $R(r,\theta)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\,\delta(x\cos\theta + y\sin\theta - r)\,dx\,dy$
sinogram
slice/tomogram
2D Projections
Tomography scanning
Inverse Radon Transform using Filtered Back Projection: $f(x,y)=\int_0^{\pi} f'(x\cos\theta + y\sin\theta,\theta)$
9
NUKLEAR UNTUK RAKYAT


Tomography Projection and 3D tomography of multielement sample
3D-CT back
3D-CT front
3D CT
Volume images
Tomography
Projections
3D-CT left
3D-CT right
3D-CT bottom
3D tomography images
10
NUKLEAR UNTUK RAKYAT


Another Examples
A
B
TOP
Neutron radiograph of
the legs section (A)
for fossilized spider
Neutron radiograph of
the head section (B)
for fossilized spider
Video : Projection
11
NUKLEAR UNTUK RAKYAT


Thank You Very Much
12
NUKLEAR UNTUK RAKYAT

2.13 Application of Nuclear Techniques for Characterization and Preservation of Artifacts: Lessons Learned on Preservation of Cultural Heritage Artefacts

Name: Laurent Cortella
Date of Presentation: 27th October 2023
Email: laurent.cortella@cea.fr

The "Lessons Learned on Preservation of Cultural Heritage Artefacts" presentation explores how nuclear techniques are applied in conserving and preserving culturally and historically significant artefacts. As heritage conservation faces the dual challenge of preserving the artefacts' integrity while eradicating biological threats, such as insects or fungi, radiation-based methods have emerged as a highly effective tool. These techniques, which include radiography, gammagraphy, neutron diffraction, and electron microscopy, offer unparalleled insights into the internal structure and composition of artefacts without causing physical damage.

One of the central themes of the presentation is the biocidal application of ionising radiation. This technique has been extensively used to eliminate biological infestations such as insect larvae, mould, and fungi, which often endanger valuable artefacts. Irradiation treatments have successfully protected ancient wooden sculptures, textiles, and paper-based artefacts in Romania, Brazil, and others. For example, in France, the irradiation of 17th-century polychrome wooden sculptures was used to eradicate insects, showcasing the precision and effectiveness of this method. Similar techniques have been applied worldwide, including in Egypt, Japan, Mexico, and Malaysia.

A significant advantage of radiation-based treatments is that they do not introduce harmful chemicals or residues, which can sometimes occur with traditional preservation methods. The absence of chemical agents helps ensure that future analysis or conservation efforts on these artefacts will not be compromised. While concerns have been raised about the potential for radiation to induce changes in the material properties of artefacts, such as altering mechanical strength or distorting chemical bonds, studies show that at the doses used for biocidal purposes (in the range of 10 to 25 kGy), these side effects are minimal. Moreover, essential characteristics like morphology, elemental composition, and even the carbon-14 ratio—critical for dating artefacts—remain largely unaffected. Thus, the integrity of the artefacts is preserved both structurally and compositionally.

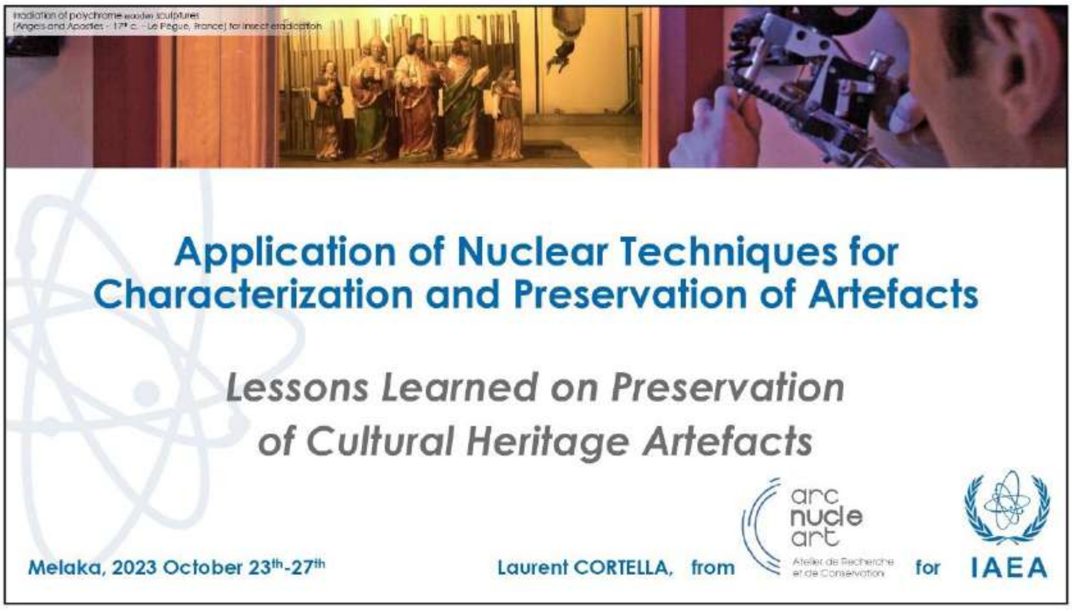
The presentation also explores various case studies demonstrating the successful use of radiation techniques in heritage preservation. One notable example is the fungicidal treatment applied to the mummy of Ramses II in 1977. Before irradiation, extensive studies were conducted to ensure that the treatment would not induce artificial ageing or otherwise compromise the mummy's materials. These preparatory studies allowed for the precise application of irradiation, successfully eradicating harmful fungi without affecting the mummy's composition. After treatment, Ramses II was encased in a sterile transparent box, ensuring long-term preservation under controlled conditions.

Another compelling case discussed is that of *Khroma*, the frozen baby mammoth. Due to potential biohazards, the mammoth had to be irradiated before further studies could be conducted. This process neutralised biological threats and facilitated subsequent scientific research by delaying biological decay, allowing the research team to study the specimen in more controlled conditions.

In addition to biological preservation, nuclear techniques are vital in analysing and dating artefacts. Methods like neutron activation analysis, X-ray fluorescence (XRF), and particle-induced X-ray emission (PIXE) provide detailed elemental analysis, which helps understand the composition and provenance of artefacts. For example, using neutron activation in studying Ramses II revealed traces of pigment in his red hair, providing valuable historical insights.

The presentation emphasises that nuclear techniques offer potent solutions for artefact preservation, but there are still limitations and uncertainties. The speaker highlights that today's best techniques may become obsolete as technology advances. This underscores the importance of balancing the immediate need for preservation with the long-term unknowns of how such treatments might be perceived or evolved.

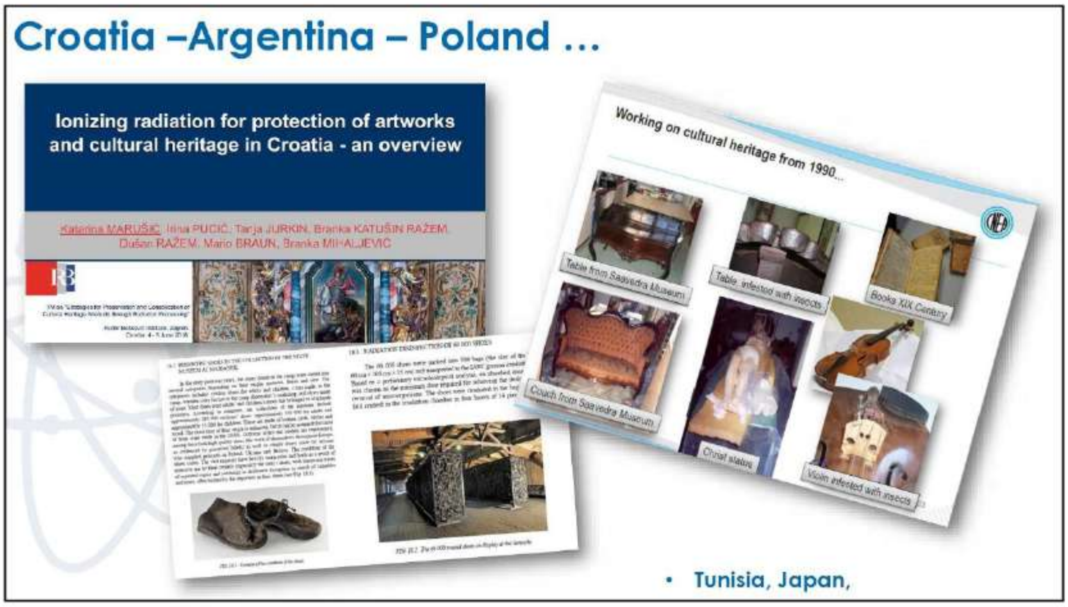
In conclusion, nuclear techniques are revolutionising the field of cultural heritage preservation by providing efficient and minimally invasive solutions for both conservation and characterization. Through case studies and the widespread application of these methods, the presentation underscores their growing importance while advocating for ongoing research and the cautious application of such powerful tools in the ever-evolving field of heritage preservation.


Application of Nuclear Techniques for
Characterization and Preservation of Artefacts
Lessons Learned on Preservation
of Cultural Heritage Artefacts
Melaka, 2023 October 23th-27th
Laurent CORTELLA, from
arc nucle art
for
IAEA


Biocidal Treatments in Romania
Radiation processing for cultural heritage preservation - Romanian experience
Conservation by Irradiation
IRASM
C.C. Ponta, 2017, The state of the art in radiation processing for cultural heritage in Romania. Uses of ionizing radiation for tangible cultural heritage conservation, IAEA (Ed), Vienna, 39-42
C.C.Ponta, 2008. Irradiation Conservation of Cultural Heritage. Nuc. Phys. News, 18, 22-24
I.V. Moise, M. Ene, C.D.I Negut, M. Cutrubinis, M.M. Manea, 2017, Radiation processing for cultural heritage preservation - Romanian experience, Nukleonika, 62(4), 253-260


Biocidal Treatments in Brazil
IPEN 60 ANOS
OUTRAS APLICAÇÕES NUCLEARES
P. Vasquez, 2017, The state of the art in radiation processing for cultural heritage in Brazil. Uses of ionizing radiation for tangible cultural heritage conservation, IAEA (Ed), Vienna, 197-201


Archive Disinfestation in Netherland
Havermanns, J., 2011. Gamma disinfection of ligno cellulose historical collections, *Approaches to Book and Paper Conservation-restoration*, Verlag Berger Horn/Wien, 559-574
Vervliet, J., 2017, Mould Disinfection Through Gamma Radiation in the Peace Palace Library. *Uses of ionizing radiation for tangible cultural heritage conservation*, IAEA (Ed), Vienna, 39-42
TNO innovation for life
PEACE PALACE (The Hague)
The Peace Palace houses
the International Court of Justice
Permanent Court of Arbitration
Hague Academy of International Law
Library:
Oldest book: 1502 (Philippe Pigouchet)
It holds the greatest collection of Hugo Grotius (1583-1645),
, father of international law
Total collection: 22 km
DE IVRE BELLI AC PACIS


Croatia –Argentina – Poland …
Ionizing radiation for protection of artworks and cultural heritage in Croatia - an overview
Working on cultural heritage from 1990...
Table from Saavedra Museum
Table infested with insects
Books XIX Century
Couch from Saavedra Museum
Christ statue
Violin infested with insects
Tunisia, Japan,


Research in Italia – Korea – Serbia – Portugal…
Side-effects thermal analyses (TG, DTG) - 1a
Two different behaviours:
Char yield
CROSS-LINKING
DEGRADATION
ENEA
GAMMA IRRADIATION OF LEATHER GLOVES IN TERMS OF CULTURAL HERITAGE PRESERVATION
Figure
Bangladesh, Bulgaria, Cuba, Sri Lanka, Thailand, Iran, etc.

Characterization and Preservation

Some common concerns

Nuclear Techniques for Cultural Heritage Science:

- *Radiography, gammagraphy, neutrography, electronmicroscopy*
- *Elemental analyses (XRF, PIXE, XANES, NAA, etc.)*
- *Crystallography (XRD,neutron diffraction)*
- *Dating*

Nuclear Techniques for Cultural Heritage Conservation:

- *Biocidal treatment (insect eradication, fungicidal treatments, etc.)*
- *Consolidation with radio-curable resins*

- **Can radiation induced side effect in cultural heritage ?**
- **Can radiation distort or impede future analysis ?**

High Doses in Characterization

- Trapping of electron leading to coloring of transparent material, (kGy)
- Modification of mechanical strength due to broken bonds and cross-linking, (ten of kGy and beyond)
- Chemical change triggered by radiation-induced radicals, (ten of kGy or hundred of kGy)
- Temperature-induced effects (at least hundred of kGy)
- Knocked out of atom with heavy or very energetic particles, giving rise to vacancies and molecular defects

Pixe, synchrotron μCT, SEM

Access to Future Analysis after Irradiation

Generally speaking

- **Living information is loosed.**
- **Chemical bonds can be affected,**
  but biocidal doses dose not means lot of ionization

Morphology hardly could be disturbed
(irradiation does not involve transfer solid of matter, if not after significant chemical effects)

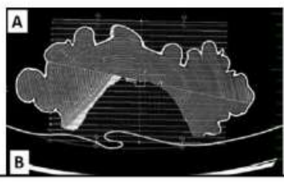
- **Elements are not transformed**
  (no nuclear reaction – no activation, apart neutron analysis)

Dating

- **Carbon 14 ratio is not affected** *(no activation)*

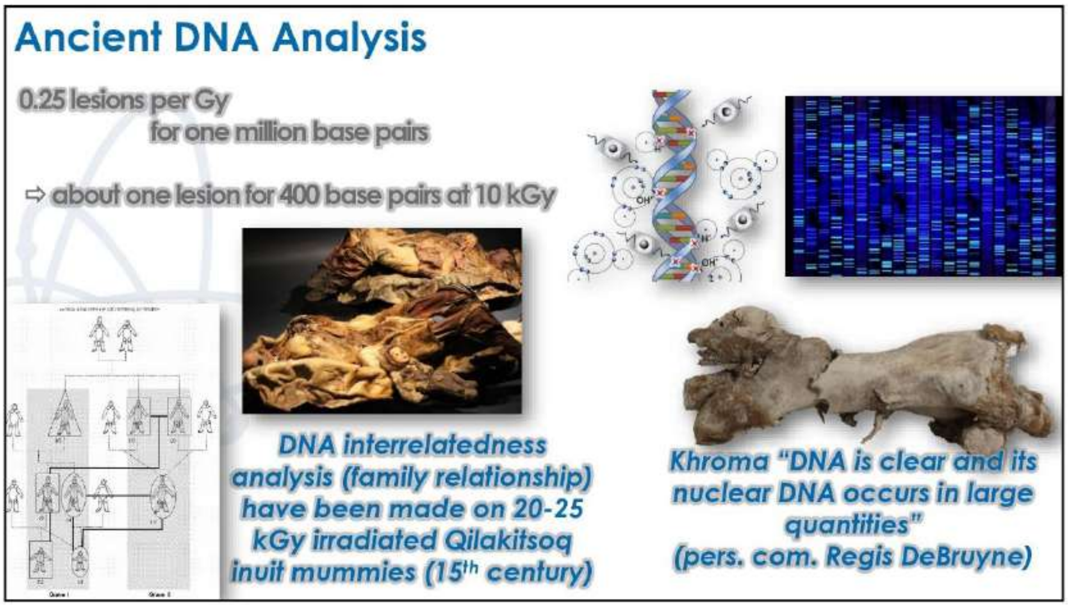
- **Thermo-luminescence dating is no more valid**
  (natural dose used for dating is modified by artificial disinfestations dose)

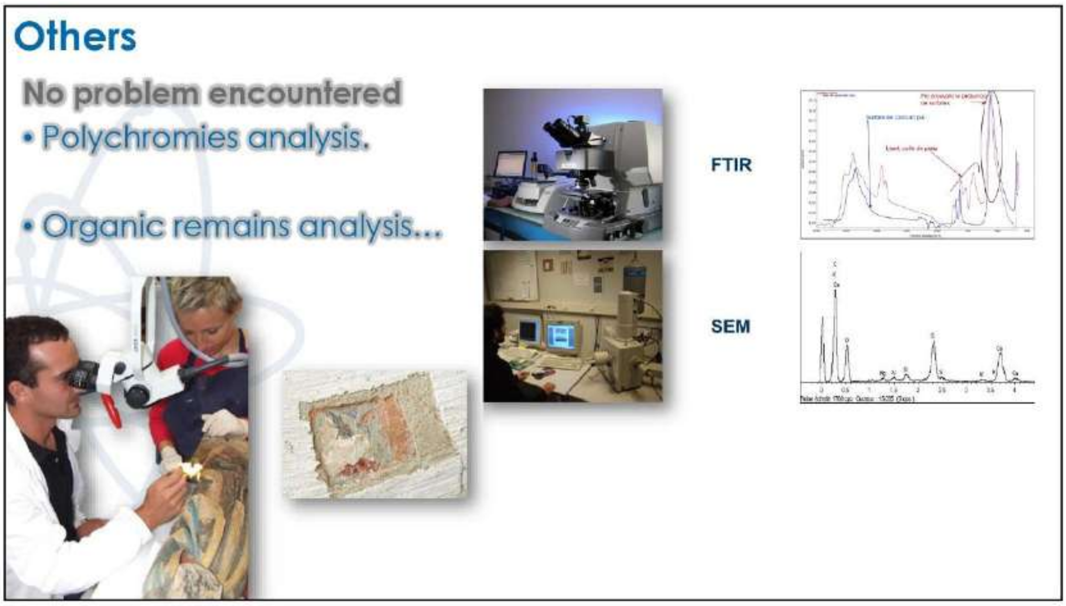
- **Dendrochronology is not affected**
  (no morphologic changes)




Ramsess II Mummy


Khroma, the Frozen Baby Mammoth
238U
234Th
234Pa
234U
β
230Th
α
226Ra
222Rn
206Pb (stable)
nombre de masse


Ancient DNA Analysis
0.25 lesions per Gy
for one million base pairs
⇨ about one lesion for 400 base pairs at 10 kGy
DNA interrelatedness analysis (family relationship) have been made on 20-25 kGy irradiated Qilakitsoq inuit mummies (15th century)
Khroma "DNA is clear and its nuclear DNA occurs in large quantities"
(pers. com. Regis DeBruyne)


Others
No problem encountered
• Polychromies analysis.
• Organic remains analysis...
FTIR
SEM

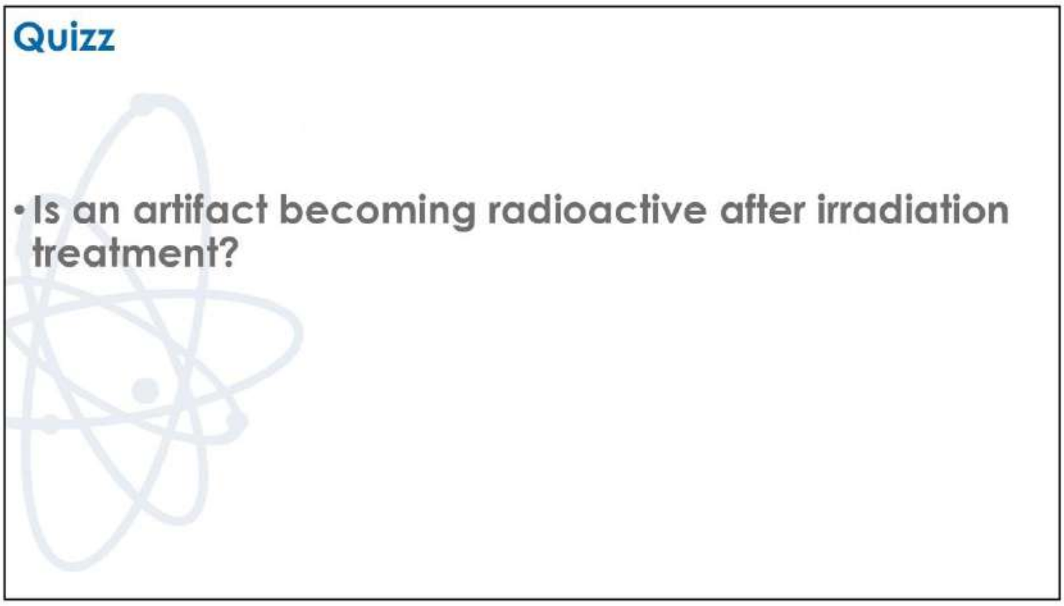

Gallo-Roman Barge, Arles, France
© R. Benali / Studio Atlantis / CG13 / Mdaa

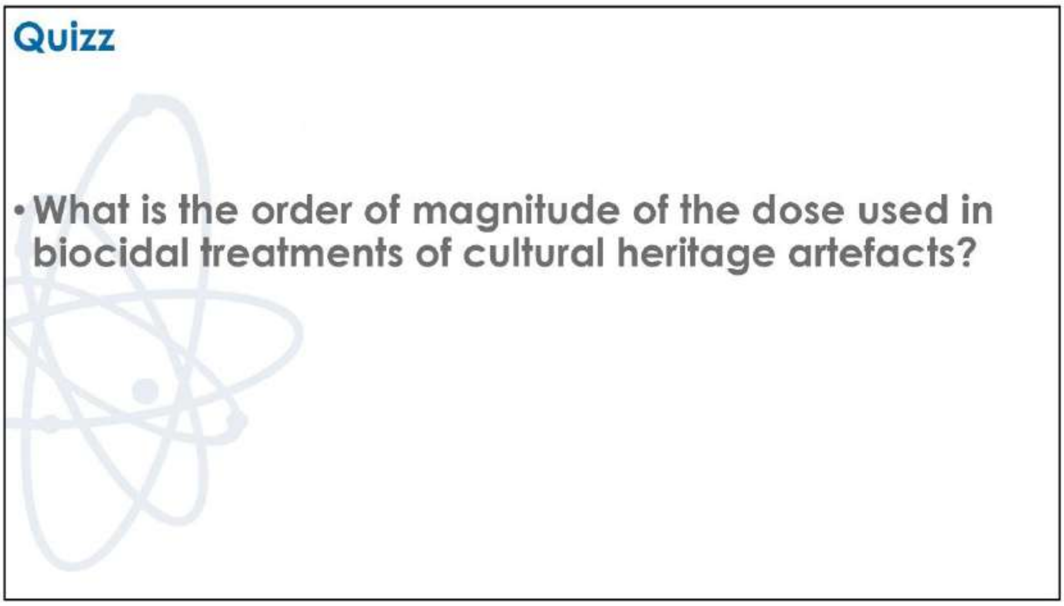

Gallo-Roman Barge, Arles, France

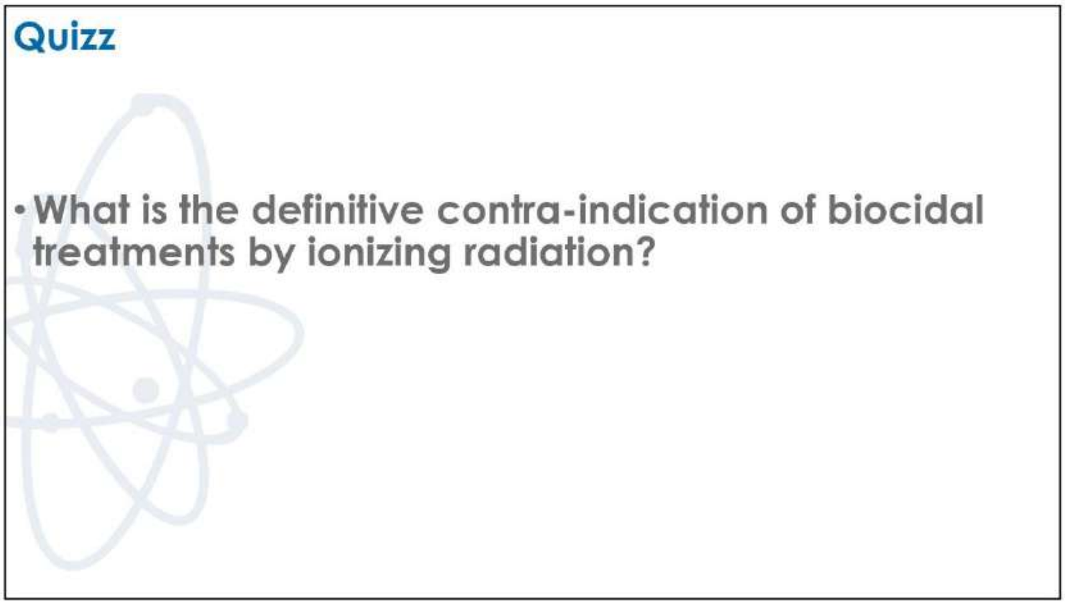

Gallo-Roman Barge, Arles, France


Gallo-Roman Barge, Arles, France
Studied and Preserved
Presented and available for further studies


Gallo-Roman Barge, Arles, France
We do not know what will be the analysis techniques in the future


Quizz
• Is an artifact becoming radioactive after irradiation treatment?


Quizz
• What is the order of magnitude of the dose used in biocidal treatments of cultural heritage artefacts?


Quizz
• What is the definitive contra-indication of biocidal treatments by ionizing radiation?

Quizz

- What is the dose better not overpass for pure cellulosic material?

Quizz

- Are all consolidation using radio-curable resins theoretically inreversible ?

Quizz

- What are the three main reasons that can justify the use of styrene polyester radio-curable resin to consolidate an artifact knowing that the technique is irreversible, both practically and theoretically?


Thank you for your attention

CHAPTER 3

CURRENT EFFORTS IN CULTURAL PRESERVATION BY COUNTRY

3. CURRENT EFFORTS IN CULTURAL PRESERVATION BY COUNTRY

Within this chapter, we embark on a journey through the diverse cultural heritage characterization and preservation endeavours of numerous countries. This compilation encompasses various nations, including Bangladesh, Cambodia, Indonesia, Iran, Iraq, Jordan, Lebanon, Myanmar, Oman, Pakistan, Palestine, the Philippines, Singapore, Thailand, Vietnam, France, and Malaysia. Each nation possesses a rich tapestry of cultural heritage shaped by its unique historical, geographical, and social contexts.

The core constituents of their cultural legacies often include various materials, including metals, wood, and ceramics. These invaluable artifacts bear the imprints of past civilisations, with their own stories to tell. These relics' complex and varied nature necessitates a tailored approach to their characterization and preservation. Indeed, it is a realm where no one-size-fits-all solution applies.

In this chapter, we embark on a journey through the characterization and preservation efforts of the aforementioned countries, unveiling the intricacies of their respective endeavours. We explore the dedicated work of scholars, archaeologists, and scientists, each applying their specialized knowledge and techniques to safeguard and document their cultural treasures. From the analysis of ancient shipwrecks to the meticulous conservation of delicate ceramics, these efforts stand as a testament to each nation's heritage's rich diversity and historical significance.

As we delve into the specifics of each country's contributions, we gain a deeper understanding of the challenges they face and the innovative approaches they employ to preserve their unique cultural legacies. This chapter serves as a window into the fascinating and dynamic world of cultural heritage characterization and preservation across the globe, demonstrating the dedication and commitment of these nations to safeguarding their past for the benefit of future generations.

3.1 Implication of Environment Factors towards Preservation of Artifacts

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Country: Malaysia
Email: azlanshah@nm.gov.my, aishahfuzi@nm.gov.my

The preservation of cultural heritage stands at the intersection of historical significance and scientific advancement, encapsulating a profound narrative of human endeavor through the annals of time. Within this scholarly domain, the conservation of archaeological artifacts and ecofacts emerges as a pivotal aspect of understanding the chronology and evolution of past civilizations. This is particularly pertinent in the changing climate, which exacerbates the degradation of these historical repositories.

The interdisciplinary efforts spearheaded by the Heritage Unit of the Malaysian Nuclear Agency's Materials Technology Group epitomize the symbiosis of cutting-edge scientific methodologies and the exigencies of cultural heritage conservation. The group's pioneering work is characterized by the meticulous excavation and analysis of archaeological materials, drawing upon sophisticated techniques to uncover, characterize, and conserve the remnants of yesteryears.

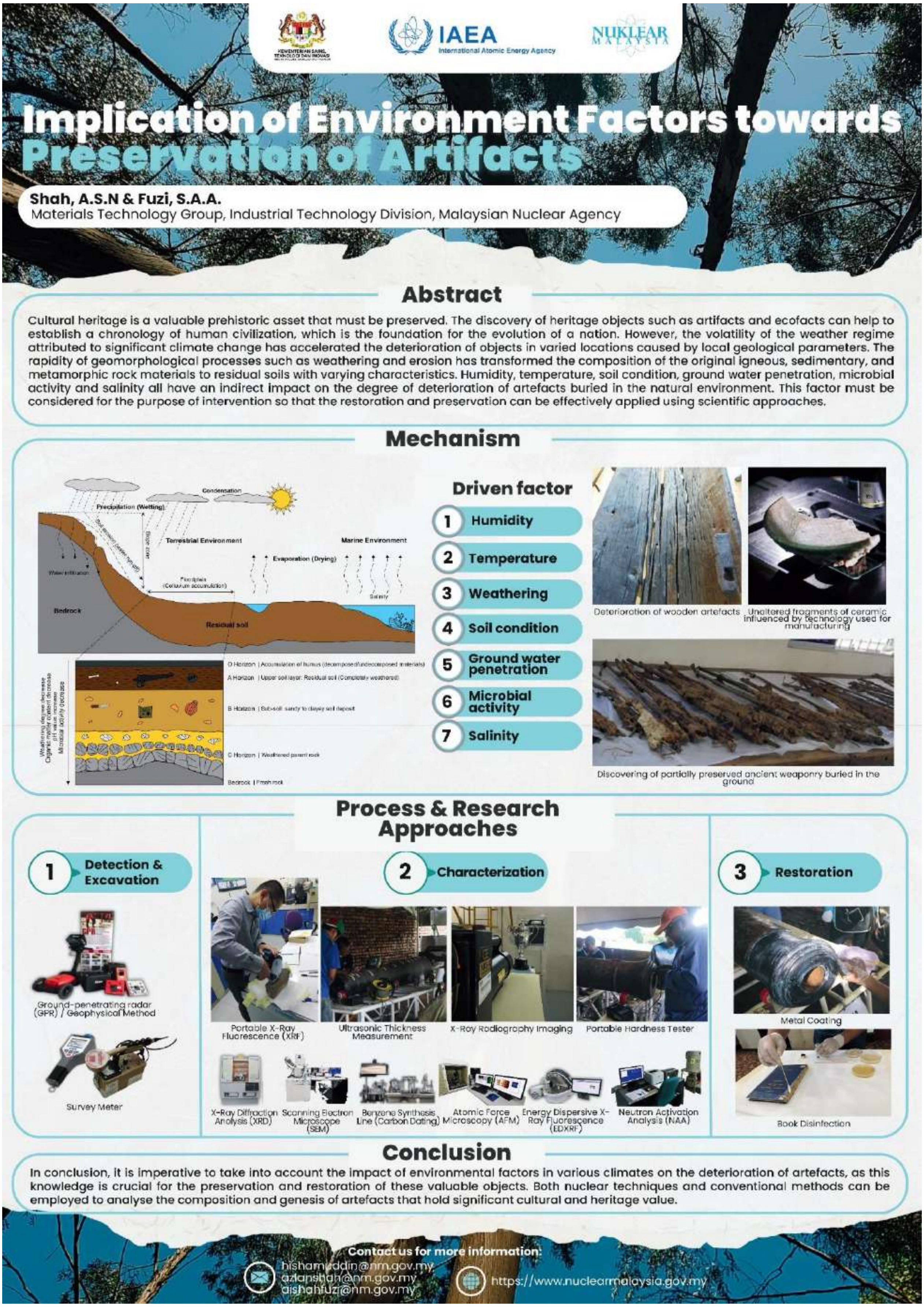
The arsenal of technological tools deployed in this scholarly pursuit includes ground-penetrating radar for subterranean detection of artifacts, complemented by X-ray diffraction analysis and scanning electron microscopy to elucidate their compositional intricacies. Radiocarbon dating, facilitated by benzene synthesis lines, provides chronological context, while portable X-ray fluorescence spectrometry renders elemental analysis with precision.

Restorative interventions employ methodologies such as neutron activation analysis to ascertain material provenance and composition, while metal coating techniques and book disinfection practices ensure the longevity of these artifacts against ongoing environmental threats.

The scholarly implication of this research is clear: the impacts of environmental factors across diverse climates on artefactual deterioration are critical considerations in the formulation of conservation strategies. The comprehensive understanding of these effects is indispensable for the implementation of effective preservation and restoration measures that are grounded in scientific empiricism.

The Malaysian Nuclear Agency's initiative is emblematic of an enlightened approach to heritage conservation, wherein empirical research and innovative application coalesce. This venture is not merely a conservationist campaign but a scholarly imperative that underscores the urgency of preserving our cultural patrimony against the relentless tide of ecological change.

In extending an invitation to the academic community and the public at large, the Malaysian Nuclear Agency beckons further inquiry into the intricate processes underpinning the preservation of our collective cultural legacy. It is through such scholarly discourse and collaborative engagement that the vestiges of human history will continue to inform and enrich future generations.


IAEA
International Atomic Energy Agency
NUKLEAR MALAYSIA
Implication of Environment Factors towards Preservation of Artifacts
Shah, A.S.N & Fuzi, S.A.A.
Materials Technology Group, Industrial Technology Division, Malaysian Nuclear Agency
Abstract
Cultural heritage is a valuable prehistoric asset that must be preserved. The discovery of heritage objects such as artifacts and ecofacts can help to establish a chronology of human civilization, which is the foundation for the evolution of a nation. However, the volatility of the weather regime attributed to significant climate change has accelerated the deterioration of objects in varied locations caused by local geological parameters. The rapidity of geomorphological processes such as weathering and erosion has transformed the composition of the original igneous, sedimentary, and metamorphic rock materials to residual soils with varying characteristics. Humidity, temperature, soil condition, ground water penetration, microbial activity and salinity all have an indirect impact on the degree of deterioration of artefacts buried in the natural environment. This factor must be considered for the purpose of intervention so that the restoration and preservation can be effectively applied using scientific approaches.
Mechanism
Condensation
Precipitation (Wetting)
Terrestrial Environment
Marine Environment
Evaporation (Drying)
Bedrock
Residual soil
Driven factor
1 Humidity
2 Temperature
3 Weathering
4 Soil condition
5 Ground water penetration
6 Microbial activity
7 Salinity
Deterioration of wooden artefacts
Unaltered fragments of ceramic influenced by technology used for manufacturing
Discovering of partially preserved ancient weaponry buried in the ground
Process & Research Approaches
1 Detection & Excavation
Ground-penetrating radar (GPR) / Geophysical Method
Survey Meter
2 Characterization
Portable X-Ray Fluorescence (XRF)
Ultrasonic Thickness Measurement
X-Ray Radiography Imaging
Portable Hardness Tester
X-Ray Diffraction Analysis (XRD)
Scanning Electron Microscope (SEM)
Benzene Synthesis Line (Carbon Dating)
Atomic Force Microscopy (AFM)
Energy Dispersive X-Ray Fluorescence (EDXRF)
Neutron Activation Analysis (NAA)
3 Restoration
Metal Coating
Book Disinfection
Conclusion
In conclusion, it is imperative to take into account the impact of environmental factors in various climates on the deterioration of artefacts, as this knowledge is crucial for the preservation and restoration of these valuable objects. Both nuclear techniques and conventional methods can be employed to analyse the composition and genesis of artefacts that hold significant cultural and heritage value.
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3.2 Materials Characterization of Artifacts

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Pottery shards from a shipwreck in Pulau Besar, Melaka, and textiles from the Terengganu Museum hold whispers of historical narratives, stories that are pieced together through meticulous scientific analysis. This narrative explores the materials characterization of these artifacts, a journey that entwines the past with the present through the lens of modern technology.

Imagine the white base color of ceramics found underwater, a ship's lost cargo from centuries past, now lying silent on the ocean floor. These remnants, discovered in the depths near Pulau Besar, Melaka, speak of their origins, which may be traced back to the United Kingdom, the Netherlands, or even the Ming Dynasty. The use of kaolin clay in their construction is evident from their color, a detail that offers a glimpse into the ancient potters' craft.

To unravel the secrets of these ceramics, scientists turned to Field Emission Scanning Electron Microscopy (FESEM), which magnifies the surface to reveal the minutiae of its microstructure and morphology. At 500 times magnification, a tale of two similarities and an odd one out emerged – two samples shared a likeness while the third presented a higher number of pores. Such details, invisible to the naked eye, are crucial in understanding the conditions and techniques under which these potteries were fired.

Furthering this scrutiny, X-ray Diffraction (XRD) revealed the crystal structure of the samples. Although they shared similar XRD spectra, variations in peak intensities indicated differences in crystallinity, which may suggest varying kiln temperatures or cooling rates, each affecting the final strength and porosity of the pottery.

Moving from the sturdy remnants of ceramics to the more delicate domain of textiles, the study dives into the fibrous world of traditional fabrics. In museum collections, textiles are among the most captivating artifacts, their value as much in their beauty as in their storytelling. Yet, their true revelation comes from understanding the materials and methods that wove them into existence.

Fourier Transform Infrared Spectroscopy (FTIR) provides a non-destructive means to identify the types of fibers used in these textiles. By analyzing the infrared spectra, which captures the vibrations of molecular bonds within the material, scientists can determine the substance of the textile. For instance, a high intensity at 1623 cm^{-1} corresponds to the vibration of amide protein, indicating silk, while a peak at 1055 cm^{-1}, related to C-O stretching, points to cotton. Viscose reveals itself through a peak at 1028 cm^{-1}, also linked to C-O stretching.

This analysis was applied to samples from the Terengganu Museum, identifying various types of textiles such as the intricate *kain batik kotak*, the finely threaeded *kain benang halus*, the elegant *kain selendang terekam*, and the luxurious *kain songket*. Each fabric, with its distinct peak position and intensity, narrates a different aspect of cultural heritage, from the attire of the common folk to the regalia of the elite.

In another instance, neutron radiographic images of Nassau pottery, facilitated by the neutron imaging facility at PUSPATI TRIGA Reactor, allowed researchers to differentiate the density of glaze and base material. Through a 250× magnified cross-section from an SEM micrograph, the layers and composition of the glaze versus the clay body were distinctively visible, further detailing the craftsmanship of historical potting techniques.

The work of the Cultural Heritage Research & Conservation Unit, Materials Technology Group at the Malaysian Nuclear Agency, transcends simple analysis. It is a homage to the legacy of craftsmanship and a testament to the unending quest for knowledge that defines our species.

TN-RAS1027 - 2300242

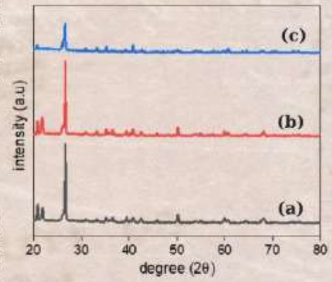
MATERIALS CHARACTERIZATION OF ARTIFACTS

POTTERY FROM SHIPWRECK IN PULAU BESAR, MELAKA

In reference to the motif, it is possible to assume that the pottery has its origins in the: **(a) United Kingdom, (b) Netherlands and (c) Ming Dynasty**

The similarity that can be observed among the potteries is that they all feature a white base color. This suggests that they were likely produced using kaolin clay.

To gather further information about the potteries, their microstructure and morphology were examined using Field Emission Scanning Electron Microscopy (FESEM). At a 500x magnification, two of the samples appear identical ((a)& (b)), while one of the samples exhibits a higher number of pores (c).



Potteries are a form of traditional ceramics. Therefore, X-ray Diffraction (XRD) characterization was carried out to identify their crystal structure. In general, all samples exhibit a similar XRD spectrum, but with varying intensity levels. This difference in intensity generally reflects the degree of crystallinity in each sample.

DETERMINATION THE TYPES OF TEXTILES USING FOURIER TRANSFORM INFRARED SPECTROSCOPY

In museum collections, textiles are the most fascinating items and highly valued. Textiles can be made from a variety of materials and processes. Determining the type of textile in cultural heritage is important for understanding the techniques and materials used in the past. To determine the type of textile, Fourier Transform Infrared spectroscopy can be used. It is practical to distinguish between various types of materials and evaluating the quality of textiles by examining the infrared spectra of textile fibers based on their peak position and intensity of the peak. This non-destructive technique allows fast and insightful findings for evaluating fibers.

Kain batik kotak *Kain benang halus* *Kain selendang terekam* *Kain songket*

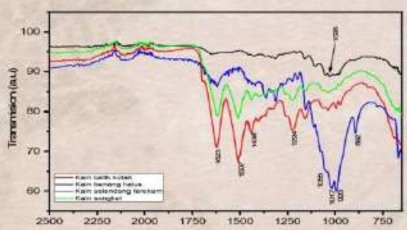
Sample of textiles from the Terengganu Museum

Kain batik kotak
- High intensity at 1623 cm-1 which belongs to vibration of amide protein
- Type of textile: Silk

Kain benang halus
- High intensity at 1055 cm-1 which belongs to C-O stretching
- Has peak at 892 cm-1
- Type of textile: Cotton

Kain selendang terekam
- peak at 1028 cm-1 which belongs to C-O stretching band
- Type of textile: Viscose

Kain songket
- High intensity at 1623 cm-1 which belongs to vibration of amide protein
- Type of textile: Silk



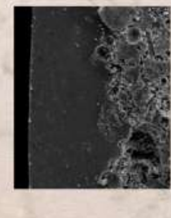
Infrared spectra of different types of textile

Conclusion

The types of textile successfully determine using peak position and intensity of infrared spectra.

POTTERY FROM NASSAU SHIPWRECK

Neutron Radiographic images of Nassau pottery conducted via Neutron imaging facility at PUSPATI TRIGA Reactor.



The difference in density of glaze and base material of the sample can easily be distinguished at 250x magnification from cross section of SEM micrograph.

SPECIAL THANKS TO:
HISHAMUDDIN HUSAIN, NADIRA KAMARUDIN, WILFRED @ SYLVESTER PAULUS, MAHDI EZWAN MAHMOUD, JACQUELINE KONES, SUHAILA HANI ILIAS, NURLIANA ROSLAN, NUR AQILAH SAPIEE & AZLAN SHAH NERWAN SHAH @ NINTIN
MEMBERS OF CULTURAL HERITAGE RESEARCH & CONSERVATION UNIT, MATERIALS TECHNOLOGY GROUP, INDUSTRIAL TECHNOLOGY DIVISION, MALAYSIAN NUCLEAR AGENCY

PREPARED BY: SITI AISHAH AHMAD FUZI & IZURA IZZUDDIN

3.3 Ceramics

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Ceramics, a term encompassing a diverse array of fired clay objects, is a testament to human ingenuity and the transformative power of fire. From ancient to the modern era, these artifacts have been a canvas for cultural expression, their durability allowing them to survive through millennia. The categorization of ceramics is based on several factors: the composition of the clay used, the temperature and process of firing, and the application of glaze, if any.

The clay, a product of the earth's tireless geological processes, forms from the weathering of igneous and metamorphic rocks. Primary clays are found at their original site of formation, typically purer due to their lack of transportation from their source. There are three main categories of ceramics, distinguished primarily by their firing temperatures and resultant porosity and color range. Earthenware, the most porous, is fired at temperatures ranging from 600 to 1100°C and often exhibits colors like yellow, buff, grey, red, and brown. Stoneware is less porous, fired between 1200 and 1300°C, and commonly found in white, buff, grey, and black hues. Porcelain, fired at about 1400°C, is non-porous and known for its pure white, translucent body.

Despite their resilience, ceramics are not immune to deterioration. Common conservation challenges include breakage, the degradation of previous repairs, flaking decorations or glaze, soiling, staining, and damage from salt efflorescence. Salt efflorescence, in particular, is a notable concern, as it manifests as a crust on the ceramic surface, which can cause further damage to the glaze and painted decoration.

The field of ceramic conservation has evolved to address these issues, focusing on preventive measures and active treatment. Preventive conservation aims to mitigate potential damage by controlling the environment where the ceramics are kept. Ceramics, while generally less sensitive to environmental fluctuations, fare best in stable conditions. Ideal environments maintain temperatures of 15-25°C and relative humidity levels of 40-60%, with minimal fluctuations within any 24 hours. Handling and storage are also critical components of preventive conservation. Ceramics should be handled as little as possible, with clean, bare hands or disposable gloves, and without grasping fragile parts like handles or protrusions. When moving multiple objects, it's advised to use trays lined with shock-absorbent materials.

Storage and display settings should be chosen to minimize the risk of damage. This includes using non-reactive shelving materials, ensuring adequate space around each object, and avoiding stacking. Metal cabinets are preferred over wooden ones for storing unglazed ceramics, as wood can emit organic acids detrimental to the artifacts.

When active treatment is necessary, cleaning, stain removal, and joining broken pieces are undertaken. Techniques must be chosen carefully to avoid further damage. Cleaning can involve gentle brushing or chemical treatments, depending on the type of soiling and the ceramic's condition. Stain removal and joining require a delicate balance of chemical knowledge and artistry to ensure that the repairs are effective and aesthetically sympathetic to the original.

In conclusion, ceramics are a rich part of our cultural heritage, offering insights into past civilizations and artistic practices. The preservation of these artifacts is a complex interplay of science and art, requiring detailed knowledge of the materials and processes involved in their creation and degradation. Through the meticulous conservation work, these historical objects can be safeguarded for future generations to study and appreciate.

Ceramics

Introduction

The term ceramic is used to describe a variety of fired clay objects. The transformation of an earthy substance by fire produces a durable material, examples of which have survived from ancient times until the present.

The basic criteria for categorizing ceramics are clay composition, firing process and glazing. Clays are formed from the weathering of metamorphic and igneous rocks in the earth's crust, by the action of hot gases, chemical and physical erosion. Primary clays are found at their site of formation and are quite pure.

Deterioration

The most common ceramic conservation problem:

- breakage;
- deterioration of previous repairs;
- flaking painted decoration or glaze;
- soiling or staining;
- loss and cracking; and
- damage from salt efflorescence (figure: 1&2)

Figure1: damage from salt efflorescence

Ceramic Categories

CATEGORIES	FIRING TEMPERATURES	POROSITY	RANGE COLOUR
Earthenware	600 – 1100 °C	> 15 %	yellow, buff, grey, red and brown
Stoneware	1200 to 1300 °C	< 3 %	white, buff, grey and black
porcelain	1400 °C	non-porous	pure white translucent body

Figure 2: damage from salt efflorescence

Preventive Conservation

Environment

- Ceramics are generally less sensitive to extremes or fluctuations in environmental conditions.
- Storing or displaying them in a stable environment.
- Temperatures in the range 15 - 25 °C
- Relative humidity range of 40 - 60 %.
- Limit temperature and relative humidity Fluctuations : 4 °C and 5 % within any 24 hour period
- Sudden changes in temperature and relative humidity levels may cause susceptible ceramics and glazes to crack. Adhesives used for repairs may also be adversely affected.

Handling

- Avoid unnecessary handling;
- Use clean, bare hands or disposable rubber gloves;
- Check for any breakages, cracks or old repairs
- Remove any loose parts such as lids before moving;
- Do not pick up objects by handles or protruding parts (figure 3)
- If a quantity of objects need to be moved, use a tray lined with bubble wrap, a thick, clean towel, cotton wool or crumpled tissue paper and pad between each object.

Figure 3:

Storage and Display

- Storing ceramic objects in boxes, closed cupboards or on shelves that are not subject to vibration, jarring or shock;
- Keeping objects clearly visible and accessible so that handling is minimised;
- Using metal cabinets in preference to unsealed wooden cupboards or display cases. These latter units may emit organic acid vapours which are harmful to low-fired, unglazed ceramic objects;
- Padding objects in boxes with bubble wrap or acid-free tissue paper;
- Lining shelves with inert polyethylene foam sheet or acid-free paper and leaving enough space around each object for easy access; and not stacking objects.

Treatments

Cleaning

Stain Removal

Joining

Department of Museum Malaysia

3.4 The Discovery of Ancient Shipwreck and Melaka Sultanate Artifacts at Pulau Melaka Archaeological Site, Melaka 25 March – 31 March 2021

Name: Department of National Heritage
Country: Malaysia
Email: -

In the dynamic tapestry of Malaysia's history, the recent archaeological undertakings at Pulau Melaka have stitched an intricate new patch. The Department of National Heritage, under the Ministry of Tourism, Arts, and Culture Malaysia, in tandem with the Melaka State Government and Melaka Museum Corporation (PERZIM), embarked on a pivotal research and excavation mission. This initiative, grounded in the National Heritage Act of 2005, was not merely an academic pursuit but a custodial one aimed at enriching historical knowledge and safeguarding the cultural sanctity of Melaka's historical treasures.

Pulau Melaka, once known as *Pulau Jawa*, has been transformed from its original state through extensive land reclamation. The island's storied past includes its role in the colonial era. It serves as an anchorage for "*Naos de Trato*," the colossal trading carracks that navigated the bustling trade routes from the East. The historical significance of this site was first chronicled by Rev. Fr. Rene Edouardo Cardon in his seminal work, "Portuguese Melaka," in 1934, offering insights into the island's pivotal role in regional commerce and conflict.

The catalyst for this archaeological journey was a report from the National Heritage Department on 17th September 2020 detailing the serendipitous discovery of remnants from the Melaka Sultanate and a shipwreck in a mangrove swamp near *Pulau Melaka*. This discovery promised a glimpse into the maritime prowess that characterized the Sultanate era.

The first phase of the excavation revealed a treasure trove of historical relics that whispered tales of yore. Archaeologists meticulously unearthed timbers from ancient ships, hidden beneath layers of silt and time within the swampy embrace of Pulau Melaka. Old coins and fragments of ceramics accompanied these skeletal remains of vessels that once mastered the seas, each piece a silent narrator of the island's grand narrative.

The coins and ceramics are not mere artifacts; they are a testament to the cultural and commercial exchanges that flourished under the Sultanate's influence. The ship timbers speak of craftsmanship and maritime technology that was advanced for its time. This technology allowed the Sultanate to thrive as a nexus of trade and cultural exchange in the region.

The significance of these findings cannot be overstated. They provide tangible links to the Sultanate of Melaka's history, offering insights into the economic, cultural, and political landscape of the era. As the excavation progresses, the artifacts will undergo meticulous analysis to glean more information about their origins and the stories they hold.

The *Pulau Melaka* site thus serves as a palimpsest, with each layer of soil revealing a new chapter in Melaka's history. This ongoing excavation not only contributes to the historical tapestry of Malaysia but also underscores the importance of preserving such sites. Through these relics, we glean the knowledge of our past, illuminating the path to our future.

As the Department of National Heritage and its partners continue to delve into the depths of Melaka's history, they not only recover artifacts; they resurrect the spirit of an era that shaped the very fabric of Southeast Asia's history. These discoveries at *Pulau Melaka* are not just remnants of history; they are beacons that guide us in understanding the complexities and the rich cultural heritage of Malaysia.

THE DISCOVERY OF ANCIENT SHIPWRECK AND MELAKA SULTANATE ARTIFACTS AT PULAU MELAKA ARCHAEOLOGICAL SITE, MELAKA 25 MARCH - 31 MARCH 2021

Introduction

The Department of National Heritage, Ministry of Tourism, Arts and Culture Malaysia, in collaboration with the Melaka State Government and the Melaka Museum Corporation (PERZIM), conducted research and studies to uncover and protect the state of Melaka's historical treasures. This research has one basic goal: to increase knowledge and understanding of history while also developing and conserving archaeological sites in compliance with the National Heritage Act of 2005 (Act 645).

Pulau Melaka, also known as the original name of Pulau Jawa is an island that has gone land reclamation. According to its history, Pulau Jawa has witnessed several episodes of war during the conquest of Melaka City. Records related to this island have been documented by Rev. Fr. Rene Edouardo Cardon (1877-1948) in his paper Portuguese Melaka (Cardon, R. 1934). This island is the anchorage area of "Naos de Trato" or large trade carracks going to or coming from east.

Findings

On September 17, 2020, National Heritage Department (JWN) has received reports of the discovery of Melaka Sultanate artifacts and the structure of a shipwreck found in a mangrove swamp area near Pulau Melaka. A number of artifacts from the Sultanate of Melaka were discovered during a field survey on Pulau Melaka.

Summary

Excavation work of Melaka Sultanate Artifacts and Historic Shipwrecks on Melaka Island, Melaka phase 1 has successfully uncovered archaeological relics in the form of ship timbers, old coins and ceramic shards buried in the swampy ground.

3.5 The Study of Thai Cultural Artifacts through Transdisciplinary Approach: An Implication towards Nuclear Science & Technology

Name: Sasiphan Khaweerat
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In heritage conservation and scientific exploration, a remarkable transdisciplinary collaboration in Thailand is setting a precedent for cultural research and preservation. Spearheaded by the Thailand Institute of Nuclear Technology (TINT), this project epitomises the intersection of science and the humanities, offering an insightful glimpse into the meticulous care of Thai cultural artifacts.

Thai cultural heritage, a tapestry of history and artistry, is integral to the nation's identity. To safeguard these treasures for future generations, TINT, in alliance with various esteemed institutions, including the Fine Arts Department, Chaosampraya National Museum, Chulachomklao Royal Military Academy, and the Faculty of Fine and Applied Arts at Chulalongkorn University, has embarked on an ambitious journey.

The focal point of this initiative is the study and conservation of artifacts through a unique blend of nuclear science and technology. Advanced imaging techniques such as neutron tomography and gamma radiography are employed to peer into the very fabric of historical objects. These non-invasive methods allow scientists to analyse and characterise materials without causing any damage to the artifacts, thus maintaining their integrity and authenticity.

Neutron tomography, for instance, utilises the penetrating power of neutrons to create detailed cross-sectional images of objects, revealing their internal structures in ways that conventional X-rays cannot. Gamma radiography takes this a step further by providing high-resolution images that showcase the composition and condition of artifacts, detecting any internal decay or structural weaknesses that may not be visible to the naked eye.

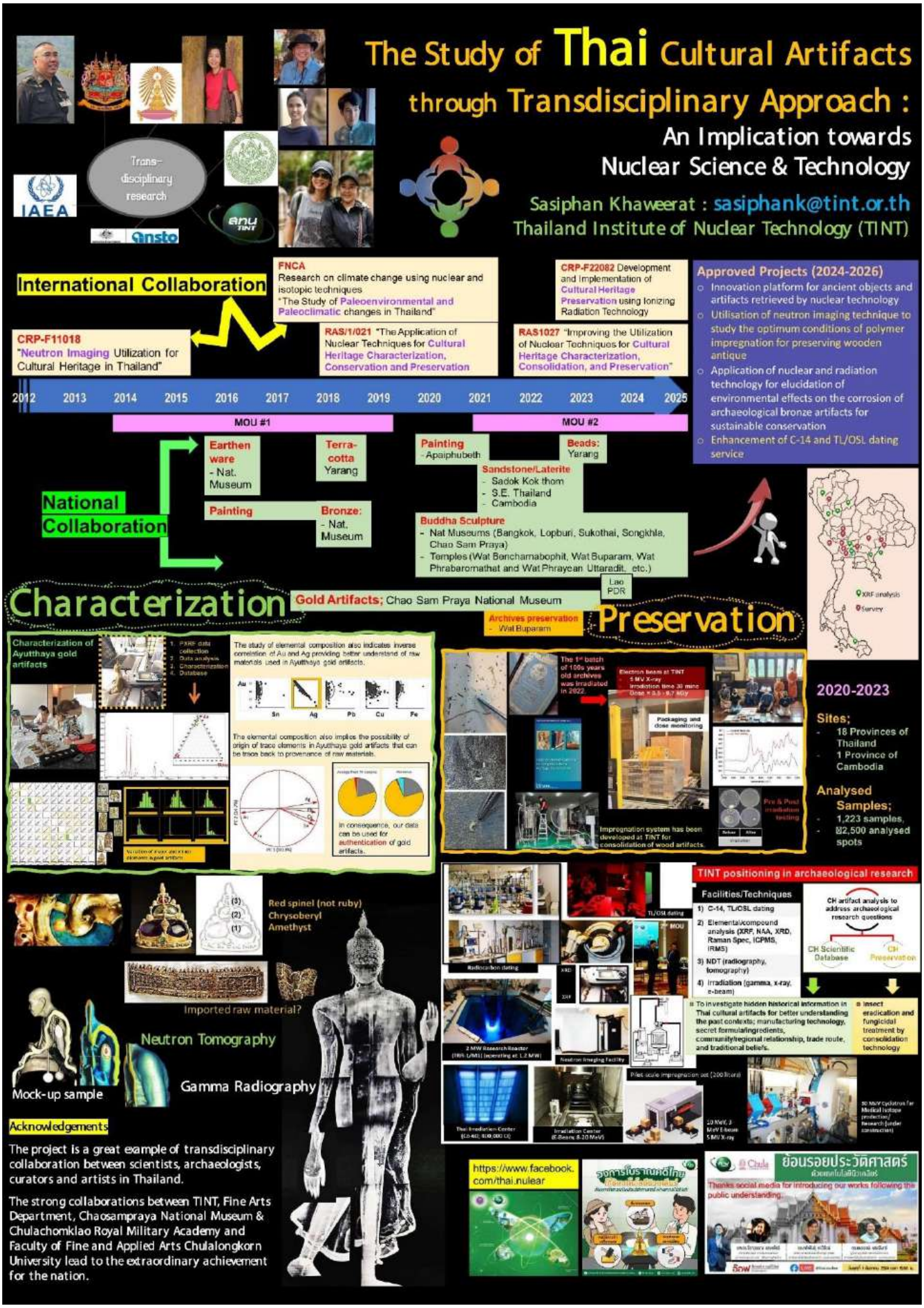
A testament to the project's success is the creation of mock-up samples that serve as benchmarks for the study. These carefully crafted replicas not only aid in the understanding of ancient crafting techniques but also serve as educational tools that help disseminate knowledge about Thai heritage.

Acknowledgements for the project's achievements are largely due to the synergistic collaboration between experts from varied fields. The convergence of nuclear scientists, archaeologists, curators, and artists has facilitated a comprehensive approach to artifact preservation, blending scientific rigour with cultural sensitivity.

This transdisciplinary method has implications far beyond the borders of Thailand. It exemplifies how integrating different scientific and cultural disciplines can lead to enhanced preservation techniques, ensuring that the legacy of past civilisations continues to enlighten and inspire.

The impact of this project is multifaceted. Not only does it contribute significantly to the conservation of national heritage, but it also advances the field of nuclear science and its application in the arts. As such, this venture stands as an extraordinary achievement for the nation, showcasing the potential for nuclear science to play a pivotal role in the stewardship of cultural heritage.

In conclusion, the study of Thai cultural artifacts through a transdisciplinary approach melding nuclear science and technology is a pioneering effort that highlights the dynamic capabilities of contemporary science in preserving the past. As we move forward, initiatives like these will ensure the endurance of our shared global heritage, enabling us to pass on the rich tapestry of human history to the generations that will follow.


The Study of Thai Cultural Artifacts
through Transdisciplinary Approach :
An Implication towards
Nuclear Science & Technology
Sasiphan Khaweerat : sasiphank@tint.or.th
Thailand Institute of Nuclear Technology (TINT)
Trans-disciplinary research
IAEA
ansto
International Collaboration
CRP-F11018
"Neutron Imaging Utilization for Cultural Heritage in Thailand"
FNCA
Research on climate change using nuclear and isotopic techniques
"The Study of Paleoenvironmental and Paleoclimatic changes in Thailand"
RAS/1/021 "The Application of Nuclear Techniques for Cultural Heritage Characterization, Conservation and Preservation
CRP-F22082 Development and Implementation of Cultural Heritage Preservation using Ionizing Radiation Technology
RAS1027 "Improving the Utilization of Nuclear Techniques for Cultural Heritage Characterization, Consolidation, and Preservation"
Approved Projects (2024-2026)
Innovation platform for ancient objects and artifacts retrieved by nuclear technology
Utilisation of neutron imaging technique to study the optimum conditions of polymer impregnation for preserving wooden antique
Application of nuclear and radiation technology for elucidation of environmental effects on the corrosion of archaeological bronze artifacts for sustainable conservation
Enhancement of C-14 and TL/OSL dating service
2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
MOU #1
MOU #2
National Collaboration
Earthen ware - Nat. Museum
Terra-cotta Yarang
Painting
Bronze: - Nat. Museum
Painting - Apaiphubeth
Beads: Yarang
Sandstone/Laterite
- Sadok Kok thom
- S.E. Thailand
- Cambodia
Buddha Sculpture
- Nat Museums (Bangkok, Lopburi, Sukothai, Songkhla, Chao Sam Praya)
- Temples (Wat Benchamabophit, Wat Buparam, Wat Phrabaromathat and Wat Phrayean Uttaradit, etc.)
Lao PDR
Characterization
Gold Artifacts; Chao Sam Praya National Museum
Archives preservation - Wat Buparam
Preservation
Characterization of Ayutthaya gold artifacts
The study of elemental composition also indicates inverse correlation of Au and Ag providing better understand of raw materials used in Ayutthaya gold artifacts.
The elemental composition also implies the possibility of origin of trace elements in Ayutthaya gold artifacts that can be trace back to provenance of raw materials.
In consequence, our data can be used for authentication of gold artifacts.
2020-2023
Sites;
18 Provinces of Thailand
1 Province of Cambodia
Analysed Samples;
1,223 samples,
≅2,500 analysed spots
Red spinel (not ruby)
Chrysoberyl
Amethyst
Imported raw material?
Neutron Tomography
Gamma Radiography
Mock-up sample
TINT positioning in archaeological research
Facilities/Techniques
1) C-14, TL/OSL dating
2) Elemental/compound analysis (XRF, NAA, XRD, Raman Spec, ICPMS, IRMS)
3) NDT (radiography, tomography)
4) Irradiation (gamma, x-ray, e-beam)
CH artifact analysis to address archaeological research questions
CH Scientific Database
CH Preservation
To investigate hidden historical information in Thai cultural artifacts for better understanding the past contexts; manufacturing technology, secret formula/ingredients, community/regional relationship, trade route, and traditional beliefs.
Insect eradication and fungicidal treatment by consolidation technology
Acknowledgements
The project is a great example of transdisciplinary collaboration between scientists, archaeologists, curators and artists in Thailand.
The strong collaborations between TINT, Fine Arts Department, Chaosampraya National Museum & Chulachomklao Royal Military Academy and Faculty of Fine and Applied Arts Chulalongkorn University lead to the extraordinary achievement for the nation.
https://www.facebook.com/thai.nulear
ย้อนรอยประวัติศาสตร์
Thanks social media for introducing our works following the public understanding.

3.6 Conservation of Artifacts from Phanom-Surin Shipwreck, Thailand

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The *Phanom-Surin* shipwreck, unearthed in 2013 in the Samut Sakhon province of Thailand, marks a significant find in the annals of Southeast Asian maritime history. Dating back to the 9th century CE, the discovery of this ancient sea-going vessel, constructed using the sewn-plank technique prevalent in Arabian and Western Indian shipbuilding traditions, has provided a unique window into the region's past trading and cultural exchanges.

The ship's remnants, including wooden structures and fiber ropes, bore the marks of natural degradation, a common fate for materials long-submerged in aquatic environments. The excavation process was meticulous, with organic and inorganic materials surfacing from the depths. Among the organic finds were rattan-braided ropes, grain, betel nuts, and various animal remains, while the inorganic collection comprised potsherds, seashells, and items made of bronze.

The mission to conserve these artifacts was twofold: firstly, to apply scientific methods to preserve the integrity of these historical pieces and, secondly, to gather information that would not only enrich our understanding of the *Phanom-Surin* shipwreck but also inform future research and conservation efforts for underwater cultural heritage.

The conservation process began with a primary assessment to classify and evaluate the deterioration of the artifacts, discerning both internal and external factors contributing to their current state. This scientific approach led to treatments tailored to the nature of each artifact—be it organic or inorganic—ranging from cleaning and desalination to consolidation. Once stabilized, these pieces were either stored or displayed, with environmental conditions meticulously controlled to ensure their continued preservation.

To delve deeper into the material composition and changes post-conservation, cutting-edge techniques such as X-ray Diffractometry (XRD) and X-ray Fluorescence (XRF) were employed. The XRD technique was instrumental in analyzing the crystalline structure of the artifacts, offering insights into the degree of crystallinity before and after the conservation process. Similarly, the XRF technique facilitated qualitative and quantitative elemental analysis, a crucial step in understanding the composition of the artifacts. For instance, the study of metal artifacts revealed a composition of copper-tin alloys—a finding further substantiated by SEM-EDX analysis to ensure data accuracy.

The study of a small metal bowl through X-ray Radiography exemplified the non-destructive approach to understanding the artifact's condition and composition without causing further damage. This method underscored the meticulousness required to preserve the integrity of such historical items.

Looking ahead, the establishment of the Conservation Science Center, anticipated to be completed in 2024, promises a dedicated space for the continued conservation and study of underwater artifacts. This facility is set to house state-of-the-art laboratories for both conservation and analytical instrumentation, marking a significant step forward in Thailand's commitment to cultural heritage preservation.

Through these concerted efforts, the Phanom-Surin shipwreck not only offers a glimpse into the rich maritime past of Thailand but also sets a precedent for the scientific conservation of underwater artifacts, ensuring that these silent witnesses of history are preserved for future generations to study, appreciate, and learn from.

CONSERVATION OF ARTIFACTS FROM PHANOM-SURIN SHIPWRECK, THAILAND

CASE STUDY : NUCLEAR TECHNIQUES FOR CHARACTERIZATION OF THE ARTIFACTS

MISS KUNTHIDA CHIMMA
SCIENCTIST PRACTITIONER LEVEL, CONSERVATION SCIENCE DIVISION,
OFFICE OF NATIONAL MUSEUM, FINE ARTS DEPARTMENT,
MINISTRY OF CULTURE, THAILAND

1. Introduction

In 2013, Phanom – Surin shipwreck was found in Samut Sakhon province, Thailand. The date of the shipwreck around the 9th century CE. This is the earliest shipwreck was found in Thailand. The ancient shipwreck is a massive sea-going vessel with a sewn-plank technique that common used for a ship of the Arabian region and Western India. Some part of the shipwreck, such as woods and fiber ropes, were severely rotten by natural degradation. After excavation in underwater site, many artefacts about organic and inorganic materials were found in this shipwreck. Organic materials consist of ship structures, rattan-braided ropes, grain, betel nut, fish bones, animal bones, fragments of animal skin and firewood. Inorganic materials consist of potsherds, seashell and bronze.

2. Objective

1. To conserve artifacts from the Phanom – Surin shipwreck site in Samut Sakhon province by using scientific methods
2. More information regarding the conservation of artifacts obtained from the Phanom – Surin shipwreck site has been acquired, and this information will be useful for future research.
3. The results of the conservation study on artifacts from the Phanom – Surin shipwreck can be utilized to develop knowledge and provide guidelines for the conservation of artifacts from underwater cultural heritage in other areas.

3. Conservation Process

Primary assessment : To be classify and assess the deterioration of the artifacts to find the cause of deterioration from internal and external factors by using the scientific method.

Treatment : Cleaning, desalination and consolidation depend on the type of artifacts.

Storage and Exhibition : After the artifacts are in stable condition those are stored or exhibited with controlled environmental conditions appropriate for the type of artifact.

The methods of conserving artifacts can be divided into two types, which include organic artifacts and inorganic artifacts.

Organic artifacts
- Cleaning
- Desalination
- Elimination and control of microorganisms
- Consolidation
- Drying

Inorganic artifacts
- Cleaning
- Desalination
- Drying
- Bonding Fragments

4. Characterization

X-ray Diffractometer (XRD) Technique

The utilization of an X-ray diffraction analyzer for the purpose of analyzing the crystalline structure and determining the degree of crystallinity of the samples, enables comparisons of crystallinity and the degree of crystallinity that occurred before and after conservation.

X-ray Fluorescence (XRF) Technique

The X-ray Fluorescence (XRF) technique is a method that uses tools for the analysis of elements in a sample, capable of both quantitative and qualitative analysis. It can be applied to various fields of study and research. The analysis results are as shown in the table below:

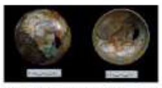


Figure 1. Metal small bowl

Table 1: Analysis Results of Metal Artifacts Using XRF Technique

The position analyzed	Tin (Sn)	Copper (Cu)	The ratio of tin (Sn) to copper (Cu).
1	51	35	1.46
2	58	38	1.53
3	55	38	1.45

The analysis results indicate that the sample is a group of Copper-Tin Alloys, which are formed by mixing copper (Cu) with alloying elements of tin (Sn).

This technique is often used with SEM-EDX to reconfirm the analysis results for the accuracy of the data.

X-ray Radiography Technique

Utilizing X-ray Radiography for non-destructive analysis artifacts:
- 2D, 3D Imaging of internal structures

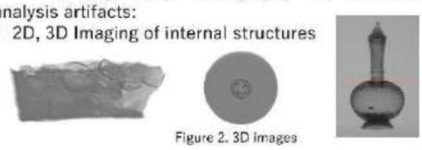
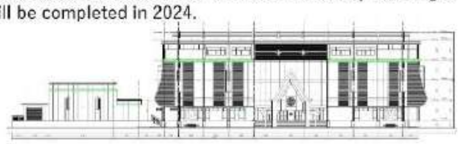


Figure 2. 3D images

5. Future Plan

The Conservation Science Center where consist of conservation laboratory, analysis instrument laboratory and conservation of underwater artifacts laboratory buildings, will be completed in 2024.



3.7 Conservation-Treatment and Preservation of Artifact Collection derived from Shipwreck in Cambodia

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For centuries, the maritime silk route has been a significant artery of commerce and culture, particularly between Cambodia and two ancient civilizations—India and China. The roots of these connections date back to the 2nd century BCE when Indian traders, in their quest for gold, reached the coasts of Southeast Asia. These traders were not just merchants of material goods but also bearers of cultural elements that profoundly influenced Cambodian society in areas such as religion, architecture, literature, and governance.

"Indianization" describes how Indian culture was assimilated into the Khmer civilization, enduring until the 15th century. This cultural osmosis was facilitated through ongoing trade and interaction, leaving behind a legacy that remains evident in Cambodia's religious and architectural landscapes.

China's engagement with Cambodia commenced in a significant way in the year 234 when Chinese ambassadors and investors made their presence felt. The Kingdom of Funan, which existed from the 1st to the 6th century CE, was notable for its shipbuilding capabilities, crafting vessels large enough to carry between 70 to 500 persons. The archeological site known as "Oc Eo" bears testimony to this era, with findings that include coins, ceramic goods, and wooden Buddhas, all suggesting a vibrant hub of trade and cultural exchange.

The Kingdom of Funan's influence and connections with China are well-documented in Chinese historical records, especially during the 5th and 6th centuries. Following the decline of Funan, the Kingdom of Chenla, which prevailed from the 6th to the 8th century CE, continued these ties with China. These connections were further cemented during the Angkor period, from the 9th to the 15th century CE, when the Yuan dynasty sent an ambassador named Chiev Ta Quaun to the region. The abundance of ceramic artifacts from various Chinese dynasties—Tang, Song, Yuan, Ming, and Qing—found in Cambodia provides evidence of these sustained interactions.

In modern times, Cambodia boasts a coastline of ~450 km, stretching from *Kep* to *Koh Kong* province, with the international port of Sihanoukville serving as a testament to the country's enduring importance as a maritime hub. In recognition of its rich underwater cultural heritage, Cambodia ratified a convention with UNESCO in 2001 to protect this legacy. This commitment was enacted by the Cambodian Assembly in 2007, highlighting the nation's dedication to preserving its maritime history.

Underwater archaeological research has uncovered around 15 shipwrecks off the Cambodian coast, but so far, only two significant wrecks have been thoroughly studied: the *Koh Sdech* Shipwreck and the *Koh Ta Kiev* Shipwreck. These submerged treasures offer a glimpse into the Khmer maritime prowess and serve as a link to the past, showcasing the vital role that naval trade routes played in shaping the history and culture of Cambodia. Through these explorations, the depths of the Khmer ocean continue to reveal the story of a nation that once stood at the crossroads of civilization, embodying the confluence of Indian and Chinese influences that have sculpted its unique cultural identity.

KINGDOM OF CAMBODIA

MINISTRY OF CULTURE AND FINE ARTS

CONSERVATION-TREATMENT AND PRESERVATION OF ARTIFACT COLLECTION DERIVED FROM SHIPWRECK IN CAMBODIA

ABSTRACT

Cambodia have long connected with India since BCE 2nd century by maritime silk route when India businessmen turned to look for gold trade in Southeast Asia. We were influent civilization : culture, religion, architecture, literature , and Royal social government . Furthermore, we have connected with China which Chinese Ambassador and investment came in Cambodia in year 234, they recorded Royal Chronology in during Kingdom of Funan (1st- CE 6th century) could build ship which could take 500 to 700 person on the ship. International port called ' OC' Ceo " found coin , ceramic trade, wooden Buddha. The evidence of influent Indianization had connected until 15th century. Cambodia also had long connected with China by maritime silk route. Depending Chinese records wrote Kingdom of Funan in 5th – 6th century. Until Kingdom of Chenla (6th –CE 8th) had connected with China , and in 13th century, during Yuan dynasty sent Ambassador call Chiev Ta Quaun to Angkor period (9th –CE 15th century). As for evidence of ceramics found in late 9th century , ceramic products in Thang dynasty, and consequence found ceramics in Song dynasty, Yuan dynasty, Ming and Qing dynast.

Cambodia presently exist coastline about 450 km from Kep, Kampot, Shinaoukville, and Koh Kong province. International port in located in Sihanoukville. We have ratified convention with UNESCO in 2001 on Underwater Law of Cultural Heritage Protection, this law was agreed to apply by Assembly in 2007. In the purpose of Underwater Research found around 15 shipwrecks. So far, only two shipwreck found which are Koh Sdech Shipwreck and Koh Ta Kiev shipwreck in Khmer Ocean.

Porcelain Conservation and Restoration

Porcelain and Celadon Restoration

-Assembling porcelain or celadon with Epoxy (Part A and Part B (1: 2). Reconstruction of broken pieces with tape and then trop Epoxy on joined lines. In general, it entire dried one week.

- Restoration : Miliput is good for porcelain restoration because hardness is similar. Mixing Miliput two parts together (1:1),

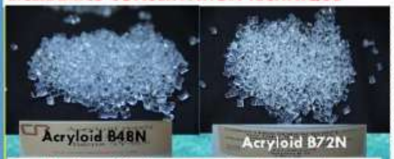
INTRODUCTION

Most of shipwrecks discovered in Southeast by fishermen, as well as in Cambodia found two shipwrecks : -Koh Sdech shipwreck found Kiri Sakor district, Koh Kong province, Feb 2006. Ship contained most of ceramic cargos from Thailand and some of ceramics from China, ivory tubes, ingots, brown tray, planks and Canon. -Koh Ta Kiev shipwreck discovered by fishermen looted the ceramics and various artifacts in 2018-20. Marine and Navy teams dived and lifting ceramics and various artifacts for Ministry of Culture Fine Arts. Amount of three thousand complete ceramics derived this shipwreck.

Therefore, present day there are only two shipwreck was discovered but depended survey there are 15 locatin of shipwreck has records by UNESCO and MoCFA in Cambodia.

Ceramics discovered from Koh Ta Kiev shipwreck 12 m depth,in 2018 and 2020.

2.CERAMICS CONSERVATION TECHNIQUE



Here are adhesive Acryloid B-72 N and Acryloid B-48 (1:1) mixed in pure Acetone. Its hardness is available for Earthenware and Stoneware and Glass transition temperature of adhesive changed is higher than the high temperature of climate is 40 degree C. We were used this adhesive by Expert on Ceramics Conservation.

Desalination of Underwater and underground Ceramics

Desalination Technique

Even though, ceramics and various artifacts derived from underwater and underground contained soluble salt (NaCl) which made clay or glaze is soft and flake off.

-Desalination is technique due to soaking the ceramics in the deionize water , we can keep ceramics for 1 day, 3 days, 1 week or months. Conductivity Metter is used to check soluble salt in the water (scale Microsm: µs). We must reduce soluble salt less that 100 µs or less than 20 µs.

-Consolidation Treatment: Mixed adhesive Acryloid B72 and Acryloid 48 (5%to 10%) in pure Acetone. And then, dropped consolidant 3 or 4 times on the glaze or clay flaking off. This technique we can conserve ceramics in good condition that protect from problem of soluble salt.

CERAMIC TRADE USED BY HIGHLAND PEROPLE: EVIDENCE FUNERAL RITUAL PRACTICE(15-17TH CENTURY).

There are Mae Nam Noi jars, Si Satchanalai Celadon, Sukhothai ware,traditional pots, Angkorian jars, and blude and white bowls derived from China.

Ceramics Restoration (Earthenware and Stoneware

Restoration of Stoneware and Earthenware : it means, stabilize the structure of pot to be good condition, but restoration is not over 50 percent. Technical method: 1) consolidation of shard edge is about three time, make mold support, put plaster and sand down plaster to form the shape as pot. After, inpaint the plaster to match the colors. Pot restoration stabilize structure and look complete shape.

Assembling ivory tube flaked off

When ivory tube very dried it made flaked off. It like the bamboo take off the shell.

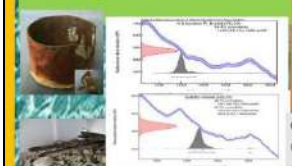
Ceramics Conservation of Burial Jars

Blue and white found at Koh Ta keiv shipwreck in 2018 by Navy Team.

1.Shipwreck Discovery

-Koh Sdech shipwreck discovered in 32m depth, Koh Kong province. We suggested Zheng He ship from China built in 15th century. Radiocarbon date of two samples:

1) Bamboo box covered lacquer date from 1428 to 1482 or 15th century.
2) Resin on wooden plank: provided date from 1409-1495 or 15th century.



2.Koh Ta Kiev shipwreck

This ship have be not done the analysis of Radiocarbon Dating but we can compare ceramic cargos found in Koh Sdech shipwreck. Ceramics assumed date from 15th century to 17th century.

Conclusion

Cambodia history of maritime silk route have long connected India and China. We have influent culture, literature, religion, architecture, Royal chronology during Kingdom of Funan. Internation port called Oc'Eo. We could build ship took 500 -700 person. There are two shipwreck discobery: 1)Koh Sdec shipwreck(15th century) and 2)Koh Takeive shipwreck fond 2018 (date 15th). Most of ceramics have conserved, ivory tube, planks. Ceramics Trade used by highland people or Khmer Doeurn "Chhorng"" at Areng Valley. Ceramic were important cargos in past because of requirement usage in daily life. It indicated ust the human social connection. Conservation of artifacts save cultural heritage.

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3.8 Protecting Our Heritage: Towards the Future of the Museums

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Email: nero.austero@nationalmuseum.gov.ph

The Philippines boasts a profound maritime legacy, featuring catalogued treasures, pristine beaches, a haven for divers exploring sunken vessels, and coral reefs showcasing nature's intricate craftsmanship. While the marine conservation efforts in the Philippines encompass marine organisms, preserving maritime objects has received comparatively less attention. To rectify this gap, the Underwater Archaeology Unit was established in 1982 under the aegis of the Underwater Cultural Heritage Division of the National Museum of the Philippines. This unit has been actively exploring shipwreck sites across the Philippine archipelago.

These sites harbor a wealth of artifacts, ranging from actual ship remnants and pottery to metallic fragments, sterns, and other nautical relics. Analyzing these artifacts presents a formidable challenge due to their varied nature and the centuries-long submersion in seawater. Conventional methods prove inadequate, necessitating the adaptation of techniques tailored for the nuanced examination of these invaluable historical remnants.

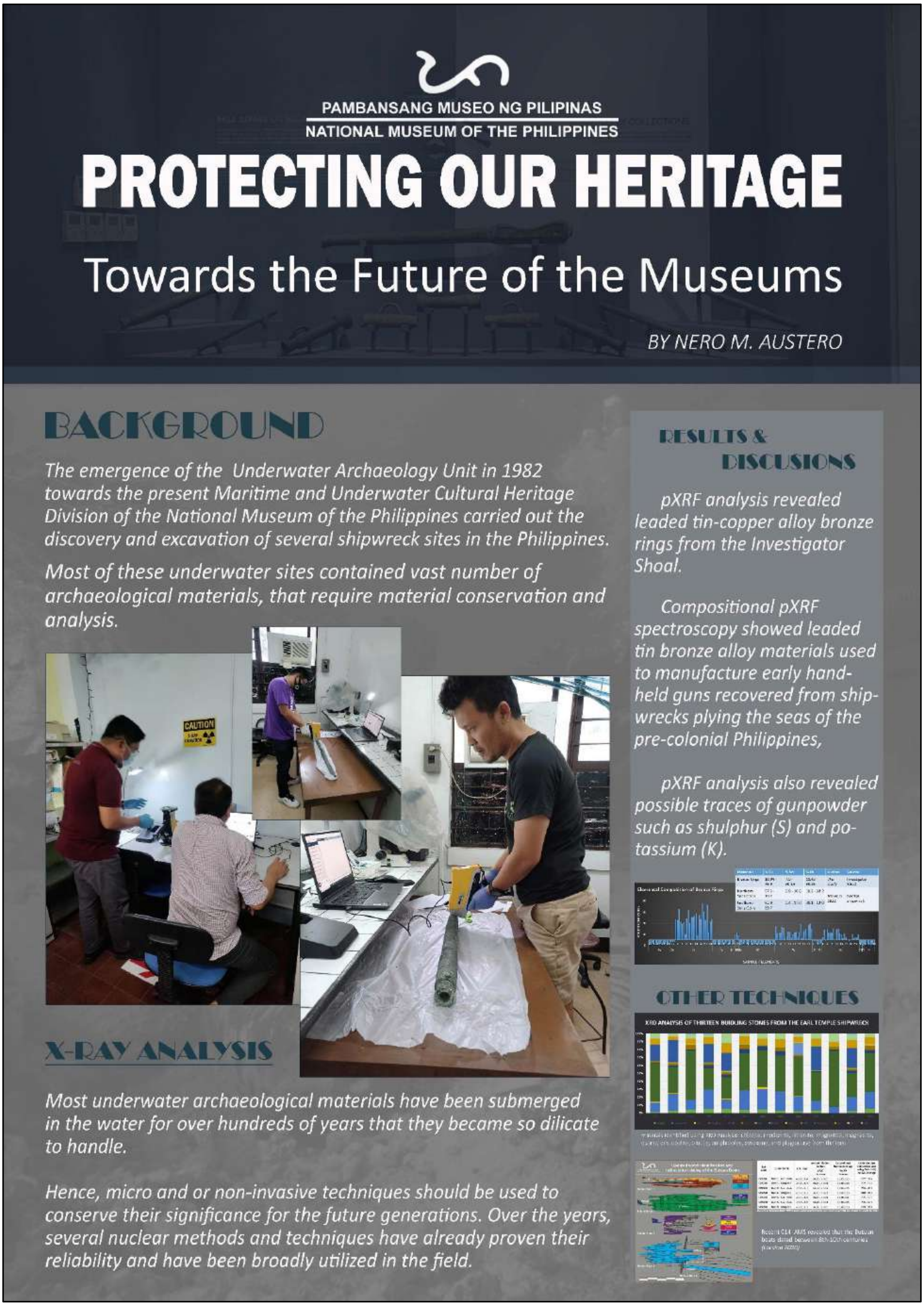
Given the fragile and brittle nature of these artifacts, employing non-invasive techniques becomes imperative. The potential damage from contact or invasive methods underscores the irreplaceable nature of these artifacts. In response to this challenge, non-invasive nuclear techniques for characterization have been proposed. These well-established methods minimize the risk of damage to the artifacts, addressing the delicate task of preserving our cultural heritage.

One such method involves using a portable X-Ray Fluorescence device (pXRF). This compact, lightweight apparatus utilizes X-rays to determine the elemental composition of a sample, proving highly effective as an on-site tool. The minimal sample preparation required ensures expediency without compromising accuracy. Analysis of shipwrecks from the pre-colonial era in the Philippines revealed traces of Sulfur and Potassium, leading researchers to infer the presence of gunpowder on these vessels.

When artifacts are damaged or fragmented, salvaging and subjecting them to additional analysis techniques, such as X-ray diffraction (XRD), becomes essential. XRD involves bombarding the sample with X-rays and collecting scattered electrons for more in-depth elemental analysis, providing nuanced insights into the nature of the cargo and the vessels.

Another valuable method for displaced or damaged samples involves C-14 carbon dating. This method determines the sample's age, shedding light on its historical timeframe. The work of Lacsina (2020), for instance, utilized this method to analyze recovered *Butuan* boats, concluding that these boats date back to the 8^{th} – 10^{th} century.

The dedication and perseverance of the Underwater Archaeology Unit, coupled with access to cutting-edge characterization methods, ensure the continuous protection and restoration of the Philippines' cultural heritage for future generations.


PAMBANSANG MUSEO NG PILIPINAS
NATIONAL MUSEUM OF THE PHILIPPINES
PROTECTING OUR HERITAGE
Towards the Future of the Museums
BY NERO M. AUSTERO
BACKGROUND
The emergence of the Underwater Archaeology Unit in 1982 towards the present Maritime and Underwater Cultural Heritage Division of the National Museum of the Philippines carried out the discovery and excavation of several shipwreck sites in the Philippines.
Most of these underwater sites contained vast number of archaeological materials, that require material conservation and analysis.
CAUTION
X-RAY ANALYSIS
Most underwater archaeological materials have been submerged in the water for over hundreds of years that they became so dilicate to handle.
Hence, micro and or non-invasive techniques should be used to conserve their significance for the future generations. Over the years, several nuclear methods and techniques have already proven their reliability and have been broadly utilized in the field.
RESULTS & DISCUSIONS
pXRF analysis revealed leaded tin-copper alloy bronze rings from the Investigator Shoal.
Compositional pXRF spectroscopy showed leaded tin bronze alloy materials used to manufacture early hand-held guns recovered from ship-wrecks plying the seas of the pre-colonial Philippines,
pXRF analysis also revealed possible traces of gunpowder such as shulphur (S) and potassium (K).
OTHER TECHNIQUES
XRD ANALYSIS OF THIRTEEN BUILDING STONES FROM THE EARL TEMPLE SHIPWRECK

3.9 The application of Nuclear Techniques for Characterization of the Artifacts in Sumatra, Indonesia

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In the verdant landscapes of Sumatra, Indonesia, the subterranean realms of *Harimau* Cave cradle a history reshaping our understanding of the region's past. Nestled in the southern swathes of Sumatra, this cave has become the epicentre of a significant archaeological discovery, revealing the earliest metal artifacts ever found in the Indonesian archipelago. The finds, comprising bronze socketed axes and bracelets dating from the fourth century BC to the first century AD, are not just remnants of bygone eras; they symbolize the dawning of the Metal Age in Sumatra and may be connected to the island's participation in the international Maritime Silk Road.

This profound discovery was made possible by employing advanced nuclear techniques to characterize these artifacts. As the bronze pieces emerged from the protohistoric occupation layer, their significance became clear—they are the harbingers of a technological revolution in Sumatra, marking a time when metal began to dominate stone. The intricate production of these items was not a simple feat; it required a sophisticated understanding of metallurgy, including the complex process of alloying copper with tin, lead, and arsenic to create bronze and the precise control of furnaces and fire necessary for metalworking.

Further research using portable X-ray fluorescence spectrometry (pXRF) has illuminated another aspect of Sumatran prehistory—identifying obsidian sources. This non-invasive technique has traced the origins of obsidian samples from *Merangin* and *Sarolangun*, revealing three distinct sources in Jambi. The meticulous application of principal component analysis (PCA) and the Independent Sample T-Test has differentiated between these sources, adding two previously unknown obsidian sources to the existing three identified by earlier studies. This advancement enriches our comprehension of the material procurement and trade networks that flourished in southern Sumatra.

In a parallel stride, the *Lampung* lowlands of Sumatra serve as a canvas for understanding the evolution of pottery. A battery of scientific techniques, including X-ray fluorescence, X-ray diffraction, inductively coupled plasma mass spectrometry (ICP-MS), petrography, and thermoluminescence, has been deployed to analyse the shape, dating, and origins of Lampung potsherds. These fragments of clay, which once took the form of bowls, cups, and vases, now reveal the daily life of a society spanning from the 12th to the 20th century. Through qualitative methods and the innovative use of Rhinoceros software, researchers have reconstructed these artifacts, suggesting that the pottery was predominantly produced in the *Kayu Agung Palembang* and *Bakung Udik* regions.

The synergy of these scientific explorations—whether it be through the analysis of metal artifacts, the sourcing of obsidian, or the study of ancient pottery—paints a picture of a society that was both complex and connected. The artifacts from *Harimau* Cave and the insights into Sumatra's material culture offer a window into a transformative era in Indonesia's history. They tell a story of technological innovation, burgeoning trade routes, and cultural exchange, emphasizing Sumatra's role in the broader narrative of Southeast Asian history.

BRIN

The application of Nuclear Techniques for Characterization of the Artifacts in Sumatra, Indonesia

The rise of the Metal Age in Sumatra: Evidence from Harimau Cave in South Sumatra

Harry Octavianus Sofian and Truman Simanjuntak

Several sites in Sumatra reveal bronze artefacts in the Dong Son style of Vietnam. Excavations in Harimau Cave in the southern part of Sumatra recovered bronze and iron artefacts from the protohistoric occupation layer. The bronze artefacts are socketed axes and bracelets that date from between the fourth century BC and the first century AD. These are the oldest metal artefacts thus far found in Sumatra and Indonesia in general. Hence, the bronze artefacts from Harimau Cave may be an indication of the rise of the Metal Age on Sumatra, which coincides with the emergence of the international Maritime Silk Road.

Artefacts were found in the top layer of the stratigraphic unit. Eight of them were made of bronze and four of iron. These objects are fragmentary and highly corroded. Our study focused on the bronze artefacts, which are socketed axes (three pieces), bracelets (three pieces) and two unidentified pieces. Bronze is a metal alloy of the elements copper (Cu), tin (Sn), lead (Pb), and arsenic (As). When copper is combined with other metals, the melting range of the resulting alloy is narrower than that of copper. Producing metal objects is not an easy task, because multiple complicated production steps are needed, as well as knowledge about metals, furnaces and fire control (Haryono 2001; Scott 1991).

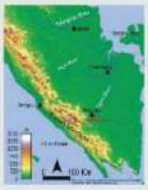


Figure 1: Metal artefacts from Harimau Cave.
Note: Artefact Nos 1–8, on the left, have been examined with X-ray fluorescence

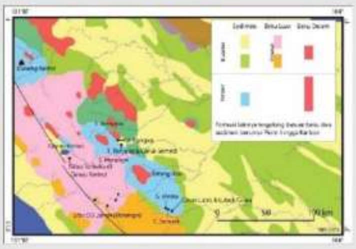
Table 1 Chemical composition of metal artefacts from Harimau Cave.

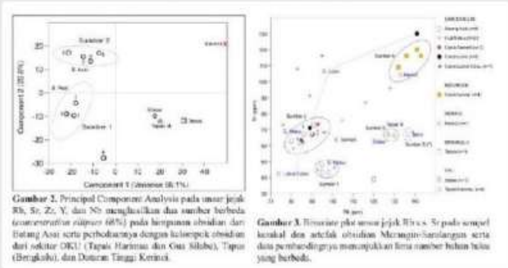
Artefact no. and description	Code	Copper (Cu)	Tin (Sn)	Lead (Pb)
1. Socketed bronze axe	P9/6/2010	X	X	
2. Socketed bronze axe	[illegible]/2010	X	X	
3. Bronze fragment	P6/3/2011	X	X	
4. Bronze fragment	Q7/7/2011	X	X	
5. Bracelets with motifs	I7/2/2012a	X	X	X
6. Bracelets without motifs	F7/7/2012b	X	X	
7. Fragment bracelets without motifs	G7/5/2012b	X	X	
8. Socketed bronze axe	P9/10/2014	X	X	

Source: Photographs by Harry Octavianus Sofian. Artefacts: Azis et al. (2011), Oktaviana et al. (2012), Oktaviana et al. (2014), Tim Penelitian Padang Bindu (2009) and Simanjuntak et al. (2013).

Multiple-Sources Identification of Obsidian in Merangin and Sarolangun (Sumatra) Based on Portable X-Ray Fluorescence Spectrometry (pXRF) Determination

Mohammad Ruly Fauzi, Andy S Wibowo, dan Rhis Eka Wibawa





Portable X-Ray Fluorescence analysis (pXRF) on obsidian samples from Merangin and Sarolangun proved the existence of three different obsidian sources in Jambi. It is obtained through the determination of pXRF on the particular trace elements: Rb, Sr, Zr, Y, Nb, Ti and Mn. The results are then analyzed by the Principal Component Analysis (PCA) to arrange the same obsidian sources. This result is then corroborated with the Independent Sample T-Test. This analysis reveals the similarity in trace-element concentration amongst the same source, as well as their differences within different sources. This study contributes to the identification of two new obsidian sources from Sarolangun that have never been reported before. As a result, there are five known-sources of obsidian in Southern Sumatra, in which three other sources were previously identified by Ambrose et al. (2009) and Reepmeyer et al. (2011).

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Shape, Datings, And the Origin of Potsherds in Lampung Lowlands, Sumatra

Rusyanti, Iwan Setiawan, and Akbar Adhi Satrio

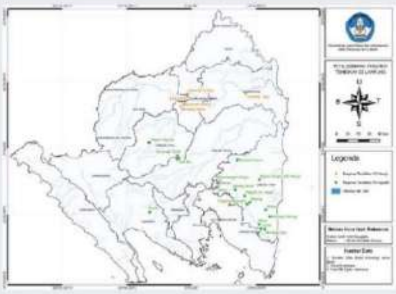
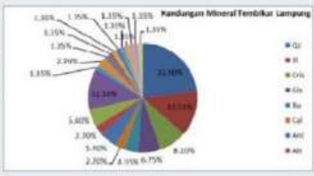
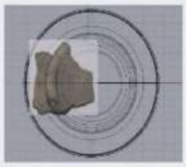


Fig. 1 The Potsherd samples from Lampung





Publication: Naditira Widya 16 (2): 107-122

X-ray fluorescence, X-ray diffraction, inductively coupled plasma mass spectrometry (ICP-MS), Petrography, and Thermoluminescence carried out to analyses the shape, datings, and the origin of the Lampung potsherds. Qualitative methods were also used to reconstruct the results of selective sampling using the Rhinoceros software supported by a historical approach. The purpose of this research is to know the favourable varieties of form, chronology, and origin of Lampung pottery in general. Dominant pottery containers common for daily use such as bowls, cups, and vases. The chronology of pottery covers from the 12th to the 20th century, and the origin of pottery production is suggested to be manufactured around the Kayu Agung Palembang and Bakung Udik regions, in Lampung.

Layout by Putra Kama Jaya

3.10 Conservation: Desalination Treatment of Artifacts excavated from the Soil

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This article delineates the systematic conservation procedures undertaken by The National Museum of Indonesia to preserve iron artifacts excavated from Central Java, detailing the scientific methodologies employed and the resulting stabilization of these culturally significant items.

In historical preservation, The National Museum of Indonesia is at the forefront, responsible for conserving iron artifacts retrieved from archaeological sites. These items, while rich in historical significance, are often afflicted with corrosion—a manifestation of the relentless onslaught of time and environmental conditions. The museum's conservation team, in conjunction with the Indonesia Heritage Agency and the National Research Institute of Cultural Heritage of South Korea, has developed a meticulous conservation regimen to mitigate these effects and ensure the artifacts' longevity for scholarly and educational purposes.

The artifacts in question, primarily composed of iron, as confirmed by portable XRF analysis, exhibit varying degrees of corrosion. The initial conservation stage entails a desalination process—a pre-emptive measure against further corrosive damage. Each artifact is enshrouded in a wire mesh fabric tailored to its form, which serves the dual purpose of maintaining structural integrity and facilitating the treatment process.

These prepared artifacts are then subjected to a 0.1M Sodium Sesquicarbonate (SSC) solution, adhering to a strict ratio of 100 grams of artifact to 1000 mL of solution. The desalination process spans over eight days, with artifacts immersed for 24-hour intervals. This phase necessitates rigorous monitoring of the temperature and chemical composition of the solution to ensure optimal desalination.

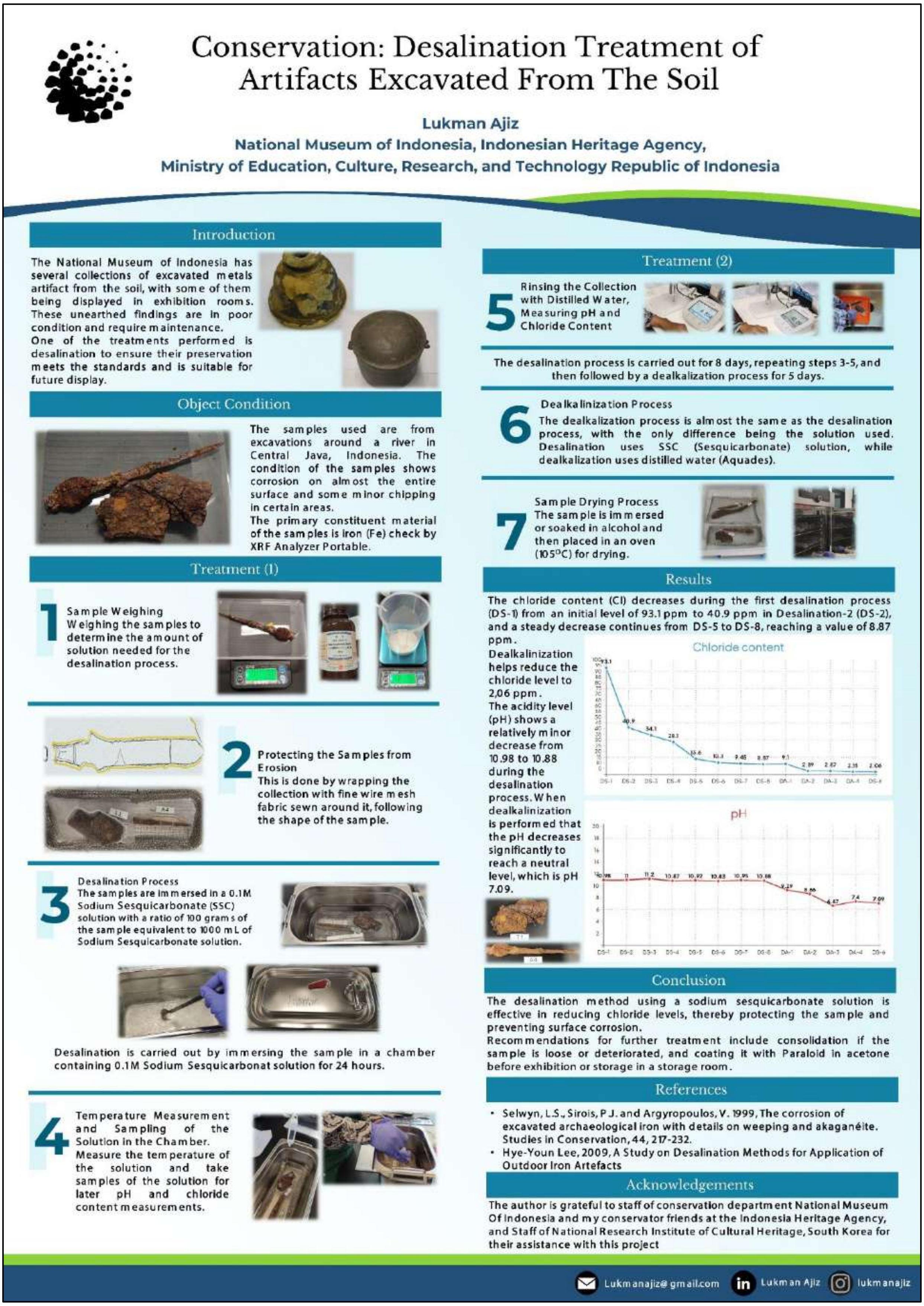
After desalination, the artifacts undergo de-alkalization using distilled water for five days to diminish chloride content further and adjust pH levels towards neutrality. The artifacts are meticulously rinsed with distilled water post each immersion cycle to eradicate any lingering solution, a critical step in preventing the recurrence of corrosive processes.

The subsequent phase involves drying the artifacts through alcohol soaking and oven-drying at 105 °C to preclude any moisture retention that could potentially reinstate corrosion. Post drying, a structural assessment is conducted to determine the necessity for consolidation—if the artifact exhibits structural deterioration or loosening.

The conservation process culminates with applying a Paraloid solution in acetone, serving as a protective layer against future environmental threats. This carefully orchestrated conservation process has yielded significant reductions in chloride levels, from a precarious 93.1 ppm to a much safer 8.87 ppm. Moreover, the pH levels have been successfully moderated to near neutrality, indicating the artifacts' readiness for storage or display devoid of imminent degradation risks.

This academic discourse not only sheds light on the specific conservation techniques applied but also underscores the collaborative nature of the conservation efforts. The empirical results presented here validate the effectiveness of the methodologies, which have been vital in preserving the integrity of these artifacts, thus contributing to the broader understanding of Indonesia’s cultural heritage.

In conclusion, the conservation practices employed by The National Museum of Indonesia serve as a paradigm of scientific rigour in historical preservation. The successful stabilization of these artifacts is not merely a triumph of conservation science but also an invaluable contribution to the continuity of Indonesia's historical narrative.


Conservation: Desalination Treatment of Artifacts Excavated From The Soil
Lukman Ajiz
National Museum of Indonesia, Indonesian Heritage Agency,
Ministry of Education, Culture, Research, and Technology Republic of Indonesia
Introduction
The National Museum of Indonesia has several collections of excavated metals artifact from the soil, with some of them being displayed in exhibition rooms. These unearthed findings are in poor condition and require maintenance.
One of the treatments performed is desalination to ensure their preservation meets the standards and is suitable for future display.
Object Condition
The samples used are from excavations around a river in Central Java, Indonesia. The condition of the samples shows corrosion on almost the entire surface and some minor chipping in certain areas.
The primary constituent material of the samples is iron (Fe) check by XRF Analyzer Portable.
Treatment (1)
1 Sample Weighing
Weighing the samples to determine the amount of solution needed for the desalination process.
2 Protecting the Samples from Erosion
This is done by wrapping the collection with fine wire mesh fabric sewn around it, following the shape of the sample.
3 Desalination Process
The samples are immersed in a 0.1M Sodium Sesquicarbonate (SSC) solution with a ratio of 100 grams of the sample equivalent to 1000 mL of Sodium Sesquicarbonate solution.
Desalination is carried out by immersing the sample in a chamber containing 0.1M Sodium Sesquicarbonat solution for 24 hours.
4 Temperature Measurement and Sampling of the Solution in the Chamber.
Measure the temperature of the solution and take samples of the solution for later pH and chloride content measurements.
Treatment (2)
5 Rinsing the Collection with Distilled Water, Measuring pH and Chloride Content
The desalination process is carried out for 8 days, repeating steps 3-5, and then followed by a dealkalization process for 5 days.
6 Dealkalinization Process
The dealkalization process is almost the same as the desalination process, with the only difference being the solution used. Desalination uses SSC (Sesquicarbonate) solution, while dealkalization uses distilled water (Aquades).
7 Sample Drying Process
The sample is immersed or soaked in alcohol and then placed in an oven (105°C) for drying.
Results
The chloride content (Cl) decreases during the first desalination process (DS-1) from an initial level of 93.1 ppm to 40.9 ppm in Desalination-2 (DS-2), and a steady decrease continues from DS-5 to DS-8, reaching a value of 8.87 ppm.
Dealkalinization helps reduce the chloride level to 2,06 ppm.
The acidity level (pH) shows a relatively minor decrease from 10.98 to 10.88 during the desalination process. When dealkalinization is performed that the pH decreases significantly to reach a neutral level, which is pH 7.09.
Chloride content
93.1
40.9
34.1
28.1
15.6
9.45
8.87
9.1
2.89
2.87
2.06
DS-1
DS-2
DS-3
DS-4
DS-5
DS-6
DS-7
DS-8
DA-1
DA-2
DA-3
DA-4
pH
10.98
11
11.2
10.87
10.92
10.83
10.95
10.88
9.29
8.66
6.67
7.4
7.09
Conclusion
The desalination method using a sodium sesquicarbonate solution is effective in reducing chloride levels, thereby protecting the sample and preventing surface corrosion.
Recommendations for further treatment include consolidation if the sample is loose or deteriorated, and coating it with Paraloid in acetone before exhibition or storage in a storage room.
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3.11 National Collection of Singapore

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In the vibrant city-state of Singapore, preserving cultural heritage is a sophisticated endeavour that intertwines tradition with cutting-edge science. The National Collection Conservation Services, a beacon of this effort, is the guardian of more than 300,000 artifacts, each a piece of the intricate mosaic of Singapore and Southeast Asia's history. These artifacts range from middle-aged antiquities to contemporary art, meticulously stored, documented, managed, and cared for at the Heritage Conservation Centre (HCC).

Established in 2015, the Conservation Science Lab within the centre is staffed by approximately 40 conservation professionals, along with a dynamic team of scientists, interns, fellows, and volunteers. The lab is organized into four specialized sections—Painting, Paper, Objects, and Textiles—each dedicated to the meticulous care and restoration of the collection.

The analytical capabilities of the lab are robust. From light microscopy to Fourier Transform Infrared Spectroscopy (FTIR) and from Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS) to Raman and X-ray fluorescence (XRF), the equipment and techniques at their disposal are as diverse as the artifacts they examine. Other tools like Pyrolysis Gas Chromatography Mass Spectrometry (Py-GC/MS) and spectrophotometers play crucial roles in materials characterization, while preventive conservation is supported by microfadeometers and Relative Humidity & Temperature (RH & T) chambers.

The centre's imaging capabilities are equally impressive, offering Visible Spectrum (Vis), Ultraviolet Fluorescence (UVF), Infrared Reflectography (IRR), multispectral imaging, X-ray, and even Computed Tomography (CT) scanning at the Singapore General Hospital (SGH). These imaging techniques reveal past secrets, hidden layers of paintings, and insights into the materials that compose ancient treasures.

One such investigation involved the sampling from a silver flask of the *Tang* shipwreck, leading to a synchrotron study of lead arsenate transfer in Peranakan glass beads. Research collaborations extend beyond the lab's walls, involving conservators, curators, archaeologists, heritage scientists, art interest groups, and universities in Singapore and internationally. These collaborations have led to significant projects, like the analysis of 14th-century Temasek gold ornaments and the study of salt efflorescence on archaeological ceramics.

The lab has also researched the fading pink of Peranakan Textiles using Surface Enhanced Raman Spectroscopy (SERS) and Liquid Chromatography Mass Spectrometry (LC-MS). Optical Photothermal Infrared (O-PTIR) imaging has unveiled the composition of zinc soaps in Peranakan portrait paintings, and studies into the glazing techniques of Changsha kiln porcelain have shed light on ancient artistic methods.

Moreover, the Conservation Services supports exhibitions across 11 museums and heritage institutions, managing research and projects while leading preventive working groups focused on combating pests, mould, and the adverse effects of light, humidity, temperature, and pollutants.

In their outreach efforts, the Conservation Services has engaged the public with initiatives like the "Little Conservators" program and professional development workshops, including a lacquer workshop that delved into the intricacies of this ancient art form.

At the heart of these endeavours is the commitment to preserve Singapore's rich heritage—a testament to the past and a legacy for future generations. Through this fusion of traditional conservation techniques and modern science, Singapore ensures that its storied past continues to illuminate the way forward.


National Heritage Board Singapore
HERITAGE CONSERVATION CENTRE
➢ More than 300,0000 pieces
➢ Stored, documented, managed and cared for at the Heritage Conservation Centre (HCC)
➢ Significant to Singapore and Southeast Asia history
➢ Ranging from middle age to contemporary art
➢ www.roots.sg
National Collection
Conservation Services
▪ 4 sections (Painting, Paper, Objects, Textiles)
▪ ~40 conservation staff, 2 scientists
▪ Temps, interns, fellows, volunteers
▪ Exhibition Support
▪ (11 museums and heritage institutions)
▪ Research and Project management
▪ Preventive working groups
▪ Pest, Mould, Light, RH, T, Pollutants
▪ Professional development
Outreach "Little Conservators" Oct 2023
Lacquer workshop Nov 2022
Analytical Capability
▪ Conservation Science Lab
▪ Established in 2015
Materials Characterization
Light microscopy, FTIR, SEM-EDS, Raman, XRF, Py-GC/MS, Cross-section polishing, spectrophotometer
Preventive Conservation
Microfadeometer, Oddy test, EGA-GC/MS, RH & T chamber
Imaging
Vis, UVF, IRR, multispectral imaging, X-ray, CT (SGH)
Sampling from silver flask of Tang shipwreck
Research Collaborators
▪ Work with conservators, curators, archaeologists, heritage scientists, art interest groups, universities
▪ Establish research agreements and MOU
▪ In Singapore and abroad
Preprime canvases from Singapore and Australia
ANSTO
Arsenic
Lead
Synchrotron study of lead arsenate transfer in Peranakan glass beads
MOU on Tang cargo research with China
陕西省文物保护研究院
Salt efflorescence on archaeological ceramics
Fading pink of Peranakan Textiles with SERS and LC-MS
SHIMADZU
Excellence in Science
Investigating glazing technique of Changsha kiln coloured porcelains
CIBA
14th century Temasek gold ornaments
ISEAS YUSOF ISHAK INSTITUTE
O-PTIR imaging of zinc soaps in Peranakan Portrait paintings
NUS
Singapore Synchrotron Light Source

3.12 Investigation Cultural Heritage in Myanmar and Thermoluminescence Laboratory

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Tucked away in the resplendent Southeast Asian landscape, Myanmar, often heralded as the "Golden Land," is a nation steeped in rich cultural heritage. This heritage encompasses many tangible and intangible treasures, illuminating the country's storied past. However, the preservation of these artifacts is not without its challenges. The country's relics face threats from natural disasters, such as earthquakes—the notable ones occurring on 8 July 1975, with a magnitude of 5.6, and on 24 August 2016, with a magnitude of 6.8—as well as fire, lightning, floods, winds, and landslides. The heavy rainfall typical of its climate, coupled with high humidity levels averaging 70% and temperatures around 25-26°C, exacerbates bio-deterioration. Human activities, including mishandling, neglect, vandalism, and illicit digging by non-archaeologists, also pose significant risks.

To combat these threats and ensure the longevity of Myanmar's cultural artifacts, specific interventions have been identified as essential. These include investigating and analyzing heritage items, calculating their absolute dating, monitoring environmental effects, conserving them against bio-deterioration, and utilizing advanced nuclear techniques.

Since joining UNESCO in 1949, Myanmar has welcomed the collaboration of numerous international expert teams dedicated to conserving and preserving its cultural heritage. These experts have brought with them a suite of sophisticated nuclear techniques, such as energy-dispersive X-ray Fluorescence (ED-XRF), X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Nuclear Magnetic Resonance (NMR), Thermogravimetry (TGA), and ATR-FTIR. These methods have revolutionized how artifacts are studied and conserved.

One of the profound examples of the application of these technologies can be witnessed in the conservation efforts of wall paintings. Through the meticulous restoration, the vivid details and vibrant colors of these paintings, which had faded over time, have been brought back to life. The transformative process, evident in the 'before' and 'after' states of the artworks, underscores the effectiveness of the techniques used.

Another notable conservation effort is seen at the Nyaung-gan Bronze Age Cultural Heritage Zone. Here, the cleaning and conservation procedures have reinstated the original splendor of the artifacts, which had been lost to time and neglect. Similarly, the restorative work on bones and earthenware artifacts demonstrates the remarkable progress made. The meticulous cleaning processes, coupled with the conservation work, have not only arrested further deterioration but have also enhanced the artifacts' resilience against future damage.

This intricate blend of science and art in the service of heritage conservation is not just about maintaining physical objects. It is about preserving the essence of Myanmar's cultural identity. Through these advanced techniques, the country safeguards the touchstones of its history, ensuring that future generations will have a tangible connection to their past. This interdisciplinary approach, where heritage conservation meets nuclear science, exemplifies the progressive stride of Myanmar in safeguarding its historical legacy. It is a testament to the country's commitment to nurturing its cultural heritage amidst the rapid pace of modernity.

IAEA REGIONAL TECHNICAL COOPERATION PROJECT RAS1027

CULTURAL HERITAGE IN MYANMAR AND THERMOLUMINESCENCE LABORATORY

Myint Myint Oo
Field School of Archaeology (Pyay), Myanmar

Regional Training Course on the Application of Nuclear Techniques for Characterisation and Preservation of Artefacts obtained from Shipwreck
RAS1027-2300242

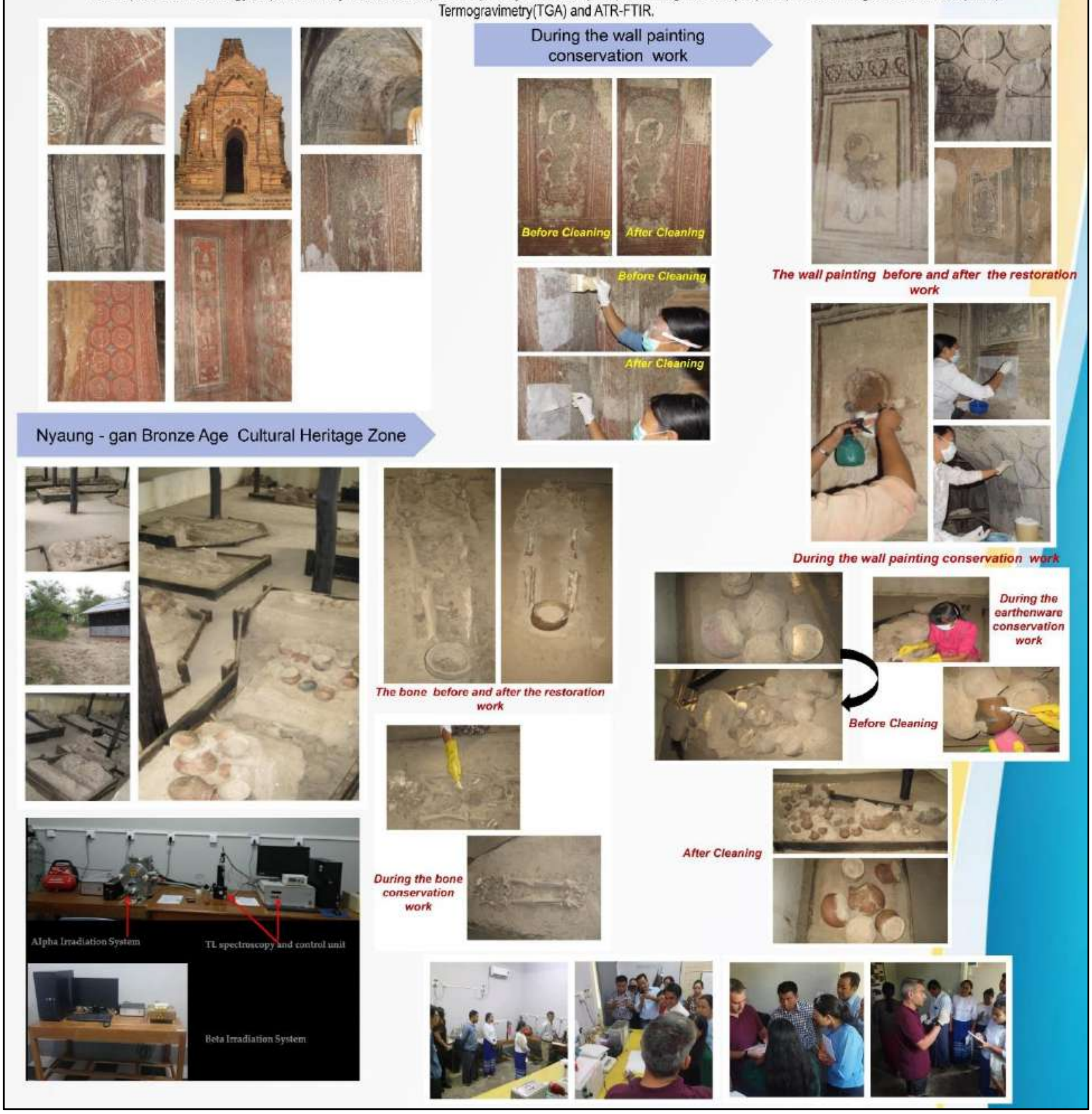
INTRODUCTION

Myanmar known as the Golden Land, because Myanmar has very rich cultural heritage both tangible and intangible cultural properties. Myanmar's Cultural Heritage vulnerability Natural disaster (Earthquake; 8 July 1975(5.6 magnitude) and 24 August 2016 (6.8 magnitude), Fire, Lightening, Flood, Wind , Land side), Climate and environment (Heavy rain water), Bio-deterioration (Tropical climate, Temperature 25-26 ºC, 70% Humidity), Human vandalism (Mishandling, neglect, vandalism , illicit digging of sites by non-archaeologists).

For our country the specific needs for interventions in cultural heritage are :

- To investigate and analysis for cultural heritage
- To calculate the absolute dating
- To monitoring the environmental effects
- To conserve the Bio-deterioration
- To apply the nuclear techniques.

Our country has joined UNESCO since 1949, so many international expert teams collaborated to preserve and conserve for our Cultural Heritage. These expert teams used the nuclear Techniques, such as Energy Dispersive X-ray Fluorescence (ED-XRF), X-ray Diffraction (XRD), Scanning Microscopic (SEM), Nuclear magnetic resonance (NMR), Termogravimetry(TGA) and ATR-FTIR.



3.13 Conservation and Preservation Practice in Bangladesh

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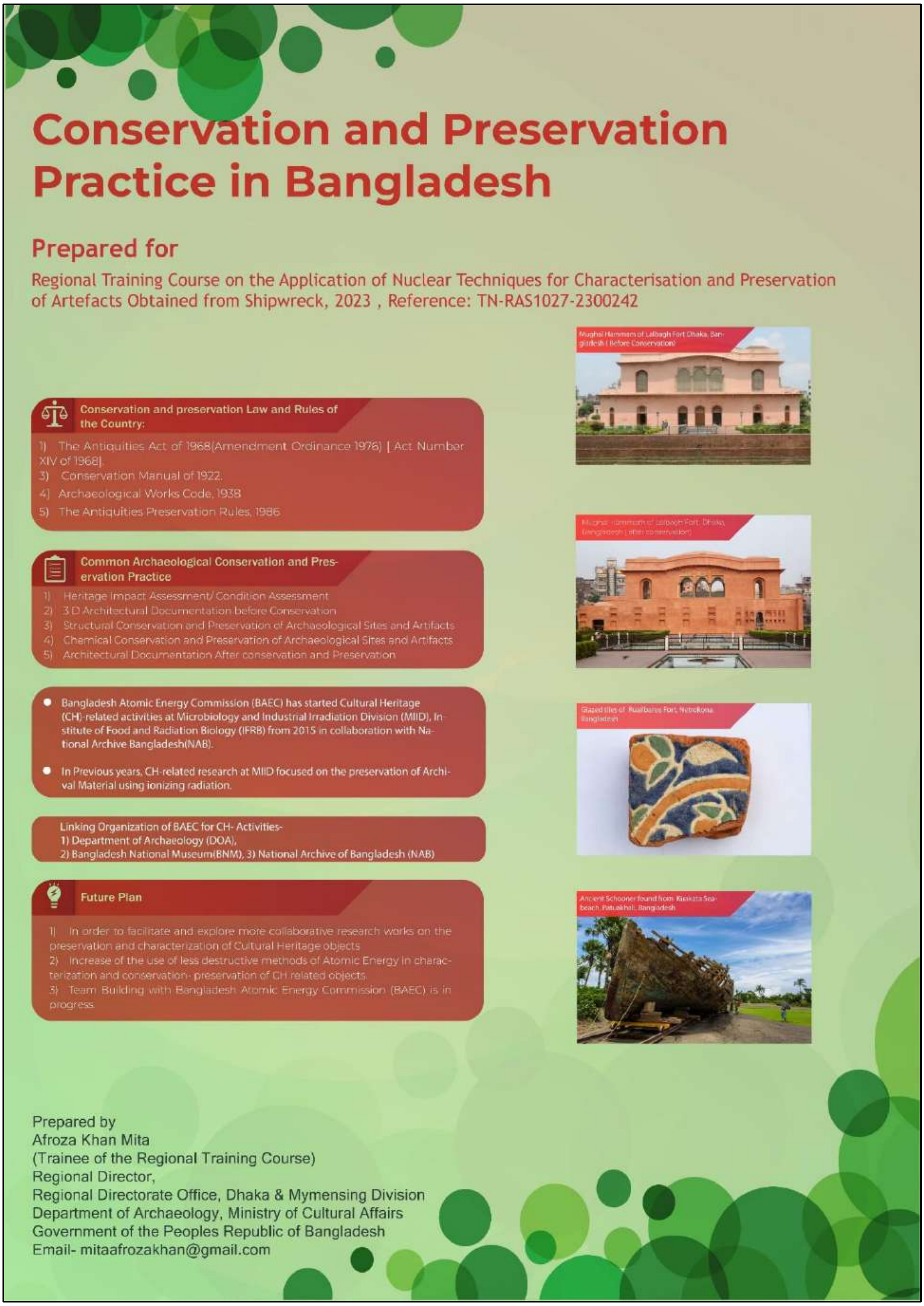
The preservation of cultural heritage is a critical task that holds immense importance for countries like Bangladesh, where history seeps from every nook and cranny. The nation has laid the groundwork for conservation and preservation practices through a robust legal framework, consisting of the Antiquities Act of 1968 with its 1976 amendment, the Conservation Manual of 1922, the Archaeological Works Code of 1938, and the Antiquities Preservation Rules of 1986. These laws and regulations form the bedrock of efforts to safeguard the rich tapestry of Bangladesh's past.

Regarding practical measures, Bangladesh adopts several standard practices in archaeological conservation and preservation. Heritage Impact and Condition Assessments are routinely conducted to gauge the status of sites and artifacts. Before any conservation work begins, 3D Architectural Documentation is created to record the condition of these historical treasures in meticulous detail. Structural Conservation follows this to preserve the integrity of archaeological sites and artifacts, alongside Chemical Conservation to address any deterioration at the molecular level. After the conservation and preservation processes are complete, Architectural Documentation is updated to reflect the interventions and their outcomes.

The Bangladesh Atomic Energy Commission (BAEC), particularly through the Microbiology and Industrial Irradiation Division (MIID) of the Institute of Food and Radiation Biology (IFRB), has been actively involved in cultural heritage-related activities since 2015. In collaboration with the National Archive of Bangladesh (NAB), the BAEC has focused its research on the preservation of archival materials using ionizing radiation. This technique has proven effective in extending the life of precious archival documents without causing further damage.

BAEC's partnerships with various organizations, including the Department of Archaeology (DOA), the Bangladesh National Museum (BNM), and the National Archive of Bangladesh (NAB), underscore the collective commitment to cultural heritage preservation. Looking forward, there are ambitious plans to enhance the preservation and characterization of cultural heritage objects. A key element of this strategy is to increase the use of less destructive methods of atomic energy in the characterization and conservation-preservation of cultural heritage-related objects. This signifies a shift towards techniques that minimize harm while maximizing the preservation of historical integrity.

Furthermore, there is a focus on team building within the BAEC, which is critical for the future success of these endeavors. By fostering a collaborative environment, the Commission aims to bolster its capability to preserve the nation's cultural heritage for future generations. The approach is both a testament to Bangladesh's dedication to its past and a beacon for innovative preservation techniques in the future. It's a delicate balance between embracing modern technology and honoring ancient legacies, and Bangladesh is at the forefront of this intricate dance of conservation and preservation.


Conservation and Preservation Practice in Bangladesh
Prepared for
Regional Training Course on the Application of Nuclear Techniques for Characterisation and Preservation of Artefacts Obtained from Shipwreck, 2023 , Reference: TN-RAS1027-2300242
Conservation and preservation Law and Rules of the Country:
1) The Antiquities Act of 1968(Amendment Ordinance 1976) [Act Number XIV of 1968].
3) Conservation Manual of 1922.
4) Archaeological Works Code, 1938
5) The Antiquities Preservation Rules, 1986
Common Archaeological Conservation and Preservation Practice
1) Heritage Impact Assessment/ Condition Assessment
2) 3 D Architectural Documentation before Conservation
3) Structural Conservation and Preservation of Archaeological Sites and Artifacts
4) Chemical Conservation and Preservation of Archaeological Sites and Artifacts
5) Architectural Documentation After conservation and Preservation
Bangladesh Atomic Energy Commission (BAEC) has started Cultural Heritage (CH)-related activities at Microbiology and Industrial Irradiation Division (MIID), Institute of Food and Radiation Biology (IFRB) from 2015 in collaboration with National Archive Bangladesh(NAB).
In Previous years, CH-related research at MIID focused on the preservation of Archival Material using ionizing radiation.
Linking Organization of BAEC for CH- Activities-
1) Department of Archaeology (DOA),
2) Bangladesh National Museum(BNM), 3) National Archive of Bangladesh (NAB)
Future Plan
1) In order to facilitate and explore more collaborative research works on the preservation and characterization of Cultural Heritage objects
2) Increase of the use of less destructive methods of Atomic Energy in characterization and conservation- preservation of CH related objects.
3) Team Building with Bangladesh Atomic Energy Commission (BAEC) is in progress.
Mughal Hammam of Lalbagh Fort Dhaka, Bangladesh (Before Conservation)
Ancient Schooner found from Kuakata Sea-beach, Patuakhali, Bangladesh
Prepared by
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3.14 Application of Nuclear Techniques in Jordan and Preservation of Cultural Heritage Remains in Jordan

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In the heart of Jordan's bustling capital, where the historical tapestry of East Amman meets its modern western counterpart, stands The Jordan Museum. This prestigious national institution, which opened its doors in 2013, is more than a mere repository of artifacts; it is a beacon of cultural heritage preservation, illuminating over 1.5 million years of Jordanian history. The museum's mission is to collect, preserve, and exhibit the nation's archaeological treasures, and in doing so, it serves as a custodian of the past for future generations.

The Jordan Museum boasts many objects that chronicle the country's rich past, from prehistoric times to contemporary culture. These objects are meticulously organized by material and condition to ensure their longevity, showcasing the museum's commitment to conservation. In addition to the artifacts on display, the museum houses thousands of items in storage, spanning more than 2,000 square meters of meticulously designed space. Equipped with modern climate control systems, fire suppression technologies, and robust security measures, the museum's storage facilities offer an optimal environment for preserving invaluable artifacts. This state-of-the-art infrastructure has garnered trust internationally, with numerous foreign expeditions entrusting their sensitive archaeological finds to the museum's care.

Beyond its role as a cultural hub, The Jordan Museum integrates cutting-edge nuclear technologies to further the preservation of its treasures. This integration of science and heritage is part of a broader national initiative supported by the Jordan Atomic Energy Commission (JAEC), established in 2008, and the Jordan Research and Training Reactor, inaugurated in 2016. These institutions represent Jordan's investment in nuclear technology, not only for energy but also for advancing scientific research and cultural preservation.

One such application is the Gamma Irradiation Facility, which has been operational since 1994. Initially starting with a Gamma cell, the facility expanded in 2000 when the International Atomic Energy Agency (IAEA) provided an Industrial Gamma Irradiator through a technical cooperation project. This technology is versatile, serving both research and industrial purposes. It is used to irradiate research samples and calibrate dosimeter systems. Additionally, it provides sterilization services for medical supplies, pharmaceutical raw materials, and even consumer goods such as spices and cosmetics. However, its potential for artifact preservation remains untapped.

Another pivotal component of Jordan's scientific landscape is the Ion Beam Analysis Facility, which houses Particle-Induced X-ray Emission (PIXE) and Rutherford Backscattering Spectrometry (RBS). These sophisticated analytical techniques are invaluable for routine analysis in archaeology, biomedical research, geology, and environmental sciences.

The collaborative efforts between the Jordan Museum and the JAEC, with the acknowledgment of international partners like the IAEA and the Malaysian Nuclear Agency, underscore the importance of interdisciplinary cooperation in preserving cultural heritage. The fusion of nuclear techniques with archaeological conservation promises a new frontier in the stewardship of historical artifacts.

In conclusion, The Jordan Museum not only serves as a guardian of Jordanian heritage but also stands as a testament to the nation's forward-thinking approach in marrying the past with the future through technological innovation. It is a clear reflection of Jordan's dedication to both its history and its progressive strides in scientific research, ensuring that the story of Jordan's rich cultural tapestry is preserved and told for many generations to come.

Application of Nuclear Techniques in Jordan and Preservation of Cultural Heritage Remains in Jordan

Anas Alwaheba, Yosha Alamri

Gamma Irradiation facility, The Jordan museum

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Jordan atomic energy commission was established in 2008, while Jordan research and training reactor was established in 2016. However, Gamma irradiation facility was established in 1994, starting by Gamma cell, while in 2000 IAEA supplied the facility with Industrial Gamma irradiator through TC project. Gamma cell is used to irradiate research samples and small size samples also to calibrate dosimeter systems.

Where Industrial Gamma Irradiator provides sterilization services to medical disposable companies, kidney dialysis units, pharmaceuticals raw materials, veterinary, herbs, spices, and cosmetics.

Not yet Gamma facility used for artifacts preservation nor XRD and XRF techniques used for characterization.

Ion beam analysis facility in Jordan, is a combination of particle-induced X-ray emission (PIXE) and Rutherford backscattering spectrometry (RBS) mainly used for routine analysis in archaeological, bio-medical, geological and environmental sciences.

The Jordan Museum is a national institution that aims at the preservation and presentation of Jordan's cultural heritage. It is Jordan's new national museum of archaeology and history, opened in 2013 and located at the heart of Jordan's capital, where East Amman meets its western half. The museum galleries cover 1.5 million years of Jordanian history and archaeology. Thanks to the Department of Antiquities, the Jordan Museum has, on loan, thousands of objects from all periods and regions of Jordan. The museum's facilities include conservation laboratories and workshop, a research library, photography studio and a large storage area for archaeological and folklore objects.

The collection of The Jordan Museum is divided into the exhibited and the stored objects. These objects are organized by physical material in order to guarantee its conservation. The museum storage, with a total size of more than 2,000 m^2, has been equipped with modern systems to maintain a suitable environment for museum collections, to extinguish fires inside the warehouse, and to protect and secure stored artifacts from damage and theft. As a result of these investments, many foreign expeditions have asked to keep sensitive artifacts discovered during excavations in The Jordan Museum.

ACKNOWLEDGEMENT

Authors would like to acknowledge IAEA and Malaysian Nuclear Agency for arranging this workshop and facilitate exchange information with state members.

3.15 Application of Nanomaterials Nano TiO_2 for Conservation of Cultural Heritage in Iraqi Musuem

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In cultural heritage preservation, the application of advanced materials is revolutionizing how we protect and maintain historical artifacts. Among the materials leading this change is nano-sized titanium dioxide (nano-TiO_2), a compound showing great promise in the conservation efforts within the Iraqi Museum.

Nano-TiO_2 has been successfully synthesized in four distinct crystalline forms: amorphous, anatase, a mixed anatase-rutile phase, and rutile. These forms are tailored through meticulous control of the calcination process, with temperatures ranging from 120 to 900ºC. The characterization of these particles is a complex process involving a suite of analytical techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), X-ray Fluorescence (XRF), Atomic Force Microscopy (AFM), and Fourier-transform infrared spectroscopy (FTIR).

The production methods include the sol-gel and hydrothermal approaches. In the sol-gel process, utilizing titanium tetraisopropoxide (TTIP) in acidic and alkaline media yields spherical particles. Interestingly, in highly acidic conditions, less aggregated and larger TiO_2 particles are formed, whereas in more neutral to basic conditions (pH 7 and 9), the particles are smaller and more prone to agglomerate. The hydrothermal method presents a diverse particle morphology with reduced agglomeration when acetic acid is used, while phosphotungstic acid results in smaller particle sizes and higher agglomeration.

The practical applications of nano-TiO_2 are vast within the conservation domain. Stone artifacts, often victims of environmental weathering and surface erosion, can be protected and consolidated with nanocomposites. Such treatments enhance the stone's resistance to water while maintaining its breathability, a crucial factor in preventing further degradation. These nanocomposites, particularly when integrated with Paraloid B-72, have significantly improved consolidating marble surfaces.

Wood, another common material used throughout history, often discolors and degrades due to exposure to atmospheric conditions and UV radiation. A UV-cured nanocomposite lacquer based on nanoscale TiO_2 has proven effective in shielding wood surfaces from these damaging effects, preserving both the integrity and appearance of the wood.

The preservation of bones and ivory presents its challenges, as these materials comprise minerals, collagen, and water. They are prone to chemical and biological deterioration, which leads to cracking and pulverization. Applying nano-TiO_2 in consolidation processes has shown to be beneficial in mitigating these issues, thereby preserving the structural integrity of archaeological bones and ivory pieces.

Metals, with their susceptibility to environmental corrosion, also benefit from the protective properties of nano-TiO_2 coatings. These coatings form a barrier against the chemical reactions that lead to corrosion, effectively extending the life and preserving the appearance of metal artifacts.

Nano-TiO_2 stands as a testament to the innovative approaches employed in preserving our cultural heritage. These advancements not only maintain the structural integrity of historical objects but also ensure that they can be enjoyed by future generations, providing a tangible link to our past. The intersection of nanotechnology and heritage conservation is a burgeoning field that promises to offer increasingly sophisticated solutions to age-old problems of decay and degradation.


Application of nanomaterials Nano TiO2 for conservation of cultural heritage in iraqi musuem
Dr.Fadhil Abed Allawi.Iraqi Musuem
Different crystalline forms of nano- TiO2 will be prepared by using the sol-gel and hydrothermal methods.
The TiO2 nanoparticles will be characterized by X-ray diffraction, scanning electron microscopy , X-ray Fluorescence (XRF), Atomic Force Microscopy (AFM) and FTIR
XRD for hydrothermal
XRD for sol-gel
AFM
SEM for sol-gel
SEM for hydrothermal
Nano sized titanium dioxide has been successfully produced in four crystalline forms (amorphous, anatase, anatase-rutile and rutile).
X- Ray diffraction pattern showed the formation of four crystalline forms of titanium dioxide at whole studied calcination temperatures from 120 to 900oC.
Application on stone surfaces and conslidation
Environmental weathering and surface erosion are always some of the most prevalent deterioration factors responsible for the decay of most of the stone artefacts and disfigure the surface details beyond reparation.
Nanocomposites have been found more suitable for the purpose of consolidation with improved properties such as permeability to water vapour and at the same time impermeability tiquid water, along with chemical andphotochemical stabilityty.(nano-TiO2) in the Paraloid B-72 network have improved consolidation properties as observed on marble surfaces
The morphology of prepared nano titanium dioxide obtained from AFM analysis and SEM images shows:
A. In sol-gel method with TTIP as source materials acidic and alkaline media the shapes of particles is spherical but in high acidity case the less aggregates and bigger TiO2 particles is formed. The size of particles at higher pH=7, 9 values is smaller and agglomerate.
B. In hydrothermal method Non uniform shape of particles with low agglomeration is observed by using acetic acid. Agglomeration and small particles size is observed by using phosphotungstic acid.
Protective coating for wood
Wood surfaces exposed to atmospheric conditions tend to get discoloured over a period of time due to UV radiation. To protect wood surfaces, nanoscaleTiO2 based UV-cured nanocomposite lacquer has been found to play a significant role.
Application for bone and ivory consolidation
Bones are mainly composed of 60–70 wt% minerals, 20–30 wt%collagen and 10% water. Chemical deterioration of mineral phase, decomposition of collagen and biodeterioration cause cracking and pulverisation of archaeological bones Surrounding atmospheric condition, overall, also plays a vital role in the degradation of archaeological bone surface
Application on metal as protective coating
Application on metal surfaces as protective coating
Most of metals are susceptible to environmental corrosion which occurs as the result of a chemical reaction between the metal and its surrounding.

3.16 Artifacts Obtained from Shipwreck in Iran

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In the exploration of Iran's rich cultural heritage, the nexus between technology and archaeology has yielded a novel approach to the preservation and understanding of antiquities. Notably, the employment of nuclear techniques has shown promise in safeguarding and scrutinizing the remnants of history, though its application has been primarily confined to terrestrial artifacts, such as paintings. Yet, its potential in characterizing and conserving underwater relics, especially those reclaimed from shipwrecks, remains largely untapped.

The Persian Gulf, with its bustling ports and strategic maritime routes, has been a witness to history's ebb and flow. Bushehr port, in particular, serves as a living museum beneath its waters, harboring secrets from bygone eras. The significance of this region extends back to the Sassanid era, as evidenced by the discovery of torpedo-shaped ceramics and pottery, which not only depict the artistic endeavors of the period but also illuminate the extensive commercial networks that thrived along the shores of the Persian Gulf.

This underwater trove, however, is not limited to Sassanid artifacts. The Achaemenid period, another golden age in Iranian history, has also left its indelible mark. A detailed examination of silver artifacts from this epoch, conducted by Oudbashi and Shekofteh in 2015, underscores the sophisticated metallurgical practices of the time. Through techniques such as Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDX), and optical metallography, researchers have been able to decipher the composition and manufacturing processes of these relics, revealing a nuanced understanding of the Achaemenid's craftsmanship.

It is not only the artifacts themselves that tell a tale but also the sunken vessels that once carried them. The northern Persian Gulf's seabed is studded with shipwrecks, silent sentinels of maritime history, many of which date back to the tumultuous years of the Iran-Iraq war. Although the exact count of these sunken ships remains unknown, they are often discovered through the cargo and remnants that have washed ashore or lie shallow beneath the waves. The full extent of these underwater caches has yet to be uncovered, as deepwater surveys have not been conducted, suggesting that a wealth of historical artifacts remains hidden in the depths.

The interplay of archaeological finds from various periods—ranging from the Late Parthian era to the early Islamic centuries—highlights the complexity of Iran's historical narrative. Items such as olive oil, wine, and cereals, once transported in these torpedo-shaped ceramics, speak volumes about the trade practices and economic interconnectivity of the region. Moreover, the presence of bitumen-coated interiors in these vessels offers a glimpse into the ingenuity applied to overcome the challenges of maritime transport.

The discovery of glazed jars and pottery in hues of turquoise and green further enriches our understanding of the Sassanid period. These artifacts not only serve as physical evidence of the Sassanid's artistic expression but also as markers of Iran's historical ties with Arabian, East African, Indian, and East Asian nations.

Despite the richness of the findings, challenges persist. The technology to fully document and preserve these underwater artifacts is yet to be fully implemented. The potential for using nuclear techniques akin to those applied in preserving land-based cultural heritage holds great promise. It beckons a new frontier in archaeological conservation, one that bridges the gap between the ancient and the atomic age.

In summary, Iran's submerged artifacts present a mosaic of historical narratives waiting to be pieced together by the hands of modern science. As we stand on the brink of uncovering these submerged chronicles, the fusion of nuclear science and technology with traditional archaeology could well be the key to unlocking the secrets of Iran's maritime legacy.

IAEA International Atomic Energy Agency Atoms for Peace and Development

Regional Training Course on the Application of Nuclear Techniques for Characterisation and Preservation of Artefacts Obtained from Shipwreck

Malaysian Nuclear Agency (Nuclear Malaysia). Malacca, Malaysia. 23 to 27 October 2023. Ref. No.: TN-RAS1027-2300242

Nuclear Science and Technology Research Institute (NSTRI)

Artefacts Obtained from Shipwreck in Iran

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In our country, the effects of nuclear techniques such as electron beams and gamma rays have been investigated to preserve cultural heritages such as paintings, but nuclear techniques have not yet been used to characterization and preservation of artifacts obtained from shipwreck sites underwater marine environment.

Characterization, conservation and preservation

Oudbashi & Shekofteh (2015), investigated four silver artefacts dated to Achaemenid period, found in Hamedan region, to identify manufacturing/ shaping process as well as alloy composition. The examined objects consist of two bowls, one decorated plate and one decorated spoon with the head of a felidae (Figure 1). SEM-EDX method has been applied on cross section samples to determine chemical composition of the alloys and the phases and optical microscopy (Metallography) and SEM techniques were used to study of microstructure and manufacturing/shaping procedure. The results showed that all samples were made of silver-copper alloys with different amount of copper in each artefact. Other elements have detected in minor/trace contents such as As, Pb, Cd, Al, S. Two-phased microstructure could be observed in two Achaemenian silver bowls because of the high amount of copper in alloy composition. Two other artefacts include single phase microstructure depending on low content of copper in alloy composition.

Figure 1. Four silver objects from Ebn-e Sina Museum, Hamedan, B-1 and B-2: large silver bowls, S-1: spoon with the head of felidae decoration and P-1: silver plate with lob and petal decorations.

Shipwrecks in the northern Persian Gulf are a common feature of the seabed. Shipwrecks are one of the oldest and most abundant man-made structures found all around the world. During the Iran-Iraq war between 1980 and 1988, 400 commercial ships were attacked.

However, the exact number of sunken ships is not known. All discoveries are based on the identification of cargo shipments found in the shallow sea.

Deepwater surveys have not so far been conducted. Therefore, surface-mounted measuring devices used for recording submerged historical shipwreck need to be employed.

Underwater archaeological surveys in the shallow seas off the coast of Bushehr port have brought to light a large variety of Sassanid pottery. But the remains of cargo material, wreckage of ships have not so far been found.

The Bushehr port is a potential region for underwater archaeology. The site is located 500 m from the coastline of the Bushehr port, between the customs wharf and the Bushehr city council building.

Sporadic occurrence of potsherds, some intact pots and apart of stone anchor indicated the presence of a sunken ship near the shores of Bushehr Peninsula. The torpedo shaped pottery, medium-sized crocks with four horizontal handles and a number of medium sized glazed crocks of turquoise colour and a few small vessels were found in the sediment, which suggest that the site can be dated precisely (Figures 2–4).

Figure 2. Discovered torpedo crock from shallow coasts off the Bushehr port.

Figure 3. The monochrome glazed jars, the coast off the Bushehr port.

The torpedo-shaped ceramics belong to the Late Parthian to the end of the Sassanid period. During the first two centuries after the Islamic period valuable liquids such as olive oil, fish salt profit, wine and sometimes cereals were transported from the Iranian ports to the destinations along the Arabian coasts of the Persian Gulf, the Indian subcontinent, East Africa and East Asia. The inside of these ceramics was coated with bitumen to waterproof them. The turquoise glazed and green coloured pottery found at the sites is good evidence to establish links with the Arabian, East African, Indian and East Asian trading nations, suggesting the widespread Sassanid commercial network in the Persian Gulf.

Along with torpedo shaped pottery and stone anchor, another typical pottery of the Sassanid period was the turquoise pottery.

Figure 4. Variety of pottery discovered in the shallow waters off the Bushehr port.

Tofighian H. (2019). Shipwrecks off the Bushehr port in the Persian Gulf. *CURRENT SCIENC.* 117(10): 1690-1692.

Oudbashi and Shekofteh. (2015). Chemical and microstructural analysis of some Achaemenian silver alloy artefacts from Hamedan, western Iran. Periodico di Mineralogia, 84, 3A (Special Issue), 419-434.

3.17 Palestine

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In the heart of the Middle East, the State of Palestine is a testament to the resilience and the rich tapestry of human history, culture, and religious significance. This land, cradled by the Mediterranean and marked by the footsteps of myriad civilizations, bears the indelible marks of the Greek, Roman, Byzantine, Crusader, and Islamic eras, each layer adding to the complex mosaic of its heritage.

The Palestinian Ministry of Tourism and Antiquities, a pillar established with the inception of the Palestinian Authority in 1995, is the guardian of this legacy. The Ministry is a fortress of cultural preservation, housing various departments including Protection, Excavations, Museums, and Restoration, alongside the National Register and several others devoted to nurturing the tourism sector.

The Ministry's endeavors are far-reaching, spanning the protection of ancient sites, overseeing systematic excavations, and the meticulous work of restoration and conservation. These activities are essential in maintaining the integrity of Palestine's cultural assets and in providing a window into the past for both locals and visitors alike. The National Register, maintained by the Ministry, serves as a comprehensive catalog of the country's treasures, ensuring that each artifact, site, and historical narrative is documented, studied, and preserved for future generations.

The religious landmarks dotting the Palestinian landscape are not only of historical and cultural value but also of profound spiritual importance. As the birthplace of the Abrahamic religions, Palestine is a sanctuary for those seeking to connect with a faith that has shaped much of the world's history. The Ministry's role extends to these sacred spaces, upholding their sanctity and ensuring they remain accessible to the faithful from around the globe.

Investing in the cultural heritage sector is also an investment in the future of Palestinian tourism. By preserving the past, the Ministry of Tourism and Antiquities is paving the way for sustainable tourism that educates and inspires. This tourism does not merely seek to show but to tell a story – the story of a land etched with the narratives of countless generations, a crossroads of civilization, and a keeper of sacred chronicles.

The work of Daoud and his colleagues at the Ministry is a continuous dialogue with history, an effort to ensure that the physical remnants of Palestine's past continue to speak to us with clarity and truth. It is a task that requires patience, precision, and a deep respect for the layers of history that make up the fabric of Palestinian identity.

In conclusion, the State of Palestine, through its Ministry of Tourism and Antiquities, stands as a steward of its own narrative, diligently working to conserve its rich historical and cultural inheritance. This is not merely an academic exercise but a vital, living process that reaffirms the Palestinian commitment to their heritage and shares it with the world as a testament to their enduring spirit and the universal value of their legacy.

Palestine | فلسطين

Dome of the Rock and Church of the Holy Sepulcher

Palestine is distinguished by its resilience, history, and rich cultural heritage due to the successive civilizations that have influenced it since the Stone Age, including the Greek, Roman, Byzantine, Crusader, and Islamic eras in all their stages. It also houses some of the most significant religious landmarks in the world, as it is the cradle of the Abrahamic religions.

Palestine
STATE OF PALESTINE
Ministry of Tourism & Antiquities

The Palestinian Ministry of Tourism and Antiquities was established, Museums and Restoration, the National Register, and otherwith the beginning of the establishment of the Palestinian Authority in 1995 .The Ministry contains many general departments and departments, such as the Department of Protection, Excavations departments related to tourism. This institution works in all its sectors to preserve cultural heritage and develop the tourism sector.

Zaid Daoud

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3.18 PIXE Contribution for a Database on Phoenician Pottery

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The quest to unravel the mysteries of the past often leads scholars and archaeologists to probe the ancient relics that have withstood the test of time. Among these relics, pottery is unique, offering information about the cultural, economic, and artistic landscapes of bygone eras. The Phoenician civilization, known for its extensive trade networks and cultural richness, has left behind a trove of ceramic artifacts that intrigue scholars today. A recent study, spearheaded by a collaborative team from the Lebanese Atomic Energy Commission in Beirut and the Institute of Studies on the Ancient Mediterranean, CNR, in Rome, Italy, has made significant strides in expanding our understanding of Phoenician pottery through Particle Induced X-ray Emission (PIXE) analysis.

The study's focal point was to enhance the existing database of chemical compositions of archaeological ceramics. The researchers sought to integrate new data from hinterland sites, mainly targeting the ancient cult place of Kharayeb, located in the rural hinterland of Tyre, southern Lebanon. This site, which dates back to the Persian and Hellenistic periods, offers a unique lens through which the interplay of Hellenistic influences in the Phoenician world can be observed and understood.

PIXE analysis has proven instrumental in characterizing the archaeological pottery from Phoenicia, which has included both hinterland and coastal sites in Lebanon. A notable finding from this research is the high calcium concentration in the pottery, a detail confirmed by thin-section analysis. This elemental signature has helped differentiate between locally produced items and those that may have been imported from coastal regions.

The implications of this research are manifold. Firstly, it addresses whether the figurines and other ceramic items were locally produced or imported, thus providing insights into the economic and cultural dynamics of the region. Secondly, it sheds light on the techniques used in ancient pottery workshops, tracking the evolution from the Iron Age to the Hellenistic period—a time marked by significant changes, such as the introduction of the double mold technique.

Furthermore, the differentiation between Persian and Hellenistic figurines is particularly striking. The study reveals that unlike the Persian figurines, the Hellenistic ones belong to a more consolidated group, indicating a possibly streamlined production process or a narrower range of sources for the raw materials.

The research team's ambition continues beyond the current findings. Plans are underway to extend the study to include other archaeological pottery of Phoenician character from the Mediterranean. This expansion is expected to provide a more comprehensive view of the Phoenician civilization's material culture, offering archaeologists and historians valuable data to decode further the complex tapestry of interactions that defined the Mediterranean in antiquity.

In essence, this academic pursuit stands as a testament to the power of modern analytical techniques in breathing new life into ancient artifacts. By applying PIXE analysis to Phoenician pottery, the team has not only broadened the scope of our existing databases but has also paved the way for future discoveries that will deepen our understanding of historical production processes, trade, and cultural exchange in the Mediterranean region.

PIXE Contribution for a Database on Phoenician Pottery

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Summary

it is proposed to study the Phoenician ancient cult place of Kharayeb, in the rural hinterland of Tyre, southern of Lebanon, dated to Persian and Hellenistic periods. Rural contexts, in fact, are particularly helpful in evaluating the complexity and variability of the so called "Hellenism" and of "Greek cultural influences" in the Phoenician world.

Archaeological Context

Enlarge the existing database, using PIXE, mainly from coastal sites in Lebanon, on chemical composition of archeological ceramics with the implementation of new data, from hinterland this time.

Understand if the figurines were locally produced or imported from the coast and how was the process of production connected to the sanctuary.

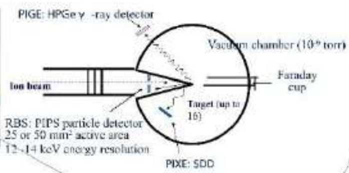
Obtain information about the technique of production of ancient pottery workshops, in view of the transition from the ancient system of production, typical of the Iron Age, to the new system of the Hellenistic period (with the introduction of the double mold technique)

EXPERIMENTAL

Sample preparation

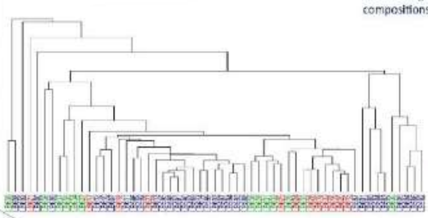
- NEC Pelletron tandem 5SDH: 3 MeV protons induced X-ray emission
- Amptek SDD X-ray detector : 8 µm Be window
- 250 µm Al funny filter
- Total deposited Charge: Q= 7 µC, I ~ 20 nA
- Na, Mg, Al, Si, P, K, Ca, Ti, V, Cr, Mn, Fe
- Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Pb

Accelerator Setup



RESULTS

SampleID	MgO	Al2O3	SiO2	K2O	CaO	TiO2	Fe2O3	Ni	Cu	Zn	Rb	Sr	Zr
LB582	1.19	7.89	24.82	0.85	57.67	0.81	5.46	58	60	91	56	931	115
LB583	1.69	12.94	34.15	1.86	41.70	0.81	5.61	69	433	213	91	1111	110
LB584	1.59	11.48	32.35	1.85	44.69	0.77	5.23	73	466	353	86	1181	125
LB585	1.38	8.24	28.66	1.17	52.87	0.83	4.72	91	499	156	45	1044	113
LB610	1.51	16.21	42.55	1.66	28.17	1.10	7.15	86	34	127	78	742	200
LB611	1.89	16.18	43.17	1.56	28.62	0.95	6.39	68	19	90	62	997	130
LB612	1.58	16.64	40.08	1.52	30.91	0.99	6.93	81	37	121	115	630	223
LB613	1.41	13.43	34.29	1.27	41.42	0.89	6.33	71	25	115	86	803	129
LB614	1.76	15.07	39.54	1.89	32.68	1.11	6.61	70	32	119	102	787	174
LB615	1.57	15.37	43.59	2.38	27.59	0.97	6.53	62	84	149	104	507	171
LB616	1.56	15.30	45.55	2.33	27.29	0.88	6.11	65	26	138	95	579	165
LB617	2.00	14.26	42.62	2.59	30.07	1.03	6.23	67	49	155	108	931	277
LB624	3.05	16.26	50.29	2.46	19.52	0.96	6.48	78	32	164	110	499	125
LB625	1.74	13.09	51.20	2.25	23.27	0.78	5.87	75	79	153	85	705	156
LB626	1.62	15.75	43.54	2.46	27.46	0.90	6.99	101	61	190	110	650	170
LB620	1.57	15.33	41.82	2.53	30.50	0.91	6.09	57	75	154	111	587	161
LB609	0.90	15.26	67.45	1.66	3.42	1.54	8.61	59	26	124	71	178	448
LB638	1.97	13.62	49.87	1.85	24.99	0.87	4.99	51	40	135	87	525	101
LB627	1.59	13.24	51.07	2.21	23.82	0.78	5.15	55	32	101	72	593	310
LB628	1.43	13.62	50.44	2.30	23.62	0.74	5.40	42	27	113	90	651	135
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LB637	1.01	11.48	58.08	1.00	20.10	1.03	6.13	57	32	74	44	592	218



Hierarchical cluster analysis, based on the standardized concentrations of 12 chemical elements, of the studied samples from Kharayeb Phoenician site

Average of elemental concentrations m and standard deviations σ for the main group derived from the statistical cluster analysis. The compositions are in % for the oxides and in ppm for trace elements.

	m	σ	min	max
MgO	1.59	0.40	0.68	3.05
Al2O3	14.51	1.74	11.48	20.62
SiO2	43.79	5.54	11.48	58.08
K2O	1.92	0.49	0.62	2.61
CaO	**29.23**	6.09	17.19	**41.73**
TiO2	0.94	0.14	0.74	1.58
Fe2O3	6.49	0.75	4.99	8.69
Ni	76	17	42	127
Cu	43	23	19	135
Zn	152	59	74	487
Rb	87	21	20	117
				1152
				310

- PIXE analysis was helpful to characterize archeological pottery of Phoenician character
- PIXE contribute to provide valuable information to archeologists, and answered some of their questions
- Enlarge the existing database by the addition of Phoenician pottery and from hinterland archeological sites
- High concentration of Ca, confirmed by thin section analysis
- Unlike the Persian figurines, the Hellenistic ones belong to the formed consolidated group
- This study will be extended to include other archeological pottery of Phoenician character from around the Mediterranean

Thin section of LIB 571 showing quartz grains (in white and grey) with cracking (x10 ; cross polarized light)

3.19 Shipwreck Artifacts in Oman

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Perched at the southeastern edge of the Arabian Peninsula, Oman is a land where the past whispers through the relics submerged in its surrounding waters. The Sea of Oman to the northeast and the Arabian Sea coupled with the Indian Ocean to the southeast have cradled Oman's maritime history, safeguarding its stories beneath waves and tides. Among the most intriguing narratives are those emerging from the shipwrecks off its coasts, particularly from the Al Hallaniyat islands, where an astrolabe tympan disc was recovered—a beacon from the past guiding us through the maritime history of Oman.

This astrolabe tympan disc, a navigational instrument used by ancient mariners to discern the position of the stars and planets, is crafted from leaded bronze and adorned with intricate decorative features. The discovery of such an artifact provides not only a physical connection to Oman's rich seafaring history but also a testament to the advanced technological capabilities of past civilizations.

The conservation of this artifact is a tale of meticulous scientific endeavor. Before its restoration, the disc was stored in tap water at a cool 5°C for two years—a preservative measure to forestall further deterioration. The X-ray examination of the Sultan Qaboos University Hospital's radiography department revealed that although the object had undergone partial mineralization, it retained most of its metallic core. This finding was pivotal, indicating that despite centuries beneath the sea, the disc had not lost its essence and could be restored.

The methodology for conserving such a historically significant artifact had to be as precise as gentle. After the prolonged submersion in tap water, the disc exhibited low chloride levels, an encouraging sign for conservators. Chlorides, often the harbingers of corrosion for metal artifacts retrieved from marine environments, were absent to the extent that after three weeks, the chloride level of the object's solution dropped to 0 ppm. This indicated that the object was ready for the next phase of conservation.

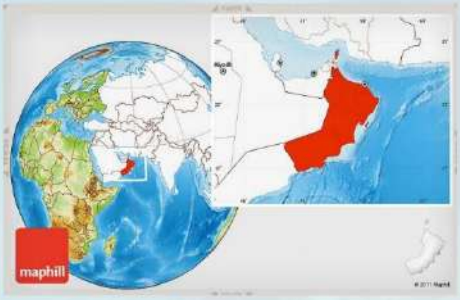
In a final bath of distilled water, the disc was allowed a respite, ensuring any residual chlorides were diffused from the metal, a crucial step to stave off future corrosion. The subsequent stage involved solvent drying in ethanol for one hour. This process was not merely about drying the artifact; it was about protecting it. The ethanol served a dual purpose: it displaced the water to prevent flash corrosion—a rapid rusting that can occur when metals are exposed to air after being submerged for long periods—and prepared the object for mechanical cleaning.

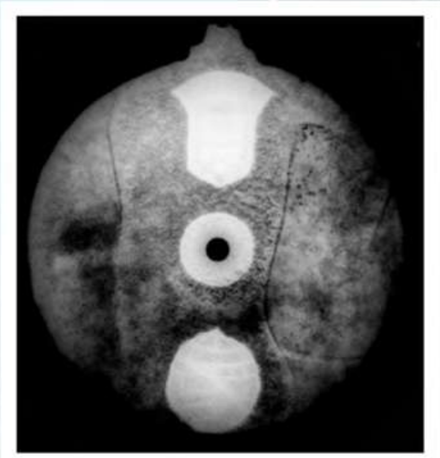
The transition from recovery to restoration is a meticulous process that requires knowledge of ancient artifacts and modern conservation techniques. The astrolabe tympan disc's journey from the oceanic depths to conservation showcases the dedication of Oman to preserving its maritime heritage. It reflects a broader commitment to understanding and safeguarding the artifacts narrating Oman's historical relationship with the sea. Through such painstaking efforts, we are reminded that preserving our cultural heritage is not just about maintaining objects from our past but about understanding the legacy of human ingenuity and ensuring its endurance for future generations to admire and study.

Shipwreck Artifacts in Oman

Oman's location

Oman is situated in the south eastern corner of the Arabian Peninsula. It is surrounded by the sea on two sides, the Sea of Oman to the Northeast and the Arabian Sea and the Indian Ocean to the Southeast.





be X-Ray: 30 seconds at 120kv

Shipwreck artifacts

Astrolabe tympan disc recovered from Al Hallaniyat islands on the coast of Oman. The object was stored in tap water at 5 Co for two years prior to conservation. The object is a leaded bronze tympan disc with decorative features. The object was X-Rayed within Sultan Qaboos university hospital radiography department. X-Ray reveals the object to be partially mineralised but to contain the majority of a metal core.

Conservation Methodology

Following two years in storage the object was found to have low chloride levels. The chloride level of the objects solution dropped to 0ppm after a period of 3 weeks in tap water. The object was then placed in a final bath of distilled water to allow for better diffusion of any residual chlorides. Prior to mechanical cleaning the object was solvent dried in ethanol for one hour to quickly remove water and prevent flash corrosion upon drying.

3.20 Status of Conservation and Characterization of Ancient Cultural Heritage Artifacts in Pakistan

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In the cradle of ancient civilizations, Pakistan holds a tapestry of human history woven over thousands of years. This country's cultural heritage, with its archaeological troves and architectural marvels, forms an unbroken narrative from prehistoric eras to the sophisticated Mughal period. It is a narrative punctuated by the grandeur of *Mohenjo-Daro* and *Harappa*, the spiritual aura of Buddhist monasteries and stupas in the Gandhara region, the elegance of Mughal architecture, and the colonial imprints of British structures.

At the intersection of preservation and study, institutions like the Pakistan Institute of Nuclear Science and Technology (PINSTECH) and the Department of Archaeology and Museums (DOAM) are custodians of this legacy. They are not merely conserving artifacts but are also deciphering their stories through advanced scientific methods.

Recently, through the collaboration under the RAS/1027 project, a significant stride was made with the signing of a Memorandum of Understanding (MOU) between DOAM and PINSTECH on 23 September 2022. This partnership has propelled nuclear science in analysing and preserving heritage artifacts, bringing to light the elemental compositions of objects that once adorned the ancient Indus Valley or the revered halls of Gandhara.

In the bustling capital city of Islamabad, within the walls of the DOAM Museum, handheld XRF (X-ray fluorescence) devices have meticulously scanned about 30 ancient artifacts. This non-destructive technology peels back the layers of time, revealing the elemental makeup of these historical treasures without causing any damage.

The scientific endeavors at PINSTECH are not confined to the museum's corridors. The institute has a 10 MW swimming pool-type reactor, PARR-I, and a 27 kW tank-in-pool type reactor, PARR-II, with a 10-20 MW PARR-III under construction. These facilities enable a range of studies, from carbon dating, which determines the age of archaeological finds, to X-ray and neutron radiography, which unveil the internal structures of these silent sentinels of history.

The first Workshop on Conservation Science, held in June 2023, became a confluence of knowledge and expertise. With distinguished talks delivered, the event illuminated the path for the future preservation of cultural artifacts. The exchange of expertise was further enriched by the visit of Korean experts from the Korea Cultural Heritage Foundation (KCHF) and DOAM members to PINSTECH, marking a day of international cooperation and shared commitment to heritage conservation.

Looking ahead, PINSTECH plans to extend its analytical prowess to the study of ancient coins and other artifacts, ensuring that even the smallest piece of history is given a voice. The institute also emphasizes the preservation of paper, an often overlooked but crucial carrier of historical knowledge.

Pakistan's journey in heritage conservation is a testament to its reverence for the past. It is a commitment set in stone and metal, in the molecules of paper and the contours of coins—a promise to safeguard the echoes of ancient wisdom for generations to come.


STATUS OF CONSERVATION AND CHARACTERIZATION OF ANCIENT CULTURAL HERITAGE ARTEFACTS IN PAKISTAN
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[2]Department of Archaeology and Museums (DOAM), Government of Pakistan, Islamabad, Pakistan
Pakistan at a Glance
Pakistan's cultural heritage dates from prehistoric era to recent times. These include;
The archaeological remains of Mohenjo-daro, Harappa and several other sites from the Indus Valley Civilization (3000 to 1500 BC)
The archaeological remains of Buddhist Monasteries & Stuppas in the Ghandhara region (500 BC to 500 AD) at Taxila
Mughal Gardens, Forts and Tombs (900 to 1500 AD)
Buildings and structures of British period
Shah Jahan Mosque (1647 CE)
Badshahi Mosque (1673 CE)
Tentative Sites
Mehargarh (7000 to 2600 BC)
Harrapa (7000-2500 CE)
CHINA
AFGHANISTAN
IRAN
INDIA
ARABIAN SEA
PINSTECH
Research Reactors
10 MW swimming pool type reactor, PARR-I
27 kW tank in pool type reactor, PARR –II
10-20 MW PARR-III under construction
Facilities with Reference to Heritage Studies
Carbon – dating facility
X-ray and Neutron Radiography
X-ray Fluorescence Spectroscopy and various destructive analytical techniques
About RAS/1027 Project
Project Outcomes
Signed an MOU with the Department of Archeology and Museums (DOAM) Islamabad on 23 September, 2022.
Two talks delivered at the 1st Workshop on Conservation Science, 12th to 16th June 2023 at DOAM, Islamabad.
Visit of 2 Korean experts from Korea Cultural Heritage Foundation (KCHF) and 2 DOAM members to PINSTECH on 15 June, 2023.
DOAM
Knowledge of Pakistani heritage
Museum with Pakistani artefacts
Laboratory with conventional testing/ conservation facilities
Future Proposed Activities
Analysis of coins and other artefacts
Paper preservation
Some Recent Activities
Analysis of ~30 ancient artefacts on display at the DOAM Museum in Islamabad was performed using handheld XRF
Sword (17-18th Century CE.)
Total Composition = 100%
Door Knocker (8th Century C.E.)
Door Knocker (Face)
Door knoker's side
Total Composition = 100%
(Lewis Light Machine Gun, 19th CENT. CE)
Machine Gun
Total Composition = 100%
Pottery
Glazed Jar
Total Composition = 33.4%
Rest of the compositions may be oxides or hydrides or low Z elements
Stone Tools
Hand Axe
Polishing tool
Total Composition = 43.4 %
Rest of the compositions may be oxides or hydrides or low Z elements
Total Composition = 60.7 %
Rest of the compositions may be oxides or hydrides or low Z elements
Ancient Axe
Kulhari
Total Composition = 99.61 %
Regional Training Course on the "Application of Nuclear Techniques for Characterization and Preservation of Artefacts Obtained from Shipwreck", Malacca, Malaysia, 23 to 27 Oct, 2023

CHAPTER 4

CONCLUDING REMARKS

4. CONCLUDING REMARKS

As we conclude this comprehensive exploration, it is evident that our journey through the multifaceted landscape of nuclear technology, cultural heritage, and preservation has unveiled an extraordinary tapestry of human ingenuity and collaboration.

The backdrop of nuclear technology, which has evolved over a century of remarkable achievements, spans diverse domains from energy production to advanced medical treatments and materials characterization. What was once shrouded in enigma and elusiveness has become an accessible frontier of scientific exploration. Nuclear technology's enduring legacy lies in its ability to redefine the boundaries of what is possible, with each milestone carving new pathways for innovation and discovery.

This book has skilfully illuminated one of the lesser-known and rarely-discussed applications of nuclear technology - the safeguarding and unravelling of our cultural heritage, primarily solid artifacts. These artifacts, ranging from pottery to ancient ships and archaeological sites, bear silent witness to the rich tapestry of human history. Many of these relics, shrouded in antiquity, have remained tantalising puzzles due to the constraints of earlier technologies, which limited our comprehensive understanding of their historical significance.

The proliferation of nuclear technology and its associated techniques has heralded a profound transformation, infusing what were once unremarkable relics with deep historical significance. X-rays, gamma rays, and neutron sources have emerged as revelation tools, capable of dissecting artifacts down to their minutiae, enabling a deeper understanding of our ancestral societies and the echoes of their existence.

The power of nuclear techniques goes beyond mere observation. They stand as vigilant custodians against the relentless passage of time and the corrosive forces of bacteria and fungi, threatening to erode our invaluable artifacts' delicate surfaces. Through nuclear interventions, we have acquired the means to protect and prolong the life of these fragile treasures.

Moreover, nuclear techniques have assumed the role of artful restoration, breathing life into damaged relics. This restoration serves as a window into the innovative minds of our forebears and helps us piece together the jigsaw puzzle of our history, enabling us to bridge the temporal gap that separates us from ancient civilisations.

Perhaps one of the most inspiring revelations of this book is the harmonious coexistence of scientific and artistic realms. Traditionally perceived as disparate disciplines, the collaboration between scholars straddling both worlds underscores the limitless possibilities that unfold when we embrace the fusion of expertise. Historians, scientists, archaeologists, and artists have synergised their knowledge and skills, orchestrating the revival of our past and offering all an enthralling invitation to explore and appreciate the treasures preserved for generations to come.

Furthermore, we have journeyed through the intricate world of cultural heritage characterization and preservation, a domain illuminated by the intellectual crucible of the IAEA-sponsored workshop. This chapter has informed us of techniques and methodologies and immersed us in the fascinating maritime history of the Malay Peninsula, teeming with shipwrecks, each harbouring its own stories of seafaring civilisations and trade routes.

4. CONCLUDING REMARKS

The chapters have underscored the pivotal role of nuclear sources and techniques. These essential tools have unlocked the concealed details of these relics. The precision and care with which gamma rays, neutrons, and X-rays have been employed have enabled us to transcend the boundaries of time, presenting us with profound insights into our past societies.

The subsequent sections of this chapter have delved into the preservation of geoarchaeological sites, ceramic potteries, and waterlogged wood, each boasting its own set of challenges and rewards. Through the discerning lenses of nuclear and imaging techniques, we acknowledge the historical significance of these artifacts and witness the scientific prowess that underscores the preservation efforts.

Lastly, this book has taken us on a global tour of current cultural heritage characterization and preservation efforts by countries with rich and diverse legacies. From the Southeast Asian nations of Bangladesh, Cambodia, Indonesia, Malaysia, and the Philippines to the Middle Eastern regions of Iran, Iraq, Jordan, Lebanon, Oman, and Palestine, and even to European nations like France, these countries have shared their unique approaches to safeguarding their cultural treasures. This chapter provides a window into the fascinating and dynamic world of cultural heritage characterization and preservation, underlining the dedication and commitment of these nations to protect their historical riches for future generations.

This book invites us to celebrate the nexus of nuclear technology, art, and cultural heritage. It beckons us to recognise the power of collaboration, innovation, and unyielding dedication to preserving our collective history. As the final chapter of our exploration, let it serve as a conclusion and a call to action - a reminder of the immense value of our cultural heritage and the inspiration to continue the voyage of discovery, preservation, and appreciation for future generations. It is a testament to the enduring power of human curiosity and the indomitable spirit of exploration that has brought us this far and will continue to guide us into the future.

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