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Scientific Methods for Preserving Archaeological Metal Artifacts in Egyptian Museum Environments.

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ABSTRACT

This research studied the significance of protecting metal artifacts in museums due to their cultural value and the challenges they face from environmental and chemical factors that cause deterioration. Types of Metal Artifacts include gold, silver, copper, bronze, iron, electrum, and platinum, each metal has different levels of resistance to corrosion. Gold and platinum were more resistant, while copper, bronze, and iron are more prone to rust and patina formation. Factors affecting deterioration include humidity, temperature, air pollutants, human contact, light (especially UV) and biological factors like microorganisms, all of them cause oxidation, corrosion, and surface damage. Preservation Methods involve controlling the environment (humidity, temperature), using protective packaging and coatings, ensuring safe display conditions, and performing regular inspections with advanced technologies like microscopes and X-rays. Cleaning techniques range from mechanical and laser cleaning to careful chemical treatments to remove dirty spots, rust, and corrosion without damaging the artifacts. Modern protective methods include Nano coatings, ultrasonic cleaning, and electronic devices like X-rays to assess and treat corrosion.

INTRODUCTION:

Ancient metal artifacts are crucial cultural heritage items that require special care due to their sensitivity to environmental and chemical factors that cause deterioration **Dardes (1998),** these artifacts widely housed in museums are among the most vulnerable to damage over time, Key types of metal artifacts include:

1. Gold: Highly resistant to corrosion, used in royal jewelry, funerary masks, and religious items, making it one of the most chemically stable metals.
2. Silver: Less resistant than gold, Silver tarnishes and forms a dark layer due to reactions with sulfates and exposure to acidic environments.
3. Copper and Bronze: Used in tools, weapons, and statues, these metals corrode easily when exposed to moisture and pollutants, leading to the formation of a patina.

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4. Iron: Susceptible to rust, especially in humid conditions, and was used for tools and weapons in ancient Egypt.
5. Electrum: An alloy of gold and silver, used in jewelry and coins, which has moderate resistance to degradation.
6. Platinum: Rare and highly resistant to corrosion, used in special tools or jewelry, These artifacts face deterioration from pollution, humidity, temperature fluctuations, and human contact, preserving them requires scientific methods to extend their lifespan and prevent degradation, this research will explore the scientific methods used for preserving ancient metal artifacts in museums, focusing on preventive and treatment techniques, including modern technologies.

MATERIAL AND METHODS

The metal artifacts in this paper

Metal Artifacts: A variety of metals including bronze, iron, silver, gold, copper alloys, and steel from different historical periods, sourced from museums, archaeological sites, and archives **Cronyn (1990).**

Preservatives and Chemical Treatments:

Preservatives and Chemical Treatments: Inorganic chemicals for corrosion neutralization (e.g., calcium hydroxide), organic solvents for cleaning (e.g., ethanol, acetone), protective coatings, anti-corrosion agents (e.g., benzotriazole for copper), and desiccants for humidity control **Fahmy (1998).**

Environmental Control Systems:

Environmental control with HVAC Systems: Climate-controlled environments, UV light filters, and controlled lighting to prevent oxidation.

Diagnostic Tools:

Diagnostic Tools: Scanning electron microscopy (SEM), X-ray fluorescence (XRF), Fourier-transform infrared spectroscopy (FTIR), electrochemical testing, and optical microscopy for condition assessment and corrosion analysis.

Materials for Rehousing:

Materials for Rehousing: Archival-quality storage materials such as acid-free boxes, tissue paper, and padded materials, along with custom-built supports to prevent damage.

Steps for stopping the metal corrosion

1. Collection and Categorization: Selection and categorization of artifacts based on material, corrosion type, and historical context.
2. Condition Assessment: Initial evaluation of artifact condition using diagnostic tools (XRF, SEM), documenting physical state and corrosion level.
3. Treatment Application: Cleaning methods (mechanical or chemical) and application of anti-corrosion treatments to stabilize artifacts.
4. Environmental Control: **Bradley and Daniels (1993).** Storing artifacts in climate-controlled environments with regular monitoring, using desiccants and UV filters to minimize deterioration.
5. Post-Treatment Evaluation **Turgoose (1982).** Reassessing the condition of artifacts after treatment, using the same diagnostic tools to evaluate the effectiveness of preservation methods.
6. Long-Term Monitoring: Continuous monitoring to track changes in artifact condition, with periodic re-evaluation and adjustment of treatments.

The research integrates advanced scientific methods with traditional preservation techniques to identify the most effective ways to protect metal artifacts from degradation in museum settings.

RESULT AND DISCUSSION

Factors Affecting the Deterioration of Metal Artifacts

Climate change is one of the most pressing global issues of our time, placing it at the forefront of all international and regional agendas. Climate action has become a direct part of the Sustainable Development Goals, specifically Goal 13, and indirectly impacts the deterioration and damage of archaeological metal artifacts.

In the case of Egypt, studies at both local and international levels highlight extreme weather events (heatwaves, flash floods, and sandstorms) as well as rising sea levels as the most significant negative effects of climate change on the country. The museum environment is sensitive for preserving artifacts, particularly metal items Therefore, it is crucial to understand the specific factors that influence metals, the following are the main factors affecting these artifacts:

1. Relative Humidity: Fluctuations in relative humidity levels are among the most significant factors leading to the deterioration of metal artifacts, High humidity reacts with metals, accelerating oxidation and corrosion processes, the optimal humidity level for preserving metals in museums is between 35-55%.

2. Temperature: Sudden changes in temperature affect the structure of metals, as thermal expansion and contraction weaken the metal's structure, which may cause micro cracks that accelerate corrosion, Thus, it is recommended to maintain stable temperatures that do not vary more than ±2°C from the ideal level.
3. Air Pollutants: Harmful gases such as sulfur dioxide, nitrogen oxides, and chloride ions react with metals to form chemical compounds that cause surface corrosion, the presence of these pollutants accelerates the degradation of copper, bronze, and silver, Therefore, air filtration systems and airtight display cases are recommended.
4. Human Contact: Human contact introduces natural skin oils and fats, which can lead to chemical reactions on the metal's surface, causing chemical corrosion, unwanted stains, or corrosion layers. Thus, wearing gloves when handling artifacts is essential.
5. Light: Light, especially ultraviolet rays, can cause chemical changes in some metals, such as silver, leading to a loss of their natural luster, Therefore, low-intensity lighting systems (less than 50 lux) and UV filters are recommended.
6. Biological Factors: Microorganisms such as bacteria and fungi can attack the surface of metal artifacts, particularly in humid environments, these organisms secrete acidic substances that accelerate metal corrosion, Therefore, it is recommended to provide a dry environment and regularly monitor humidity levels.

Scientific Methods for Preserving Metal Artifacts in the Museum Environment

There are a variety of scientific methods used in museums to protect metal artifacts from damage, these methods include:

1. Environmental Control:

Regulating Relative Humidity: Relative humidity should be maintained between 35% and 55% in storage rooms or exhibition areas for metals. This can be achieved using dehumidifiers or air conditioning systems.
Controlling Temperature: A stable temperature between 18-22°C should be maintained using temperature control devices to prevent sudden changes.
Air Filtration and Purification: It is essential to use air purification systems to eliminate gaseous pollutants, such as activated carbon filters and other modern scientific techniques.

2. Preventive Conservation Methods:

Safe Packaging: Packaging metal artifacts using chemically inert materials (such as polyethylene, Japanese paper, Tyvek, and other suitable materials) is one of the primary methods for protecting them from interaction with the surrounding environment **Blades et al (2000).**
Using Desiccants: Placing desiccant bags (like silica gel) alongside metal artifacts inside display cabinets helps to reduce their exposure to excess moisture.

3. Surface Protection:

Watkinson and Lewis (2005). In some cases, artifacts are isolated using thin layers of special wax, such as microcrystalline wax, to protect the metal surface from harmful environmental effects and corrosion, Metals can also be coated with a corrosion-resistant layer, such as acrylic resin, after performing durability tests.

4. Implementing Secure Display Methods:

Placing metal artifacts in airtight display cases equipped with moisture-absorbing materials like silica gel.
Using light isolation systems to avoid the impact of excessive lighting.

5. Conservation Treatments:

Restoring metal artifacts involves precise scientific methodologies aimed at preserving the integrity of the original materials and minimizing damage caused by environmental or temporal factors, in recent years, advanced techniques have emerged that significantly contribute to the preservation of ancient metal artifacts, including:

Periodic Monitoring:

Conducting regular inspections using microscopes and modern analytical techniques such as X-ray fluorescence (XRF) to monitor the development of any corrosion or damage., Spectral imaging and 3D scanning are also recommended for documenting the original state of the artifacts.

6. Study and Documentation:

Before starting the restoration process, the artifact's condition is documented in detail, including all dimensions, damage, and surface characteristics.
Using photographic imaging and X-ray or infrared (IR) imaging techniques to identify cracks or internal defects **Turgoose (1982).**
Analyzing metal elements using techniques such as XRF spectroscopy to determine the composition of metal alloys.
Relying on thermal imaging technology to identify weak areas in the metal structure.

7. Cleaning:

These methods vary depending on the type of metal (bronze, iron, gold, silver) and the current condition of the artifact, Therefore, a treatment plan must be established based on a precise evaluation of the condition, which can generally be implemented as follows **International Council of Museums - Committee for Conservation (ICOM-CC) (2010).**

Mechanical Cleaning:

This includes using fine tools (scalpels and fine needles, soft brushes, and rough brushes) to remove surface dirt and impurities, in some cases, automated equipment and devices are used, as removing rust layers from ancient metal artifacts may require precise techniques and devices to preserve the artifact's integrity without causing damage, the most important tools and methods used in this field include:
Laser Cleaning: This technique is used to remove unwanted calcifications and layers with high precision without affecting the original metal surface.
Manual Precision Tools:
Scalpels and Tweezers: Used to gently remove surface rust layers.
Soft Toothbrushes: Utilized for removing rust residues in a manner that does not harm the metal surface.
Precision Drilling Tools: Such as miniature cleaning tools for gradually removing hardened rust.

Mechanical Devices:

Precision Rotary Drills: Used to remove rust from small and complex areas.
Vibratory Tools: Employed to remove deep rust layers without damaging the artifact, Vibratory tools are crucial for rust removal from ancient metal artifacts, especially when there is a need to gently eliminate rust layers without harming the surface.
Below are some examples of the devices used in this field:
1. Micro Chisels:
These tools are used to remove rust from delicate and complex areas. Examples include the Micro Chisel Set and Micro-Jack Tools, which offer high control when removing unwanted materials.
2. Vibratory Engraving Pens:
These tools are used for precise engraving and rust removal in small areas. Examples include the Dremel Engraver, which features an interchangeable head suitable for different metal types, and the Graver Max, which utilizes micro-pulse technology for engraving.
3. Multi-Tool Rotary Engravers:
The speed of these devices can be adjusted to match the nature of the rust and the type of metal. Examples include the Proxxon IBS/E Rotary Tool, a versatile tool that allows for precise control during rust removal, and the Foredom Rotary Tool, equipped with a vibratory handle designed for delicate work on sensitive surfaces.
4. Pulse Tools:
These tools operate using alternating vibration technology to gradually remove rust layers. Examples include the Chicago Pneumatic CP9160, which provides balanced control during rust removal, and the Nitto Kohki Air Sonic, a pulse device used to remove hardened rust and dirt layers from metal surfaces.

High-Frequency Ultrasonic Devices:

Ultrasonic scalers utilize ultrasonic waves to generate fine vibrations that remove rust without direct contact **Salazar, et al. (2020).** Some examples include:
Elma Ultrasonic Device: Typically used for cleaning sensitive metals.
FARO Ultrasonic Cleaning System: An advanced system that uses ultrasonic waves for cleaning.
These devices vary in their ability to adapt to delicate surfaces. Therefore, it is recommended to use them cautiously and under the supervision of a specialist in artifact restoration to ensure the preservation of historical items **Romanengo, et al. (2020)**.
Electrochemical Techniques:
This method is used to remove rust from ferrous metals by passing a low electrical current, which breaks down oxides, this technique is effective in restoring the luster of metals without compromising the original layers.

Chemical Techniques:

This method employs diluted chemical solutions to remove metal oxides (rust layers and compounds) with extreme caution and prior testing to prevent harmful reactions, removing rust from ancient metal artifacts using chemical solutions is a delicate process that requires careful selection of materials to maintain the integrity of the artifact and prevent any undesirable reactions, Chemical solutions are used to dissolve and break down rust layers without affecting the original metal. Examples of these solutions include:
1. Oxalic Acid: $C_2H_2O_4$.
Used at low concentrations (usually between 2-5%) to remove rust from iron, copper, and bronze surfaces.
2. Tannic Acid: $C_7H_6O_6$.
Used to stabilize and reduce the rate of iron rusting by converting iron oxide into a chemically stable and inert compound, thus preventing future metal corrosion.
3. Ethylene diamine tetra acetic Acid (EDTA): $C_{10}H_{16}N_2O_8$
Works as a chelating agent that removes rust layers from metals without damaging the surface, making it suitable for sensitive metals like bronze and copper.
4. Citric Acid: $C_6H_8O_7$

Used at low concentrations to remove light rust layers.
5. Phosphoric Acid: H_3PO_4.
Converts rust (iron oxide) into iron phosphate, a stable and inert compound.
6. Sodium Hexa meta phosphate (SHMP): $(NaPO_3)_6$
Used to remove hardened rust from iron surfaces. It is suitable for high-value artifacts as it gently removes rust without damaging the surface.

Chemical Inhibitor Solutions:

These solutions are added to water or other chemical substances to reduce the corrosion effect on the metal surface. Examples include:
Benzotriazole: Used with copper and bronze metals to minimize corrosive reactions.
Diluted Bicarbonate Solutions: Utilized for rust cleaning by reacting with oxides to produce easily removable compounds.

Nano coating:

This method involves applying transparent, Nano-scale protective layers that shield the metal from corrosion without altering its original appearance, it is commonly used on precious metals such as gold and silver.
Recently, it has become possible to fabricate nanoparticles from metals, insulators, semiconductors, and hybrid structures (such as coated nanoparticles), as well as semi-solid nanoparticles like liposomes, Other forms of nanoparticles include semiconductor quantum dots and nanocrystals.
Copper nanoparticles, with sizes less than 50 nanometers, exhibit high hardness and are neither malleable nor ductile, unlike conventional copper, which can be easily bent, hammered, and drawn. These nanoparticles can be utilized in the restoration and conservation of metal artifacts, particularly in reinforcement, strengthening, and completing missing parts.

Electrochemical Cleaning:

This technique involves passing a moderate electrical current to convert harmful metal oxides back to their original elements, such as reducing rust in iron, it is only applied in specific cases when the artifact is at high risk of degradation.
Overall, these solutions must be used with extreme caution and under the supervision of specialized conservators to prevent any unwanted reactions or damage to the artifacts.

Physical Techniques:

Ultrasonic Cleaning: Removes dirt and rust using vibrations that reach fine cracks.
Laser Cleaning: Carefully removes rust layers without directly touching the artifact's surface.
Compressed Air or Fine Particle Cleaning: Used cautiously on non-decorative areas.

Corrosion Removal:

In cases where there is severe corrosion or thick rust layers, these are carefully removed using precise mechanical tools until only a light surface layer remains (patina), This layer is then removed using appropriate chemical agents **North and MacLeod (1987).**

Electronic Devices:

X-Ray Examination Devices: Used to determine the depth of rust and assess the metal's condition beneath the surface, X-Ray Fluorescence Spectroscopy (XRF) techniques are also employed to determine the metal composition and gain a thorough understanding of its structure, aiding in selecting the most suitable restoration materials.
Microscopic Analysis (Spectroscopy): Identifies the nature of corrosion and the metals involved in rust formation.

Electroplating:

In some cases, the metal artifacts are re-coated with thin layers of metal (such as gold or silver) using the electroplating process, this is applied in very limited circumstances and follows strict guidelines, it is only performed in cases of severe damage to the artifact, aiming to preserve its historical, artistic, and material value without causing any changes that would lead to the loss of the artifact's identity.

Treatment and Stabilization:

Stabilizing the Condition: After cleaning, the artifact's condition is stabilized using special materials that prevent further metal reactions with environmental factors.
Protective Coating: Applying layers of protective materials, such as specialized wax or polymers, to create a barrier that prevents future corrosion.

Structural Damage Repair:

Welding and Reinforcement: Precision welding techniques (e.g., laser welding) are used to repair cracks or fractures while preserving the material and authenticity of the artifact **Scott (2002).**
Internal Reinforcement: Installing internal supports made from materials compatible with the original metal to strengthen fragile parts.

Aesthetic Restoration:

Partial Renewal: Reconstructing missing or eroded parts using compatible materials, ensuring that the original shape of the piece remains unchanged.
Color Matching and Visual Integration: Using special pigments or coloring agents to unify colors and mask discrepancies without compromising the artifact's historical value.

Storage and Display:

Environmental Control: Artifacts should be stored and displayed in a controlled environment with stable temperature and humidity levels to prevent corrosion or deterioration.
Proper Packaging: Using specially designed containers to isolate the metal artifacts from environmental pollutants and chemical reactions.

Museum Display and Preservation Methods:

The purpose of preventive conservation, to minimize the occurrence of mechanical, physicochemical, human, or biological activities that may lead to the deterioration of museum collections, before implementing preventive conservation measures on museum collections, it is essential to assess the museum in terms of its location, design, and the risks affecting it, there is no doubt that the Preventive conservation is the first step in preserving bronze archaeological artifacts, It involves taking measures to maintain artifacts in their current condition and preventing further degradation:
Careful Handling and Proper Handling Techniques: Metal artifacts should be handled using gloves and tongs when necessary, avoiding direct hand contact.

Environmental Monitoring:

Relative Humidity: Maintain a relative humidity range of 35% to 55%. Low humidity causes the binding material on the surface to dry out, while high humidity increases chemical reactions.
Temperature Stability: The temperature should remain stable, ideally between 18-22°C, to reduce expansion and contraction.
By implementing these methods, museums can ensure that metal artifacts are preserved in optimal conditions, minimizing the risk of further damage or deterioration.

Air Purification Systems:

It is recommended to use air filtration systems equipped with activated carbon filters to remove harmful gases such as sulfur dioxide and hydrogen chloride.
Lighting Control:
Avoiding Excessive Lighting: Metal artifacts should not be exposed to intense lighting or ultraviolet (UV) rays, as these can accelerate chemical deterioration.
Specific Lighting Techniques: Certain lighting techniques should be employed to preserve archaeological metal artifacts and enhance the visual experience for museum visitors:
Natural Light: Direct exposure to sunlight should be avoided, as UV rays can cause metal pieces to degrade. It is preferable to use windows with UV filters.
Artificial Light: LED lights are an excellent choice because they consume less energy and produce less heat, thereby reducing the risk of damage to artifacts.
Spotlights: These can be used to highlight specific pieces, but care should be taken not to direct them at the artifacts for extended periods.
Backlighting: This can create an appealing visual effect, but caution should be exercised when using it on metal materials that may be affected by heat or radiation.
Lighting Distribution: It is important to distribute lighting evenly to enhance visibility from all angles of the piece.
Changing Lighting: Periodically changing angles or levels of lighting can help avoid the effects of constant exposure on metal artifacts.
Controlling Light Intensity: Systems should be in place to adjust light intensity as needed, especially during periods when visitors are not present.
Low Lighting: Using low light levels is preferable to minimize harmful effects on metals, as high illumination can lead to chemical reactions that may damage metal artifacts.
Backlighting for Visual Depth: Backlighting can enhance the overall form of bronze pieces, giving them visual depth and making them more appealing to visitors.
Proper Storage:
Metal artifacts should be stored in boxes covered with acid-free materials, It is preferable to use materials such as polyethylene or polypropylene to avoid any chemical reaction with the metal surface.
Sealed Display Cases: These should be designed to be airtight to minimize exposure to environmental pollutants, Humidity levels inside the display cases can be controlled using moisture-absorbing materials.
By implementing these practices, museums can effectively preserve metal artifacts while enhancing their presentation to the public.

Modern Technology in Preserving Archaeological Metal Artifacts:

The field of preserving archaeological metal artifacts is witnessing notable advancements through the use of modern techniques **Selwyn (2004).**, including:

Use of Nanotechnology: Nano materials are being developed to protect metals from corrosion by forming ultra-thin protective layers.
3D Printing: This technology is used to precisely reproduce missing parts of archaeological metal artifacts, contributing to the preservation of original shapes without affecting the original piece.
Advanced Spectral Imaging: Techniques such as infrared imaging is utilized to analyze and identify layers of corrosion and rust, aiding in the design of precise treatment strategies.
Use of Freezing Preservation Techniques: This is one of the latest technologies used to preserve metals that have suffered biological damage, where the artifact is frozen at low temperatures to kill microorganisms.

The Application of Artificial Intelligence (AI) Technologies in the Preservation of Metal Artifacts:

AI is effectively used in archaeological museums to preserve metal artifacts through various technological applications that rely on artificial intelligence, automation, and digitization. These systems contribute to improving documentation, preservation, and analysis of artifacts, some examples of these applications include the use of 3D scanning systems, advanced imaging, and smart tracking systems for the condition of metal pieces, which enhance the digital preservation process and prolong the lifespan of artifacts.
The use of AI technologies in preserving archaeological metal artifacts in museum environments represents an innovative solution in this field, providing advanced tools for imaging artifacts using 3D techniques, helping to create accurate digital models of metal artifacts without needing to touch the original pieces. It also offers sophisticated tools that contribute to assessing the condition of artifacts, identifying risks, and suggesting appropriate protection strategies, the most important of which include:
1. Environmental Data Analysis: AI systems are used to analyze data on humidity, temperature, and the concentration of harmful gases (such as sulfur dioxide), helping to understand the environment surrounding the artifacts. They are also used to analyze data related to the condition of metallic materials, such as corrosion, by integrating advanced sensors and machine learning techniques. These systems provide the capability to predict the impact of damaging factors and forces on metallic artifacts over time, causing degradation of the pieces, thus aiding in timely preventive measures.

2. Damage Diagnosis:

Insect damage

It is known that beetles in general cannot chew metal. However, some insects may can make small holes in soft metals such as aluminum through nesting behavior or other means, but they do not feed on it like wood or do damage like they do with plastic. Generally, some hard beetles may cause scratches in metal during its movement.
Machine learning can be used to analyze digital images of metal artifacts and identify signs of corrosion or deterioration, This technique provides high accuracy in detecting small changes that may not be visible to the naked eye.
3. Risk Management and Prioritization:
Artificial intelligence can rank artifacts according to their level of exposure to risks, making it easier for museum staff to prioritize maintenance, These technologies can also develop protection and maintenance plans based on historical and environmental data analysis.
4. Artifact Recognition and Classification:
AI is used for the automatic recognition of metal types and the techniques used in their manufacture by analyzing spectral and chemical data, This contributes to accurate classification of artifacts and aids in making informed decisions regarding their preservation, Additionally, AI technologies are employed in managing archaeological collections using big data analytics to improve the organization and display of items, Furthermore, deep learning techniques can be used for classifying and indexing artifacts, making them more accessible and interactive for researchers and visitors.
6. Recommending Appropriate Preservation Methods:
Intelligent systems analyze material data and recommend the best preservation methods, such as controlling humidity levels or using specific packaging materials. AI technologies can suggest optimal storage conditions based on continuous analysis of the surrounding environment **Barceló (2008).**
Some Examples of AI Applications in Preserving Metal Artifacts:
1. CHIRON Project: A European research project that uses artificial intelligence to assess and document the condition of archaeological metal artifacts and provide tools for museum maintenance.
2. Augmented Reality (AR) Technologies: These are used to train museum staff in handling artifacts by simulating different scenarios for preserving metal pieces.
3. Use of Intelligent Robots **Thrun, et al (1998).** Robots equipped with AI technologies can perform cleaning and precise restoration operations, reducing human errors.
Challenges Facing the Use of Artificial Intelligence:
1. Need for Accurate Data: AI techniques rely on the availability of accurate and comprehensive data, which can be challenging for ancient artifacts.
2. High Costs: The costs of developing and implementing intelligent systems in museums can be high, limiting their widespread adoption.

3. Training and Development Challenges: Museum staff need specialized training to effectively understand and apply AI techniques.

CONCLUSION

Preserving archaeological metal artifacts presents a significant challenge in the museum environment, as it is necessary to balance the preservation of pieces in a way that ensures their long-term stability with their display in a manner that highlights their aesthetic and historical value. This requires the use of various techniques and precise scientific methods, along with maintaining an ideal museum environment suitable for the nature of the metal.

Increased research and development in this field are recommended to achieve more effective and sustainable solutions for protecting cultural heritage, the use of artificial intelligence in the preservation of archaeological metal artifacts is an advanced step towards safeguarding cultural heritage, by leveraging these technologies, methods for preservation and maintenance can be improved, risks can be predicted, and better protection can be provided for these artifacts. However, implementing AI requires the collaboration of researchers, technology specialists, and museum staff to ensure maximum benefit is achieved.

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