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Restoration, preservation, and interpretation of the royal chariot from the Sinauli excavation in India: Safeguarding a remarkable discovery

Manoj Kumar Bhatnagar¹, Sanjay Kumar Manjul², Rina Parmar¹, and Dharmendra Kumar^{1*}

¹Science Branch Unit, Pt. Deendayal Upadhyaya Institute of Archaeology, Archaeological Survey of India, Ministry of Culture, Greater Noida, Uttar Pradesh, India

²Archaeological Unit, Pt. Deendayal Upadhyaya Institute of Archaeology, Archaeological Survey of India, Ministry of Culture, Greater Noida, Uttar Pradesh, India

Abstract

The novel discovery of the royal chariot from the Sinauli excavation in India has sparked a global debate among archaeologists and historians regarding India's ancient history and the Aryan invasion theory. The chariot is a remarkable piece of engineering, showcasing advanced metalworking techniques that challenge previous assumptions about the technological capabilities of ancient India. Its design closely resembles chariots depicted in ancient Indian texts and art, underscoring its cultural significance. The royal chariot is a fascinating combination of materials and craftsmanship. Its construction features a wooden frame adorned with intricate copper-inlay decorative work. After millennia underground, the wooden structure had transformed into mud, leaving behind only the fragile, corroded copper elements. This necessitated the restoration and preservation of the royal chariot for future research, with the aim of arresting or slowing down the rate of further deterioration, using the appropriate methodology as required. This article describes the restoration and preservation of the royal chariot.

Keywords: Royal chariot; Inlay copper work; Corrosion; Restoration; Preservation

*Correspondence author:
Dharmendra Kumar
(paldkasi@gmail.com)

Citation: Bhatnagar MK, Manjul SK, Parmar R, Kumar D. Restoration, preservation, and interpretation of the royal chariot from the Sinauli excavation in India: Safeguarding a remarkable discovery. *Arts & Communication*. 2024;2(4):2437.
doi: 10.36922/ac.2437

Received: December 14, 2023

Accepted: March 20, 2024

Published Online: August 29, 2024

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1. Introduction

In the heart of India, at the historic site of Sinauli, an extraordinary and unprecedented discovery has sparked a global debate among archaeologists and historians. The find – a royal chariot unlike any other – has the potential to rewrite India's ancient history and reignite discussions surrounding the Aryan invasion theory.^{1,2} This chariot is a remarkable piece of engineering, showcasing advanced metalworking techniques that challenge previously held beliefs about the technological capabilities of ancient India. Its design closely resembles chariots depicted in ancient Indian texts and art, providing further evidence of their cultural significance in India.³

Beyond its craftsmanship, the discovery of the royal chariot has sparked heated discussions among scholars regarding the Aryan invasion theory. This theory, proposed in the 19th and early 20th centuries, suggested that the migration of Indo-European

Aryans from Central Asia into the Indian subcontinent around 1500 BCE played a pivotal role in shaping India's early civilization.⁴ The existence of the royal chariot raises questions about the timeline and origins of advanced civilizations in India. The dating of the Sinauli burials to around 1900 BCE⁵ has led some historians and archaeologists to argue that the sophistication of the chariot indicates a well-established indigenous culture, challenging the notion that ancient Indian civilizations were primarily shaped by external migrations. They propose that instead of an invasion, cultural exchanges and internal developments within the Indian subcontinent contributed to the growth of these early societies. However, proponents of the Aryan invasion theory point to linguistic and textual evidence indicating interactions between Indo-Aryans and other indigenous cultures.^{4,6} They argue that the chariot's design could result from cultural exchanges between different groups, which could still fit within the broader framework of the Aryan invasion theory.

As the scientific community grapples with these intriguing discoveries, it is essential to maintain a balanced, evidence-based approach to interpreting the past.⁷ The royal chariot from Sinauli has provided a wealth of new information, offering fresh insights into India's ancient history. However, it is crucial to remember that a single artifact cannot definitively resolve debates that have persisted for centuries. Ongoing excavations and research at Sinauli are expected to reveal more about the ancient societies that once thrived there, potentially shedding further light on the Aryan invasion theory and the broader history of India. Until then, scholars will continue to exchange ideas and theories, gradually moving toward a more comprehensive understanding of India's remarkable and diverse past.

Renowned Indian archaeologist Dr. S. K. Manjul of the Archaeological Survey of India and his team began extensive excavations at Sinauli. Among their findings, the royal chariot stood out for its fascinating combination of materials and artistic craftsmanship. The chariot features a wooden frame, which serves as its structural foundation, providing the necessary strength and durability for transportation. This frame is complemented by intricate copper-inlay decorative work that enhances its exquisite beauty (Figure 1).

The skilled artisans of ancient India crafted this wooden framework, showcasing their expertise in working with woodworking and their ability to create both functional and elegant designs.⁸⁻¹⁰ The full-sized, two-wheeled chariot measured 135 cm in length and featured a fixed axle supporting a semi-circular wooden platform covered with thick copper plates. The platform, with inner dimensions of 60 cm × 52 cm, was framed with copper pipes that attached

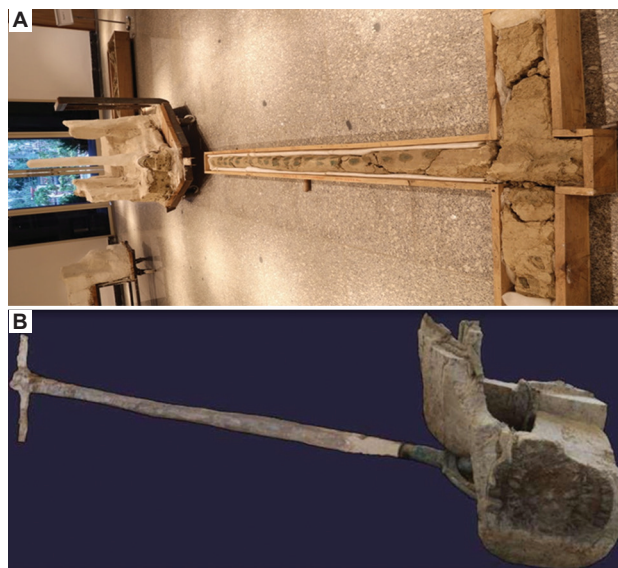


Figure 1. Preservation and visualization of the royal chariot. (A) The royal chariot excavated from Sinauli kept in a safe house at the Pt. Deendayal Upadhyaya Institute of Archaeology, Greater Noida. (B) The actual visualization of the royal chariot. Source: Archaeological Survey of India

the side panels, which stood approximately 100 cm high from the base of the chariot. A single pipe supported a canopy positioned 100 cm from the chariot's end. The solid wheels were adorned on both sides with triangular copper sheets arranged in three rows, radiating from the central hub to the outer rim. These sheets were affixed with 2-cm long copper nails. Similarly, triangular decorations adorned the 230-cm long pole and the 95-cm long yoke (Figure 2).

The first challenge faced by the excavation team was moving the royal chariot to a secure location for further research and conservation. The copper inlay on the chariot's wooden structure suggests that it was a luxurious and opulent piece, likely associated with a person of significant power and influence in ancient Indian society. The motifs and patterns created with the copper inlay may offer valuable insights into the cultural and aesthetic preferences of the time. Archaeologists and historians will meticulously study this copper inlay work to discern its symbolism, style, and possible connections to other artifacts or historical records from the same era. Such an analysis could provide a deeper understanding of the cultural and societal context in which the chariot was crafted and used. The combination of wood and copper inlay showcases the fusion of artistic expression and functional design characteristic of ancient Indian craftsmanship. As researchers continue their analysis, the royal chariot of Sinauli is poised to reveal new chapters in the rich tapestry of India's ancient history and contribute further to the ongoing debates surrounding the Aryan invasion theory.^{4,11}

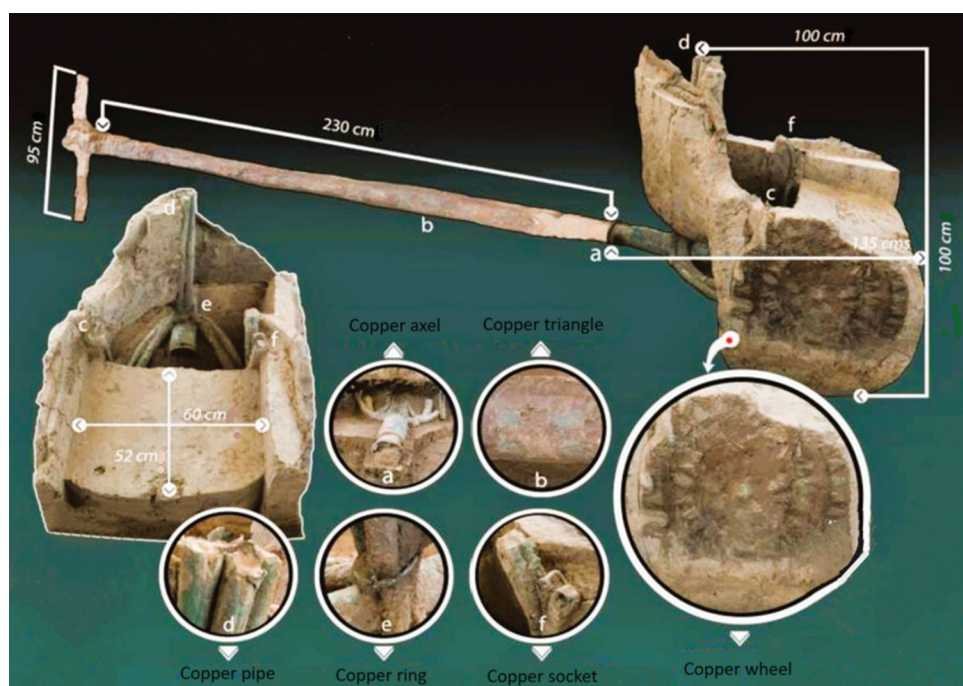


Figure 2. Detailed documentation of the royal chariot. Source: Archaeological Survey of India

It was a significant challenge for the science branch of the Archaeological Survey of India to restore and preserve the royal chariot, with the aim of arresting and slowing its deterioration. A team of archaeological chemists, led by Dr. M.K. Bhatnagar, played a crucial role in the conservation and restoration efforts. The first step was to shift the royal chariot to a secure location to facilitate the next phase of research and conservation.

2. Materials and methods

2.1. Instruments and reagents

A cutter kit, assorted surgical knives and blades, and soft nylon brushes of various sizes were procured from the local market for opening and cutting the straps and slings, as well as for superficial and mechanical cleaning of the royal chariot. Most of the inorganic and organic chemicals used in this study, such as Plaster of Paris (POP), acetone, toluene, isopropanol, and benzotriazole (BTA), were supplied by Central Drug House Ltd., India. Polyvinyl acetate (PVA), with an average molecular weight of 1,00,000, as determined by gel permeation chromatography beads, was procured from Sigma-Aldrich (Switzerland). Bandages for straps and slings, as well as binder and adhesive (animal glue), were supplied by the local market. Mud bricks retrieved from the excavation site were used to repair missing parts of the royal chariot, a necessary step for its restoration.

A handheld X-ray fluorescence (XRF) from the Olympus Vanta C Series, Model VCR (Japan), was used

for the elemental analysis of materials. This handheld XRF operates with a 4-watt X-ray tube optimized with a-W-40 kV anode material. It features a silicon drift detector, an 8-position auto-selected filter per beam per mode, and is powered by a removable 14.4 V Li-ion battery with hot-swap capability. The device can function within a temperature range of -10°C – 50°C and humidity levels of 10 – 90% relative humidity (non-condensing).

2.2. Process of moving the royal chariot from the excavation site to the safe house

The process of lifting the royal chariot from the Sinauli excavation site to a safe house was meticulous and delicate, given its historical significance and fragile state. The Archaeological Survey of India team undertook the following steps:

2.2.1. Documentation and assessment

The condition of the chariot was thoroughly documented and assessed by a team of expert archaeologists and conservators before being lifted. Detailed drawings, photographs, and 3D scans were conducted to record every aspect of the royal chariot (Figure 2 and Supplementary Video S1).

2.2.2. Support and reinforcement

Archaeologists, conservators, and experts assessed the structural integrity of the royal chariot to identify potential weak points and areas that needed support during the lifting

process. Temporary, reversible supports were added using POP straps and slings (bandages dipped in aqueous sludge of POP) to reinforce the chariot and prevent damage to its outer surface. The base of the royal chariot was secured to a steel frame with the help of jacks under the supervision of structural conservation experts. The attachment points were strategically chosen to evenly distribute the weight and minimize stress on the artifact.

2.2.3. Excavation and detachment

The royal chariot was carefully excavated from the surrounding soil to ensure that no part of it was damaged in the process. This required precise tools and techniques to avoid any accidental damage.

2.2.4. Lifting equipment

Specialized lifting equipment, including cranes for shifting and gantries for lifting, was brought to the site. The selection of equipment was based on the weight and dimensions of the chariot to ensure safe handling and even weight distribution, minimizing stress on the royal chariot.

2.2.5. Controlled lifting

With all safety measures in place, the lifting process was carried out gradually and under the close supervision of experts. The royal chariot was lifted inch by inch to ensure stability and avoid sudden movements. At each stage of the lift, archaeologists and other experts paused to assess the chariot's condition and adjust the rigging as necessary. This careful approach was critical to preventing accidental damage during the process.

2.2.6. Transport to the safe house

Once the royal chariot was safely lifted, it was carefully transferred to a specially designed container for transportation. The container provided adequate protection to prevent any movement that could cause damage during transit. On arrival at the safe house, the Science Branch of the Archaeological Survey of India in Greater Noida took over the stabilization and conservation of the artifact. This process included removing the straps and slings, cleaning, documenting, and repairing the chariot to ensure its long-term preservation. Details of the restoration and preservation efforts, which involve the removal of straps and slings from the royal chariot, are outlined as follows:

- Before applying POP straps and slings, the royal chariot was covered with a non-stick polythene sheet. Subsequently, straps and slings were applied to make the chariot's surface non-sticky and reversible. The removal of these straps and slings was carried out using a cutter and assorted surgical knives and blades (Figure 3).



Figure 3. Removing straps and slings from the royal chariot using grinders and surgical knives and blades at the safe house. (A) Using grinder. (B) Using surgical knives and blades. Source: Archaeological Survey of India

2.2.7. Conservation state of the royal chariot

The conservation state of the royal chariot unearthed from Sinauli in 2018, dating back to the Bronze Age, presents several challenges and opportunities for restoration and preservation. The left wheel portion of the chariot, adorned with metal pieces, was consolidated with Paraloid B-72 (thermoplastic resin). The remaining sections were reinforced and coated with plaster gauze using POP. Originally crafted from wood and copper, the wooden components of the wheel have eroded over time, leaving numerous pointed triangular copper pieces embedded in the mud, along with the shaft connecting to the yoke. These copper fragments, which display green incrustations, notably form a circular motif within the wheel. The mud encasement, now robust and retaining its form, lacks any traces of wood. Although the copper plates were well preserved within the mud, the yoke segment shows faint impressions and scant remnants of copper. The shaft, which is in a fragile state with multiple breaks, is supported by a plywood case and shielded with a transparent Perspex sheet. Similar triangular copper pieces with green incrustations were also found in the long shaft portion and the copper axle linking the shaft to the chariot.

While the exposed mud wheel appears structurally sound, its core strength remains uncertain until the packaging material is fully removed. The lower base of the chariot exhibits visible lacunae, voids, and pits (Figure 4). Due to the fragile nature of the shaft and yoke, extreme caution is required during handling for restoration and preservation. Overall, the conservation state of the chariot requires careful examination and treatment to ensure its long-term preservation and display.

2.2.8. Superficial and mechanical cleaning

To remove loose dirt and dust from the surface of the chariot, archaeologists used soft-bristled brushes made of nylon hair. Brushes of various sizes and shapes were employed to reach different areas effectively. Mechanical

cleaning was carried out using wooden picks and spatulas to gently dislodge debris without scratching or damaging the surface.

Both superficial and mechanical cleaning requires the utmost care and caution. Archaeological chemists first assessed inconspicuous areas to ensure that no adverse effects would result. The goal was to enhance the royal chariot's appearance and stability without altering its original state. Before undertaking any scientific treatment, a detailed assessment and documentation of the royal chariot's condition have been conducted. This includes noting any existing coatings, varnishes or pigments, and areas of particular vulnerability, such as fragile decorations or corroded metals. It is important to emphasize that the cleaning process was carried out by experienced and trained archaeological chemists with specific expertise in handling and preserving such artifacts. The preservation of the royal chariot's integrity and historical value was paramount throughout the cleaning process.

2.2.9. Restoration and preservation of the royal chariot

The restoration and preservation of the royal chariot involved meticulous and specialized tasks aimed at stabilizing, conserving, and repairing the royal chariot to its closest original condition while preserving its historical and archaeological value (Figure 5). This process was comprehensive and multi-step, ensuring its long-term protection and its effective presentation to the public.

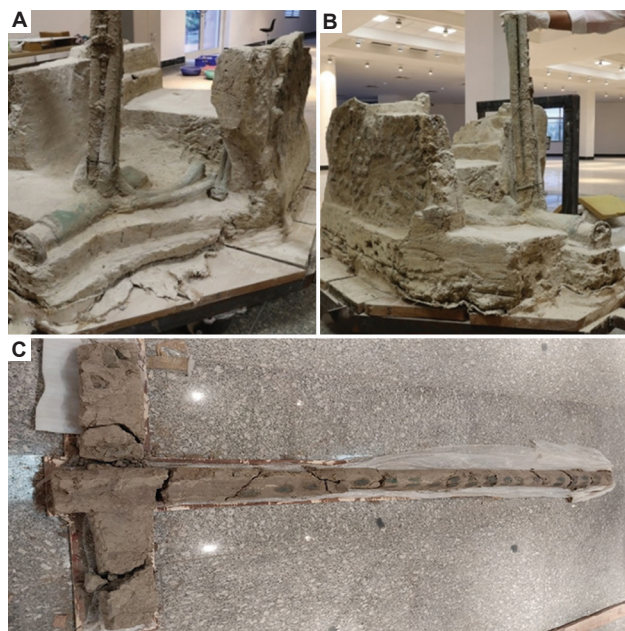


Figure 4. On opening the straps and slings from the royal chariot. (A) Left side view. (B) Right side view. (C) Yoke and shaft view. Source: Archaeological Survey of India

A detailed overview of the process is explained in the subsequent sections.

2.2.10. Removal of consolidate, adhesive, or preservative

During the excavation of the royal chariot, consolidants, adhesives, and preservatives were applied to prevent further damage to the structure. Thus, before proceeding with restoration and preservation, it was essential to remove any excess coating from the artifacts. The choice of chemicals/solvents for the removal of those coatings was based on trial methods using specially formulated chemical solutions that were safe and compatible with excavated objects. Organic solvents such as toluene 100%, toluene 60% + acetone 40%, toluene 40% + acetone 40% + isopropanol 20%, and distilled water as per requirement were used along with cotton swabs to remove old adhesive, consolidate, and preservatives (Figure 6). The protective coatings were gradually removed, and any unwanted material was cleaned from the surface.

2.2.11. Structural stabilization

The royal chariot exhibited signs of structural instability or fragility in its wooden parts and pole. Fragile or deteriorated sections were stabilized using non-invasive and appropriate methods. For example, a mixture of mud powder and animal glue in distilled water was used in a

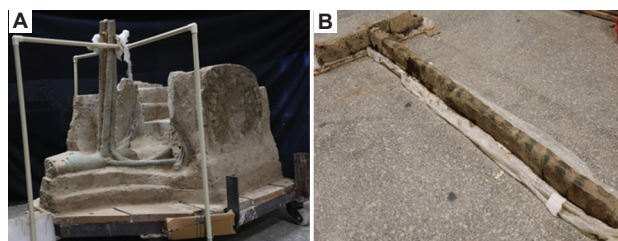


Figure 5. Restoration and preservation of royal chariot. (A) Canopy pole. (B) Yoke and shaft. Source: Archaeological Survey of India

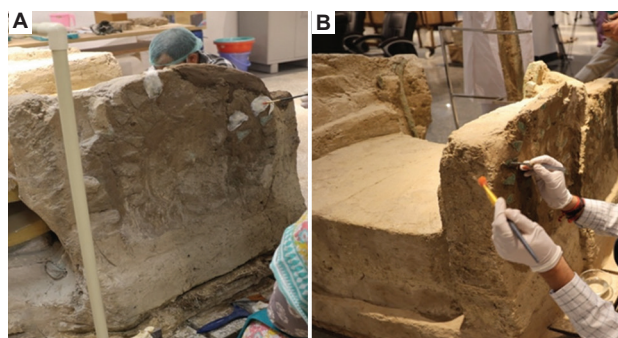


Figure 6. Removal of consolidate, adhesive, or preservative coating and hard encrustation. (A) Left wheel. (B) Right wheel. Source: Archaeological Survey of India

ratio of 3:1:1. Damaged parts of the wheel were restored to ensure its structural integrity and enhance public understanding. To strengthen and support the weak areas, stainless steel rods and adhesives were used to stabilize the wooden frame and other elements, including the pole.

2.2.12. Non-destructive XRF analysis of the royal chariot

XRF is a powerful analytical technique that was crucial in studying the royal chariot excavated from Sinauli. XRF is a non-destructive method¹²⁻¹⁴ used to determine the elemental composition of materials through single-beam and double-beam methods. In our analysis with a hand-held XRF instrument, we examined the composition of the copper plates on the chariot, revealing a range of copper concentrations, from approximately 99% to 58%, depending on the position tested. We employed the alloying method, utilizing the single beam for 10 s (Supplementary Figures S1 and 2). These variations in composition could be attributed to the presence of surface accretions or deterioration; further investigation is needed to understand the implications of these variations in composition.

Moreover, the analysis of the wood, which had transformed into mud, revealed a silica content of approximately 20 – 28% (Figures 7 and 8). This analysis was conducted using the double-beam geochemical method. Beam-1 was directed at the sample for 20 s, while beam-2 was applied for 40 s, aiding in on-site assessments for the identification and quantification of the elemental composition (Supplementary Figures S3 and 4). These findings underscore the need for ongoing investigation to ensure accuracy and reliability. Additional research is

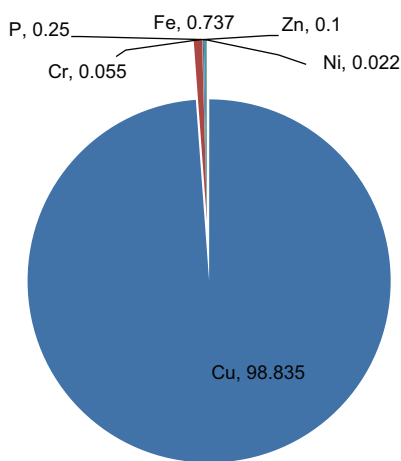


Figure 7. Handheld energy dispersive X-ray fluorescence data (%) of the copper plating and decorated copper metal on the wooden frame of the royal chariot

crucial to understanding the implications and significance of the observed differences in material composition within the historical context of the chariot.

2.2.13. Scientific treatment

After removing the preservative coating and other incrustations and identifying the construction material, it was found that the full-sized two-wheeled chariot with pole and yoke was nearly intact. However, the axle, chassis, and dashboard were partially damaged. Nevertheless, it is evident that the chariot had a fixed axle supporting a semi-circular wooden platform covered with thick copper plates. The copper metallic portion of the royal chariot was brushed with alcohol to remove sand and dirt from the surface. Following the removal of incrustations and cleaning, the metal parts were rinsed with hot distilled water once they were completely dry (Figure 5).

Active corrosion areas were meticulously cleaned and treated with a corrosion inhibitor (1 – 3% BTA solution in isopropanol) using cotton swabs, applied every half hour over the course of 3 days. Any excess powdery BTA was removed using isopropanol. Loose copper chips were joined or repositioned using acrylic resin. A protective coating of a 1% PVA solution in toluene was applied to the cleaned, stabilized, and dried copper metal. In some cases, toluene-soaked swabs were used to remove any excess coating or gloss from the surface.

3. Results and discussion

The royal chariot discovered in the Sinauli excavations is a unique discovery on the entire subcontinent, dating back to the Bronze Age. The primary structural material of the ancient royal chariot was wood, supported by thick metal sheets (plates) and adorned with copper triangles. The metal components were identified using a hand-held portable energy dispersive XRF (EDXRF) (Figures 7 and S1). Over

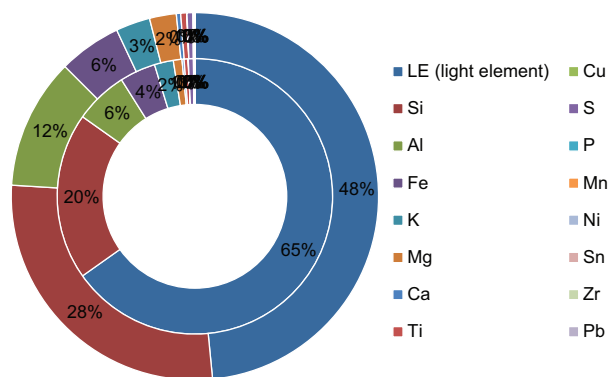


Figure 8. Handheld energy dispersive X-ray fluorescence data of the mud and wooden frame that has transformed into mud in the royal chariot

the course of several millennia, the wooden materials have completely transformed into mud. The transformation, where organic matter converts into clay minerals, is a complex process that occurs over a long period of time under specific environmental conditions. When wood is exposed to moisture, microorganisms such as fungi and bacteria begin to break down its organic components, including cellulose and lignin. This initial decay weakens the wood structure. As the decay progresses, soluble components of the wood, such as sugars and other organic molecules, leach out into the surrounding environment. This leaching can contribute to the formation of a muddy or sludgy substance around the decaying wood. In environments with high levels of clay minerals, such as certain soils or sedimentary environments, these leached organic compounds can interact with mineral particles, leading to the formation of new clay minerals. This process, known as mineralization or pedogenesis, involves complex chemical reactions that transform the organic matter into inorganic mineral structures. Over time, the muddy or sludgy substance surrounding the decaying wood becomes compacted, further enhancing the transformation into a solid, clay-rich material.^{9,10,15} EDXRF analysis has also been performed on the mud portion transformed from wood as well as on the original mud bricks recovered from the Sinauli excavation (Figures 8 and S2). Investigating the variation in the composition of metals and wood transformed into mud will be a focal point of our upcoming research. We plan to employ more sophisticated techniques and compare our findings with those of similar copper objects. The analysis will also examine impurity concentrations and specific areas associated with the relevant historical period. This comprehensive approach aims to provide a nuanced understanding of the material transformation, shedding light on the broader historical and archaeological context.

The semi-circular wooden platform of the ancient royal chariot was covered with thick metal plates, approximately 99% copper (Supplementary Figures S1 and 2), as analyzed using the non-destructive hand-held EDXRF technique (Figure 7). Pure copper was commonly used for inlay work in ancient royal-class artifacts due to its malleability, conductivity, and durability.¹⁶ The chariot was heavily decorated with copper inlays, hence its designation as the royal chariot. The platform was constructed using copper pipes to secure the side panels and a pipe to connect the canopies and inner-outer edges of both solid wheels. Triangular copper inlays, arranged in three rows extending from the central hub to the outer rim, adorned the wheel, pole, and yoke.

This chariot was discovered at a depth of about 1.5 m beneath the alluvial soil in agricultural fields. Over time,

copper artifacts can develop a natural patina or corrosion product on their surface. Metals are thermodynamically unstable and release free energy to attain a stable state, resulting in surface changes as they react with various environmental agents, a process known as corrosion. Corrosion is a chemical or electrochemical process where metal is converted into its mineral form, and it is a continuous process.

The corrosion mechanism of pure copper metal under the earth involves a combination of chemical reactions with various components present in the soil or surrounding environment. The patina forms through a combination of copper oxide, copper carbonate, and other copper salts. The primary corrosion process is known as oxidation, where copper reacts with oxygen and other substances to form corrosion products. A simplified overview of the mechanism is given below:

Formation of copper oxide:

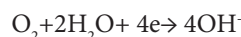
Copper + Oxygen + Water → Copper (I) oxide + Hydrogen ions

Formation of copper carbonate:

Copper (I) oxide + Carbon dioxide + Water → Copper carbonate + Hydrogen ions

The copper carbonate formed in this process is typically green in color.

The problem of corrosion is severe in unearthed decorated copper inlay and thick plates of royal chariot because cuprous ions rapidly oxidize to cupric ions, influenced by various factors.¹⁷ The symbolic mechanism is:



The unearthed copper plates and decorated inlay work of the royal chariot exhibit patina or encrustation of chlorides, oxides, and copper carbonates on the surface. The copper metal from the excavated royal chariot underwent scientific treatment, involving both mechanical and chemical methods. This treatment, guided by the expertise of archaeological chemists, aimed to remove the corrosion products and hazardous compounds present within the corrosion crust.

To prevent potential issues in the future, comprehensive documentation of every step was carried out. After the removal of straps and slings from the royal chariot, it was delicately brushed to eliminate dust and dirt, and detailed photographs of its surface were taken. A surface

investigation was conducted before any scientific treatment to assess the extent of corrosion, abnormal corrosion characteristics, mineral deposits, etc. A detailed condition report for the ancient royal chariot was also generated for future reference.

To control reactions during chemical treatment and avoid complications, mechanical treatment was prioritized for the royal chariot. Different levels of corrosion removal were employed, with minimal cleaning for less corroded copper metal parts and careful cleaning for parts with heavy calcareous deposits and encrustations. Fine tools such as paint brushes, fiber brushes, points, needles, dental picks, metal scalpels, surgical blades, and wooden or stick tools were utilized.

The patina on the metal surface serves as a natural preservative, helping to reduce further deterioration of the metal. Therefore, it is crucial to minimize the loss of patina during scientific treatment.

Active corrosion areas on the clean and dry metal surfaces were treated separately and with care for stabilization. A 1 – 3% solution of BTA in isopropanol was applied to these clean and dry areas of active corrosion to prevent further deterioration. The mechanism of action of BTA with copper metal for corrosion inhibition is as follows:

The initial step involves the adsorption of BTA molecules onto the copper surface. This process relies on weak chemical interactions, including van der Waals forces, π - π interactions, and electrostatic interactions between the BTA molecules and the copper surface. Once adsorbed, BTA molecules tend to form a monolayer on the copper surface, with their aromatic rings aligning parallel to the metal surface. The nitrogen atoms in the BTA molecules, which have lone pairs of electrons, coordinate with copper ions on the surface, acting as a chelating agent and forming coordination bonds with copper atoms (Figure 9). This coordination inhibits the dissolution of copper ions, thereby slowing down the corrosion process. The adsorbed BTA molecules create a protective barrier on the copper surface, limiting the access of aggressive species such as oxygen and water. This restriction reduces the corrosion rate. Notably, BTA exhibits a remarkable self-healing property as a corrosion inhibitor. If the protective layer is damaged or removed in certain areas, the remaining adsorbed BTA molecules can diffuse to these sites, re-establishing the protective barrier and ensuring continuous corrosion protection.^{18,19}

PVA is a widely used polymer in adhesives, coatings, and surface treatments. When applied as a protective coating to copper surfaces, PVA provides several beneficial

properties. It forms a continuous, impermeable barrier on copper surfaces, preventing direct contact with moisture, oxygen, and other corrosive substances. This barrier helps to slow down the corrosion process and protects the underlying copper from degradation. PVA exhibits strong adhesion, ensuring that the protective coating remains intact over time without peeling or delaminating. Its hydrophobic nature repels water, which is useful in preventing moisture-induced corrosion, as water is one



Figure 9. Benzotriazole acting as a chelating agent with copper atoms. Image created using ChemDraw

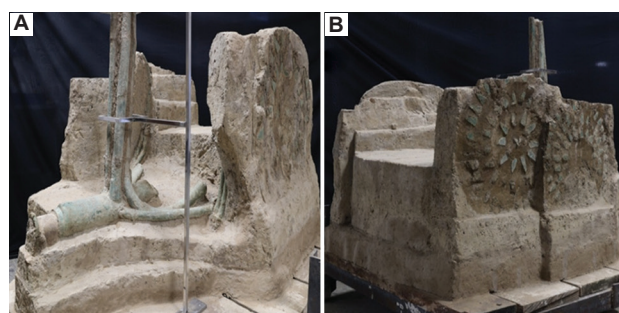


Figure 10. After the complete restoration and preservation of the royal chariot. (A) Left side front view. (B) Right side rear view. Source: Archaeological Survey of India

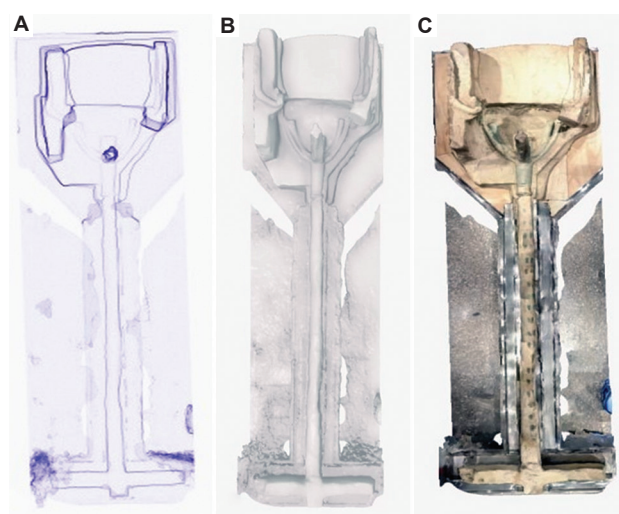


Figure 11. 3D images of the royal chariot excavated from Sinauli after restoration and preservation. Source: Archaeological Survey of India. (A) Sketch image. (B) Black and white image. (C) Color Image

of the main factors that accelerate copper corrosion. In addition, PVA films are relatively flexible, allowing them to accommodate slight movements or vibrations in the copper substrate without cracking or becoming brittle. This flexibility maintains the integrity of the protective coating. PVA is considered non-toxic, making it a safe choice for applications involving direct human contact.²⁰⁻²² Due to these properties, a 0.5 – 1% solution of PVA in toluene is commonly used as a preservative coating.

The results of the 3D documentation of the royal chariot (Supplementary Video S1), conducted after the completion of its restoration and preservation are shown in [Figures 10](#) and [11](#).

4. Conclusion

The discovery of a royal chariot at Sinauli has provided valuable insights into the Chalcolithic era, highlighting its significance in archaeology and history. The numerous copper artifacts found at the site indicate a sophisticated society with advanced technology and intricate cultural practices. These artifacts not only showcase the metallurgical skills of the time but also suggest that copper played an important role in daily life, potentially including religious practices. While the Sinauli findings have greatly enriched our understanding of this ancient civilization, several questions remain unanswered, and there are opportunities for future research. Ongoing investigations aim to explore the cultural connections of the Sinauli people with neighboring regions, offering a more comprehensive view of their history. Continued exploration and detailed analysis of the artifacts may reveal additional layers of cultural complexity. Future investigations, employing more sophisticated techniques, are expected to unveil new insights into the variations in material composition compared to similar objects.

The excavation of the royal chariot not only safeguards a significant archaeological discovery but also enhances our collective understanding of the past.²¹ The conservation and restoration efforts have been meticulous and specialized, involving a range of techniques and materials to ensure the chariot's long-term preservation. These efforts included removing consolidators and preservatives, applying corrosion inhibitors, and using protective coatings to stabilize and protect this remarkable artifact. By preserving and showcasing this cultural heritage, we honor the achievements of our ancestors and contribute to humanity's shared history. This underscores the importance of preserving and studying cultural heritage as a means to unravel the mysteries of bygone eras.

Overall, the discovery and conservation of the royal chariot from Sinauli offer a fascinating glimpse into ancient India's

rich history. As research continues, it is hoped that further discoveries will shed more light on the ancient societies that once thrived there, leading to a more comprehensive understanding of India's diverse past.

Acknowledgments

We express our sincere gratitude to the Director General and Additional Director General (conservation) of the Archaeological Survey of India, New Delhi, for their invaluable contributions through fruitful discussion and suggestions, which greatly enhanced the quality of this research work.

Funding

None.

Conflict of interest

The authors declare that they have no conflicts of interest.

Author contributions

Conceptualization: Manoj Kumar Bhatnagar, Sanjay Kumar Manjul, Dharmendra Kumar

Formal analysis: Dharmendra Kumar

Investigation: Manoj Kumar Bhatnagar, Dharmendra Kumar

Methodology: Rina Parmar, Dharmendra Kumar

Writing-Original draft: Dharmendra Kumar

Writing-review & editing: Manoj Kumar Bhatnagar, Rina Parmar

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Data used in this work are available from the corresponding author on reasonable request.

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