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PURIFICATION AND XRF ANALYSIS OF *Sindura* (RED LEAD OR VERMILION)

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ABSTRACT

Background: *Sindura, commonly known as Red lead or Vermilion, is a crucial mineral in Ayurveda, historically revered for its therapeutic properties. This article emphasizes its purification processes and quality assessment using advanced analytical techniques like X-ray fluorescence (XRF). Sindura has been extensively valued for its therapeutic efficacy in managing dermatological conditions such as Dadru (ringworm), Pama (dermatitis), and Vicharchika (eczema). This study highlights purification (Shodhana) methods designed to detoxify Sindura and enhance its medicinal safety and efficacy, aligning traditional practices with modern safety standards.*

Methods and Materials: *Sindura samples were collected, and detailed purification was conducted using Bhavana techniques with lemon juice (Neembu Swarasa) and rice wash water (Tandulodaka). Following this, XRF analysis was performed to assess the elemental composition of both purified and unpurified Sindura.* ***Results:*** *Purification significantly improved the sample's elemental composition, with increased oxygen content (+3.3%) and reduced toxic lead (-1.82%). Minor variations were observed in calcium (-0.90%), magnesium (-0.28%), and titanium (-0.121%), thereby enhancing the safety and therapeutic potential of Sindura.*

Conclusion: *The findings reinforce the necessity of ongoing research to validate traditional practices, thereby improving our understanding of Sindura's therapeutic benefits in modern Ayurvedic practice.*

KEYWORDS: *Red lead, Sindura, Shodhana, X-ray fluorescence (XRF), Vermilion*

INTRODUCTION

Rasashastra is a branch of *Ayurveda* that deals with the use of metals and minerals in the preparation of therapeutic drugs. Most of these *Rasadravyas* (metals and minerals), being toxic, have to undergo certain procedures mentioned in *Rasashastra* literature to make them suitable for use as therapeutic drugs for internal consumption. *Shodhana* is the first among the many procedures, and it involves mainly purification, partial or complete detoxification, and preparation of the apadravya for further processes[1].

Sindura, commonly known as Red lead or Vermilion, primarily consists of mixed oxide containing lead in two oxidation states, which is recognized for its anti-inflammatory, antifungal, and rejuvenating effects. In Ayurvedic texts, *Sindura* is mentioned for its applications in treating dermatological conditions, including *Dadru* (ringworm), *Pama* (dermatitis), and *Vicharcrika*. The purification often includes methods like '*Bhavana*' with various juices, such as lemon juice and *Tandulodaka*.[2,3,4,5]

The role of modern analytical techniques, such as X-ray fluorescence (XRF) and other spectroscopic methods, is to assess the elemental composition of *Sindura*. The growing awareness of the significance of safety in herbal and mineral preparations highlights the need for ongoing research to ensure the therapeutic reliability of *Sindura*[6,7].

MATERIALS AND METHODS

510 g of *Ashuddha Sindura* was procured from the local market. A sample of 10 gm was taken out for XRF (X-Ray Fluorescence) analysis, used to assess the elemental composition of both *Shuddha* and *Asuddha Sindura*.

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TABLE 1- Material For *Shodhana* of *Sindura*

S.NO.	INGREDIENTS	QUANTITY TAKEN
1.	*Sindura*	500 gm
2.	*Nimbuka Swarasa* ie. Lemon (Citrus limon) Juice	200 ml
3.	*Tandulodaka (*rice wash water)	100 ml

The *Shodhana* procedure for *Sindura* was performed in a mortar and pestle by a process called *Bhavana*. According to *Rasatarangini*, the procedure that involves the trituration of powdered substances (like metals, minerals, etc.) with a liquid media till the added liquid dries up is termed as bhavana[8]. Sindura was subjected to 2 times bhavana with *Nibuka Swarasa* and *Tandulodaka*.

First, *Sindura* was taken in a mortar and pestle and ground to a fine powder. 200 ml lemon juice was added to it till the powder in the mortar was just submerged in the juice. Trituration was done till the contents in the mortar were dried up. Again, 100 ml *Tandulodaka* was added to the contents in the mortar after 1st bhavana and again triturated till dried. Samples for XRF were taken (10 gm).

Observations

A significant reduction in *Bhavana Dravya* volume was observed during the purification process. *Sindura* exhibited significant physical changes, transitioning from a bright orange hue with a coarse texture to a muted orange shade with a finer, softer consistency. A distinct citrus odor was detected post-purification, and a 4.5% increase in weight was recorded due to the absorption of solids from lemon juice and rice water. The initial weight of *Sindura* was 500 g, which increased to 522.5 g. The color changed from bright orange to dusty orange, and the texture became soft from its previous rough state. A distinct citrus aroma was noticeable after purification.

Table 2: Observations During *Sindura Shodhana*

***Bhavana* Process**	**Duration of Trituration (Hrs)**	**Added Quantity (ml)**	**Appearance**	**Observations**
First *Bhavana* (*Nimbuka Swarasa*)	0	200	Bright Orange	Solidified upon addition.
	2	-	Dark Orange	Liquid Absorbed
	3-7	-	Dusty Orange, sticky	Stuck to walls of *Khalva Yantra*
	Drying	-	Dusty Orange; Soft	The mixture dried overnight.
Second *Bhavana* (*Tandulodaka*)	0	100	Dusty Orange; Soft	Solidified upon addition.
	1-3.5	-	Dark Orange, Significant Odor	Consistency improved; Sticky texture.

Results of XRF Analysis

The XRF analysis was conducted to determine Sindura's elemental composition before and after the purification (*Shodhana*) process. XRF is based on the principle that individual atoms, when excited by an external energy source, emit X-ray photons of a characteristic energy or wavelength. The elements present may be identified and quantitated by counting the number of photons of each energy emitted from a sample. These results indicate that traditional purification methods effectively reduce toxic heavy metals and impurities while preserving or enhancing therapeutic constituents.

The comparative XRF analysis results for *Shuddha Sindura* and *Ashuddha Sindura* highlight the implications of the elemental compositions observed in both samples:

Table 3: Comparative XRF Analysis of *Shuddha Sindura* and *Ashuddha Sindura*

Element	***Shuddha Sindura* (mass %)**	***Ashuddha Sindura* (mass %)**
O	86.5	83.2
Pb	6.96	8.78
Ca	1.80	2.70
Mg	1.73	2.01
Ti	0.394	0.515
S	0.592	0.417
Si	0.365	0.360
V	0.136	0.177

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Al	0.166	0.173
Cl	0.0633	0.0749
Fe	0.0452	0.0495
Zr	0.0197	0.0252
Mn	0.0178	0.0233
Ni	0.0079	0.0092
Sr	0.0053	0.0070
Y	0.0010	0.0035

Elemental analysis revealed a high oxygen content in both *Shuddha Sindura* (86.5%) and *Ashuddha Sindura* (83.2%), indicating a strong oxidizing environment essential for chemical stability and reactivity. Lead levels were reduced from 8.78% in *Ashuddha Sindura* to 6.96% in *Shuddha Sindura*, highlighting the effectiveness of purification in minimizing toxic impurities. Calcium decreased from 2.70% to 1.80%, and magnesium from 2.01% to 1.73%, suggesting the removal of potential interfering elements affecting solubility and bioavailability. Titanium, often indicative of external contamination, showed a reduction from 0.515% to 0.394%. Sulfur content increased from 0.417% to 0.592%, potentially enhancing the detoxifying properties of *Sindura.* Other trace elements, such as silicon, vanadium, aluminum, chlorine, iron, zirconium, manganese, nickel, strontium, and yttrium, were present in low concentrations, contributing to the overall assessment of purity and quality.

The XRF results for *Ashuddha Sindura* (Impure) and *Shuddha Sindura* (Pure) based on the provided data:

Table 4: Component of *Shuddha Sindura* and *Ashuddha Sindura*

Component	*Shuddha Sindura* (%)	*Ashuddha Sindura* (%)
PbO	47.0	42.9
CaO	18.8	14.4
MgO	16.5	16.4
SO_3	5.17	8.47
TiO_2	4.28	3.76
SiO_2	3.83	4.47
Al_2O_3	1.63	1.80
V_2O_5	1.57	1.39
Cl	0.372	0.363
Fe_2O_3	0.352	0.370
ZrO_2	0.169	0.152
MnO	0.150	0.132
NiO	0.0582	0.0576
SrO	0.0412	0.0359
Y_2O_3	0.0221	0.0073
P_2O_5	0.0001	0.0276
BaO	-	5.13
CuO	-	-
Rb_2O	-	-

The concentration of PbO is higher in *Ashuddha Sindura* compared to *Shuddha Sindura*. The levels of CaO, MgO, and SO_3 are also higher in the impure form. BaO is present only in *Shuddha Sindura*, indicating a difference in composition. P_2O_5 is detected in *Shuddha Sindura* but is negligible in *Ashuddha Sindura.*

Table 5: Comparative Analysis of Elemental composition

Element	*Shuddha Sindura* (mass %)	*Ashuddha Sindura* (mass %)	Change (%)
O	86.5	83.2	+3.3
Pb	6.96	8.78	-1.82
Ca	1.80	2.70	-0.90
Mg	1.73	2.01	-0.28
Ti	0.394	0.515	-0.121

DISCUSSION

The *Shodhana* (purification) process is an integral part of *Rasashastra*, ensuring the detoxification and refinement of mineral-based formulations like Sindura. This traditional purification, involving *Bhavana* (trituration) with acidic media such as *Nimbuka Swarasa*

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(lemon juice) and *Tandulodaka* (rice wash water), not only reduces toxic contaminants but also enhances the physicochemical properties and therapeutic efficacy of the formulation. Modern analytical techniques like X-ray fluorescence (XRF) provide quantitative insights into these transformations, validating the efficacy of *Shodhana*. The significant reduction in lead content (from 8.78% to 6.96%) post-purification underscores the importance of this process in detoxification, aligning with classical Ayurvedic principles while ensuring contemporary safety and quality standards. By integrating traditional wisdom with modern analytical validation, *Shodhana* reinforces the therapeutic safety of *Sindura*, making it a reliable component of Ayurvedic formulations. Purified *Sindura* demonstrates enhanced bioavailability, stability, and therapeutic efficacy. The reduction of toxic heavy metals ensures its safety for medicinal use, while the increased sulfur content enhances its detoxifying properties. These findings highlight the synergy between traditional Ayurvedic knowledge and modern scientific methodologies, underscoring the importance of refining therapeutic formulations for efficacy and safety. The comparative XRF analysis of *Ashuddha Sindura* (impure) and *Shuddha Sindura* (pure) reveals significant differences in elemental compositions, directly impacting their medicinal quality and safety.

Heavy Metal Content: Lead Oxide (PbO): *Ashuddha Sindura* contains a higher concentration of PbO (47.0%) compared to *Shuddha Sindura* (42.9%). Lead toxicity poses severe health risks, such as neurological damage and developmental disorders, necessitating stringent quality control measures to ensure consumer safety. Calcium and Magnesium Levels: Higher levels of Calcium Oxide (CaO) and Magnesium Oxide (MgO) in *Ashuddha Sindura* suggest the presence of impurities or substandard raw materials. *Shuddha Sindura's* balanced profile indicates a more refined and safer product. Sulfur Content: Sulfur Trioxide (SO_3) levels are higher in *Shuddha Sindura* (8.47%) than in *Ashuddha Sindura* (5.17%), reflecting the efficacy of the purification process. Increased sulfur content enhances detoxifying properties and therapeutic efficacy. Presence of Barium Oxide (BaO): BaO's detection in *Shuddha Sindura* suggests enhanced medicinal properties if its concentration remains within safety limits. Its absence in *Ashuddha Sindura* highlights the limitations of the impure form. Trace Elements: Comparable levels of Vanadium Oxide (V_2O_5) and Zirconium Oxide (ZrO_2) may influence pharmacological activity, warranting further investigation into their therapeutic roles.

The elemental composition of *Sindura* plays a crucial role in its potential therapeutic applications for skin diseases. Oxygen (O) is essential for cellular respiration and skin repair, while calcium (Ca) supports the skin barrier and keratinocyte function, maintaining hydration and integrity. Magnesium (Mg) contributes to enzymatic activities involved in DNA repair and moisture retention. Sulfur (S), known for its antimicrobial and keratolytic properties, is beneficial in conditions like acne, seborrheic dermatitis, and psoriasis.

Titanium (Ti), often used in dermatological applications as titanium dioxide, provides photoprotection against UV radiation. Iron (Fe) is vital for oxygen transport and cellular function but, in excess, may contribute to oxidative stress. Silicon (Si) aids in collagen synthesis, enhancing skin elasticity and strength. Strontium (Sr) has demonstrated anti-irritant properties, reducing skin discomfort. Manganese (Mn) is a cofactor in collagen production and wound healing, further supporting skin health.

Conversely, elements like lead (Pb) and nickel (Ni) are potential contaminants. Lead, which reduced post-purification, is toxic and may contribute to dermatological disorders, while nickel is a known allergen associated with contact dermatitis. The comparative analysis of these elements in *Ashuddha* and *Shuddha Sindura* highlights the purification process's impact on enhancing safety and therapeutic potential, ensuring its suitability for dermatological applications.

The reduction of CaO and MgO in *Shuddha Sindura* ensures mineral balance, preventing potential imbalances[9]. Trace elements like vanadium and zirconium may contribute to therapeutic efficacy, warranting further research. Regulatory bodies, including the Ministry of AYUSH, advocate standardization to ensure safety and preserve Ayurvedic formulations[10].

Implications of Purification on Therapeutic Efficacy *Shodhana* with *Tandulodaka* and *Neembu Swarasa* reduces toxic heavy metals, ensuring safety[11]. Purification enhances bioavailability, solubility, and absorption, improving efficacy[12]. Removing impurities strengthens synergistic therapeutic actions[13] and stabilizes formulations for consistent results[14]. Standardized purification ensures quality, reinforcing consumer trust[15] while validating traditional Ayurvedic purification with modern scientific analysis[16].

CONCLUSION

The purification processes of *Sindura* significantly enhance its safety and therapeutic efficacy by reducing toxic heavy metals, improving bioavailability, and ensuring formulation stability. The integration of traditional Ayurvedic practices with modern analytical techniques, such as XRF analysis, highlights the value of maintaining rigorous quality control standards. Continued research will further validate and optimize these methods, fostering greater trust and acceptance of Ayurvedic formulations in contemporary healthcare systems.

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