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Original Article

Pharmaceutical Standardization of Shilasindur: A Comparative Study of Formulation Techniques and Analytical Methods

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ABSTRACT

Background: *Shilasindur* (SS) is a mercurial *Kupipakwa rasayan* (sublime product) composed of purified mercury (*Parada*), sulphur (*Gandhaka*), and realgar (*Manahshila*). Traditionally used to treat skin and respiratory disorders, this study aims to evaluate and establish pharmaceutical and analytical standardization for SS by comparing traditional and modern manufacturing techniques. **Materials and Methods:** The study involved preparing SS through two distinct methods: the traditional Valuka Yantra (sand bath) and the modern Electric Muffle Furnace (EMF), with three batches prepared for each. The formulations were evaluated based on pharmaceutical observations and standardized using organoleptic tests, physicochemical analysis, and advanced analytical parameters, including AAS, XRD, FTIR, and ICP-OES. Microbial contamination was also monitored to ensure safety. **Results:** The EMF method demonstrated a significantly higher average yield of 59.93% compared to 43.46% in the Valuka Yantra method. Pharmaceutical observations revealed that the Valuka Yantra method required more fuel, manual labor, and time than the EMF method. Analytical testing confirmed the absence of microbial load in both samples. Both methods produced chemically stable products, with XRD identifying *α*-mercury sulphide as the predominant crystalline phase and FTIR confirming stable metal–sulphur and metal–oxygen bonding. **Conclusion:** The Electric Muffle Furnace is a superior, more efficient, and reproducible alternative to the traditional Valuka Yantra for the large-scale manufacturing of *Shilasindur*. Both preparation methods yield formulations that are chemically stable, microbiologically safe, and pharmaceutically potent, aligning with both Ayurvedic principles and modern scientific standards.

Keywords: AAS, Analytical Methods, Electric Muffle Furnace, FTIR, ICP-OES, Kupipakwa Rasayan, Microbial load, Shilasindur, Valuka Yantra, XRD.

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INTRODUCTION

Ayurveda, the science of life, emphasizes the application of natural laws for the maintenance and restoration of health. Historically, medicinal flora was abundant; however, over time, many therapeutically important plant resources became scarce. Hence, an alternative was searched and medicines were prepared from metals and minerals for therapeutic benefit and metallic pharmaceutical preparations, which are comparatively stable, quick in action, rich in potency, lesser dosage and longer shelf life (Sarkar, 2000). Ayurveda has its own unique parameters for qualitative and quantitative analysis of a drug or formulations *Kupipakwa rasayana* is a unique pharmaceutical preparation where the drug is prepared in a glass bottle called *Kachakupi*, and the processing is done in a traditional furnace with a pattern of gradual temperature rise (Joshi, 2000).

Kupipakwa yogas have mineral and metallic formulations, including both *Sagandha* (presence of sulphur) and *Nirgandha* (absence of sulphur), prepared with mercury as ingredients (Harisharananandji, 2000).

Shilasindur is *Sagandha, Sagni* (with heating process), mercurial preparation processed by the *Kupipakwa* method. Shilasindur is *Galastha kupipakwa rasayana* (final product collected near the neck of the bottle), which is the best and fastest-acting arsenic medicine, having Mercury, Sulphur, and Realgar (AS2S2-Arsenic disulphide) as ingredients mainly used in ailments like *Kustha* (a group of skin disorders), *Shwasa* (respiratory problems including bronchial asthma), *Sannipataja roga* (disease caused due to involvement of 2 of the 3 bodily humours) and helps in rejuvenation (Shrilakshmi *et al*., 2013). Physical and chemical properties help develop quality in the final product. This is one of the essential aspects to evaluate the fixed standards of

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physicochemical features to ensure the desired action, due to the wide diversity of identification and manufacturing procedures. It was felt necessary to evaluate the induction of new physicochemical properties of these drugs by their unique method of preparation, which can be investigated scientifically through chemical analysis (Sarkar *et al*., 2008).

Sindur Kalpana is another name for *Kupipakwa Rasayana Kalpana*. The key ingredient in the unique *Kupipakwa* method is *Kajjali* (Shirish *et al*., 2013). In order to achieve the intended and advantageous effect in the finished product, temperature plays a critical role. The *Kupipakwa Rasayana* method involves numerous observations and safety measures. This has involved the widespread use of Mercury (Hg), also known as *Parada*, and the frequent use of Sulphur, also known as *Gandhaka.* The final product exhibits multiple chemical transformations. These days, the chemical reactivity of *Parada* and *Gandhaka* is well established (Gokarn *et al*., 2012).

Rasendra Chintamani, by Sri Dundukanatha (12th century A.D.), is the pioneer *acharya* who first introduced the preparation of *Kupipakwa Rasayana*. The concept of *Kramagani Paka* (*Mrudu, Madhyama,* and *Tivragni*), is mentioned in the text Rasendra Chintamani. The *Kupipakwa Rasayana* was developed in the thirteenth century by the *Siddha Sampradaya*. Rasa Prakash Sudhakar, authored by Acharya Yashodhara Bhat, mentions *Sindura Kalpana* by the name of *Udaya Bhaskar Rasa*, and labels Rasa Karpura by the name "*Ghanasara-Rasa*.". *Udaya Bhaskar Rasa* is prepared with the help of *Sikata yantra* and *Kachaghati* (*Kupi*). Under the name *Sindura Rasa, Kupipakwa Rasayana* is explained in the 15th, 16th, and 17th centuries. The particular process carried out with *Parada* and *Gandhaka* was carried out under controlled temperature. In summary, *Gandhaka Jarana* is primarily responsible for the invention of *Kupipakwa Kalpana*, which ultimately results in the desired outcome in the form of *Balijarita Parada*. During the eighth century A.D. the *Gandhaka Jarana* procedures was described by Govinda Bhagavatpada in his text Rasa Hridaya Tantra which is eventually developed into *Kupipakwa Rasayana* (Mishra, 2005).

Shilaisindur, a Kupipakwa Rasayana, is *Sagandha* (processed with sulphur), *Sagni* (processed with heat, i.e., temperature in ascending order), *Galastha* (found in the glass bottle neck), and *Murchhita Parad Jarita* (processed with mercury). It is recommended for all forms of infectious diseases, respiratory tract conditions, and skin conditions (Kumar *et al*., 2024).

The classical therapeutic indications of Shilasindur show meaningful correlation with its reported pharmacological activities. The formulation contains mineral components such as processed mercury (*Parada*), sulphur (*Gandhaka*), and arsenic compounds (*Manashila*), which after proper *shodhana* and *Kupipakva* processing are reported to exhibit antimicrobial, anti-inflammatory, immunomodulatory, and antipyretic activities (Shrilakshmi *et al*., 2012). These properties provide a scientific basis for its traditional use in *Raktavikara*, including *Kuṣṭha* and *Visarpa*, which are now understood to involve inflammatory, infective, and immune-mediated mechanisms

MATERIALS AND METHODS

Analytical research offers a set of parameters for evaluating the drug's quality and assists in the interpretation of the pharmacokinetic and pharmacodynamic properties of both the raw as well as finished pharmaceuticals (Dutta, 1996). Determining a specific chemical configuration and identifying the physico-chemical transformations and implications of various *Samskara* (*Shodhana, Marana*, etc.) are crucial goals of analytical research (Bhoyar & Khiyani, 2014).

The present study was conducted to compare the pharmaceutical preparation and analytical profile of Shilasindur (SS) prepared by two distinct classical methods — *Valuka Yantra* (traditional sand bath) and Electric Muffle Furnace (EMF)—in order to standardize and validate the process through both Ayurvedic and modern analytical perspectives.

Statistical analysis

Data were expressed as mean percentages. Comparative analysis was performed based on yield and physicochemical parameters.

Ethical clearance

Ethical clearance was not required as this study involved pharmaceutical standardization and *in vitro* analysis without the use of animal or human subjects.

Methodology

Authentication of Raw Material.

Organoleptic and Physico-chemical Parameters of the ingredients and the processing material of Shilasindur.

Physico-chemical Parameters**,** AAS, XRD, FTIR, ICP-AES of Shilasindur.

Microbial contamination evaluation.

Major materials

Procurement and Authentication of Raw Material

Parada, Gandhak, and *Manashila*, were the raw materials used in the study. They were procured according to the acceptable characters mentioned in the classics and authenticated by experts from the Department of Rasshastra and Bhaishjya kalpana of MGACH & RC, DMIHER, Wardha.

Other material required for *Shodhan*

Churna (Lime stone powder), *Rason* (Garlic-*Allium sativum*), *Saindhava* (Rock salt), *Go Ghrita* (Cows Ghee), *Go Dugdha*

(Cows' Milk) and *Ardrak* (Ginger-*Zinziber officinale*) were procured from the local market.

Equipment required

Khalva yantra (mortar and pestle) was used for the purification of mercury (Hg) and arsenic disulphide (AS_2S_2). A stainless steel vessel, a Gas burner with a cylinder (*Dhalan* procedure) was used for the purification of sulphur. *Valuka yantra* and an Electric Muffle furnace were used for the preparation of Shilasindur (SS).

Pharmaceutical processing

All the pharmaceutical processes were carried out in the Department of Rasashastra, MGACH and RC, DMIHER, Wardha, India.

They include the following steps:

Shodhana of raw drugs.

Preparation of *kajjali.*

Kajjali with Manhshila.

Preparation of Shilasindur (SS). EMF Method and Valuka Yantra Method.

Shodhana of Raw Drugs

Shodhan of Parad (Mercury) (Sharma, 2000)

Churna (Safed Chuna) powder is placed in the *Kharala.*

Ashuddha Parada is added into this *Churna.*

This mixture is triturated for three days.

Then it is filtered through cotton cloth.

Nistusha Rasona was made into a paste.

Rasona Kalka was put in a *Kharala* and *filtered Parada* and *Saindhav* were added into it.

This mixture was triturated until *Rasona Kalka* attained a blackish colour.

This mixture is then washed with cold water.

Shuddha Parada was collected from this paste carefully.

शिलासिंदूर

मनःशिलामार्द्र रसै विमर्द्देकाधिकं विंशतीकृत्व आद्यम ।
संशोष्य तया समेशं तत्तुल्यगन्धेन मसिंच कुर्यात ॥
भृत्वा च कुप्यामथ वालुकाख्ये यंत्रे पचेदघस्त्वचतुष्टयं तत ।
काष्ठाऽग्निना शीतमथावर्तायं गले विलग्नं रसमाददित ॥
चन्द्रोदयश्चैष मनःशिलादीः कुष्ठादीरोगापनयाय दिष्टः ।
इष्टश्च गुञ्जाद्वयमात्रो हेमन्तकाले पुरुषाय यूने ॥

Shodhan of Gandhak (Sulphur) (Madhava, 1987)

Gandhaka was coarsely powdered and placed in a stainless steel vessel containing *Goghrita* and subjected to *Mandagni* (Max 120°C) till it melted completely.

Hot *Godugdha* was placed in another stainless steel vessel. A piece of cotton cloth smeared with *Goghrita* was tied over this vessel.

When *Gandhaka* was completely melted, it was poured into *Godugdha* through the cloth.

Gandhaka was allowed to become cool in *Godugdha.*

After cooling, *Gandhaka* was taken out and washed with hot water and allowed to dry.

The same procedure was repeated thrice, and at the end of the procedure, *Gandhaka* was washed carefully with hot water and allowed to dry in open air at room temperature.

After drying it was preserved in air tight glass jar.

Shodhan of Manashila (Sharma, n.d.)

Ashuddha Manashila was placed in *Khalvayantra* and finely powdered.

Ardraka Swarasa was added to the fine powder and levigated till the mass was completely dried. This was considered as one *Bhavana.*

This dried mass was added with more *Ardraka Swarasa,* and the same process of *Bhavana* was repeated. At the end of this procedure, it was considered as completion of the second *bhavana.*

Similarly, 21 *Bhavanas* were offered to *Manashila.*

After completion of 21 *Bhavanas,* it was dried at room temperature and preserved in air tight glass container.

Preparation of *kajjali* (Sharma, 2000)

Equal parts of *Shuddha Parada* and *Shuddha Gandhaka* were taken in *Khalva Yantra* and triturated well for 18 hr till a fine, soft, *Nischandra Kajjali* was formed.

Fine powder of *Shuddha Manahshila* was added to the *Kajjali*, triturated for 12 hr, till the blend attains homogeneity to prepare *Samaguna kajjali* (Hg+S). They were triturated for about 30 hr till *Kajjali siddha lakshanas* (complete formation of *Kajjali*) were attained (Table 1).

Preparation of Shilasindur by *ValukaYantra* and Electric Muffle Furnace

Reference text used for preparation of Shilasindur is Rasyogsagar (Sharma, n.d.)

After drying above above-mentioned samples, *Kajjali* was filled in *Kachakupi* (glass bottle), covered with seven consecutive layers of cloth smeared with *Multani mitti* (fuller's earth) up to

the mouth of *Kachakupi* and placed in *Valukayantra* (apparatus designed with an iron vessel filled with sand) and subjected to an Electric Muffle Furnace (Shrilakshmi & Lakshmi, 2016). After the entire apparatus was ready, wood was set to fire (V*aluka Yantra*), following a gradual heating pattern. Hourly temperatures near the base of the glass bottle were recorded with a pyrometer. The temperature was maintained between 150°C – 250°C for mild heat, raised to 350°C – 600°C for moderate heat and intense heat up to 750°C. After the stage of fumes and flames, the bottom of the bottle appears like a rising sun that is red in colour (*Udayabhaskara varna*). After confirming with the copper coin test, the bottle was corked and intense heat was continued for 2 hr. Later, *Kachakup*i was left for self-cooling, bottle was removed from *Valukayantra*. The cloth with *Multani* mitti was scraped off, and the bottle was broken 2 inches below the collection of the SS. Later, the drug was collected by tapping over the outer surface of the glass bottle. The same procedure was repeated to prepare two other batches using the same *Valuka yantra* and Electric Muffle Furnace to establish pharmaceutical standardization (As shown in Figure 1).

Collection of Final Product

Three samples of each method of SS were prepared; among them, one batch was selected for further analysis on the basis of the highest yield.

Comparative Images of Shilasindur Prepared by both methods

Analytical Study

An analytical study was conducted with a view to knowing the particular chemical configuration of intermediate and final products. It includes qualitative and quantitative analysis. Qualitative data included organoleptic characters and quantitative tests for the identification of heavy metals and minerals using AAS, ICP-OES, XRD and FTIR parameters. All three samples of Shilasindur are brick red in color, smooth on the outer surface, and after powdering the final product, both samples are soft, smooth powder, tasteless and odorless.

To check solubility, 10 mL of each solvent is taken separately in a test tube. Then 100 mg of each sample of the drug is added to taken solvent. Then it is shaken for every 15 minutes up to 12 hr. After 12 hr, solubility was observed. Estimation of microbial contamination was done by the 'Plate Count Method'. Assay of Mercury, Sulphur and Arsenic was done to estimate the quantity of respective material in intermediate and final Products (Government of India, Ministry of Health and Family Welfare, Department of AYUSH, 2007)

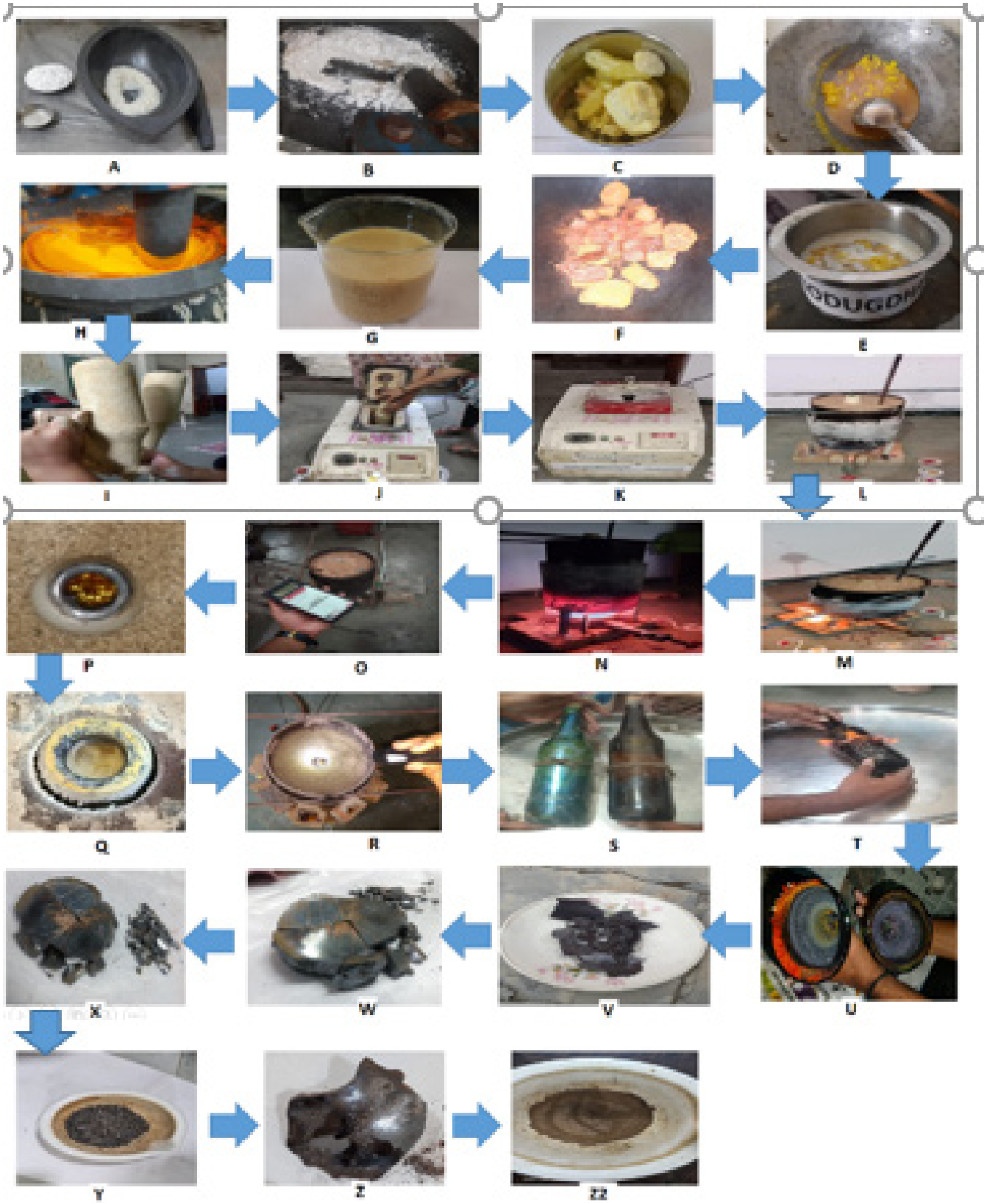
OBSERVATIONS AND RESULTS

Pharmaceutical study

After 7 days of triturating mercury with garlic, mercury disintegrated into tiny globules. This homogenious mixture of mercury and garlic attains blakish colour and disintegrated

Table 1: Results of Purification (*Shodhana*) of Raw Drugs and Preparation of *Kajjali*.

Stage of Processing	Raw Material	Quantity Before Processing (g)	Quantity After Processing / Obtained (g)	Loss / Gain (g)	Percentage Yield / Loss (%)	Duration of Processing (hr)	Remarks
Shodhana	Parada	450	425	−25 (Loss)	94.45 (Yield)	—	Loss attributed to removal of impurities
Shodhana	Gandhaka	450	431	−19 (Loss)	95.77 (Yield)	—	Loss due to melting, filtration, and handling
Shodhana	Manashila	450	478	+28 (Gain)	106.22 (Yield)	—	Weight gain due to absorption of processing media
Kajjali Preparation	Shuddha Parada (410 g) + Shuddha Gandhaka (410 g) + Shuddha Manashila (410 g)	1210	1190	−20 (Loss)	1.66 (Loss)	30	Kajjali prepared by trituration till Nishchandra and Siddha Lakshaṇas were attained



A) Ashuddha parad and churna B) Parad shodhan C) Ashudha Gandhak D) Gandhak shodhan in Goghrita E) Gandhak shodhan in Milk F) Ashudha Manshila G) Adrak swaras H) Manshila Shodhan I) preparation ok kachkupi J) Placing of kupi in EMF K) Preparation of SS in EMF L) Preparation of SS in Valuka Yantra M) Madhyamagni stage in SSVY N) Tivragni stage in SSVY O) Temperature recording with pyrometer P) Melting of kajjali Q) Gandhak fumes formation R) Arsenic fumes observation S) Taking out of Kupi from VY and EMF(cleaning of kupi) T) Burning of thread wraped on kupi U) Breaking of Kupi and collection of sample V) Final product SS VY1 W) Final Product SSVY2 X) Final product SSEMF1 Y) Powder of sample SSVY Z) Final product SSMF2 Z2) Powder of sample SSEMF.

parad globules remains entrapped into garlic paste. On washing the blackish paste with hot water, mercury globules start mixing with each other to regain its original state. After purification of sulphur, the bright yellow crystal was changed to pleasant yellow small beads, with reduced pungent odour. After purification, the *Manashila* coarse powder was changed to fine, dull orange colour powder with strong, pungent ginger odour. Shiny liquid mercury was triturated with purified beads of sulphur that changed to grey coloured powder, and after triturating for 36 hr, uniform collodion-like *Kajjali* was prepared that attained all *Samyak Siddha Kajjali Lakshanas.*

Observations of Methadology

Different phases of the desired characteristics during the process were observed according to temperature pattern, namely sulphur fumes, melting and boiling of *Kajjali*, stage of flames and confirmatory tests like disappearance of flame, *Sheeta Shalaka* (cold thin iron rod) test, red hot appearance of the bottom of the bottle and copper coin test were observed and recorded in all three batches, each of SS (As showed in Figure 2). The final product was collected from the neck of *Kachakupi* from all the batches of SS. They were weighed and calculated for the percentage of absolute and relative yield. The batch-wise yield of Shilasindur showed variation between the two preparation methods. In SSVY batches (SSVY1–3), the percentage yield was observed as 43%, 41%, and 46.4%, respectively. In contrast, the SSEMF batches (SSEMF1–3) demonstrated comparatively higher yields of 58.4%, 65.5%, and 55.9%, respectively. These findings indicate that the EMF method yielded a greater percentage of final product than the Valuka Yantra method (Tables 2 and 3). The output of the final product in all 6 samples was around 50-60%. The highest yielded batch was subjected to various organoleptic and physicochemical parameters (Table 4).

Preparation of Shilasindur (SS). EMF Method and Valuka Yantra Method.

Analytical Study

Organoleptic Characters, Physicochemical analysis and Solubility Test of Shilasindur

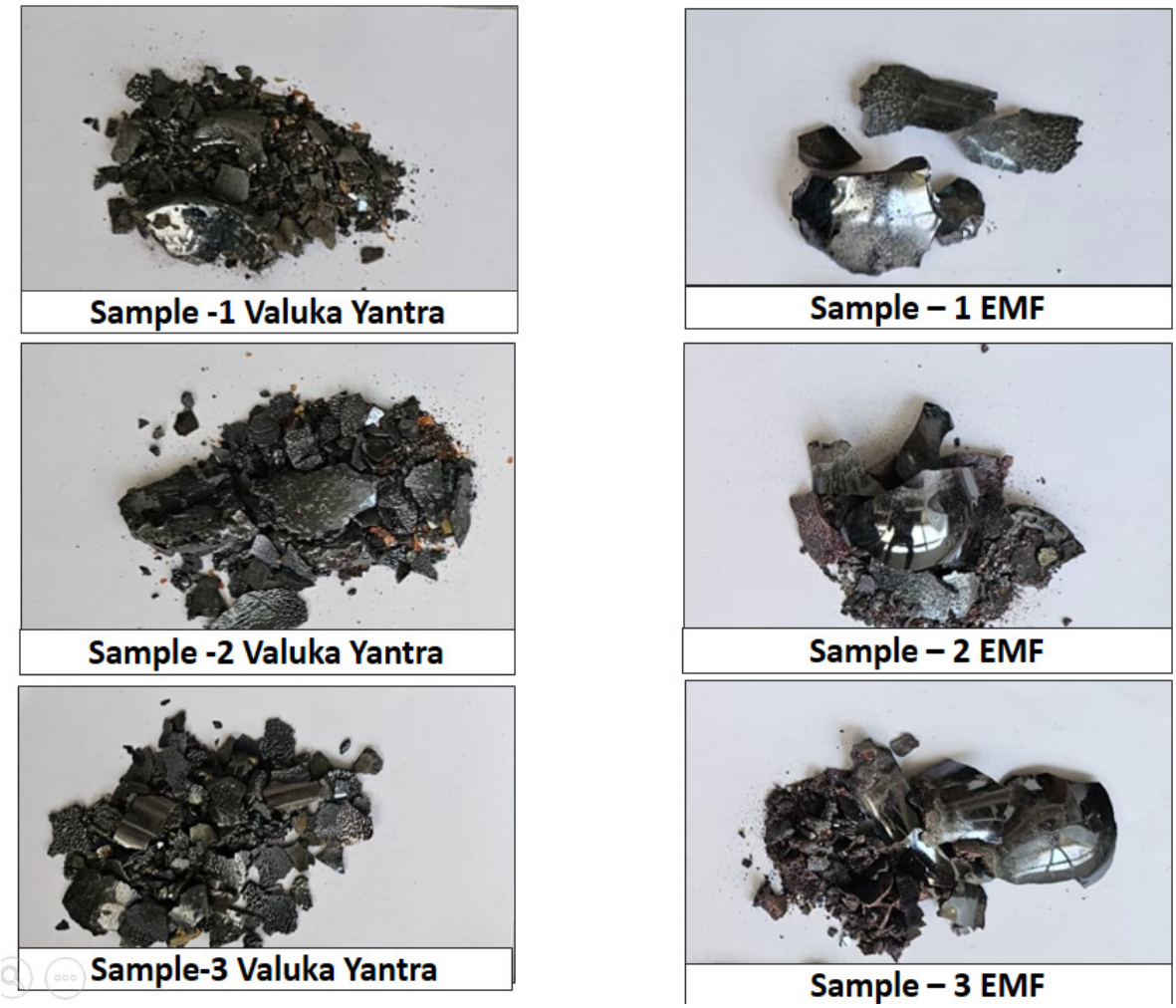


Figure 1: Comparative Images of Shilasindur all sample.

Results of Solubility profile

The solubility profile of the Shilasindur samples indicated that SSVY3 was soluble in chloroform, Carbon tetrachloride (CCl_4), Isopropyl Alcohol (IPA), benzene, acetone, methanol, and Methylene Dichloride (MDC). It was partially soluble in water, hydrochloric acid, petroleum ether, and ether, while remaining insoluble in glycerine. In comparison, SSMF2 exhibited a similar solubility pattern; however, it showed partial solubility in glycerine.

Estimation of Microbial contamination of Shilasindur

Microbial contamination analysis of Shilasindur samples SSVY3and SSMF2 revealed the absence of all tested microorganisms. Total viable count, *Enterobacteriaceae*, and total fungal count were not detected in either sample. Additionally, specific pathogenic organisms including *Escherichia coli, Salmonella, Staphylococcus aureus,* and *Pseudomonas aeruginosa* were also absent. These findings indicate that both samples

Table 2: Periodic Observations, Heating Profile, and Yield of Shilasindur Prepared in Three EMF Batches.

Sl. No.	Observation / Stage	SSEMF1	SSEMF2	SSEMF3
1.	Initial temperature (°C)	30	29	30
2.	Heating started (h)	0.00	0.00	0.00
3.	Initial heating acceleration	30	15	15
4.	No visible change	1.00 hr (110°C)	0.35 hr (100°C)	1.50 hr (80°C)
5.	Yellow fumes (first → dense)	4.00 hr (225°C) → 7.50 hr (255°C)	3.05 hr (147°C) → 6.45 hr (242°C)	3.15 hr (154°C) → 7.15 hr (240°C)
6.	White fumes appearance	5.35 hr (220°C)	6.00 hr (200°C)	6.25 hr (215°C)
7.	Kajjali hardness / softening	Hardness not observed; softened at 13.35 hr (320°C)	Hard at 7.30 hr (250°C); softened at 8.00 hr (255°C)	Hard at 7.45 hr (250°C); softened at 8.15 hr (255°C)
8.	Melting of Kajjali	Started: 9.55 hr (250°C); ++/+++ NR	Started: 11.30 hr (275°C); ++ at 13.45 hr (351°C); +++ at 15.25 hr (360°C)	Started: 11.45 hr (275°C); ++ at 14.00 hr (351°C); +++ at 15.40 hr (360°C)
9.	Orange fumes (first → dense)	11.50 hr (300°C) → 15.55 hr (355°C)	17.15 hr (403°C) → 18.30 hr (425°C)	17.50 hr (403°C) → 19.10 hr (425°C)
10.	White flame & red bottom	17.35 hr (400°C); 18.50 hr (450°C)	19.15 hr (453°C); 20.45 hr (469°C)	19.50 hr (453°C); 21.15 hr (469°C)
11.	Product deposition at kupi neck	NR	20.45 hr (469°C)	21.15 hr (469°C)
12.	Copper coin test	NR	NR	Negative at 22.15 hr (474°C)
13.	Reduction of fumes & corking	18.50 hr (450°C)	21.30 hr (480°C)	24.00 hr (490°C)
14.	Tīvragni (start → end)	19.05 hr (440°C) → 22.05 hr (500°C)	22.45 hr (500°C) → 28.45 hr (548°C)	26.00 hr (525°C) → 29.00 hr (550°C)
15.	Maximum temperature (°C)	550	552	570
16.	Heating stopped / total duration	23.35 hr / ~23.5 hr	31.00 hr / ~31.0 hr	31.30 hr / ~31.5 hr
17.	Final step	Kupi left for Svangasheeta	Kupi left for Svangasheeta	Kupi left for Svangasheeta
18.	Kajjali taken (g)	200	200	200
19.	Galastha yield (g)	116.8	131.0	111.8
20.	Talastha yield (g)	—	—	—
21.	Total yield (%)	58.4	65.5	55.9

NR: Not recorded.

comply with acceptable microbiological quality standards and are free from microbial contamination.

Results of Heavy metal analysis by ICP-OES (Inductively Coupled Plasma Optical Emission Spectroscopy)

ICP-OES analysis of Shilasindur samples SS1 (EMF) and SS2 (*Valuka Yantra*) was carried out to evaluate their heavy metal composition and assess pharmaceutical quality. The analysis revealed mercury and arsenic as the principal constituents in both samples, which is consistent with the classical formulation of Shilasindur as a *Kupipakwa Rasayana*. Sample SS1 showed slightly higher levels of mercury (23.98%) and arsenic (12.95%) compared to sample SS2, which contained 20.38% mercury and 12.39% arsenic, indicating minor variations attributable to differences in the heating and processing methods (As showed in Table 5).

Results of Elemental Analysis by AAS (Atomic Absorption Spectroscopy)

Mercury was detected in higher concentration in SS EMF (24.01%) compared to SS VY (21.23%), indicating greater retention of mercury during EMF processing. Arsenic levels were comparable in both samples, measuring 13.11% in SS EMF and 13.33% in SS VY, suggesting uniform incorporation of arsenic-containing mineral components irrespective of the processing method. Sulphur content showed a marked difference between the two samples, with SS EMF exhibiting a higher percentage (11.59%) than SS VY (6.21%), reflecting method-dependent variations in sulphur stabilization during preparation (As showed in Table 5).

XRD Results of Shilasindur

Shilasindur (Electric Muffle Furnace) SS-1

Shilasindur (Valuka Yantra) SS-2

Table 3: Periodic Observations, Heating Profile and Yield of Shilasindur Prepared in Three Valuka Yantra Batches.

Sl. No.	Observation / Stage	SSVY1	SSVY2	SSVY3
1.	Initial temperature (°C)	30	30	33
2.	Agnisthāpana started (h)	0.00	0.00	0.00
3.	Yellow fumes (first → dense)	1.50 hr (180°C) → 9.30 hr (350°C)	1.45 hr (170°C) → 7.45 hr (350°C)	1.30 hr (180°C) → 12.45 hr (400°C)
4.	White fumes (appearance → increase)	6.05 hr (250°C) → 13.30 hr (445°C)	3.50 hr (257°C) → 14.15 hr (430°C)	6.15 hr (290°C) → 16.45 hr (455°C)
5.	Kajjali melting (start → ++ → +++)	8.00 hr (290°C) → 11.55 hr (400°C) → 18.30 hr (480°C)	6.30 hr (320°C) → 9.35 hr (425°C) → 13.45 hr (425°C)	9.50 hr (340°C) → 14.00 hr (420°C) → 19.30 hr (475°C)
6.	Bluish flame & orange fumes	18.30 hr (480°C) → 23.00 hr (500°C)	10.15 hr (430°C) → 16.00 hr (450°C)	19.30 hr (475°C) → 22.50 hr (495°C)
7.	Red base / copper coin test	21.00 hr (495°C); NR	19.00 hr (469°C); NR	21.50 hr (488°C); Negative at 23.30 hr (490°C)
8.	Reduction of fumes & corking	After 23.30 hr (510°C)	21.20–22.20 hr (490–492°C)	27.50 hr (530°C)
9.	Tīvrāgni (start → end)	26.30 hr (530°C) → 31.30 hr (559°C)	23.00 hr (500°C) → 28.00 hr (565°C)	30.00 hr (550°C) → 32.00 hr (575°C)
10.	Maximum temperature (°C)	580	589	590
11.	Heating stopped / total duration	35.00 hr / ~35 hr	31.15 hr / ~31 hr	34.00 hr / ~34 hr
12.	Kajjali (200 g) → Galastha yield (%)	86 g (43.0%)	82 g (41.0%)	92.8 g (46.4%)

NR: Not recorded.

X-ray Diffraction (XRD) Results of Shilasindur EMF (SS-1)

Phase Identification

The XRD of Shilasindur (SS-1) exhibited sharp and well-defined diffraction peaks (As shown in Figure 3), indicating the crystalline nature of the formulation. Phase identification revealed α-mercury sulphide (HgS) as the predominant crystalline phase (≈62.5%), with characteristic intense peaks observed in the 2θ range of approximately 26–31°. Minor phases corresponding to mercury–manganese sulphide (≈15.0%) and tin arsenide (Sn_4As_3) (≈22.5%) were also detected. No diffraction peaks of free metallic mercury were observed, confirming its complete conversion into stable crystalline compounds during processing.

X-ray Diffraction (XRD) Results of Shilasindur – Valuka (SS-2)

Phase Identification

Qualitative and quantitative phase analysis, based on matching with standard reference diffraction data, revealed the presence of multiple stabilized crystalline phases. The major identified phases included α-sulphur (≈28.8%), mercury sulphide (HgS, ≈28.0%), and α-mercury sulphide (cinnabar, ≈17.7%). Additionally, tetraarsenic oxide (As_4O_6) was detected as a significant phase, contributing approximately 25.5% of the crystalline content.

The XRD of Shilasindur (SS-2) exhibited multiple sharp and intense diffraction peaks, indicating a predominantly crystalline nature of the formulation. Phase analysis revealed the presence of sulfur-based and mercury-based crystalline compounds.

The identified phases included α-sulfur as a major constituent (≈28.8%), mercury sulphide (HgS (≈28.0%), and α-mercury

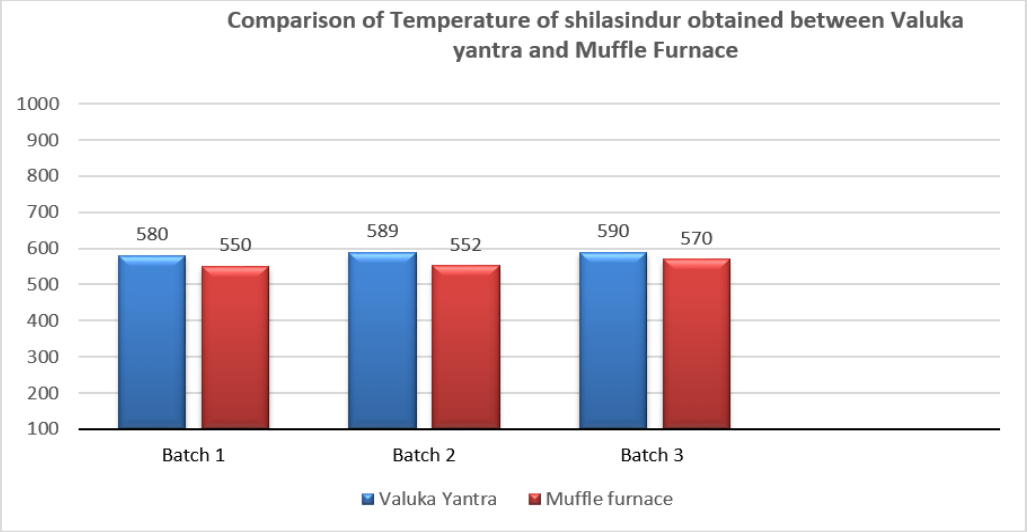


Figure 2: Comparison of Temperature of Shilasindur obtained between Valuka Yantra and Muffle Furnace.

Table 4: Results of Both Samples of Shilasindur showing Organoleptic characters & Physicochemical Analysis.

Sl. No.	Parameter / Test	Shilasindur (Valuka Yantra)	Shilasindur (EMF)
1.	Organoleptic characters: Shabda	Scratch sound on rubbing with stone	Scratch sound on rubbing with stone
	Sparsha	Inner: slightly rough; Outer: smooth	Inner: slightly rough; Outer: smooth
	Rupa (Varna & Chandrika)	Reddish black; shining cut surface	Reddish brown; shining cut surface
	Rasa	Tasteless	Tasteless
	Gandha	Not specific	Not specific
2.	Physicochemical Parameters Loss on drying at 105 °C (%)	2.73 (SSVY)	2.30 (SSEMF)
	Total ash (%)	1.2	1.5
	Acid-insoluble ash (%)	0.05	0.07
	Water-soluble extractive (%)	0.8	0.6
	Alcohol-soluble extractive (%)	8.8	10.8

Table 5: Comparative Heavy Metal and Elemental Analysis of Shilasindur (EMF and Valuka Yantra).

Sl. No.	Element / Parameter	Unit	Analytical Method	Shilasindur (EMF)	Shilasindur (Valuka Yantra)
1.	Lead (Pb)	%	ICP-OES	ND	ND
2.	Mercury (Hg)	%	ICP-OES	23.98	20.38
3.	Cadmium (Cd)	%	ICP-OES	ND	ND
4.	Arsenic (As)	%	ICP-OES	12.95	12.39
5.	Mercury (Hg)	%	AAS	24.01	21.23
6.	Arsenic (As)	%	AAS	13.11	13.33
7.	Sulphur (S)	%	AAS	11.59	6.21

ND = Not Detected.

sulphide (cinnabar) (≈17.7%), with characteristic peaks mainly observed in the 2θ range of 26–31°. In addition, peaks corresponding to tetraarsenic oxide (As_4O_6) were detected, contributing approximately 25.5% of the crystalline content. The sharpness and high intensity of the peaks reflect good crystallinity and phase stability of the formulation. No diffraction peaks corresponding to free metallic mercury were observed, indicating its complete conversion into stable sulfide and oxide forms during the *Valula yantra* processing.

FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)

Observation of Shilasindur: (Electric Muffle Furnace) SS-1 EMF

Observation of Shilasindur-(Valuka Yantra) SS-2 VY

DISCUSSION

Pharmaceutical Process

Shodhana of Parad: Purification of *Parad* (mercury) was done by triturating with *Rason* (Garlic- *Zinziber officinale*), *Saidhav* (rock salt) and *churna*(lime powder), which may decrease the surface tension, leading to the disintegration of mercury molecules. While triturating with *churna, parad* completely mixed with powder. This powder is filtered through cotton cloth to regain pure mercury. After triturating with *rason* and *saindhav*, the small globules of *Parada* disintegrated completely to form a uniform batter; this may be due to the binding of mercury, garlic and rock salt. This paste is converted into blackish colour. Remaining impurities of *Parada* may be separated during washing of this mercury garlic blackish paste with hot water. The active constituent of garlic might have reacted with the impurities, especially with mercury salts present along with mercury which help in the removal of mercury impurities, thus purifying *Parada* chemically (Reddy *et al*., 2014). After *shodhan Parada* obtained was brighter compared to the raw drug, which indicates the absence of physical impurities; it matches with tests described in the classics, which may indicate the absence of physical impurities like soot, etc. The loss of amount of purified mercury can occur during the process of triturating, washing and collection of purified mercury.

Shodhana of Gandhak: *Gandhaka* (Sulphur) purification mainly serves 3 purposes: purification, detoxification and potentiating therapeutically. During the process, when the temperature reaches 115°C, sulphur melts and dribbles down into the milk in the form of granules, leaving behind the physical impurities like mud, stones, etc., on the cloth. Since these impurities do not change at this temperature. This can be considered as purification. Sulphur is available in a combined state along with copper, lead, zinc, iron, limestone, etc., which are unwanted and retained on the cloth at 115°C. Even if these toxins pass through the cloth and fall into milk, the fat content of milk, which is in the form of microglobules, will remove the fat-soluble impurities. Melted sulphur comes in contact with milk and solidifies, preventing chances of remixing of impurities settled at the bottom. Purification of sulphur is similar to sublimation, followed by granulation. When sulphur was heated, molten sulphur passed through the cloth and condensed in the milk. Since milk has fatty acids and lipids, this helps the condensation of sulphur. Through sublimation, granulation can be achieved by melting sulphur and passing it through a small hole and cooling. The vapours of sulphur reach the bottom of the collecting flask and solidify. Sublimation always purifies the crude products (Chaudhary, 2015). Hence above purification process purifies sulphur chemically and enhances the properties of milk.

Shodhana of Manshila: During the purification of *Manashila* (Realgar-AS2S2), the quantity of *Ardraka (Zinziber officinale) swarasa* for *Bhavana* reduced after the 3rd *Bhavana* and remained constant till the 7th *Bhavana*. This might indicate absorption of moisture content initially and hence the quantity of ginger juice might have reduced in the consecutive *Bhavana*. There was a colour change in *Manashila* from bright reddish orange to orange, which might be due to a chemical reaction (Baragi *et al*., 2019). Active principle in *Ardraka swarasa* (Ginger- *Zinziber officinale*) are gingerol [(S)-5-hydroxy-1-(4-hydroxy-3-methoxyphenyl)-3 -decanone] and shogaol [(E-1-(4-Hydroxy-3-methoxyphenyl) dec-4-en-3-one)]. Shogal is the reason for the pungent odour in ginger. There could be a weak interaction between As_2S_2 and

gingerol and shogaol (Nduka, 2013). The weight increase is due to the absorption of organic molecules, *Ardraka sattva*/starchy portion, into the powder of As2S2.

Preparation of Kajjali: The gradual colour change of *Kajjali* from ash colour to complete black suggests the gradual process of amalgamation. The absence of lusture may indicate the physical absence of free mercury. When Hg is treated with S, the resultant product is HgS. This can be in two forms (alpha-red, beta-black). The black colour of *Kajjali* might be because of the formation of black sulphide of mercury (Joshi *et al*., 2021). Wet trituration helps in attaining homogeneous mixture than dry trituration. It acts as a binding agent that may help in further complex bonding of *Kajjali*.

Kupipakwa Kalpana Methodology: The objective of the seven layers of *Mrith lepana* for *Kachakup*i is to strengthen it for sustained heating by preventing the breaking of *Kachakupi* during the process. A lump of *Mrith lepana* was applied at the base of the bottle before wrapping, so as to avoid the air gap. Only the lower 1/3rd of the *Kachakupi* was filled with the drug, to provide space inside the bottle for melting, boiling and sublimation of *Kajjali* inside the bottle, else a large quantity may hinder the sublimation and may lead to overflow of boiling *Kajjali* from the mouth of *Kachakupi* during the process (Choudhary, 2004). *Valuka yantra* is specially designed for the distribution of uniform indirect heat, which may prevent temperature fluctuation of the *Kachakupi. Valuka* (sand) is inert, and it may render resistance to the apparatus from atmospheric temperature variations.

The temperatures recorded at the base level of the *Kachakupi* indicate the temperature at which the drug is being processed. Though there was an association of arsenic with *Gandhaka* during the stage of fumes in all samples of SS, there was a prolonged stage of fumes with a strong odour of arsenic during the process of SS, with more orange-yellow fumes deposited on *Shalaka.* Appearance of sulphur fumes after 2 hr of heating indicates the melting of *Kajjali*, which was confirmed by the *Sheeta shalaka* test. Appearance of dense and profuse fumes is suggestive of the melting of *Kajjali* and the processing of *Parada* with *Gandhaka.* Appearance of flames may indicate the burning of extra sulphur and organic matter. The haziness was observed after the stage of flames; the bottom of *Kachakupi* couldn't be seen clearly when viewed with torchlight. This may be due to vapours of sulphur, as the high temperature might inevitably cause the evaporation of sulphur before coming in contact with oxygen. The copper coin test may help to confirm the absence of free sulphur and the escaping of white mercury fumes. Loss in the final product compared to that of *Kajjali* taken may be due to the loss of major proportions of sulphur, minimum quantity of arsenic and traces of mercury (Puranik & Dhamankar, 1964). Before corking, yellowish-orange and red particles were observed in the middle portion of the bottle. This might be due to the presence of arsenic along with mercury and sulphur.

Completeness of preparation was confirmed by the following observations, like absence of flame may indicate completeness of burning organic and excess sulphur. Cessation of fumes might indicate complete escape of excess free sulphur. A copper coin turned greyish white, which was placed over the mouth of the *Kachakupi*; this may be due to the reaction of mercury with copper. When cold *Shalaka* was sent in *Kachakupi* without touching the sides of bottle, a yellowish orange layer was formed over the *Shalaka*, indicative of deposition of fumes of Shilasindur, which is due to the presence of arsenic and no remnant material adhered to the tip of the *Shalaka*. These tests confirm the completion of *Sindura* preparation and are suitable for corking

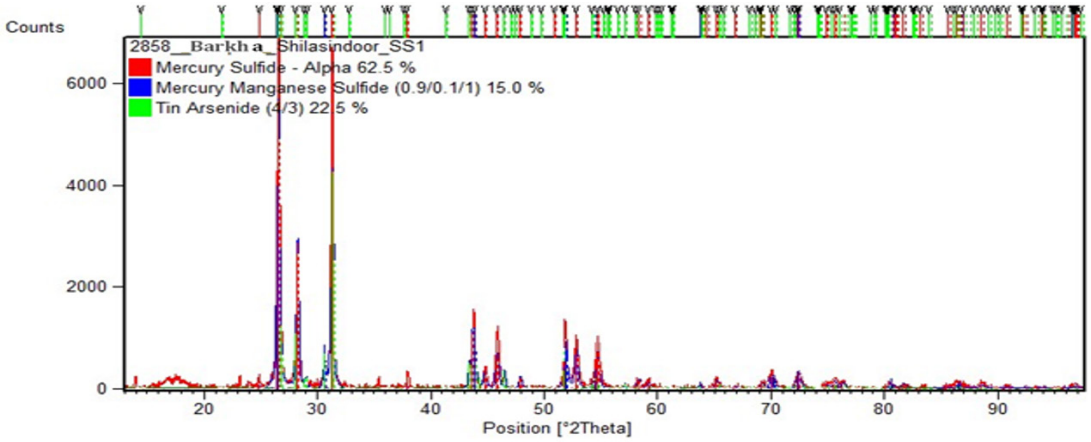


Figure 3: XRD Analysis of SS1-EMF.

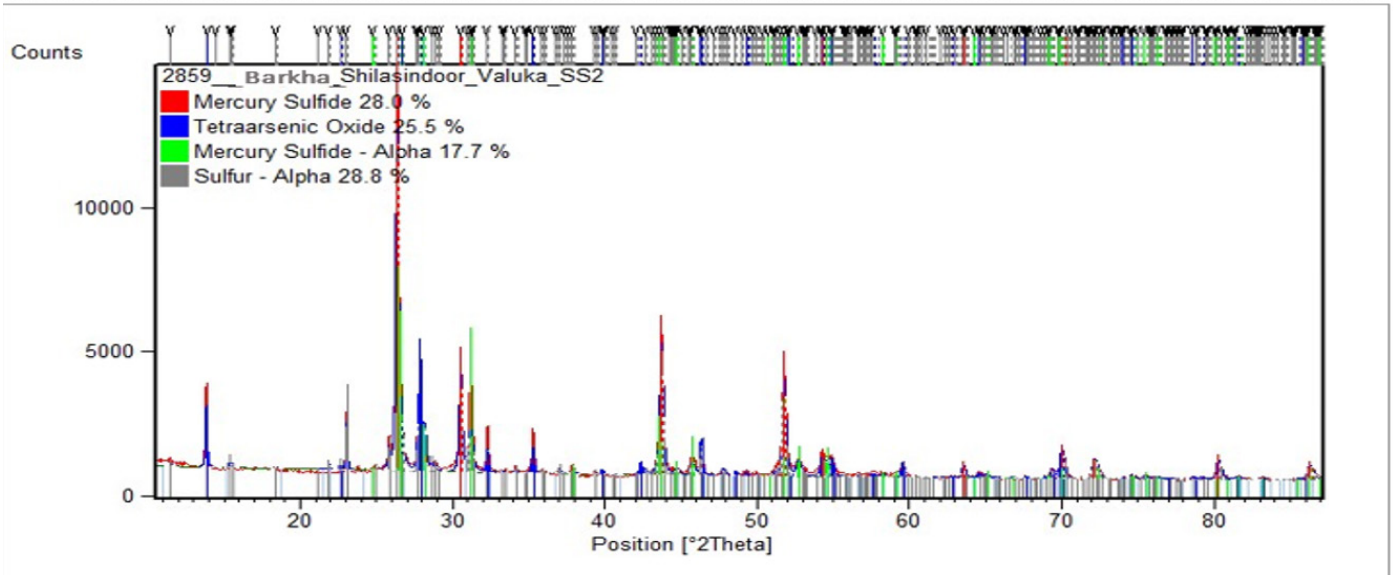


Figure 4: XRD Analysis SS2-VY.

of the bottle. Appearance of redness in the bottom of *Kachakupi "Arunachandrodaya varna"*, might suggest complete sublimation of *Kajjali* and the visibility of the red-hot bottle bottom. Before corking, reddish yellow shining particles were observed below the neck of bottle, which might be the initial phase of condensation of the fumes of the Shilasindur. (Dhundhukanath & Mishra, 2006)

For the collection and storage of final products, *Kachakupi* was removed from the sand, and then the outer *multani* layer was removed after self-cooling to avoid mixing of unwanted sand material in medicine. *Kachakupi* was broken by burning thick thread dipped in kerosene, which causes a sudden increase in temperature around the glass bottle. After the thread had burned totally, the bottle was covered with a wet cloth. Due to a sudden fluctuation in temperature, the glass bottle breaks as it cannot accommodate a sudden variation in temperature. This method of breaking helps heat the glass bottle and avoids small pieces while breaking. Shilasindur was more reddish may be due to the presence of Realgar. The change in the black colour of *Kajjali* to red coloured *Sindura* after the heat contact may be due to a change in their allotropic form and re- arrangement of crystalline structure. Orpiment and realgar vary with one sulphur atom, varying in colour from yellow to red. Similarly, the slight change in colour of Shilasindur might be due to the amount of arsenic and sulphur, exhibiting variation in colour and crystal lattice structure of final products.

ANALYTICAL STANDARDIZATION

Ayurved Prameters: Ayurveda have described subjective organoleptic parameters. The ancient parameters to evaluate *Kajjali* and SS were positive, suggestive of following the appropriate methods of preparation. *Kajjali* obtained after trituration was a black fine powder that was *Slakshna* (smooth), *Sukshma* (subtle), which could pass *Rekhapurna* (filled in furrows of fingers), which may denote the fineness and reduced particle size to enhance bioavailability. *Nishchandratva* (absence of lustre) and *Tamra pareeksha* (rubbing *Kajjali* over Copper foil) may denote the absence of free mercury in *Kajjali. Varitara Kajjali* (floating on water) indicates the lightness, though both mercury and sulphur are heavy enough to sink in water, but after processing, it could float on water. The final products of Shilasindur, were *Kathora* (hard) and solid mass (*Sindura*). When rubbed against paper, red colour streaks were observed, indicative of the presence of mercuric sulphide in it.

Modern Parameters

Solubility Test: Conducted in 12 media found no change in solubility by the two methods.

Microbial Load: Samples were tested for contamination of TBC-total bacterial count (CFU/g), total fungal count (CFU/g), *E. coli, Salmonella, P. aeruginosa* and *S. aureus.* The microbial profile was conducted by inoculating the sample into agar media. If there were microbes in samples, they proliferated in colonies, and each colony was counted as one microbe and so the unit was given as 'Colonies for Unit' (CFU). Permissible TBC and total fungal counts were 105 CFU/g and 100 CFU/g, respectively. All the samples had counts below the normal limits for bacteria and fungi. The presence of a minimum amount of microbes in samples might be due to atmospheric exposure. Absence of bacteria like *E. coli, Salmonella, P. aeruginosa* and *S. aureus* indicates that the medicine prepared will not induce any infection. This may be inferred as hygienic methods of preparation; hence, medicine is safe for consumption in regard to microbial contamination.

Physico-chemical Parameters

Ash content: 1.2%–1.5%, indicating very low inorganic non-volatile residue, typical for purified metallic compounds.

Acid Insoluble Ash: Extremely low (0.05%–0.07%), ensuring absence of sand or siliceous contaminants.

Loss on Drying (LOD): 2.3%–2.73%, suggesting minimal moisture content and excellent shelf stability.

Water and Alcohol Soluble Extractives: Revealed acceptable solubility profiles, signifying the removal of unwanted organic impurities.

These parameters collectively confirmed the processed Shilasindur's purity and stability.

Quantitative analysis: Evaluation with estimation of total mercury, is less in Shilasindur. This may be due decrease in the concentration of sulphur due to the evaporation of free sulphur and a few mercury particles while heating in open air. This mercury might have bonded with sulphur and arsenic (i.e., mercuric sulphide with arsenic). The quantity of free sulphur was comparatively SS, traces in final products denote the quantum of heat given to these products, as sulphur starts vaporising and escaping around 120°C and above, the rest of the sulphur gets bonded with mercury. Total sulphur content chronologically decreases in the final products, which may signify sulphur in bonded form after escaping of free sulphur due to the quantum of heat given to these products. The quantity of arsenic was comparatively higher in SS. This might suggest evaporation of arsenic also during this process. Odour of arsenic during the stage of fumes was more in the SS in all the trials. Quantitative analysis indicates a lower percentage of arsenic in SS. Both of them might suggest loss of more amount of arsenic in SS.

Heavy Metal Analysis by ICP-OES

In ICP-OES analysis notably, lead and cadmium were not detected in either sample of Shilasindur SSEMF and SSVY, confirming effective purification (Shodhana) of raw materials and absence of extraneous toxic contamination (Kumar *et al*., 2014). Overall, the ICP-OES findings demonstrate chemical consistency between both preparations, validate adherence to classical pharmaceutical procedures, and support the safety and quality of Shilasindur prepared by both EMF and Valuka Yantra methods.

Elemental Analysis by AAS

Atomic Absorption Spectroscopy (AAS) was employed to determine the elemental composition of Shilasindur samples prepared by EMF (SS EMF) and Valuka Yantra (SS VY) methods. The analysis confirmed the presence of mercury, arsenic, and sulphur as major elements in both samples, which are characteristic constituents of classical Shilasindur (Paudel *et al*., 2016). Overall, the AAS results demonstrate consistency with the expected elemental profile of Shilasindur and highlight minor quantitative differences attributable to pharmaceutical processing techniques rather than compositional deviation, thereby supporting the quality and authenticity of both formulations.

XRD ANALYSIS

The XRD study (as shown in Figures 4 and 5) of Shilasindur (SS-1) confirms the formation of a stable, crystalline formulation predominantly composed of α-HgS along with minor sulphide and arsenide phases. These findings validate the effectiveness of traditional Rasashastra processing methods in achieving chemical stabilization of mercury and support the pharmaceutical safety and quality of Shilasindur (Klug & Alexander, 1974).

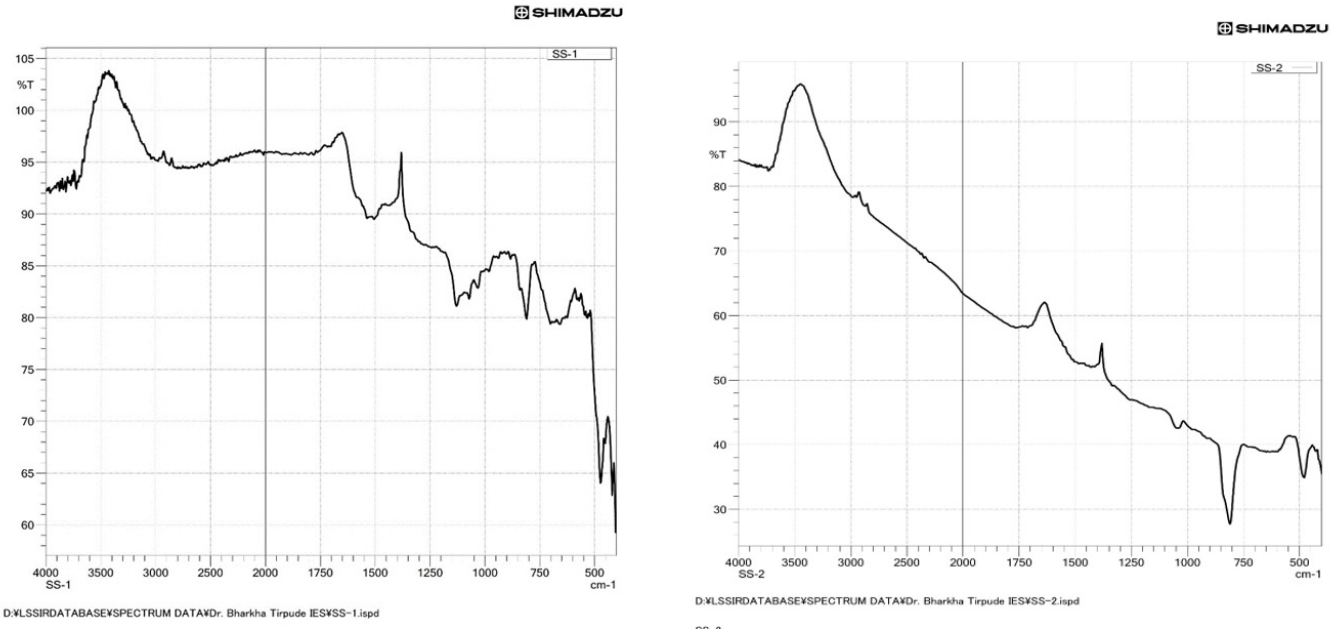


Figure 5: FTIR of sample SS1 EMF and sample SS2 VY.

Table 6: Comparative FTIR Spectral Interpretation of Shilasindur (EMF and Valuka Yantra).

Sl. No.	Peak Region (cm^{-1})	Shilasindur (EMF) – Interpretation	Shilasindur (Valuka Yantra) – Interpretation
1.	3450–3300	Broad O–H stretching indicating hydroxyl groups / adsorbed moisture	Broad O–H stretching indicating bound moisture or hydroxyl–metal complexes
2.	2950–2850	Weak aliphatic C–H stretching suggesting trace organic remnants from levigation media	Weak aliphatic C–H stretching indicating minimal organic residues
3.	1650–1600	Medium H–O–H bending / C=C stretching indicating bound water or residual organic structures	Medium H–O–H bending / C=C stretching indicating structurally bound water
4.	1450–1380	Weak–medium C–H bending / CO_3^{2-} vibration suggesting atmospheric carbonation	Weak–medium C–H bending / CO_3^{2-} vibration due to mineral matrix interaction
5.	1250–1000	Moderate M–O and S–O stretching confirming metal–oxygen and sulphur–oxygen complexes	Strong, broad M–O, As–O and S–O stretching indicating stable inorganic/organometallic complexes
6.	900–700	Sharp M–S / As–S stretching confirming metal–sulphur bonding	Sharp, intense M–S / As–S stretching indicating well-formed metal–sulphur bonds
7.	650–500	Strong metal–S / metal–O lattice vibrations confirming stable inorganic lattice	Medium metal–S / metal–O lattice vibrations indicating crystalline / semi-crystalline structure

The XRD analysis of Shilasindur SS-2 prepared by Valuka Yantra demonstrates the formation of a stable, crystalline mineral formulation comprising sulphur, mercury sulphide, and arsenic oxide phases. These findings validate the effectiveness of Valuka Yantra processing in achieving controlled mineral transformation and chemical stabilization, thereby supporting the pharmaceutical quality and toxicological safety of the Shilasindur formulation.

Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR spectral profile confirms the presence of stable metal–sulphur and metal–oxygen bonds with minimal residual organic functional groups (Table 6). This indicates effective transformation of raw materials into a chemically stable form through classical pharmaceutical processing. The absence of peaks corresponding to free toxic functional groups supports the safety and stability of the formulation, validating the traditional purification and incineration procedure (Ruban *et al*., 2009).

The FTIR spectrum of sample SS-1: Demonstrates the presence of hydroxyl groups, minimal residual organic matter, and well-defined metal–oxygen and metal–sulphur bonds. The dominance of inorganic lattice vibrations in the lower wavenumber region confirms successful transformation of raw materials into a chemically stable processed form. The spectral pattern supports effective purification and processing, indicating reduced free organic content and enhanced structural stability.

The FTIR spectrum of sample SS-2: Reveals dominant metal–sulphur and metal–oxygen stretching vibrations with minimal organic functional group presence. This confirms effective transformation of raw materials into a stable inorganic form through classical pharmaceutical processing.

Thus, the analytical studies not only verified the standardization and quality of the final product but also built scientific credibility for its therapeutic use.

Pharmaceutical Findings

The entire pharmaceutical process — including *Shodhana (purification) of Parada, Gandhaka*, and *Manahshila*, followed by *Kajjali* preparation and *Kupipakwa* process — was carried out meticulously in accordance with Rasashastra guidelines.

During the *Shodhana* of *Parada*, it was observed that trituration with *Sudha Churna, Rason* and *Saindhav* effectively reduced surface tension and helped in complete disintegration of mercury globules, ensuring purification both physically and chemically.

Gandhaka Shodhana through *Goghrita–Godugdha* medium eliminated impurities, detoxified the raw sulphur, and potentiated its pharmaceutical properties.

Manashila Shodhana through *21 Bhavanas* with *Ardraka Swarasa* brought about a uniform colour and texture change, indicating the conversion of the toxic arsenical compound into a therapeutically safe form.

During the *Kupipakwa* process, a series of classical *Pariksha* (tests) such as *Sheeta Shalaka, Tamra Pariksha*, and *Arunachandrodaya Varna* were successfully employed to confirm the proper transformation and completion of the product.

Among the two methods, the Electric Muffle Furnace offered a more controlled and consistent heating environment, leading to reduced manual labour, less fuel consumption, and improved reproducibility indicates the superior alternative for large scale manufacturing.

Analytical and Comparative Observations Traditional and Modern Method

The average yield of Shilasindur prepared in the Electric Muffle Furnace (≈60%) was higher than that of the Valuka Yantra method (≈43%), demonstrating superior thermal efficiency and reduced material loss.

Physicochemical parameters such as Loss on drying, Total ash, Water and Alcohol extractive values were within acceptable limits, reflecting the stability and purity of the formulations.

Heavy metal estimation confirmed by parameters like AAS, XRD, FTIR and ICP-OES demonstrates that, the presence of Mercury (Hg), Sulphur (S), and Arsenic (As) by w/w% in permissible proportions. No traces of lead or cadmium were detected, affirming the safety of the prepared formulations.

Microbial contamination studies revealed complete absence of bacterial and fungal species such as *E. coli, Salmonella, Enterobacteriaceae, Staphylococcus aureus,* and *Pseudomonas aeruginosa,* signifying that the preparations were carried out under hygienic and aseptic conditions.

Solubility analysis demonstrated partial solubility in polar and non-polar solvents, supporting the presence of stable sulphide and arsenical compounds as described in classical literature.

Interpretative Insights

The observed transformations during the process — such as change in *Kajjali* colour from black to red, and the development of a smooth, brick-red crystalline *Sindur* — indicate successful formation of mercuric sulphide-arsenic compounds with desirable physicochemical stability.

The Electric Muffle Furnace offered greater uniformity in heating and minimized Sulphur loss, ensuring better reaction kinetics and enhanced yield, while maintaining the classical properties and efficacy of Shilasindur.

Overall Inference

The study reaffirms that Shilasindur prepared by the Electric Muffle Furnace method meets the classical standards of *Kupipakwa Rasayana* in terms of colour, texture, yield, purity, and analytical profile.

Both methods successfully yielded pharmaceutically acceptable products; however, the EMF method is with reduced manual labour, more efficient, safer, eco-friendly, and suitable for standardization in modern Ayurvedic pharmaceutical industries.

CONCLUSION

Hence, it can be concluded that:

- Electric Muffle Furnace can be confidently adopted as a modern alternative to the traditional *Valuka Yantra*, ensuring consistency, precision, and reproducibility.
- The prepared both *Valuka yantra* and EMF samples of Shilasindur are microbiologically safe, chemically stable, and pharmaceutically potent, aligning with both Ayurvedic principles and modern scientific validation.
- Establishing such standardized analytical parameters and controlled heating techniques can serve as a benchmark for the large-scale production of *Kupipakwa Rasayana*, ensuring quality, safety, and therapeutic efficacy of mercurial formulations in Ayurveda.
- Clinical studies and Toxicity studies can be ruled out further to evaluate its toxicity and validation.

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ABBREVIATIONS

SS: Shilasindur; **SSMF:** Shilasindur prepared by Electric Muffle Furnace; **SSVY:** Shilasindur prepared by Valuka Yantra; **VY:** Valuka Yantra; **EMF:** Electric Muffle Furnace; **Hg:** Mercury; **S:** Sulphur; **AAS:** Atomic Absorption Spectroscopy; **FTIR:** Fourier Transform Infrared Spectroscopy; **ICP-OES:** Inductively Coupled Plasma Optical Emission Spectroscopy; **XRD:** X-ray Diffraction.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

SUMMARY

This study standardized the preparation of Shilasindur, a mercurial Ayurvedic formulation, comparing the traditional *Valuka Yantra* method with the modern Electric Muffle Furnace (EMF) method. Three batches were prepared using each method. The EMF method demonstrated significant advantages, including a higher average yield (59.93%) compared to *Valuka Yantra* (43.46%), reduced fuel consumption, and shorter duration. Analytical evaluation using AAS, ICP-OES, XRD, and FTIR confirmed that both methods produced chemically stable

products free from toxic microbial loads. The study concludes that EMF is a viable, efficient, and eco-friendly alternative for the large-scale manufacturing of Shilasindur.

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