PHARMACEUTICAL STANDARDIZATION AND STAGE WISE ANALYTICAL CHARACTERIZATION OF SWARNAMAKSHIKA WSR SHODHANA AND MARANA PROCESSES USING SEM-EDX AND XRD

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ABSTRACT

Swarnamakshika Bhasma is an important Herbo-mineral preparation described in Ayurvedic Rasa shastra and is traditionally prescribed for conditions such as Pandu (anaemia), Anidra (insomnia), Apasmara (seizure disorders), Mandagni (reduced digestive capacity), and Kushta (skin disorders). It is also esteemed for its Rasayana (rejuvenative) and Vrishya (aphrodisiac) properties, contributing to its broad therapeutic applicability. However, its wider acceptance within contemporary scientific systems has been hindered by limited standardization and insufficient validation through modern analytical methodologies. Therefore, the present investigation aimed to prepare Swarnamakshika Bhasma according to classical Ayurvedic pharmaceutical principles and to systematically evaluate the physicochemical and structural changes occurring during its processing.

The preparation involved conventional Shodhana (purification) and Marana (incineration) procedures. Samples representing four processing stages Raw Swarnamakshika, Shodhita Swarnamakshika, Marita Swarnamakshika after the sixth Puta, and the final Bhasma were subjected to comprehensive analysis. Evaluation included physicochemical testing along with characterization by Scanning Electron Microscopy coupled with Energy Dispersive X-ray Analysis (SEM–EDX) and X-ray Diffraction (XRD).

The finished Bhasma successfully satisfied all classical quality parameters, namely Nishchandra, Rekhapurnatva, Varitara, Unnam, Nisvadutvam, Amla, Avami, and Dantagre Kachkachabhava. SEM–EDX observations demonstrated a sequential reduction in particle size throughout processing, decreasing from approximately 1.66 mm in the raw mineral to 91 nm in the final product, thereby indicating the attainment of a nanometric particle range. Elemental profiling revealed progressive oxidation accompanied by a gradual decline in sulphur content, culminating in its complete absence in the finished Bhasma. XRD studies further established a distinct mineralogical transformation, showing conversion of tetragonal chalcopyrite ($CuFeS_2$) into cubic spinel cuprospinel ($CuFe_2O_4$) without detectable residual sulphide phases. The combined findings from classical and modern analytical assessments substantiate the transformative effects of the Marana process and provide a robust scientific framework for the quality control and standardization of Swarnamakshika Bhasma.

KEYWORDS: Swarnamakshika, Chalcopyrite,Bhasma, Shodhana, Marana, SEM-EDX, XRD, Standardization.

1.INTRODUCTION

Swarnamakshika, mineralogically recognized as chalcopyrite ($CuFeS_2$), is an important mineral drug in Ayurveda with a wide range of therapeutic applications after appropriate pharmaceutical processing. Classical Ayurvedic texts such as the Rasa Tarangini, Rasendra sara sangrah and Ayurveda Prakasha classify it under Updhatu Varga and emphasize that it should be administered only after undergoing prescribed Shodhana (purification) and Marana (incineration) procedures. The raw mineral is considered unsuitable for direct therapeutic use because of the presence of impurities and the potential risk of undesirable effects.

In Ayurvedic pharmaceutics, Shodhana and Marana are regarded as essential procedures for converting the crude mineral into a therapeutically effective and biologically assimilable form known as Bhasma. Although these pharmaceutical processes are extensively described in classical Rasashastra literature, their validation through modern physicochemical and analytical techniques remains limited. The gradual reduction in particle size during successive Marana cycles, often reaching the nanometric range, is believed to enhance bioavailability and improve systemic absorption. This phenomenon also provides a scientific rationale for traditional quality assessment parameters such as Rekhapurnatva and Varitara.

A review of the available literature indicates that most previous studies have focused primarily on the characterization of the final Bhasma, while comparatively little attention has been given to the transformations occurring during intermediate stages of processing. Detailed stage-wise investigations of Swarnamakshika using advanced analytical tools, including Scanning Electron Microscopy coupled with Energy Dispersive X-ray Analysis (SEM–EDX) and X-ray Diffraction (XRD), across different Puta stages are scarce. Examination of intermediate stages, particularly the 6th Puta, may provide valuable insights into the progressive physicochemical, elemental, and crystallographic changes that occur during the Marana process.

Therefore, the present study was undertaken to standardize the pharmaceutical preparation of Swarnamakshika Bhasma and to perform a comprehensive stage-wise analytical evaluation using SEM–EDX and XRD. The study aims to establish a scientific correlation between classical Ayurvedic pharmaceutical procedures and the physicochemical as well as mineralogical transformations that take place during the conversion of raw Swarnamakshika into Bhasma.

2.AIM AND OBJECTIVES

Aim

To scientifically characterize the stage-wise physicochemical, elemental, and crystallographic transformations of Swarnamakshika during Shodhana and Marana using SEM-EDX and XRD.

Objectives

1. To prepare Swarnamakshika Bhasma as per classical Ayurvedic procedures.
2. To evaluate final Bhasma using traditional Bhasma Pariksha tests.
3. To analyze morphological and elemental changes at each stage (Raw, Shodhita, 6^{th} puta, Marita) via SEM-EDX.
4. To determine crystallographic phase transformation from raw to final Bhasma using XRD.
5. To correlate classical observations with modern analytical findings for standardization.

3.MATERIAL & METHODS

This study was carried in the following steps:

3.1. Collection of Raw Material
3.2. Shodhana of Swarnamakshika
3.3. Marana of the Swarnamakshika

3.1. COLLECTION OF RAW MATERIAL

Ashuddha Swarnamakshika was procured from Surat, Gujarat, possessing all the Grahya Lakshanas described in the classical texts. The raw material was authenticated by the Department of Rasa shastra and Bhaishajya Kalpana, Government Ayurveda College, Raipur, Chhattisgarh.

3.2. SHODHANA OF SWARNAMAKSHIKA

S.No.	Ingredient	Quantity(gm/L)	Duration
1.	Raw Swarnamakshika	610gm	3day
2.	Nimbu Swarasa	1500mL (100 pieces)	

Equipment

The present study employed pounding apparatus (Mortar & Pestle) and Puta Yantra (incineration apparatus) as primary pharmaceutical equipment. Additional instruments and materials utilized during the preparation included a steel vessel, pounding apparatus, calibrated weighing machine, wooden stirring rod, knife, mechanical juice extractor, thread, muslin cloth (Mulmul), fuller's earth (Multani Mitti), and spatula, among other ancillary items.

Procedures

Swarnamakshika was subjected to Shodhana employing the Bharjana (roasting) technique as described in classical Rasa texts.

1. Raw Swarnamakshika was finely powdered using a pounding apparatus to obtain a uniform particle size.
2. The powdered material was transferred to a clean, dry iron pan and subjected to heating over a charcoal furnace.
3. The material was heated at an approximate temperature range of 850–900°C. During the heating process, fresh lemon juice (Nimbu Swarasa) was added intermittently. Continuous stirring was maintained using an iron darvi to ensure uniform exposure to heat.
4. To minimize material loss due to dusting during the addition of lemon juice, the iron pan was partially covered with an iron plate.
5. The roasting process was continued until the Cessation of Sulphur fumes, indicating the completion of the primary stage of purification.

6. The entire procedure was repeated for three consecutive days, with each session lasting approximately 2 hours.
7. The process was terminated when the base of the iron vessel attained a Red-hot condition, ensuring adequate heat exposure.

Observations

Table No. 1.1. Observations during Swarnamakshika Shodhana

S.No.	Time/Stage of Heating	Observation
1.	Initial heating (0–50 min)	Continuous evolution of Sulphur fumes with characteristic odour observed
2.	During lemon juice addition	Heavy dusting of material noted; precaution required
3.	Early stage	Colour changed from light greenish to dark greenish; mixture became paste-like
4.	Intermediate stage	Bubble formation observed; mixture became more liquid in consistency
5.	25–30 minutes	Mixture turned sticky and semi-solid; colour changed to blackish-grey
6.	Further heating	Complete evaporation of moisture; mixture converted to powder form; colour became dark purple
7.	Prolonged heating	Gradual Change to dark rust-brown colour
8.	Final stage	Heating stopped when bottom of iron vessel became red-hot
9.	Total duration	Shodhana completed over 3 days (2 hours/day)

Table No. 1.2. Observations during Swarnamakshika Shodhana

Ashodhita Swarnamakshika (gm)	No. of *Nirvapa*	Qt. of Nimbu Swaras (ml)	Duration of heating (hr)/ (temp °C)	Shodhita Swarnamakshika (gm)	Shodhita Swarnamakshika loss %/(gm)
610gm	1	500mL	2 hours (850-900°C)	580gm	4.92% (30gm)
580gm	2	500mL	2 hours (850-900°C)	560gm	3.44% (20gm)
560gm	3	500mL	2 hours (850-900°C)	540gm	3.57% (20gm)
TOTAL		1500mL	6 hours	-	11.48% (70gm)

Fig. 1. Stage-wise weight change and percentage weight loss during Shodhana of Swarnamakshika

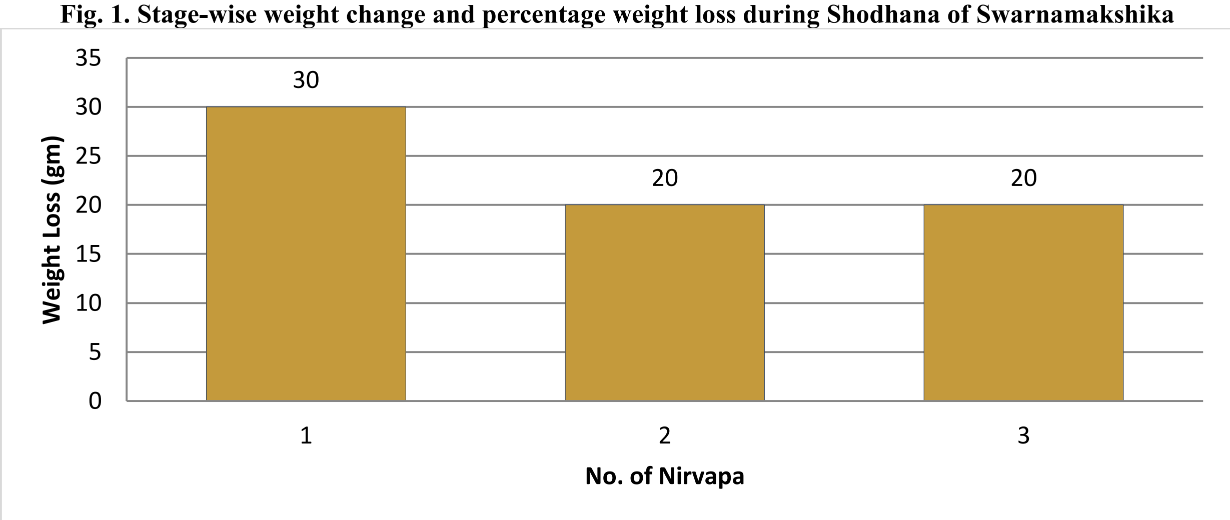


Table No. 1.3. Organoleptic Characteristics of Swarnamakshika

S.No.	Parameters	Swarnamakshika	
		Before Shodhana	**After Shodhana**
1.	Appearance	Shiny and hard in look	Red brownish
2.	Colour	Brassy golden yellow	Rust Brown Colour
3.	Touch	Hard crystalline	Brittle, course powder
4.	pH	4.5	6.8
5.	Odour	Odourless	Metallic Sulphur

Precaution's

1. Sufficient quantity of Nimbuka Swarasa was taken for total immersion of the mixture.
2. Care was taken to avoid the spilling of the mixture from the iron vessel.
3. Care was taken to avoid the adherence of the mixture to the iron vessel.
4. The iron vessel was cleaned and dried thoroughly before use.
5. Continuous and uniform trituration was maintained throughout the process.
6. A protective mask was worn by the operator to prevent inhalation of fine particles.
7. The prepared mass was stored in a clean, dry, airtight container away from moisture and direct sunlight.

4.MARANA OF SWARNAMAKSHIKA

Material – Shuddha (Bharjita) Swarnamakshika- 540gms and Nimbuka Swarasa - 180 mL each process of Marana.

Equipment

Two earthen Sharavas of equal size, Khalva Yantra (mortar and pestle), muslin cloth (Mulmul), fuller's earth (Multani Mitti), Vanopalas (cow dung cakes), camphor, calibrated weighing machine, and pyrometer

Principle: Wet Triturations & Puta system of heating.

Procedure

A quantity of 540 g of Bharjita Shuddha Swarnamakshika was subjected to Bhavana (wet trituration) with freshly prepared Nimbuka Swarasa, using approximately 180 mL per Puta, in a Khalwa Yantra for about three hours. Trituration was continued until a smooth and uniform mass was obtained. The prepared mass was then manually molded into small, uniformly sized Chakrikas (pellets/discs) and spread over a clean plastic sheet for drying under ambient conditions. After complete drying, the Chakrikas were weighed and the observations were recorded.

The dried Chakrikas were placed in an earthen container (Sharava) and covered with another Sharava to prepare a Sharava Samputa. The junction between the two earthen dishes was sealed securely with clay-smeared cloth strips (Sandhi Bandhana) and allowed to dry thoroughly before subjecting it to heating.

The sealed Samputa was then processed according to the Varaha Puta method. The dried cow dung cakes (Vanopalas) were arranged as a lower bed and an upper covering over the Samputa, with the total quantity gradually increased across successive Puta cycles from about 4 kg in the initial Putas to nearly 10.5 kg in the final Puta averaging approximately 5 kg per Puta. In each Puta cycle, heating was carried out in a gradual and controlled manner, reaching the maximum temperature over a period of approximately two hours, after which the Samputa was left undisturbed for natural self-cooling (Swangasheeta) to room temperature. The peak temperature attained ranged between 630°C and 900°C, increasing progressively with successive Putas.

After completion of heating and Swangasheeta, the material obtained after incineration was collected and again triturated with fresh Nimbuka Swarasa, averaging approximately 180 mL for each Puta cycle. The entire sequence of Bhavana, Chakrika preparation, drying, sealing, incineration, and self-cooling was repeated successively. This procedure was continued for a total of thirteen (13) Puta cycles, until the product satisfied all the prescribed Bhasma Siddhi Lakshanas. On average, each Puta cycle required about 180 mL of Nimbuka Swarasa and a heating duration of approximately two hours up to the maximum temperature followed by Swangasheeta, while both the quantity of cow dung cakes and the peak temperature showed a gradual increase with successive Puta cycles. The weight of the material reduced progressively from 540 g to a final 470 g on completion of the Marana process.

Observation

Before the first Puta, the Shodhita Swarnamakshika Chakrikas were rust-brown, lustrous discs weighing 540 g. During each Puta, sulphurous (SO_2) fumes evolved and subsided after ~45 minutes. Each cycle involved ~2 hours of heating followed by 24-hour self-cooling (Swangasheeta). The maximum temperature rose progressively from 630°C (1st Puta) to 900°C (13th Puta), with cow dung cake increasing from 4 to 10.5 kg and Nimbu Swarasa reduced from 200 to 160 mL. After thirteen Puta, a fine, lustreless (Nischandra) blackish-brown Bhasma weighing 470 g was obtained a cumulative loss of 70 g

Table No.1.4. Observation during Marana process

No. of Puta	Qt. of Nimbu Swarasa (mL)	Wt. of Shodhita Swarnamakshika Before Marana (gm)	Wt. of Cow Dung Cake Used (gm)	Max. Temp. (°C)	Total Duration (Heating up to Max. Temp. then swangasheeta)	Wt. of Shodhita Swarnamakshika After Marana (gm)	Wt. of Marita Swarnamakshika Loss (gm)
1.	200mL	540gm	4kg	630°C	2 hours	537gm	3gm
2.	200mL	537gm	4kg	650°C	2 hours	534gm	3gm
3.	195mL	534gm	4kg	680°C	2 hours	530gm	4gm
4.	190mL	530gm	4kg	700°C	2 hours	525gm	5gm
5.	190mL	525gm	4kg	720°C	2 hours	520gm	5gm
6.	185mL	520gm	4.2kg	750°C	2 hours	516gm	4gm
7.	180mL	516gm	4.2kg	770°C	2 hours	510gm	6gm
8.	180mL	510gm	4.2kg	800°C	2 hours	503gm	7gm
9.	175mL	503gm	4.5kg	820°C	2 hours	496gm	7gm
10.	170mL	496gm	4.5kg	850°C	2 hours	488gm	8gm
11.	170mL	488gm	6kg	870°C	2 hours	481gm	7gm
12.	165mL	481gm	9kg	890°C	2 hours	476gm	5gm
13.	160mL	476gm	10 ½kg	900°C	2 hours	470gm	6gm

Fig. 2. Maximum Temperature Attained During Each Puta of Marana

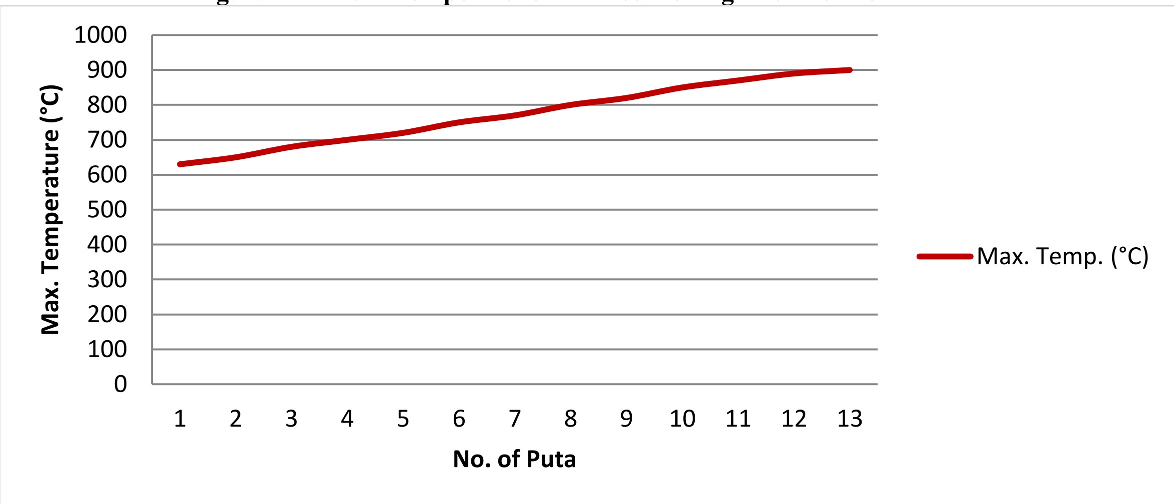


Fig. 3. Weight Loss per puta During marana

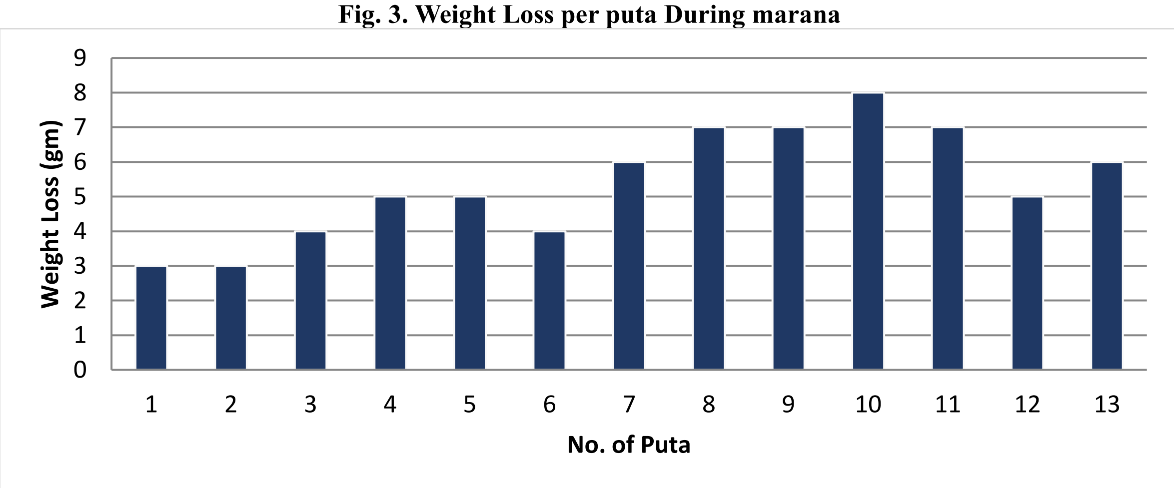


Fig.4. Progressive Weight Reduction of Across Successive Puta

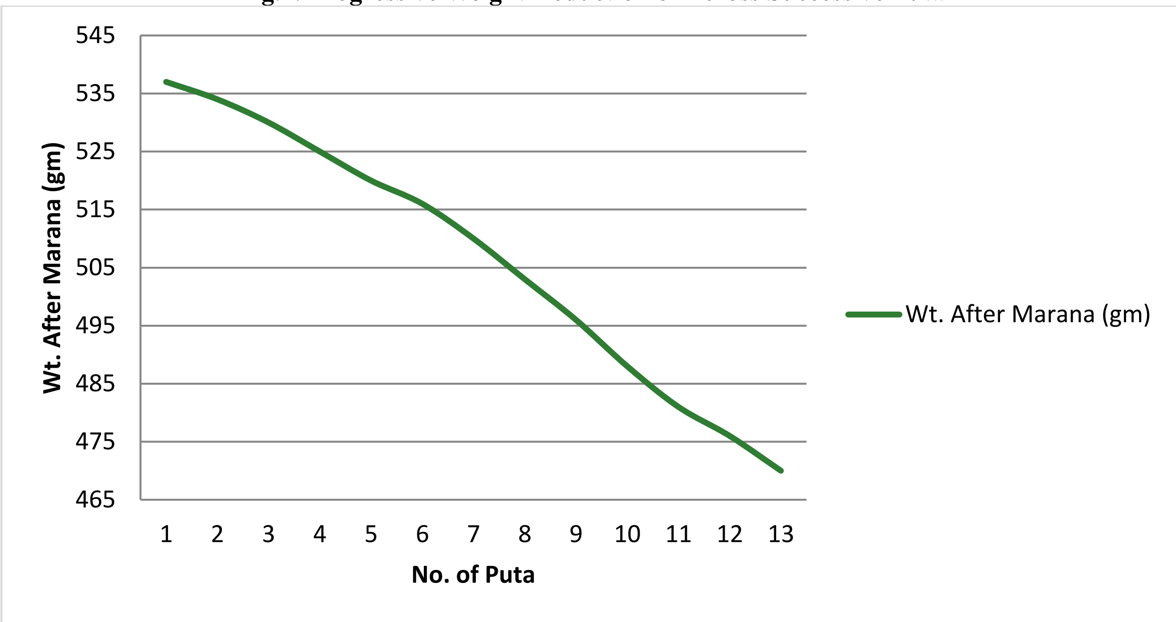


Fig.5. Serial Puta (Incineration) Cycles in the Preparation of Swarṇamakṣika Bhasma

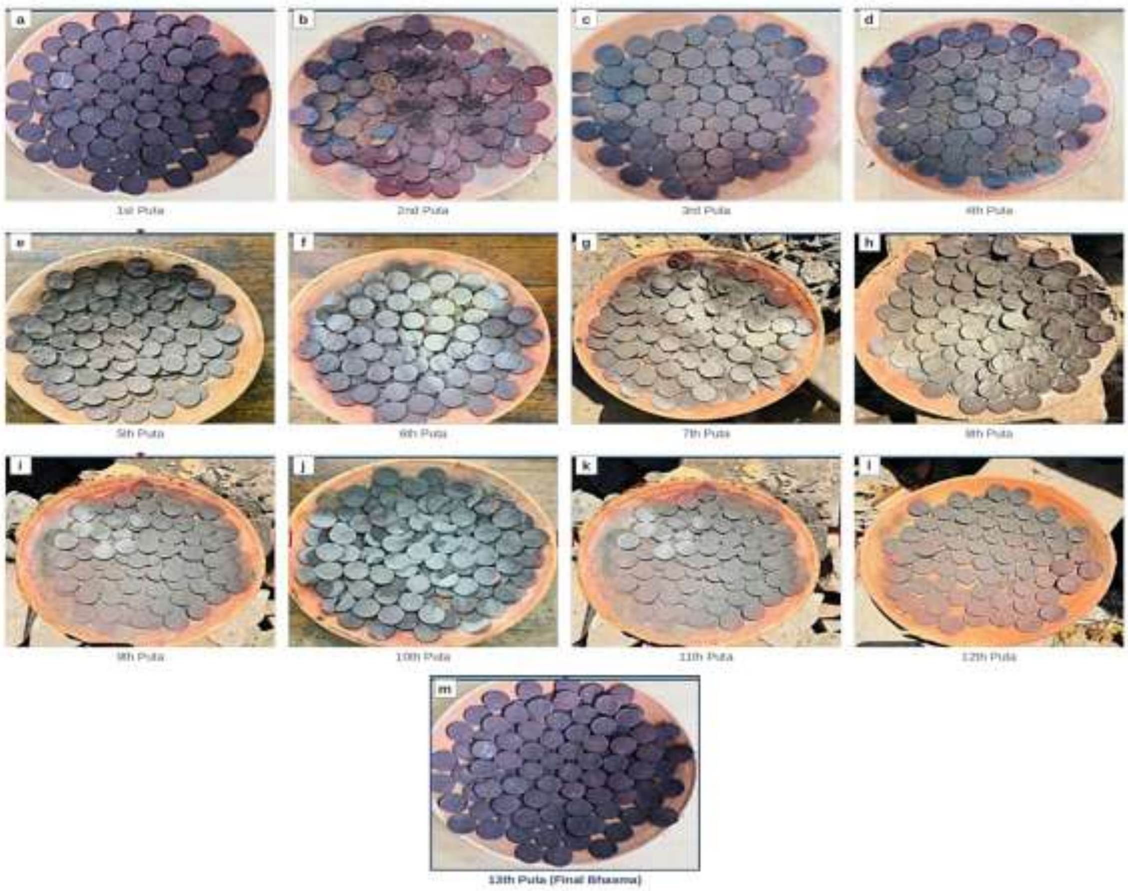


Table No.1.5. Organoleptic Characteristics of Swarnamakshika Bhasma

Parameter	***Swarnamakshika Bhasma***			
	1st *Puta*	**5th *Puta***	**10th *Puta***	**13th *Puta* (Final)**
Appearance	Coarse, Irregular Powder with Metallic Sheen	Fine Powder, Partially Lustrous	Fine Powder, Non-Lustrous (Nischandratva)	Very Fine, Amorphous Powder, Non-Lustrous (Nischandratva)
Colour	Dark Brown	Brick Red	Reddish Brown	Reddish Brown

Touch	Hard	Soft, Fine Powder	Soft, Fine Powder	Soft, Very Fine Powder
Odour	Metallic With Sulphur	Metallic With Mild Sulphur	Faint Metallic, Trace Sulphur	Odourless
Taste	Metallic	Mild Metallic	Faint Metallic	Tasteless

5.ClASSICAL BHASMA PARIKSHA

5.1. Nischandratva

Bhasma must be Nischandra (lusterless) after completion of pharmaceutical procedure pinch of Bhasma brought to sunlight and carefully observed, noted that Prescence of shiny or any luster. The presence of lustre implies that the Bhasma still requires further incineration. This test is especially mentioned to Abhraka bhasma and Swarna Makshika (copper pyrite) Bhasma.

5.2. Rekhapurnatvam

A pinch of Bhasma was taken in between the thumb and index finger and rubbed. It was observed that the Bhasma entered into the lines of the finger, and was not easily washed out from the cleavage of the lines.

5.3. Varitaratavam

A small amount of the prepared Bhasma was sprinkled over the still water in a beaker. It was found that the Bhasma particles floated over the surface of the water.

5.4. Unnam

Unnam test is further continued stage or step of varitara test. Little quantity of Bhasma sprinkled over water and a grain is placed over it. After placing grain over that floating bhasma Bhasma not supposed to sink. Which particle won't sink indicates good quality of Bhasma

5.5. Nisvadutvam

The prepared Bhasma was found to be tasteless when a small amount was kept on the tongue.

5.6. Amla Pariksha

This Bhasma Pareeksha is not for all Bhasma and is ment for few Bhasma. In this Bhasma Pareeksha pinch of Bhasma will be placed over amla Dravya like curd, lemon juice, etc., for few minutes and observed for changes in the colour of amla Dravya is noted. Change of colour indicates Bhasma still needs to be continued to puta as it is is apakwa and no discoloration in Amla Dravya indicates Bhasma is Pakwa. No need to continue to the puta further again. It is the specific test described for Tamra (Copper) Bhasma

5.7. Avami Pariksha

Pinch of Bhasma when asked to take orally it should not produce either nausea or vomiting sensation. This Bhasma pareeksa is specially recommended to Tamra (copper) and Copper Containing material etc.

5.8. Dantagre Kachkachabhava

When very small quantity of Bhasma placed over lower molar teeth asked to crush it or rub it with upper molar teeth. One should not feel gritty on chewing i.e., Kachkachaabhava and has a consistency like pollen grains of Ketaki (Pandanus odoratissimus), then it is said to be formed properly for use.

Table No. 1.6. Classical Bhasma Pariksha Raw, Shodhita and 6th Marita Puta and Final Bhasma

S. No.	Parameter	Raw Swarnamakshika	Shodhita Swarnamakshika	After 6th puta	Final Bhasma
1.	Varitar	Sink immediately	Sink	Partial Floating (50%)	Floating
2.	Unnam	0 Secound	0 secound	5 minutes (Partial)	30 minutes <
3.	Rekhapurnatva	Negative	Negative	Partial	Enters finger lines
4.	Nischandratva	High metallic Luster Present	Dull Partial Luster	No Luster	Completely Absent
5.	Nisvadutvam	Metallic Taste	Slightly Metallic	Very Mild	No taste

6.	Amla Pariksha	Effervescence present	Mild Effervescence present	Very Mild Effervescence present	Absent
7.	Avami	Nausea induced	Mild	No	No

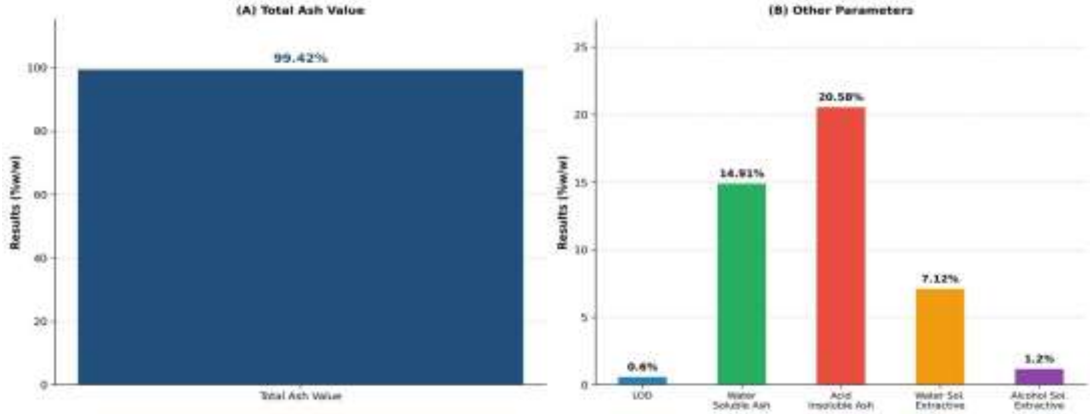
ANALYTICAL STUDY

1.Physicochemical Parameters of Swarnamakshika Bhasma (SMB)

Table No. 1.7. Physicochemical Parameters of Swarnamakshika Bhasma

S. No.	Parameter	Results (%w/w)	Method
1.	Loss On Drying (LOD)	0.6%	Heated at 105°C for 4 hours
2.	Total Ash Value	99.42%	Ignited at 450°C ± 50°C
3.	Water Soluble Ash	14.91%	Boiled Total ash with water, filtered, ignited
4.	Acid insoluble Ash	20.58%	Boiled Total ash with dilute HCl, filtered, ignited
5.	Water Soluble Extractive	7.12%	Macerated with chloroform/Distilled water
6.	Alcohol Soluble Extractive	1.2%	Macerated with Alcohol

Fig.6. Physicochemical Parameters of Swarnamakshika Bhasma



2.SEM Analysis

Table No. 1.8. Stage Wise Particle Size of Swarnamakshika

S. No.	Stage	Particle Size
1.	Raw Swarnamakshika (RSM)	1.66mm
2.	Shodhita Swarnamakshika (SSM)	201nm
3.	6th Puta Marita Swarnamakshika (6P-SMB)	206nm
4.	Final Bhasma (SMB)	91nm

Fig. 7. Line Graph Particle Size of Swarnamakshika different stages

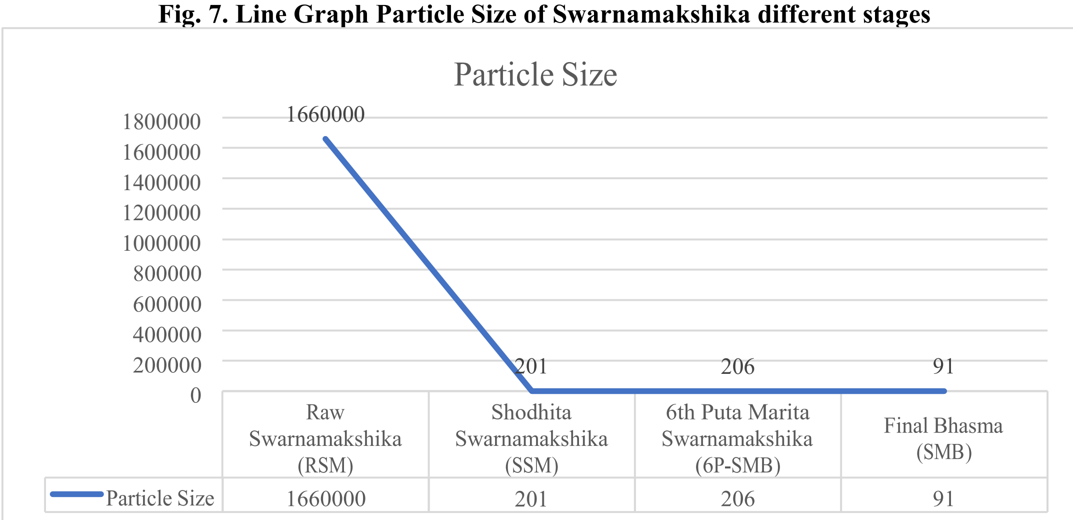
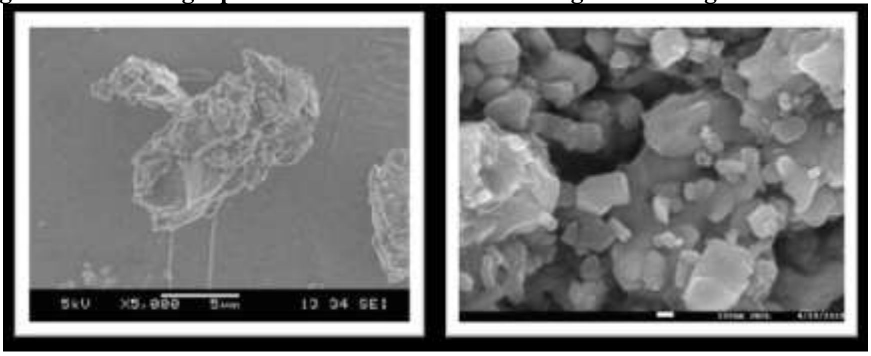
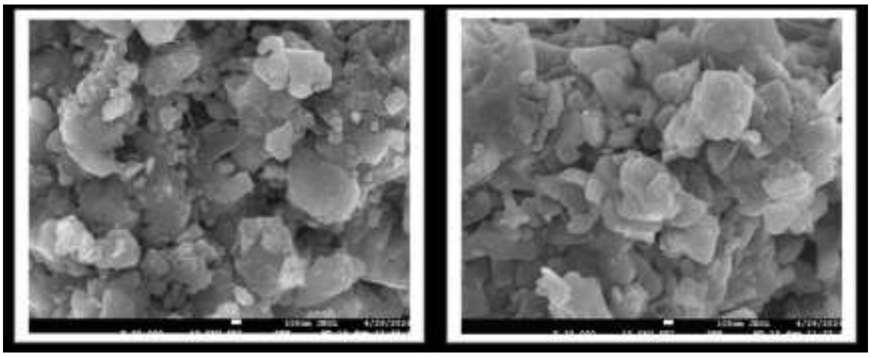


Fig.8: SEM Micrographs of Swarnamakshika at Progressive Stages of Processing



1. Raw Swarnamakshika **2.Shodhita Swarnamakshika**



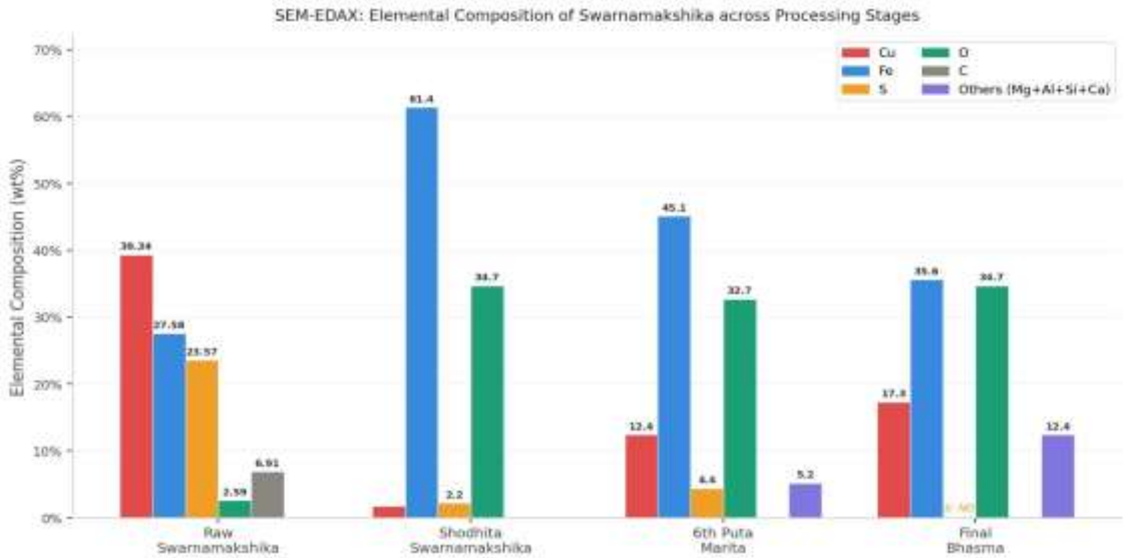
3.After 6th Puta **4. Swarnamakshika Bhasma**

3.EDX Analysis

Table No. 1.9. Stage Wise Elemental Composition of Swarnamakshika

Stage	Elemental Composition								
	Cu (Wt .%)	Fe (Wt. %)	S (Wt. %)	O (Wt.%)	C (Wt.%)	Mg (Wt.%)	Al (Wt.%)	Si (Wt.%)	Ca (Wt.%)
Raw Swarnamakshika	39.34	27.58	23.57	2.59	6.91	-	-	-	-
Shodhita Swarnamakshika	1.7	61.4	2.2	34.7	-	-	-	-	-
6th Puta Marita Swarnamakshika	12.4	45.1	4.4	32.7	-	1.0	1.3	2.9	-
Final Bhasma	17.3	35.6	ND	34.7	-	0.8	-	8.9	2.7

Fig.9. Comparative Bar Chart of Elemental Composition (Wt.%) of Swarnamakshika across Processing Stages



4.XRD Analysis

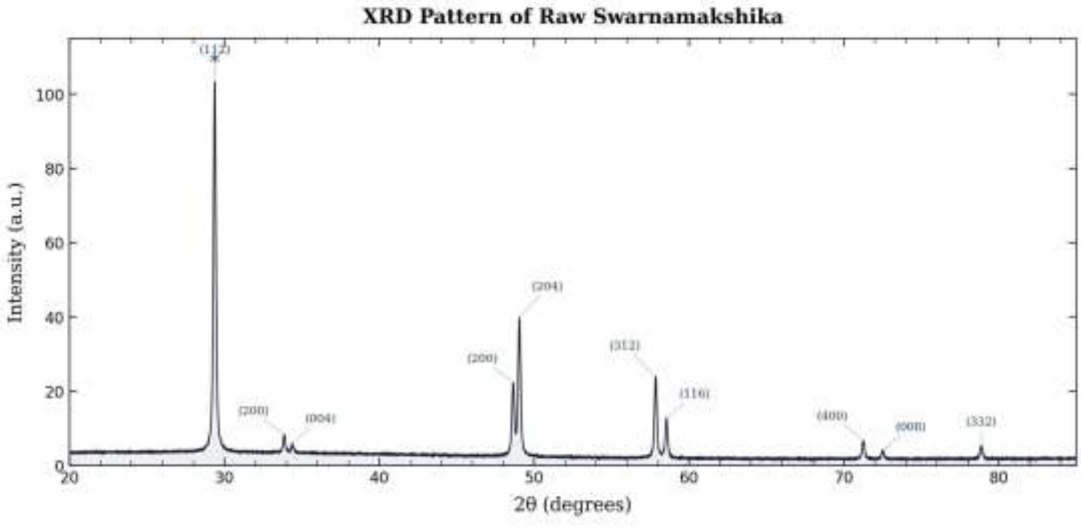
4.1. Raw Swarnamakshika (RSM)

Reference Code	96-901-5235
Mineral name	Chalcopyrite
Compound Name	Chalcopyrite
Common name	Chalcopyrite
Chemical formula	Cu4.00Fe4.00S8.00
Crystal system	Tetragonal

Table No. 1.10. XRD Peaks of Raw Swarnamakshika

S. No.	2θ (deg)	d-spacing (Å)	h k l	Relative Intensity (%)
1.	29.37	3.03875	112	100.0
2.	33.86	2.64500	200	4.6
3.	34.39	2.60550	004	2.2
4.	48.64	1.87030	200	18.9
5.	49.04	1.85617	204	36.9
6.	57.84	1.59278	312	21.9
7.	58.54	1.57543	116	10.5
8.	71.25	1.32250	400	4.8
9.	72.50	1.30275	008	2.3
10.	78.87	1.21263	332	3.5

Fig. 10. XRD Pattern of Raw Swarnamakshika (RSM)



4.2. Swarnamakshika Bhasma (SMB)

Reference Code	96-591-0029
Compound Name	Cuprospinel
Common Name	Cuprospinel
Chemical formula	Cu8.00Fe16.00O32.00
Mineral Name	Cuprospinel
Crystal system	Cubic

Table No. 1.11. XRD Peaks of Swarnamakshika Bhasma

S. No.	2θ (°)	d (Å)	Hkl	I (%)

1.	18.35	4.831	111	6.9
2.	30.18	2.958	022	55.1
3.	35.55	2.523	311	100.0
4.	37.19	2.415	222	21.3
5.	53.60	1.708	242	14.9
6.	57.14	1.610	151	19.1
7.	62.75	1.479	044	18.8
8.	71.20	1.323	062	4.7
9.	74.25	1.276	353	7.0
10.	89.98	1.089	173	7.3

Fig.11. XRD Pattern of Swarnamakshika Bhasma (SMB)

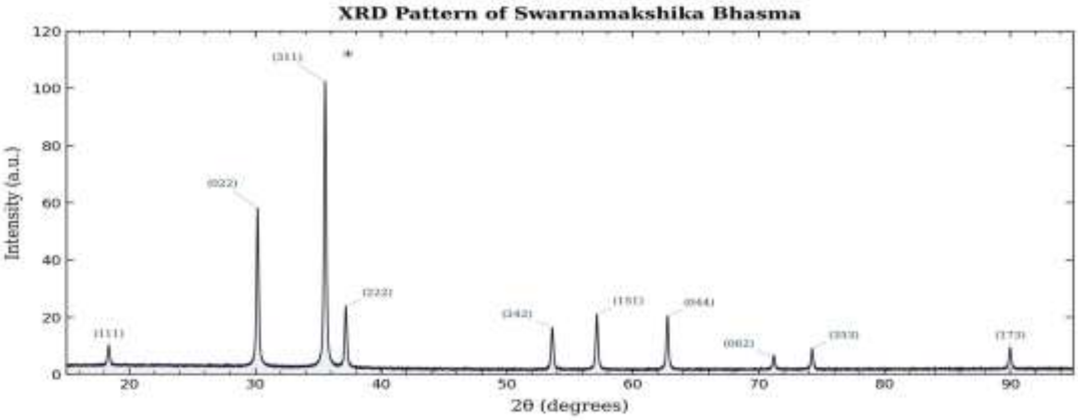


Fig. 12. Shodhana Process of Swarnamakshika

1. Raw SM 2. Sieving of Swarnamakshika 3. Fine Powder 4. Nimbu Swarasa

5. Bhavana of Nimbu Swarasa 6. Bharjana of SM 7. Raktatapta SM 8. Shodhita SM

Fig. 13. Swarnamakshika Marana Process

1. Nimbu Swarasa Bhavana 2. Mardana 3. Chakrika Nirmana 4. Chakrika Shoshana

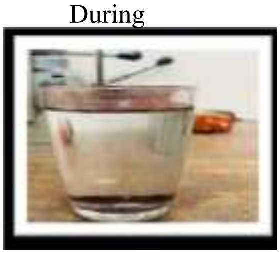



5. Sandhibandhana | 6. Before Puta | 7. After Puta | 8. SMB

Fig.14. Bhasma Pariksha of Swarnamakshika Bhasma




1. Amla Pariksha Before | 2. Amla Pariksha During | 3. Amla Pariksha After | 4. Rekhapurnatva

5.Varitara — I | 6. Varitara — II | 7. Nischandra | 8. Unnama

5.DISCUSSION

Shodhana of Swarnamakshika was successfully achieved using the Bharjana technique (850–900°C; three cycles of 2 hours each, employing 1500 mL of Nimbu Swarasa for 610 g of raw mineral) through three simultaneous mechanisms: thermal oxidation of sulphide ions ($S^{2-} \rightarrow SO_2\uparrow$), citric acid-mediated chelation of surface Cu^{2+} and Fe^{3+} ions, and steam flash-induced microfracture propagation. Together, these processes facilitated desulphurization, lattice disruption, and solubilisation of impurities in the liquid medium.

The progressive colour transition from brassy yellow to rust-brown and the transformation of crystalline lumps into a brittle powder reflect stage-wise formation of Fe_2O_3 and CuO, along with thermally induced lattice fragmentation. The increase in pH from 4.5 to 6.8 further indicates gradual neutralization of reactive Sulphur-containing acidic constituents present in the raw sulphide ore.

The cumulative weight loss of 11.48%, distributed as 4.92% in the first cycle, 3.44% in the second cycle, and 3.57% in the third cycle, is attributable to the elimination of sulphur, moisture, and other volatile impurities. The greater loss during the initial cycle and reduced losses in subsequent cycles indicate preferential removal of labile constituents followed by attainment of a thermally stabilised mineral state, confirming satisfactory Shodhana and suitability for subsequent Marana.

During Marana, the mass declined monotonically from 540 to 470 g (12.96% cumulative loss) over thirteen Puta, reflecting progressive oxidative desulphurization ($CuFeS_2 \rightarrow$ mixed oxides; sulphur expelled as $SO_2\uparrow$). Per-cycle loss peaked mid-process (8 g at the 10th Puta) and tapered terminally, marking a compositionally stable endpoint (Bhasma Siddhi). This required escalating input (temperature 630→900°C; fuel 4→10.5 kg) to complete oxidation and reduce particle size, while reduced Nimbu Swarasa (200→160 mL) reflected a finer, more friable material. The loss of metallic lustre (Nischandratva) further corroborated the sulphide-to-oxide conversion.

Physicochemical parameters validated successful pharmaceutical transformation. The low LOD value (0.6% w/w) indicated minimal residual moisture, while the high total ash value (99.42% w/w) reflected near-complete inorganic composition and thorough incineration. The negligible alcohol-soluble extractive value (1.2% w/w) further confirmed the absence of significant organic residues. Water-soluble ash (14.91% w/w) represented the soluble mineral fraction, whereas acid-insoluble ash (20.58% w/w) suggested silicate incorporation from the earthen Sharava during repeated Puta cycles, a finding corroborated by EDX analysis (Si: 8.9 wt.%).

SEM analysis demonstrated progressive nanoscale transformation, with particle size decreasing from 1.66 mm in raw Swarnamakshika to 91 nm in the final Bhasma, representing approximately an 18,241-fold reduction through repeated Bhavana–Puta cycles. The attainment of sub-100 nm dimensions substantially increases surface area and dissolution kinetics, providing a mechanistic basis for enhanced bioavailability.

EDX analysis revealed complete desulphurization (S: 23.57 wt.% → ND) accompanied by a corresponding increase in oxygen content (2.59 wt.% → 34.7 wt.%), confirming progressive conversion of the sulphide mineral into a stable oxide form. Trace amounts of Si, Al, Ca, and Mg likely originated from the Sharava and Bhavana media during successive Puta cycles.

XRD analysis confirmed complete crystallographic phase transformation from tetragonal chalcopyrite ($CuFeS_2$; space group I-4̅2d, No. 122; characteristic (112) reflection at 2θ = 29.37°, d = 3.039 Å, c/a = 1.97) to phase-pure cubic cuprospinel ($CuFe_2O_4$; space group Fd3̅m, No. 227; principal (311) reflection at 2θ = 35.55°, lattice parameter a = 8.369 Å). The absence of residual chalcopyrite peaks, intermediate phases, and amorphous humps provides definitive crystallographic evidence of complete Marana. The thermodynamically stable inverse spinel structure of $CuFe_2O_4$ further offers a molecular basis for the concept of Apunarbhavatva.

6.CONCLUSION

Swarnamakshika is maharasa dravya considered to be rasayangrya and sarvarogahara. It is a good rasa formulation which can be independently prescribed. Properly shodhita and marita swarnamakshika bhasma does broad spectrum action due to its nanoparticle form and in bound properties.

The present study successfully standardized Swarnamakshika Bhasma through classical Shodhana and Marana procedures. Classical Bhasma Pariksha confirmed proper Bhasma formation. SEM analysis showed significant particle size reduction from 1.66 mm to 91 nm, indicating nanoscale transformation. EDX analysis revealed progressive desulfurization and oxidation with complete absence of sulphur in the final product. XRD confirmed phase transformation from tetragonal chalcopyrite ($CuFeS_2$) to cubic cuprospinel ($CuFe_2O_4$). These findings scientifically validate the transformation of raw Swarnamakshika into a stable and standardized Bhasma.

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