WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
Coden USA: WJPRAP Impact Factor 8.63
Volume 15, Issue 13, 1516-1535. Review Article ISSN 2277–7105

CRITICAL REVIEW OF RAJATA BHASMA (INCINERATED SILVER)

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Article Received on 09 June 2026,
Article Revised on 29 June 2026,
Article Published on 01 July 2026

https://doi.org/10.5281/zenodo.21093196

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How to cite this Article: Dr. Vidyawati P. Mathpati*[1], Dr. Pravin M. Tate[2] (2026). Critical Review Of Rajata Bhasma (Incinerated Silver). World Journal of Pharmaceutical Research, 15(13), 1516-1535.

ABSTRACT

Background:- Rajata Bhasma (RB) is a highly regarded formulation in Rasashastra (Ayurvedic pharmaceutics) widely used for metabolic, neuromuscular and infective disorders. Despite its traditional longevity, modern biomedical safety requires systematic characterization and validation. **Objective:-** This critical review maps and synthesizes the existing peer-reviewed literature on the pharmaceutico-analytical methodologies, pre-clinical and clinical evaluations of Rajata Bhasma. **Methods:-** Academic database screening was performed to evaluate traditional processing steps (Shodhana, Marana), modern physico-chemical characterizations, and pre-clinical (toxicological and antimicrobial) and clinical studies**. Results:-** RB undergoes structural reduction into ultra-fine or spherical nanoparticle aggregates (ranging between 10 to 400 nm) shifting the raw silver phase predominantly into bio-compatible silver sulfide (Ag_2S) and silver oxide (Ag_2O) crystalline structures. Pre-clinical bio-assays validated that Rajata Bhasma showed broad-spectrum antimicrobial properties and a clear non-toxic profiling onset (e.g. safe under 5 µg /ml zebrafish embryo assays). **Conclusion:-** The classic multi-step Bhasmikarana technique successfully converts metals into absorbable therapeutic formulation.

KEYWORDS: Rajata Bhasma, Incinerated Silver, Pharmaceutical, Analytical, Experimental, Clinical studies.

1. INTRODUCTION

Ayurveda is a traditional Indian medicine since Vedic time.[1,2] The sources of medicine are plants, animals, metals and minerals which are converted into herbal, herbo-mineral and metallic formulation, it is used in various diseases. Metals have been used in various disease conditions since ancient time, but their use expanded after development of *Rasashastra*, which is a fundamental part of Ayurveda. *Bhasma* of metals or minerals are one of the main pharmaceutical forms in *Rasashastra*. *The characteristics of b*hasmas are quick acting, requires in small doses, have a longer shelf life, have catalytic properties and are Immunomodulaters in action. RB is recognized as a clinically more used bhasma prior to Swarna (Gold). Ancient scholars systematically utilized a process known as Bhasmikarana- a series of purification and Incineration - to alter the metals into a bio-compatible, absorbable state. Now a days, modern science frequently questions metalo-mineral therapeutics due to heavy metal toxicity concerns. However, growing scientific evidence shows that ancient bhasmas closely align with modern nanomedicines. To build global clinical trust, modern physical and chemical evaluation parameters must be standardized alongside classical diagnostic tests (Bhasma Pariksha). RB is indicated in diabetes, hepatic disorders, respiratory disorders, burning sensation, uterine disorders, neurological disorders. And acts as a Rasayana (Immunomodulator), Balya (energizer), Smrutivardhaka (nootropic), Vrushyam (aphrodisiac).[6] Considering the effectiveness of RB, the present study compiles the available research on RB.

This critical review synthesizes the scientific literature on the pharmaceutical processing, modern analytical testing, experimental validation profiles and clinical studies of Rajata Bhasma.

2. MATERIALS AND METHODS

The Ayurvedic Samhitas and compilation studies were reviewed to provide detailed information on RB. Published articles have considered Rajata Bhasma. *Rajata* was processed through *Shodhana* and Marana to prepare *Rajata Bhasma*. (Table 1 shows Rajata Shodhana and Table 2 shows Rajata Marana process).

2.1 PREPARATION OF RAJATA BHASMA

The pharmaceutical manufacturing of Rajata Bhasma is divided into two fundamental stages: Shodhana (purification) and Marana (levigation and incineration).

2.1.A. Shodhana (Purification Phase)

Shodhana represents more than chemical purification; it alters the structural malleability of raw metal sheets.

Samanya Shodhana (General Purification):- Raw silver foils are heated to a red-hot state and repeatedly quenched (typically 7 times) in a sequence of liquid media like Tila Taila (sesame oil), Takra (buttermilk), Gomutra (cow urine), Kanji (sour gruel), and Kulattha Kwatha (horse gram decoction). (Table No.1)

Vishesha Shodhana (Specific Purification):- Eliminates persistent metallic shine. Silver foils are specifically quenched in acidic plant juices or lime juice, inducing surface oxidation, micro cracking, and the removal of trace target impurities. The table below compiles the classical methods, specific pharmaceutical media, processing methods (Nirvapa or heating and quenching), and cycles as described in standard authoritative Rasashastra texts. (Table No.1)

2.1.B. Marana (Incineration Phase)

Purified silver foils cannot be broken down by heat alone without an intermediate media. Therefore, incineration is required. (Table 2 shows the Rajata marana process with references).

There are two methods

1. Using Kajjali/ Mercurial Media:- Shodhita silver is mixed with Kajjali (a black amalgam of processed mercury and sulfur). Studies have shown that adding Kajjali forms a smooth amalgam over the silver foil.

2. Using Herbal Media:- Levigating the metal with specific plant extracts (e.g., Aloe Vera juice or Lemon juice). The organic compounds within these plant juices act as natural reducing and stabilizing agents during heating.

Calcination is carried out in tightly sealed clay crucibles (Sharava Samputa) using traditional cow-dung pits (Laghu Puta) or specialized modern industrial Muffle Furnaces at controlled temperatures between 600°C and 800°C.

2.2. ANALYTICAL STUDIES OF RAJATA BHASMA

To bridge traditional validation with modern pharmacology, research papers have evaluated Rajata Bhasma using both classical and Modern parameters.

2.2.A. Classical Parameters

1. Varitara (Water floating):- The sample floats freely on a water surface due to high surface tension and low particle mass.

2. Rekhapurnatva:- The ultra-fine particles easily lodge within the micro-creases of human fingertips.

3. Nishchandratva (Lusterless):- Complete absence of metallic reflection under direct sunlight, confirming full chemical conversion.

4. Niruttha:- Non-reversibility; Heating a weighed amount of Bhasma along with a fixed weight of Rajata Patra (Silver sheet) in a closed crucible at high heat.There was no increase in the weight of the silver sheet after cooling.This proves that the Bhasma is perfectly incinerated and will not alloy back into free metal or pick up elements when heated.

5. Apunarbhava:- Triturating Bhasma with Mitrapanchaka [synergistic / binding agents like jaggery / Guggul resin, borax, ghee, honey, Gunja (Abrus precatorius)] and exposing it to strong heat (Puta). The compound did not revert to a shiny metallic silver bead. It confirms a permanent, irreversible physico-chemical transformation into a bio-safe therapeutic structure.

6. Unnama (Buoyancy):- Placing a few grains of raw rice (Shali Dhanya) are carefully placed on top of the floating Bhasma layer. The Bhasma continued to float despite the added weight of the rice grain. Validates an advanced grade of lightness and particle floatability.

7. Niswadu & Nirdgandha (Taste & Odor):- Placing a small sample on the tongue; smelling the dry powder. Lacking any metallic, sour, or bitter taste; completely odorless. It ensures the absence of unreacted raw materials, excess sulfur, or free acidic processing fluids.

2.2.B. Modern Parameters

Material characterization is the keystone of materials science, chemistry and quality control. Analytical techniques are required to determine the physical, chemical and structural properties of sample.

1. SEM- Scanning Electron Microscopy

Principle:- SEM provides high-resolution, three-dimensional imagery topography of a sample's surface by scanning it with a focused beam of electrons. First, prepare the sample it includes drying of sample, mounting onto a metal stub and coating with a thin layer of gold,

platinum, or carbon using a sputter coater to prevent charging. Then the procedure will be done step wise such as venting the SEM specimen chamber with nitrogen gas to bring it to atmospheric pressure then loading the sample and evacuating the chamber. Subsequently, the electron filament (tungsten or field emission source) is turned on and the voltage ($<10^{-4}$ to 10^{-7} Pa.)(i.e. beam activation), adjust the working distance (WD), focus, and astigmatism are adjusted at a lower magnification before zooming in on the target region (that is Focus and Align) then capture the images.

OBSERVATION:- SEM- visualizes surface morphology that is irregular, micro-porous, spherical, aggregated nanoparticle structures ranging mostly from 10- 60 nm and 170- 210 nm.[8] Confirms its identity as a biologically produced nanoparticle capable of cellular absorption[8]. (Kalimuthu, K., K, et al.2020)

2. EDX / EDS- Energy Dispersive X-ray Spectroscopy (Morphology)

Principle:- EDX is almost coupled with SEM. It measures the energy of the characteristic X-rays emitted from a sample when bombarded by the SEM's electron beam to identify its elemental composition. Preparation of sample is identical to SEM preparation. However, “carbon coating” is preferred over gold/ platinum if you need to quantify light elements accurately, as heavy metal peaks can overlap with sample elements. During the Procedure, locate area of interest that is Using the SEM interface, find the specific spot, line, or area you want to analyze. Then configure EDX software. After that set beam conditions like increase the SEM accelerating voltage so that it is at least 1.5 to 2 times higher than the highest critical excitation energy of the elements you expect to find. The acquired spectrum indicates the start of X-ray collection. Ensure that the "dead time" (the percentage of time the detector is processing signals and is unable to accept new ones) is ideally between 20 % and 40 %. Then the software was allowed to automatically identify peaks, manually correct any misidentified overlapping peaks, and run the quantification matrix.

OBSERVATION:- EDX - provides elemental wt. Percentages.Detects Ag, S and Oxygen with no heavy metal contaminants.Confirms the absence of raw free metal sheets & screens for toxic impurities. [8](Kalimuthu, K., K, et al.2020)

3. XRD - X-ray Diffraction (Crystalline Phase)

Principle:- XRD is a non-destructive technique used to determine the crystalline structure, phases, and orientation of materials by measuring the angles and intensities of diffracted X-

rays. The preparation of sample included, grinding the sample into a fine, homogeneous powder and packing it tightly and flatly into a glass or Poly methyl methacrylate (PMMA) sample holder. The surface must be perfectly flush with the holder edge to prevent displacement errors. Ensure that the sample surface is flat and fits within the geometric constraints of the diffractometer. In the XRD process, initialize the instrument by power on the X-ray generator and setting the current and voltage to the manufacturer's specified operating levels (e.g., 40 kV, 40 mA). Then mount the sample (Secure the sample holder onto the goniometer stage). After that, set scan parameters, then execute the scan and finally identify the phase of diffractogram and match the characteristic with a standard database.[30]

Observations:- A complete shift from elemental cubic silver to crystalline Silver Sulfide (Ag_2S) or multi-elemental forms was identified. Sharp metallic peaks shift to (Ag_2S) and (Ag_2O) matrices.[8](Kalimuthu, K., K, et al.2020). Confirms complete transformation from raw elemental silver into a safe, bio-active crystal structure.[13] (Gokarn R.A, et al.2017)

4. FTIR - Fourier Transform Infrared (Surface Chemistry)

Principle:- FTIR identifies chemical bonds and organic functional groups within a molecule by measuring how the sample absorbs infrared radiation at different wavelengths. Prepare the sample, Grind a tiny amount of sample (1mg) with spectroscopic grade Potassium Bromide (KBr 100 mg-200 mg) and compress it using a hydraulic press to form a translucent pellet (KBr pellet). Then for Attenuated Total Reflection (ATR - non destructive analytical technique) Mode, no preparation required. Solids, liquids, or gels can be placed directly onto the ATR crystal (diamond, Zn Se, or Ge). During the procedure, clean the ATR crystal or sample holder with a volatile solvent like isopropyl alcohol or acetone. Allow it to dry completely. Then run a background scan of the ambient air or clean crystal). The software will automatically subtract this background from the sample spectrum to eliminate atmospheric and water vapor interference. Place your sample onto the ATR crystal and lower the pressure clamp until it engages securely. If using a KBr pellet, place it into the transmission holder. Run the scan (typically scanning from 4000 cm^{-1} to 400 /cm^{-1} over 16 to 32 co-added scans for optimal signal-to-noise ratio).Analyze the Bands.

Observations:- Distinct alkene, hydroxyl, amide, and aldehyde functional groups were detected on the particle surfaces. Proves that organic fractions from herbal juice successfully coat the silver, altering its bio-availability.[8](Kalimuthu, K., K, et al.2020).

5. XRF - X-ray Fluorescence (Elemental)

Principle:- XRF is used for rapid, non-destructive elemental analysis of major and trace elements in solids and liquids. It works by exciting the sample with a primary X-ray source and measuring the secondary (fluorescent) X-rays emitted. Prepare the sample means pour the sample directly into a plastic sample cup fitted with a thin Mylar or Prolene film support. Then powdered samples are mixed with a binder (like wax or boric acid) and pressed under high tonnage to form a solid disc. The sample is melted with a lithium borate flux at high temperatures (> 1000° C) and cast into a glass disk to eliminate mineralogical matrix effects. During the procedure, select the method means choose between Energy Dispersive (ED- XRF) for quick multi-element screening or Wavelength Dispersive (WD- XRF) for high-resolution quantitative work. Then place the cup, pellet, or bead into the auto-sampler tray. After that, configure atmosphere i.e. select a "vacuum" atmosphere for solid samples (essential for detecting light elements like Na, Mg, Al) or helium for liquid samples. Then run the Calibration/ Analysis.

Observations:- Confirms silver content values (ranging from 17% up to 70% based on the sulfur or mercury media utilized).

6. Particle Size Analysis (PSA)

Principle:- Laser diffraction calculates particle size by measuring the angle of diffracted light as a laser beam passes through a dispersed particulate sample. Larger particles scatter light at narrow angles, while smaller particles scatter light at wider angles. While preparing the sample, disperse the powder in a liquid vehicle (water, ethanol, or oil) in which the sample is completely insoluble. Use surfactants or ultrasonication to break up agglomerates. For dry dispersion, feed the dry powder directly using a compressed air venturi system (suitable for robust, free-flowing materials). Then input the refractive index (RI) and absorption index of both the sample material and the dispersant medium into the system software. Fill the glass cell with clean dispersant fluid and run a blank measurement to establish a baseline. Gradually add the pre-dispersed sample into the system's bath until the software indicates the optimal "obscuration range" (typically 10 % to 20 %). Turn on the internal pump/ stirrer to keep the particles suspended, and initiate the laser measurement. Then analyze the particle size distribution curve, focusing on D (10), D (50) (median), and D (90) values.[30]

Observations:- Measures the mean hydrodynamic diameter and size distribution of particles. Range: 150 nm to 450 nm (average sub-micron level). Confirms nano-structure status,

explaining its rapid bio-availability and cellular permeability. [12](Sharma, R., Bhat, A.,et al.2016)

7. Loss on Drying (LOD) at 105°C

Principle:- Loss on Drying (LOD) is a standard analytical method used to measure the total volatile matter (solvents) present in a sample. The process begins by drying and taring an empty glass weighing bottle to ensure ambient moisture does not skew the results. A sample of 1 to 2 grams is then finely ground, evenly distributed in the bottle, and weighed to establish its initial mass. This prepared sample is placed into a preheated oven typically set to 105° C with its stopper removed so volatile components can freely escape. After heating for a specified duration, the bottle is re-stoppered and transferred to a desiccator to cool safely without absorbing atmospheric moisture. Finally, the cooled sample is weighed a final time to calculate the mass lost during the heating cycle. The overall percentage of LOD is then determined by dividing the lost mass by the initial sample mass and multiplying by 100.[30]

Observation:- Quantifies total moisture content and volatile substances. Less than 1.0% w/w (typically ~0.4%). Lower moisture levels prevent microbial growth and extend shelf life.[7] (Chaturvedi, R., & Jha, C. B. 2011).

8. Total Ash Value

Principle:- Determines the amount of non-volatile inorganic residual matter (minerals, salts) left behind after a sample is incinerated. Then prepare the sample, burn up a clean silica or platinum crucible at 600°C for until free from carbon (white ash), cool it completely in a desiccator, and record its weight (W1). add 2 to 3 grams of air-dried sample to the crucible and weigh precisely (W2). Then heat the crucible gently over a Bunsen burner or on a hot plate until the sample is thoroughly charred and stops smoking. After that, transfer the crucible to a muffle furnace preheated not exceeding 600°C . Incubate for several hours until the ash becomes completely white or grey, indicating the absence of carbon. Cool the crucible in a desiccator and weigh (W3). Calculate the value.[30]

Observation:- Measures the non-volatile inorganic portion remaining after incineration. 90 - 92 % w/w Verifies total compound conversion and the elimination of raw plant fibers.[13] (Gokarn R.A, et al.2017)

9. Acid Insoluble Ash value

Principle:- Measures the amount of sand, silica, and dirt within the ash that cannot be dissolved by Hydrochloric acid. In this test, add 25 ml Hydrochloric acid (HCl) directly to the crucible containing the ash obtained from the Total Ash test. Cover with a watch glass and boil gently on a hot plate or water bath for 5 minutes. Filter the insoluble matter through an ash less filter paper (e.g., Whatman No. 41). Rinse the residue thoroughly with hot distilled water until the washings test neutral to litmus. Then place the filter paper containing the residue back into the original crucible. Dry it on a hot plate, then incinerate it in the muffle furnace at 550°600°C until constant weight is achieved (W4). Finally, calculate the value.[30]

Observation:- Measures the amount of ash insoluble in dilute Hydrochloric acid (HCl). 60% to 70% w/w Reflects the percentage of highly stable, insoluble compounds that act via systemic carrier mechanisms.[17] (Pritika et al.2019).

10. pH Determination (10% aqueous. sol.)

Principle:-Measures the hydrogen ion activity in an aqueous solution. Calibrate the pH meter using at least two standard buffer solutions (typically pH 4.01, 7.00, and 10.01) that bracket the expected pH of your sample. Ensure temperature compensation is active. Dissolve or suspend a known weight of the sample in distilled/ de-ionized water (e.g., a 10% w/v solution) and stir thoroughly. Rinse the electrode with de-ionized water, blot it dry with a lint-free wipe, and submerge it into the sample solution. Wait for the reading on the display to stabilize before recording.[30]

Observation:- Evaluates the basic or acidic nature of the suspension. Weakly acidic to neutral (pH 5.5 to 7.0). Ensures compatibility with gastrointestinal fluids, preventing tissue irritation.[17] (Pritika et al.2019).

2.3. EXPERIMENTAL STUDIES OF RAJATA BHASMA

Pre-clinical evaluation data addresses safety and confirms the underlying pharmacological activity of the processed medicines.

2.3.A. Toxicology and Safety Profiling

A focus of experimental papers is validating that the traditional preparation process provides the metal safe for consumption.

Systemic Safety:- Zebra-fish embryos at an early blastula stage were exposed to RB for 48 h and embryonic malformation rates were noticed at 72 hpf. 5 µg/ml of RB did not significantly slow down the growth of zebra-fish embryos [16]. However, the malformation rate was approximately 60% at 25 µg/ml. This bio-compatibility is attributed to the presence of stable silver sulfide (Ag_2S) phases and a coating of protective organic molecules derived from the herbal processing agents.[8](Kalimuthu, K., Kim, J. M. et al.2020)

In Vivo Teratogenicity

Zebra-fish embryos (10 embryos /petri plate) at early blastula stage were transferred to a petri plate. These embryos were treated with RB at different concentrations (5, 10, 15, 20 and 25 µg/ml) in 10 ml distilled water for 48 h at room temperature. At 72 hr post fertilization (hpf) malformation rates (%) were calculated as percentage of dead embryos relative to the total number of embryos to estimate embryonic toxicity. Edema, the most common malformation, along with tail and yolk abnormalities were macro-scopically quantified. Each experiment was performed in triplicate. Advanced animal models, including zebra-fish embryo assays, have defined precise safety boundaries. Research shows that RB induces zero toxic or developmental defects in embryos at exposure levels below 5 µg/ml) and the malformation rate was approximately 60% at 25 µg/ml.[8](Kalimuthu, K., Kim, J. M. et al.2020)

2.3.B. Hepato-protective & Antioxidant Activity

When evaluated against Carbon Tetra-chloride (CCl 4) induced liver cirrhosis in experimental rats, Rajata Bhasma displayed exceptional Hepato-protective action. It successfully countered the spikes in serum biomarkers- notably decreasing Serum Glutamic Oxaloacetic Transaminase (SGOT), Serum Glutamic Pyruvic Transaminase (SGPT) and Bilirubin. Mechanistically, this protection stems from its free-radical scavenging capacity, which prompts an up regulation of internal antioxidant enzymes like catalyse, glutathione per oxidase, and super-oxide dismutase (SOD).[16] (Rai A.P., Tripathi S. et al.2019)

2.3.C. Anti-Diabetic Activity, Lipid Optimization and Cardio-protective Lipid Balance

The two different batches that is RB1 (9 *puta*) and RB2 (17 *puta*) were prepared. After the treatment with RB1 and RB2 to streptozotocin (STZ) treated rats for 28 days, it significantly lowered the blood glucose level. It also significantly decreased the elevated total cholesterol, triglycerides (TGL), and low-density lipoprotein (LDL) level while increased the high-density lipoprotein(HDL). Standard drug used was Glibenclamide at a dose of 0.50 mg/kg

body weight. The study proved that RB have anti-diabetic activity. The animals of diabetic control showed significant increase in serum TGL, total cholesterol, and LDL while increase in HDL when compared with normal animals. The animals treated with Glibenclamide also decreased TGL, total cholesterol, LDL, and increased HDL compared to diabetic control group. The RB1 and RB2 treated animals showed a significant decrease in total cholesterol, LDL, TGL, and a significant increase in HDL.[20] (Rai A.P. et al, 2019)

2.3.D. Anti-microbial Activity

This study indicate that Rajata Bhasma possesses significant broad-spectrum antimicrobial properties. Agar well-diffusion assays demonstrate that RB is active against Gram-positive bacteria, particularly Staphylococcus aureus. Its efficacy against certain Gram-negative organisms (like Escherichia Coli and Pseudomonas aeruginosa) varies depending on the specific manufacturing method and final particle size, stimulating the action of chemically synthesized silver nanoparticles (SNPs). The mechanism is driven by the steady release of silver ions (Ag+), which disrupt bacterial cell wall integrity and induce intracellular oxidative stress.[22]

2.3.E. Anti-convulsant activity

The RB was screened for anticonvulsant action, by Maximal electro shock method using convulsiometer on albino rats. The parameters observed in this method - tonic hind limb flexion, tonic hind limb extension, clonus, stupor (post-ictal depression) and recovery /death. The time span of tonic hind limb extension was noted to interpret the anti-convulsant action of the drug. The mean time span of the tonic hind limb flexion was 7.61, seconds., 4.70 Sec. and 5.60 sec. respectively in control, std. and test group. The mean time span of the tonic hind limb extension was 11.28 sec, 0 sec. and 4.68 sec. respectively in control, std. and test group. The mean time span of clonus was 7.40 secs, 3.83 sec and 4.60 sec respectively in control, std. and test group. The mean time span of post-ictal depression (stupor) was 122 secs, 87.35 sec and 99.35 sec respectively in control, std. and test group. All animals appearing tonic hind limb flexion, tonic limb extension, clonus and post-ictal depression were followed by recovery, no evidence of death was noted. So the study shows that the test drug provided a noticeable protection against the convulsion at significance level of $p < 0.01$.[9] (Ganesh naik et al, 2013)

2.3.F. Medhya activity

This study was investigated for acquisition (learning) memory in *Wistar albino* rats. Three groups of rats were taken, Test group was administered with *RB* (11.25 mg /kg per day), Std Gr. was administered piracetam (100 mg /kg per day) and control Gr. was fed with food and water, to rule out the *Medhya* activity in *Wistar albino* rats followed by the Morris water maze test. The acquisition memory were recorded, results were examined statistically with the help of parameters to assess the memory. Results indicate that *Rajata* (silver) *Bhasma* has moderate effect on learning and acquisition, statistically significant result on the paradigm of thigmostatic behaviour average duration and frequency. The conclusion was that *RB* has stimulatory effect on acquisition memory (learning and memory).[29] (*Kajree C Pardeshi ,2018)*

2.3.G. Anti- arthritic

In this study, using adjuvant-induced arthritic models (five groups of albino rats,six in each), autoimmune arthritis may be brought on by mycobacterial infections, mostly through T-cell-mediated reactions. Rats were given injections of dead mycobacteria in liquid paraffin to create arthritis. Six rats four gr. were randomly selected i.e. Control Gr. I,Gr II,Gr III and Gr IV were acquired the treatment distilled water, drug Indomethacin at 10 mg /kg body weight, 25 mg /kg body weight and 25 mg /kg body weight respectively for 28 days. Then observed for severe, time-dependent reduction in paw thickness and chronic inflammation. When differentiated to the standard and fraction-treated rats, the rat paw volume of the FCA-injected (Freunds Complete Adjuvant- very toxic chemical which causes severe inflammation) control rats had much more inflammation. In this anti-arthritic study, the investigations shows elevated ESR, decreased Hb and RBC count. In adjuvant induced arthritic rats prominently increased Leukocyte count might be the output of Immune system being stimulated to flight off antigens. This strongly establishes its utility as a potent anti-inflammatory agent for joint and musculoskeletal disorders so in this study, RB nanoparticles give its anti-arthritic properties.[27] (Afrin Alam et al 2024)

2.4. CLINICAL STUDIES OF RAJATA BHASMA

2.4.A. Medhya activity of RB

In this study, all 10 selected volunteers were studied in a single group. *RB* was given in a dose of 100 mg O.D. with Luke warm water and Shankhapushpi *syrup* 10 ml B.D. for 30 days. And the follow up advised after *15 days*. Then Memory Scale sub-tests like- in Remote memory test 17.02 % improvement was found which is *statistically highly significant* (<

0.001). In Recent memory test 13.63 % improvement was found which is *statistically significant* (< 0.05). Mental balance test improvement was only 3.4 % although which was *non- significant* (>0.05) might have due to short duration of trial. In Attention and concentration test only 10.47 % improvement was found which indicates *statistically significant result* (< 0.05). Immediate recall sub test, 14.44 % improvement was found which shows *highly significant result* (< 0.001). Delayed recall only 12.32 % improvement was found, which shows *significant result* (< 0.001). Verbal retention for similar pair, no change was found. Verbal retention for dissimilar pair, 62.96 % improvement was found i.e. highly significant. Recognition mean score, before treatment was 9.60 and after treatment was 10.0 with percentage relief was only 4.16 %, even observations were *statistically non- significant.* Above sub tests done at the beginning and the end of the study.It shows the significant result on Memory Scale.[17] (Pritika Devi et al.2019).

2.4.B. Dental and Antimicrobial Applications

A notable randomized interventional trial evaluated the efficacy of Rajata Bhasma compiled into an intra-oral delivery matrix. Prevention of opportunistic bacterial accumulation - (Streptococcus mutant and Lactobacillus) in patients undergoing fixed orthodontic treatment noted. Comparative evaluation of standard Chlorhexidine mouthwash versus Triphala mouthwash used along with a specialized Rajata Bhasma Jelly (125 mg RB). The therapeutic matrix leverages the synergistic, anti-adherent, and oligodynamic properties of processed silver to minimize plaque formation without structural alteration to orthodontic assemblies.[26] (Agarwal et al., 2023)

Table No. 1: Samanya and Vishesh shodhan of Rajata.

Sr. No.	Type of Shodhana	Liquid Media (Dravya)	Procedure	No. of Cycles	Reference
1.	**Samanya Shodhana**	1.Tila Taila (Sesame oil) 2.Takra (Buttermilk), 3.Gomutra (Cow's urine) 4.Kanji/Arnala (Sour fermented rice) 5.Kulattha Kwatha (Horsegram decoction)	Nirvapa- Heat silver foils until red-hot and quench sequentially into each medium.	3 or 7 times each	1. Rasa Ratna Samuchchaya [5] (5/13) 2.Rasa Tarangini (15/4-6) [6] 3.Ayurveda Prakasha (4/42)
2.	**Vishesh Shodhana**				
	2.1	Nimbu Swarasa (Lemon juice)	Nirvapa	7 times	Rasa Tarangini (16/6-12)
	2.2	Agastyapatra Swarasa (Juice	Nirvapa	3 or 7	Rasa Ratna

		of Sesbania grandiflora leaves)		times	Samuchchaya (5/23) [5] Ayurved Prakash, 3/20
	2.3	Jyotishmati/Malkangni Taila (Oil of Celastrus paniculatus seeds)	Nirvapa	7 times	Rasendra Sara Sangraha (Dhatu Shodhana)
	2.4	Agastya Patra Swaras (Sesbania grandiflora Leaves)	Nirvapa	7 times	Rasa Tarangini (16/10)[6]
	2.5	Shuddha Naga (Lead) + Jyotishmati taila	Dhaman	3 times	Ayurveda Prakasha (1/93-96)

Table 2: Marana of Shodhita Rajata.[31]

Sr. No.	References	Marana dravyas	Prescribed Media	Heating Protocol (Puta)
1.	**Rasendra Chudamani**	Swarn makshik + Shudha gandhak (sulphur)same proportion	Lemon juice	Ardha (half) Gajputa
2.	**Anandkanda**	Shudha Vanga (Tin) + same Shudha Gandhak (sulphur)	Lemon juice	3 puta (25 cow dung each)
3.	**Rasa Ratna Samuchchaya[5]**	Kajjali (pure Mercury + Sulphur) /Swarna Makshika	Jambir swaras (lemon/ citrus fruit)	Laghu Puta (30) cow dung cakes for multiple repetitive cycles
4.	**Rasendra chintamani**	Parada(mercury) + Shuddha Hartala (As_2S_3) + Suddha Gandhak (sulphur)	lemon juice	2/3 Puta
5.	**Ras Padhati**	Shuddha Hingula + Shuddha Gandhak (sulphur)	Jambir swaras (lemon/ citrus fruit)	Kukkuta puta (14)
6.	**Ras Prakash Sudhakar**	Shuddha Parada (mercury)	Lemon juice	12 puta in Valuka yantra (4 prahar for each puta)
7.	**Ayurveda Prakash**	Talaka (Arsenic Trisulphide / Haratala) or Hingula (Cinnabar)		Kukkuta Puta or Laghu Puta
8.	**Ras Kamdhenu**	1.Swarn makshik + Shudha gandhak (sulphur) same proportion	Lemon juice	Ardha (half) Gajputa

		2.Shudha Vanga (Tin)+ same Shudha Gandhak (sulphur)	Lemon juice	3 puta (25 cow dung each)
9.	**Ras Chandanshu**	Swarn makshik + Shudha gandhak (sulphur) same proportion	Snuhi Arka ksheer	Ardha (half) Gajputa
10.	**Rasa Tarangini**[6]	Pure Parada (Mercury) + Gandhaka (Sulphur)	Kumari Swarasa (Aloe vera juice)	Series of 9 to 17 Laghu Putas or controlled electrical muffle furnace cycles
11.	**Rasamrut**	Shuddha Hingula	Lemon juice	11 puta in Damru yantra
12.	**Rasayan saar**	Shuddha Hingula	Lemon juice	Damru Yantra 4 Prahar heat
13.	**Bharat Bhaishjya Ratnakar**	Kajjali (pure Mercury + Sulphur)	Kumari Swarasa (Aloe vera juice)	2 puta (30 cow dung each)
14.	**Ras Tantra Saar**	Shuddha Parada (mercury) + Shuddha Gandhak (sulphur) + Shuddha Hartaal (As_2S_3)	Lemon juice	30 puta (5 ser cow dung)
15.	**Ras Yog Sagar**		Karela juice (Bitter gourd)	100 puta (2 ser -5 puta, 2 and 1/2 ser 20 puta, 5 ser 15 puta, 20 ser 10 puta then Gaja puta)

3. DISCUSSION

The conversion of bulk silver sheets into an ash requires careful selection of processing media. Shodhana involves repeatedly heating silver foils to red-hot status and quenching them into distinct media, including Tila Taila (sesame oil), Takra (buttermilk), Gomutra (cow urine), Kanji (sour gruel), and Kulattha Kwatha (horse gram decoction). This processing changes the color from a shiny white sheet to a dull greyish format, generating micro-cracks and surface corrosion that prepares the metal for structural breakdown. Traditional methods utilizing only plant juices or sulfur media require prolonged processing, often exceeding 17 distinct heating cycles, or Putas. In contrast, a Kajjali paste (a specialized mix of purified mercury and sulfur in same proportion) reduce the thermal cycles significantly, down to between 3 to 11 Putas, generating high quality bhasma that satisfies all traditional parameters.[28] (Fursule d. Gandhi P,2025). Furthermore, comparative technical studies confirm that using an Electric Muffle Furnace (EMF) at controlled temperatures.[27] offers

clearer quality control and a more uniform end product than traditional cow-dung pit heating.[7](Chaturvedi & Jha et al.2011). Modern analytical characterization powerfully validates the ancient Bhasma Pariksha (classical tests). Physical tests like Varitara (water floating) and Rekhapurnatva (lodging in fingertip creases) directly correspond to a drastically reduced particle mass and sub-micron scale geometry. This is specifically confirmed by Particle Size Analysis (PSA), which shows an average hydrodynamic diameter between 150 nm and 450 nm, along side Scanning Electron Microscopy (SEM) mapping irregular, micro-porous, and spherical nano-particle aggregates (predominantly 10-60 nm and 170-210 nm). Furthermore, structural integrity tests like Niruttha and Apunarbhava assure that the metal has undergone an irreversible chemical shift. X-ray Diffraction (XRD) supports this by showing a complete transition from raw elemental cubic silver into stable, bio-compatible crystalline silver sulfide (Ag_2S) and silver oxide (Ag_2O) matrices, entirely filtering out free metallic fractions or heavy metal contaminants. Meanwhile, FTIR analyses show that organic fractions from the plant juices successfully form a surface coating on the nanoparticles, which acts as a natural stabilizer to enhance cellular permeability and bio-availability. From a pharmacological perspective, raw silver can cause tissue accumulation and Argyria (Blue gray or slate-gray discoloration of the skin and mucous membranes) but pure Rajata Bhasma passes through physiological systems safely. The systemic safety threshold is highlighted by zebra-fish embryo models, which display zero developmental toxicity or defects at exposure levels below 5 g/ml. The review of pre-clinical data confirms that Rajata Bhasma exhibits broad-spectrum antimicrobial action driven by the oligodynamic release of silver ions (Ag+), effectively disrupting bacterial cell walls in pathogens like S. aureus and E. coli.[22] Furthermore, in neuroprotective & cognitive benefits showed stimulatory effects on acquisition memory and learning in Wistar rats, an action verified in human clinical trials where patients exhibited statistically significant improvements in remote memory, attention, and immediate recall.[29] In anti-arthritic & anti-inflammatory tested models showed a marked reduction in paw thickness and chronic inflammation, countering autoimmune responses.[27] In Hepato-protective & Metabolic Support, it successfully regulates serum biomarkers (SGOT, SGPT and bilirubin) in CCl_4 induced liver cirrhosis via internal antioxidant upregulation[16]. In Anti-diabetic & Lipid Optimization, administered RB significantly lowers blood glucose levels in streptozotocin-treated diabetic rats while correcting lipid profiles by lowering LDL and triglycerides, and raising HDL.[20] In clinical Adaptations, Interventional clinical studies demonstrate its practical versatility, such as using a Rajata Bhasma jelly (125 mg) to exploit

its anti-adherent properties to successfully prevent opportunistic bacterial plaque accumulation during orthodontic treatments.[26]

4. CONCLUSION

This critical review highlights that Rajata Bhasma is a nano-structured medicine. Modern analytical tools confirm that the ancient preparation methods successfully reduce particle size to the nanoscale and changes the metal into bio-assimilable crystalline silver sulfide (Ag_2S) and oxide phases, completely free of native heavy metal toxicity when prepared authentically. Pre-clinical testing confirms its safety and therapeutic potential, validating its traditional clinical use as a potent metabolic, anti-convulsant, anti-diabetic, hepato-protective, anti-microbial, anti-arthritic and nootropic (Medhya) agent. To establish global clinical trust and integrate this medicine into mainstream healthcare, Future research should focus on conducting multi-center, human clinical trials and mapping exact cellular absorption and metabolic pathways.

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