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Review Article

Sustainable *Puta* Systems in *Rasashastra*: Energy Efficiency, Green Chemistry and Pharmaceutical Standardisation

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Abstract

Background: *Puta* is the planned delivery of heat used during the preparation of many metal- and mineral-based medicines in *Rasashastra*. Classical systems use measured arrangements of biomass fuel, whereas present-day manufacture increasingly uses electric furnaces. Objective: To examine how the thermal logic of *Puta* can be retained while improving energy efficiency, process control, worker safety and environmental performance. Methods: This narrative review considered classical texts, official Ayurvedic standards, comparative pharmaceutical studies, green chemistry literature and quality-system guidance. Greater weight was given to studies that recorded temperature-time profiles or compared products made by traditional and electric methods. Main findings: Evidence from *Swarna Makshika*, *Lauha*, *Tamra*, *Rajata* and *Naga Bhasma* shows that controlled electric heating can reproduce acceptable products in selected preparations, but equivalence cannot be assumed from peak temperature alone. Heating rate, holding time, cooling pattern, furnace load, number of cycles and intermediate processing also matter. A sustainable system should measure energy per acceptable batch, yield, waste, emissions and batch reproducibility, while confirming classical and physicochemical quality. Conclusion: Sustainable *Puta* is best understood as process-specific thermal validation, not the simple replacement of cow-dung fuel with electricity.

Keywords: *Puta*; *Rasashastra*; *Bhasma*; green chemistry; energy efficiency; pharmaceutical standardisation

Introduction

Heat is central to the preparation of many *Rasaushadhi*. Metals and minerals may pass through *Shodhana*, *Bhavana*, pellet formation and *Marana* before the finished material is accepted as *Bhasma*. In this sequence, *Puta* does not mean heating in a general sense. It refers to a planned quantity and pattern of heat chosen for a particular substance and pharmaceutical purpose [1-3]. Official Ayurvedic formularies and pharmacopoeial standards also place these operations within a defined manufacturing framework [4,5].

The classical descriptions arose in a setting where biomass fuel, especially cow-dung cakes, was locally available. The size of the heating arrangement, amount and placement of fuel, sealed container, duration of combustion and natural cooling together produced the intended thermal exposure. This practical system was based on repeated pharmaceutical observation. Modern reviews of *Rasashastra* likewise emphasize that the processed medicine should not be treated as identical to the raw metal or mineral [6,7].

Contemporary manufacture faces additional demands: batch consistency, temperature records, equipment qualification, reduced smoke, occupational safety and efficient use of energy. Electric muffle furnaces offer greater control, yet a change of equipment can also change the product if the full thermal profile is not reproduced. The practical question is therefore not whether traditional *Puta* should be abandoned. It is how the classical thermal intention can be preserved while unnecessary variation, emissions and energy use are reduced.

Aim and Scope

This review examines sustainable *Puta* systems with four linked concerns: pharmaceutical fidelity, thermal reproducibility, environmental efficiency and regulatory traceability. It focuses on the heating stage, while recognising that *Bhavana*, grinding, herbal media, drying and material handling also influence the total resource burden of a finished *Bhasma*.

Review Method

A narrative approach was used. Classical descriptions of *Puta*, *Marana* and *Bhasma Nirmana* were examined alongside official Ayurvedic standards. Modern literature was reviewed using combinations of the terms "*Puta Rasashastra*," "electric muffle furnace *Bhasma*," "temperature profile," "traditional versus electric *Puta*," "green chemistry," "pharmaceutical energy efficiency," "process validation" and "life-cycle assessment." Experimental studies were prioritised when they documented heating schedules, intermediate stages or comparative product characteristics. Green chemistry, GMP, quality-by-design and environmental standards were used to frame the sustainability discussion. Because the available studies differ markedly in substances, batch size and methods, the findings were synthesised qualitatively rather than pooled.

The Thermal Logic of *Puta*

A process, not merely a device

Classical *Rasashastra* describes more than one form of *Puta* because different materials require different thermal treatment[1-3]. The useful part of this principle is its specificity. Standardisation should not mean one furnace programme for every preparation. It should mean a validated programme for each substance, batch range and processing route.

Peak temperature alone is not an adequate description. Two processes may reach the same maximum temperature but differ in heating rate, time near the maximum, total exposure, atmosphere and cooling rate. Traditional biomass combustion produces a natural rising and falling curve. An electric furnace can imitate that curve only after it has been measured and translated into a complete temperature-time programme. Table 1 lists the minimum thermal information needed for a meaningful comparison.

Table 1: Thermal variables that should be recorded for each Puta cycle

Variable	Why it matters	Suggested record
Starting condition	Affects the early heating phase	Material mass, container, furnace load and initial temperature
Heating rate	Influences reactions and gas release	Degrees Celsius per minute over defined ranges
Peak temperature	Shows maximum thermal intensity	Highest chamber and sample-proximal temperature
Holding time	Determines exposure near the target	Minutes or hours within the validated band
Cooling profile	May affect phase formation and structure	Natural or forced cooling and time to defined temperatures
Cycle history	Repeated grinding and heating are cumulative	Number of cycles, intervening *Bhavana* and yield after each stage

Evidence from Selected Preparations

The most useful comparative evidence comes from studies that treated the heating system as a pharmaceutical process rather than as a convenient heat source. In *Swarna Makshika Bhasma*, investigators measured the thermal behaviour of traditional *Varaha Puta*, developed a corresponding electric-furnace schedule and found comparable classical and laboratory characteristics in the studied batches [8]. This work offers a sound method: measure the classical curve, reproduce the relevant thermal exposure, and then compare the products.

Studies of *Lauha Bhasma* also show why temperature optimisation matters. A standard manufacturing procedure for *Teekshna Lauha Bhasma* used a controlled electric muffle furnace schedule of about 650 degrees Celsius with a one-hour holding period during *Putapaka* and obtained an acceptable product after repeated cycles[9]. The lesson is simple: more heat is not necessarily better. Excess heat can harden pellets or produce an unwanted change, while insufficient heat may leave the process incomplete.

For *Tamra Bhasma*, each pharmaceutical operation was treated as a separate unit process. A defined electric muffle furnace pattern was used across successive cycles, and the final product was examined by classical tests and instrumental methods [10]. A standard procedure for *Rajata Bhasma* similarly documented the preparation and controlled heating schedule [11]. These studies show the value of recording starting mass, media, temperature, duration, number of cycles and final yield.

Evidence from *Naga Bhasma* gives an important warning. A metallurgical comparison of traditional and electric methods found progressive transformation in both routes, but reported a more homogeneous lead-sulfide phase in the product made by the traditional method [12]. The finding does not prove that one system is always superior. It shows that equipment substitution must be tested for pharmaceutical and physicochemical equivalence.

Modern analytical studies of *Swarna Makshika*, *Tamra* and other *Bhasma* preparations support the use of X-ray diffraction, elemental analysis and electron microscopy for defining the finished material [13-17]. These methods add detail to classical *Bhasma Pariksha*; they do not replace it, and they do not by themselves prove clinical efficacy or safety. Table 2 summarises the practical message from the principal heating studies.

Table 2: Selected evidence relevant to *Puta* modernisation

Preparation	Process observation	Practical interpretation
Swarna Makshika Bhasma[8]	Traditional *Varaha Puta* profile was measured and reproduced in an electric furnace	Profile-based substitution was feasible for the studied batches
Teekshna Lauha Bhasma[9]	A defined electric schedule produced an acceptable product after repeated cycles	Temperature and holding time should be optimised, not maximised
Tamra Bhasma[10]	Each operation was documented as a controllable unit process	Heating records should be linked with yield and final quality
Rajata Bhasma[11]	A standard manufacturing procedure used controlled furnace heating	Reproducibility depends on the complete preparation sequence
Naga Bhasma[12]	Traditional and electric routes differed in reported phase homogeneity	Matching peak temperature alone cannot establish equivalence

Green Chemistry and Energy Efficiency

Green chemistry is built around prevention, safer processing, efficient use of energy and resources, real-time monitoring and accident prevention [18,19]. Not every principle maps directly onto repeated mineral calcination, and the framework should not be used to label a traditional process as “green” without measurement. It is more useful as a set of questions: Was unnecessary waste avoided? Was the required transformation achieved with no more energy than needed? Were workers and the environment protected? Was the process monitored well enough to prevent failed batches?[20]

Energy should therefore be treated as a manufacturing variable. At minimum, a study should report kilograms of biomass or kilowatt-hours of electricity per cycle, number of cycles, batch mass and acceptable final yield. A useful comparison is specific energy consumption: total energy used to divide by the mass of acceptable finished *Bhasma*. Green metrics such as the E-factor and process mass intensity show why waste and yield must be

considered along with the energy entering the furnace[21-24].

Electric heating is cleaner at the point of use because it removes direct fuel smoke and makes temperature recording easier. It is not automatically low-carbon. Its environmental burden depends on the electricity source, furnace efficiency and load. Biomass is renewable in origin, but wet or poorly burned fuel may create substantial particulate pollution. Reviews of sustainability in pharmaceutical manufacturing support the use of transparent metrics rather than simple technology labels[25-27].

Practical improvements include better insulation, sound door seals, an appropriate chamber size, validated minimum and maximum loads, prevention of material loss and avoidance of repeat cycles caused by poor control. Renewable electricity may reduce the footprint of an electric furnace, but only after the pharmaceutical process has been validated. Table 3 gives a compact set of sustainability indicators for future studies.

Table 3: Suggested sustainability indicators for Puta systems

Domain	Indicator	Reporting unit or approach
Energy	Consumption per cycle and per acceptable product	MJ or kWh per cycle; kWh/kg of finished *Bhasma*
Fuel or power source	Quantity and source	Fuel mass and calorific value; electricity source and carbon factor
Material efficiency	Yield and loss at each stage	Percentage yield; mass lost during grinding, sealing and transfer
Emissions	Fuel- and material-related releases	Particulate matter, relevant gases and controlled residues
Process reliability	Rejected or repeated cycles	Failed-cycle rate and deviation frequency
Worker protection	Control of smoke, heat and dust	Ventilation, local exhaust, exposure monitoring and incidents
Product quality	Classical and instrumental acceptance	Batch pass rate against predefined specifications

Process Validation and Pharmaceutical Standardisation

GMP requires products to be consistently made and controlled through documented procedures, suitable equipment, calibration, validation and in-process checks [28,29]. Applied to *Puta*, the batch record should identify the furnace, calibration status, programme, actual temperature curve, container, load, cooling period, deviations and yield. Temperature near the sample may be more informative than chamber temperature alone, particularly during scale-up.

Quality-by-design and quality-risk principles are also relevant. The critical quality attributes of the finished *Bhasma* should be linked with critical process parameters such as heating rate, maximum temperature, holding time, atmosphere, cooling and cycle number [30-32]. This link is essential when a research-scale batch is moved to an industrial furnace because heat transfer, material depth and temperature uniformity change with scale.

A sustainability claim should extend beyond the pharmacy wall. Life-cycle assessment can compare upstream fuel or electricity production, on-site emissions, waste and equipment use, while energy-management standards can support routine monitoring and improvement [33-35]. The analysis need not be complex in every small study, but its system boundary and assumptions should be stated clearly.

A Validation Model for Sustainable *Puta*

A safer route to modernisation is a staged comparison. The classical process is first measured, not discarded. An alternative furnace programme is then developed from the observed thermal profile. Parallel batches are compared for quality and resource use, and the new method is accepted only when predefined equivalence criteria are met. Table 4 presents this model.

Table 4: Five-stage validation model for a sustainable Puta system

Stage	Main work	Decision point
1. Characterise	Record fuel, geometry, temperature-time curve, batch mass	Is the reference process described well enough to reproduce?

	and cooling of the classical process	
2. Translate	Develop a furnace programme that reflects the relevant profile, not only the peak	Are heating and cooling within the proposed operating range?
3. Compare	Prepare parallel batches and assess classical tests, phase, composition, morphology and yield	Are products pharmaceutically and physicochemically comparable?
4. Measure	Compare energy, emissions, labour, loss, deviations and processing time	Does the alternative reduce a measured burden without shifting it elsewhere?
5. Validate	Set acceptance criteria, qualified load range, controls, records and revalidation triggers	Can routine batches remain within the approved range?

Discussion

The literature supports controlled modernisation, but not universal furnace conversion. The classical value of *Puta* lies in a substance-specific thermal exposure. The most convincing modern study is therefore not the one that uses the newest furnace; it is the one that explains how the alternative programme was derived and shows that the finished product remains within a justified acceptance range.

Sustainability and pharmaceutical quality can often support the same goal. Better insulation, correct loading, continuous temperature recording and fewer failed cycles save energy while improving reproducibility. Other trade-offs need direct measurement. Electric heating reduces smoke inside the pharmacy but may use carbon-intensive power. Biomass may be locally renewable but can create dust and particulate exposure. A claim of "pollution-free" or "green" manufacture is therefore premature without a stated system boundary and measured data.

The whole manufacturing chain must also be considered. Repeated *Bhavana* may use medicinal plants, water, grinding energy and drying time. Material can be lost during transfer, pellet making, sealing and collection. A process that consumes less furnace energy but produces a lower usable yield may not be more sustainable per dose or per kilogram of finished medicine.

Digital batch records and automatic furnace logs can improve traceability. In the future, accumulated batch data may help identify relationships between starting material, thermal profile, cycle number, energy use and analytical quality. Such tools should support, not replace, classical pharmaceutical knowledge and experimental validation.

Limitations and Research Priorities

Current evidence is limited by small research batches, different raw materials, incompletely reported heating curves and a lack of common analytical acceptance limits. Few studies measure electricity, fuel use, particulate emissions or carbon impact alongside product quality. Results from one *Bhasma* or one furnace size cannot be transferred automatically to another preparation or industrial scale.

Future work should publish substance-specific thermal profiles, furnace-load maps, energy and emission data, stage-wise yield, and parallel classical and instrumental assessments. Comparative studies should include at least one traditional reference batch, a controlled electric batch and, where feasible, an energy-optimised or renewable-electricity condition. Stability, toxicology and clinical efficacy remain separate research questions and should not be inferred from a successful process comparison.

Conclusions

Puta should be understood as a controlled thermal process, not simply as the burning of a particular fuel.

Classical practice recognised that different substances need different intensities, durations and repetitions of heat. Modern electric furnaces can improve control, documentation and workplace cleanliness, and comparative studies show that they can reproduce acceptable outcomes for selected preparations.

However, equal peak temperatures do not guarantee equal products. Heating rate, holding time, cooling, atmosphere, furnace load and intermediate processing must be considered together. A sustainable system should therefore be adopted only after thermal mapping and pharmaceutical equivalence testing.

The most defensible future model is a process-specific, energy-efficient and well-documented *Puta* that meets classical quality criteria, modern analytical specifications and measurable environmental goals. This approach preserves the thermal logic of *Rasashastra* while making contemporary manufacturing more reproducible, safer and responsible.

References

[1] Vagbhata. Rasa Ratna Samuccaya. Mishra S, editor. Varanasi: Chaukhambha Orientalia; 2011. Chapter 10.

[2] Sharma S. Rasa Tarangini. Shastri K, editor. 11th ed. New Delhi: Motilal Banarsidass; 2009. Taranga 3.

[3] Madhava. Ayurveda Prakasha. Mishra GS, editor. Varanasi: Chaukhambha Bharati Academy; 2007. Chapters on Marana and Puta.

[4] Government of India, Ministry of Health and Family Welfare, Department of AYUSH. The Ayurvedic Formulary of India. Part I. 2nd revised ed. New Delhi: Department of AYUSH; 2003.

[5] Government of India, Ministry of Health and Family Welfare, Department of AYUSH. The Ayurvedic Pharmacopoeia of India. New Delhi: Government of India; 2008.

[6] Savrikar SS, Ravishankar B. Introduction to Rasashastra: the iatrochemistry of Ayurveda. Afr J Tradit Complement Altern Med. 2011;8(5 Suppl):66-82. doi:10.4314/ajtcam.v8i5S.1.

[7] Chaudhary A, Singh N. Herbo-mineral formulations (Rasaushadhies) of Ayurveda: an amazing inheritance of Ayurvedic pharmaceutics. Anc Sci Life. 2010;30(1):18-26.

[8] Pathiraja PMYS, Ranatunga YMMK, Herapathdeniya SKMK, Gunawardena SHP. Swarna Makshika Bhasma preparation using an alternative heating method to traditional Varaha Puta. J Ayurveda Integr Med. 2020;11(3):206-212. doi:10.1016/j.jaim.2018.02.136.

[9] Singh TR, Gupta LN, Kumar N. Standard manufacturing procedure of Teekshna Lauha Bhasma. J Ayurveda Integr Med. 2016;7(2):100-108. doi:10.1016/j.jaim.2015.08.003.

[10] Jagtap CY, Prajapati PK, Patgiri B, Shukla VJ. Standard manufacturing procedure of Tamra Bhasma. Ayu. 2012;33(4):561-568. doi:10.4103/0974-8520.110528.

[11] Chaturvedi R, Jha CB. Standard manufacturing procedure of Rajata Bhasma. Ayu. 2011;32(4):566-571. doi:10.4103/0974-8520.96135.

[12] Gautam DNS. A metallurgical study of Naga Bhasma. Anc Sci Life. 2017;36(4):182-186. doi:10.4103/asl.ASL_206_15.

[13] Mohapatra S, Jha CB. Physicochemical characterization of Ayurvedic Bhasma (Swarna Makshika Bhasma): an approach to standardization. Int J Ayurveda Res. 2010;1(2):82-86. doi:10.4103/0974-7788.64409.

[14] Mohapatra S, Jha CB. Analytical study of raw Swarna Makshika (chalcopyrite) and its Bhasma through TEM and EDAX. Ayu. 2013;34(2):204-208. doi:10.4103/0974-8520.119682.

[15] Wadekar MP, Rode CV, Bendale YN, Patil KR, Prabhune AA. Preparation and characterization of a copper-based Indian traditional drug: Tamra Bhasma. J Pharm Biomed Anal. 2005;39(5):951-955. doi:10.1016/j.jpba.2005.06.015.

[16] Kumar A, Nair AGC, Reddy AVR, Garg AN. Bhasmas: unique Ayurvedic metallic-herbal preparations, chemical characterization. Biol Trace Elem Res. 2006;109(3):231-254. doi:10.1385/BTER:109:3:231.

[17] Pal D, Sahu CK, Haldar A. Bhasma: the ancient Indian nanomedicine. J Adv Pharm Technol Res. 2014;5(1):4-12. doi:10.4103/2231-4040.126980.

[18] Anastas PT, Warner JC. Green Chemistry: Theory and Practice. New York: Oxford University Press; 1998.

[19] Anastas PT, Zimmerman JB. Design through the twelve principles of green engineering. Environ Sci Technol. 2003;37(5):94A-101A. doi:10.1021/es032373g.

[20] Winterton N. Twelve more green chemistry principles? Green Chem. 2001;3:G73-G75. doi:10.1039/B110187K.

[21] Sheldon RA. The E factor: fifteen years on. Green Chem. 2007;9:1273-1283. doi:10.1039/B713736M.

[22] Sheldon RA. Metrics of green chemistry and sustainability: past, present, and future. ACS Sustain Chem Eng. 2018;6(1):32-48. doi:10.1021/acssuschemeng.7b03505.

[23] Constable DJC, Curzons AD, Cunningham VL. Metrics to green chemistry: which are the best? Green Chem. 2002;4:521-527. doi:10.1039/B206169B.

[24] Jimenez-Gonzalez C, Constable DJC, Ponder CS. Evaluating the greenness of chemical processes and products in the pharmaceutical industry: a green metrics primer. Chem Soc Rev. 2012;41(4):1485-1498. doi:10.1039/C1CS15215G.

[25] Becker J, Manske C, Randl S. Green chemistry and sustainability metrics in the pharmaceutical manufacturing sector. Curr Opin Green Sustain Chem. 2022;33:100562. doi:10.1016/j.cogsc.2021.100562.

[26] Gupta P, Mahajan A. Green chemistry approaches as sustainable alternatives to conventional strategies in the pharmaceutical industry. RSC Adv. 2015;5:26686-26705. doi:10.1039/C5RA00358J.

[27] Chaturvedi U, Sharma M, Dangayach GS, Sarkar P. Evolution and adoption of sustainable practices in the pharmaceutical industry: an overview with an Indian perspective. J Clean Prod. 2017;168:1358-1369. doi:10.1016/j.jclepro.2017.08.184.

[28] World Health Organization. WHO good manufacturing practices for pharmaceutical products: main principles. WHO Technical Report Series No. 986, Annex 2. Geneva: World Health Organization; 2014.

[29] World Health Organization. Good manufacturing practices: guidelines on validation. WHO Technical Report Series No. 1019, Annex 3. Geneva: World Health Organization; 2019.

[30] International Council for Harmonisation. ICH Q8(R2): Pharmaceutical Development. Geneva: ICH; 2009.

[31] International Council for Harmonisation. ICH Q9(R1): Quality Risk Management. Geneva: ICH; 2023.

[32] International Council for Harmonisation. ICH Q10: Pharmaceutical Quality System. Geneva: ICH; 2008.

[33] International Organization for Standardization. ISO 14040:2006 Environmental management-

life cycle assessment-principles and framework. Geneva: ISO; 2006.

[34] International Organization for Standardization. ISO 14044:2006 Environmental management-life cycle assessment-requirements and guidelines. Geneva: ISO; 2006.

[35] International Organization for Standardization. ISO 50001:2018 Energy management systems-requirements with guidance for use. Geneva: ISO; 2018.