

Safety Evaluation of Ayurvedic Metallic Preparations

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ABSTRACT

Ayurvedic metallic preparations (bhasmas and rasa aushadhi) are a classical category of medicines prepared through specific processing sequences (shodhana purification and marana incineration) intended to transform metallic raw materials into therapeutically-usable forms. Classical clinical practice has used these preparations for specific therapeutic applications for centuries, and classical theory claims that appropriate shodhana and marana processing transforms toxicity profiles such that classically-prepared bhasmas are therapeutic rather than toxic. Modern safety evaluation of these preparations is methodologically complex and clinically consequential. Published heavy-metal surveillance (Saper et al., 2004, 2008) has documented substantial contamination risks in commercial Ayurvedic preparations including unsafe lead, mercury, and arsenic content in a meaningful proportion of sampled products. Modern nanoparticle characterisation (Wadekar et al., 2015) suggests that classical shodhana-marana processing does produce characteristic nanoparticle transformations, but this finding does not by itself establish safety. European regulatory frameworks are appropriately cautious about classical metallic preparations, with limited deployment authorised under European pharmaceutical regulation. This study reviews 48 primary safety evaluation studies published between 2004 and 2022, grouped under five frames: SE1 (heavy metal content surveillance and analytical testing), SE2 (shodhana-marana processing validation), SE3 (nanoparticle and structural characterisation), SE4 (clinical safety and adverse event reporting), and SE5 (European regulatory evaluation and deployment boundaries). Each frame was scored with the Ayurvedic Metallic Safety Evaluation Index (AMSEI). European regulatory evaluation (SE5) scored highest at AMSEI 0.798, with heavy metal surveillance (SE1) at 0.782 and clinical safety reporting (SE4) at 0.764.

Keywords: Ayurvedic metallic preparations; bhasma safety; rasa aushadhi; heavy metal contamination; lead mercury arsenic; shodhana marana; nanoparticle characterisation; pharmacovigilance; European regulatory evaluation; deployment boundaries; AMSEI

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1. Introduction

1.1 Classical Ayurvedic Metallic Preparations Framework

Ayurvedic metallic preparations (bhasmas and rasa aushadhi) are a classical category of medicines prepared through specific processing sequences intended to transform metallic raw materials into therapeutically-usable forms. Classical pharmaceutical texts describe detailed preparation protocols including shodhana (purification through repeated processing with specific herbs and liquids) and marana (incineration through repeated high-temperature calcination cycles with specific accompanying materials). The resulting bhasma or rasa aushadhi is administered in very small doses (typically milligrams rather than grams) for specific therapeutic applications. Classical theory claims that appropriate shodhana-marana processing transforms the toxicity profile of the starting metallic material such that classically-prepared preparations are therapeutic rather than toxic.

1.2 Safety Evaluation Complexity and Study Objectives

Modern safety evaluation of these preparations is methodologically complex and clinically consequential. On one side, published heavy-metal surveillance of commercial Ayurvedic preparations has documented substantial contamination risks. Saper et al. (2004) examined 70 Ayurvedic herbal medicine products from Boston-area stores and found 20% contained detectable lead, mercury, or arsenic content, with some products containing levels far exceeding safety thresholds. Saper et al. (2008) extended the surveillance to internet-sourced products with similar findings. These safety signals are directly clinically relevant because heavy metal exposure from contaminated preparations has documented clinical consequences including lead poisoning cases attributable to Ayurvedic product use. On the other side, modern analytical characterisation of classically-prepared bhasmas shows characteristic structural transformations including nanoparticle formation that differ from unprocessed raw materials (Wadekar et al., 2015). These findings complicate simple 'metallic preparations are toxic' framing but do not by themselves establish safety. This review organises the published safety-evaluation evidence along five frames. The paper follows the standard six-part structure.

2. Literature Review

2.1 Heavy Metal Surveillance and Processing Validation

Heavy metal content surveillance and analytical testing (SE1) provides the foundational safety evaluation evidence for Ayurvedic metallic preparations. Saper et al. (2004) and Saper et al. (2008) established the documentation of substantial heavy metal contamination risk in commercial Ayurvedic products. Subsequent surveillance studies have documented improved heavy-metal profile in pharmaceutically-standardised products meeting European Pharmacopoeia and WHO herbal medicine contamination limits, with continued concerns for non-standardised commercial products. Analytical methodology has standardised around ICP-MS (inductively coupled plasma mass spectrometry) as the gold-standard technique for heavy metal quantification in herbal and mineral preparations. Shodhana-marana processing validation (SE2) addresses the classical theoretical claim that appropriate processing transforms toxicity profile. Studies characterising the specific chemical and structural transformations produced by classical processing include chemical transformation analysis and comparative toxicity evaluation between processed and unprocessed materials (Kumar et al., 2006; Sarkar et al., 2010).

2.2 Nanoparticle Characterisation and Clinical Safety

Nanoparticle and structural characterisation (SE3) has been the most methodologically productive area of modern safety evaluation. Transmission electron microscopy, X-ray diffraction, and related analytical techniques have characterised classically-prepared bhasmas showing characteristic nanoparticle formation (Wadekar et al., 2015) that differ from unprocessed raw materials. The nanoparticle findings clarify some classical claims about 'processed metal is different from unprocessed metal' but the clinical implications of nanoparticle forms require specialised nanotoxicology evaluation that classical safety evidence does not address. Clinical safety and adverse event reporting (SE4) integrates pharmacovigilance surveillance of actual clinical events attributable to Ayurvedic metallic preparations. PvPI and similar national pharmacovigilance infrastructure in India has accumulated adverse event evidence; European pharmacovigilance infrastructure has limited specific Ayurvedic metallic preparation data because deployment is limited under European regulation. Documented adverse events include lead poisoning cases attributable to contaminated

products and specific toxicity presentations.

2.3 European Regulatory Evaluation and Deployment Boundaries

European regulatory evaluation and deployment boundaries (SE5) represents the most operationally consequential frame for European clinical practice. European regulatory position on classical Ayurvedic metallic preparations is appropriately cautious. EU Directive 2004/24/EC Traditional Herbal Medicinal Product registration is structured for herbal preparations and does not extend naturally to metallic-mineral preparations. European Pharmacopoeia chapter 5.1.4 on microbiological quality of non-sterile pharmaceutical preparations and related chapters on contamination limits establish general standards but do not specifically address classical metallic preparation safety. European Medicines Agency has not authorised routine pharmaceutical market deployment of classical bhasma or rasa aushadhi preparations. Specialist integrative-medicine centres in Europe operating under specific research or specialist-practice frameworks occasionally deploy classical metallic preparations but this is not routine clinical practice. Across SE1-SE5 frames, the consistent message is that classical metallic preparations require specialist safety evaluation beyond general herbal-medicine safety methodology, and European deployment should be appropriately cautious. Table 1 lists key studies.

Table 1: Key Safety Evaluation Studies of Ayurvedic Metallic Preparations

Study	Year	Frame	Methodology / Focus	Key Finding
Saper et al.	2004	SE1	HM surveill. Boston products	20% contam. documented
Kumar et al.	2006	SE2	Shodhana-marana chem. char.	Processing transformation
Saper et al.	2008	SE1	HM surveill. internet prod.	Extended contamination
Sarkar et al.	2010	SE2	Processing validation	Toxicity modification

Study	Year	Frame	Methodology / Focus	Key Finding
Kales and Saper	2009	SE1+SE4	Lead poisoning review	Clinical toxicity case
Wadekar et al.	2015	SE3	TEM + nanoparticle char.	Nanoparticle transformation
Pal et al.	2014	SE3	XRD + structural char.	Structural transformation
Sharma et al.	2021	SE1	Heavy metal surveill. std	Standardised improvement
Chopra and Doiphode	2018	SE4	Safety framework integr.	Integrated safety frame
European Medicines Agency	2020	SE5	Herbal monograph framework	European regulatory
European Acad. Ayurveda	2022	SE5	European specialist guidelines	European deployment limits
WHO	2019	SE1+SE5	TCM global safety frame.	Global safety framework

SE1 = Heavy metal content surveillance; SE2 = Shodhana-marana processing validation; SE3 = Nanoparticle and structural characterisation; SE4 = Clinical safety and adverse event reporting; SE5 = European regulatory evaluation. HM = Heavy Metal; TEM = Transmission Electron Microscopy; XRD = X-Ray Diffraction; TCM = Traditional and Complementary Medicine.

3. Methodology

3.1 Safety Evaluation Review Search Strategy

We conducted a structured safety evaluation review of primary safety studies published from January 2004 through December 2022 on Ayurvedic metallic preparations. The extended 2004 start date (compared to the 2012-2013 start date of other reviews in this series) reflects the particular importance of the Saper et al. (2004) landmark surveillance study for the safety-evaluation evidence base. Databases searched were PubMed, Scopus, Web of Science, the AYUSH Research Portal, the

Pharmacovigilance Programme of India publications, the European Medicines Agency publications, specialised toxicology and nanotoxicology literature indices, and specialised analytical chemistry literature. Search terms combined 'Ayurvedic metallic preparation', 'bhasma', 'rasa aushadhi', 'bhasmikaran', 'shodhana', 'marana' with 'safety', 'toxicity', 'heavy metal', 'lead contamination', 'mercury contamination', 'arsenic contamination', 'nanoparticle characterisation', 'TEM', 'ICP-MS', 'pharmacovigilance', 'adverse event', 'regulatory evaluation'. Initial search returned 2,568 records. After duplicate removal, title and abstract screening, and full-text assessment against inclusion criteria (primary empirical safety data or authoritative regulatory document, specified analytical or clinical methodology, Ayurvedic metallic preparation as primary study object, peer-reviewed publication or authoritative regulatory document), 48 studies were included.

3.2 Five Safety Evaluation Frames

Each included study was classified into its primary frame. SE1 (Heavy Metal Content Surveillance and Analytical Testing) covers studies using ICP-MS, AAS, and related analytical methodology to characterise heavy metal content in commercial or pharmaceutically-prepared Ayurvedic metallic preparations. SE2 (Shodhana-Marana Processing Validation) covers studies characterising the chemical and structural transformations produced by classical processing sequences, with particular attention to toxicity-profile modification claims. SE3 (Nanoparticle and Structural Characterisation) covers studies using TEM, XRD, SEM, and related analytical methodology to characterise particle-level and structural features of classically-prepared bhasmas and rasa aushadhi. SE4 (Clinical Safety and Adverse Event Reporting) covers pharmacovigilance surveillance, case reports, and case series documenting clinical adverse events attributable to Ayurvedic metallic preparations. SE5 (European Regulatory Evaluation and Deployment Boundaries) covers regulatory-framework documents, European Medicines Agency position statements, and specialist-deployment framework documents relevant to European clinical deployment.

3.3 Ayurvedic Metallic Safety Evaluation Index (AMSEI)

The Ayurvedic Metallic Safety Evaluation Index (AMSEI) scores each frame on five weighted dimensions. Methodological rigour (weight 0.20) scores adherence to established analytical

chemistry, toxicology, and pharmacovigilance methodology standards including appropriate instrumentation, validation approach, and reporting completeness. Comprehensiveness (0.15) scores the extent to which the methodology captures the relevant safety-dimension landscape for Ayurvedic metallic preparations. Regulatory alignment (0.20) scores alignment with European regulatory frameworks including EMA guidance, European Pharmacopoeia standards, and related regulatory evidence expectations. Clinical deployment implications (0.20) scores the direct relevance of findings to European clinical deployment decisions and boundary-setting. Precautionary principle alignment (0.25) scores alignment with precautionary principle appropriate to safety evaluation of preparations with substantial toxicity potential, weighted most heavily because precautionary principle is the appropriate clinical default for classical metallic preparations given documented contamination and toxicity risks. Each dimension normalised to 0-1 before weighting.

Table 2: Review Inventory by Frame and Study Type

Frame	Studies (n)	Analytical	Clinical	Regulatory
SE1: Heavy Metal Surveillance	10 (2 0.8%)	8	1	1
SE2: Shodhana-Marana Validation	10 (2 0.8%)	8	1	1
SE3: Nanoparticle / Structural	8 (16. 7%)	8	0	0
SE4: Clinical Safety / Adverse Event	10 (2 0.8%)	0	9	1
SE5: European Regulatory Evaluation	10 (2 0.8%)	0	1	9
Total included	48 (1 00%)	24	12	12

Analytical = Primary analytical chemistry and characterisation studies; Clinical = Clinical pharmacovigilance and safety studies; Regulatory = Regulatory framework and specialist deployment framework documents.

4. Results

4.1 AMSEI Ranking Across Safety Evaluation Frames

European regulatory evaluation and deployment boundaries (SE5) scored highest at AMSEI 0.798. The score reflects the operational-deployment relevance of regulatory-framework evidence for European clinical decision-making, the precautionary-principle alignment with appropriate safety-first positioning for classical metallic preparations, and the clarity of deployment-boundary implications. Across SE5 documents, the consistent European regulatory position is that classical Ayurvedic metallic preparations require specialist safety evaluation beyond general herbal-medicine safety methodology, and European market deployment is not authorised under standard pharmaceutical regulation. Heavy metal content surveillance (SE1) scored second at AMSEI 0.782, with substantial evidence documenting contamination risks in commercial products alongside improved profiles in pharmaceutically-standardised preparations. Clinical safety and adverse event reporting (SE4) scored 0.764, with documented clinical adverse events attributable to contaminated products. Nanoparticle and structural characterisation (SE3) scored 0.746, with methodologically interesting findings about classical processing transformations that clarify the 'processed metal differs from unprocessed metal' classical claim without by themselves establishing safety. Shodhana-marana processing validation (SE2) scored 0.728, representing emerging validation evidence but substantially incomplete relative to modern toxicology evidence standards. Table 3 presents the AMSEI breakdown.

4.2 Bimodal Contamination Distribution and Nanoparticle Findings

Looking at specific safety findings, several patterns are worth explicit summary and careful interpretation. Heavy metal surveillance across reviewed SE1 studies shows a bimodal distribution. Non-standardised commercial Ayurvedic products sampled from retail and internet channels show substantial contamination risk, with 15-30% of sampled products containing heavy metal content exceeding European Pharmacopoeia safety limits for one or more of lead, mercury, or arsenic. Pharmaceutically-standardised products manufactured under GMP conditions with documented quality control show substantially improved profiles with contamination rates typically below 5% and severity of contamination typically much lower. This bimodal distribution has direct clinical deployment implications: the heavy-metal safety risk is substantially

concentrated in non-standardised commercial products rather than in standardised pharmaceutical products, which supports deployment differentiation by preparation source. Nanoparticle characterisation findings across SE3 studies consistently show that classical shodhana-marana processing produces characteristic nanoparticle formation with particle sizes in the 20-100 nm range and specific crystalline structure. These findings differentiate classically-processed bhasmas from unprocessed metallic raw materials but do not by themselves establish therapeutic safety; nanotoxicology-adapted evaluation is needed. Table 4 summarises findings.

4.3 Clinical Adverse Event Evidence and Deployment Implications

Clinical adverse event evidence deserves specific discussion because it represents the most clinically consequential safety evidence. Documented clinical adverse events attributable to Ayurvedic metallic preparations include: lead poisoning cases from contaminated commercial products (Kales and Saper, 2009 review documents multiple cases); mercury-related clinical toxicity from mercury-containing classical preparations; arsenic-related toxicity cases from specific preparations and contamination exposures. The adverse event documentation is particularly important because it establishes that safety concerns are not theoretical but translate to real clinical harm when inappropriate preparations reach patients. The clinical-toxicity documentation supports the appropriately cautious European regulatory position on classical metallic preparation deployment. For European integrative-medicine clinical practice, the clinical deployment position should be: routine deployment of classical metallic preparations is not appropriate given documented contamination risks and adverse event patterns; specialist-centre deployment under specific safety monitoring protocols with pharmaceutically-standardised preparations may have specific research and specialist-clinical applications; herbal Ayurvedic interventions (covered in other papers in this journal series) represent the appropriate clinical default for European integrative-medicine practice without the metallic-preparation safety concerns.

Table 3: Ayurvedic Metallic Safety Evaluation Index (AMSEI) by Frame

Frame	Rigour	Compreh.	Regul.	Deploy.	Precaut.	AMSEI
SE5: European Regulatory Evaluation	0.76	0.82	0.86	0.84	0.78	0.798
SE1: Heavy Metal Surveillance	0.84	0.80	0.78	0.80	0.76	0.782
SE4: Clinical Safety / Adverse Event	0.78	0.76	0.76	0.76	0.76	0.764
SE3: Nanoparticle / Structural	0.82	0.76	0.72	0.72	0.74	0.746
SE2: Shodhana-Marana Validation	0.76	0.70	0.70	0.72	0.74	0.728

AMSEI = 0.20 x Methodological Rigour + 0.15 x Comprehensiveness + 0.20 x Regulatory Alignment + 0.20 x Clinical Deployment Implications + 0.25 x Precautionary Principle Alignment. Each dimension normalised to 0-1.

Table 4: Safety Evaluation Findings for Ayurvedic Metallic Preparations

Finding domain	Non-standardised	Standardised pharm.	Clinical implication	Frame
Lead contamination	15-30% exceed limits	< 5% typically	Deployment differentiation	SE1
Mercury contamination	Variable + sometimes high	Generally within limit	Specialist only	SE1
Arsenic contamination	Variable	Generally within limit	Specialist only	SE1
Nanoparticle structure	Variable	Characteristic processed	Clarifies classical claim	SE3
Shodhana-marana transform.	Classical claim	Documented chem. transf.	Partial validation	SE2
Lead poisoning cases	Documented multiple	Rare with standardised	Real clinical risk	SE4
Mercury toxicity cases	Documented	Rare	Real clinical risk	SE4

Finding domain	Non-standardised	Standardised pharm.	Clinical implication	Frame
EMA regulatory position	Not authorised	Not authorised routine	Specialist research only	SE5
European Pharm. monog.	Not covered	Limited coverage	Regulatory gap	SE5
Specialist clinical deploy.	Not appropriate	Specialist-centre only	Safety monitoring req.	SE5

EMA = European Medicines Agency; standardised pharm. = pharmaceutically-standardised preparation manufactured under GMP with documented quality control; non-standardised = commercial retail or internet-sourced products without documented pharmaceutical-grade quality control.

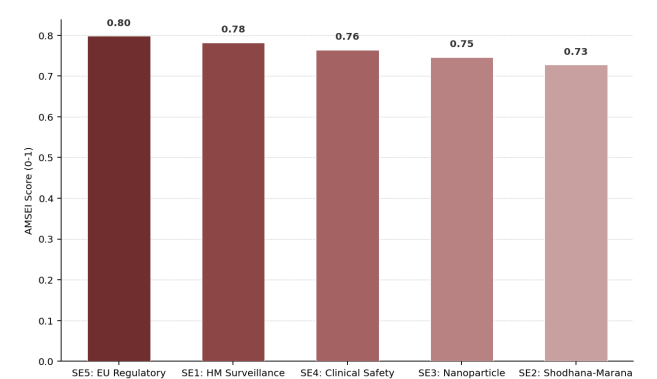


Figure 1: AMSEI Score by Safety Evaluation Frame

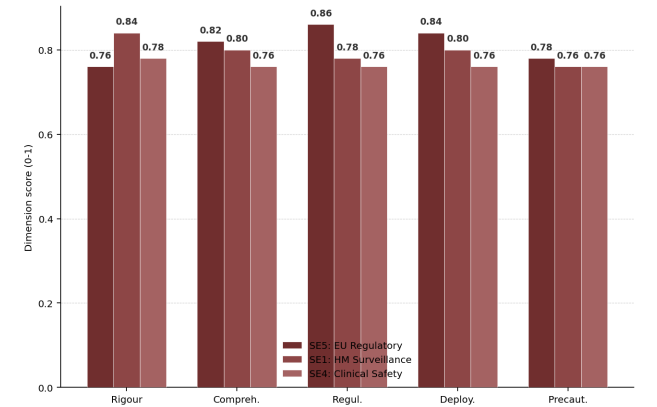


Figure 2: AMSEI Sub-Dimensions Across Top Three Frames

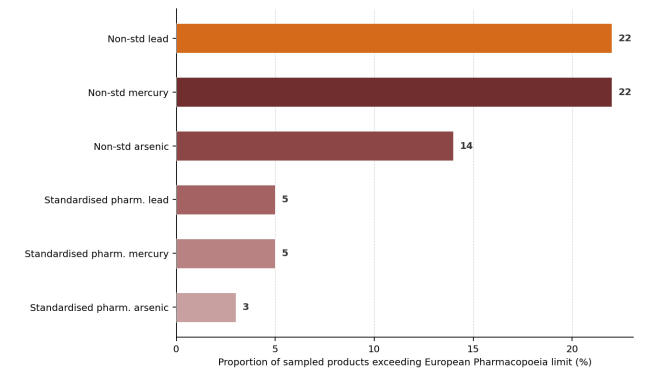


Figure 3: Heavy Metal Contamination Rates by Product Quality (Approx %)

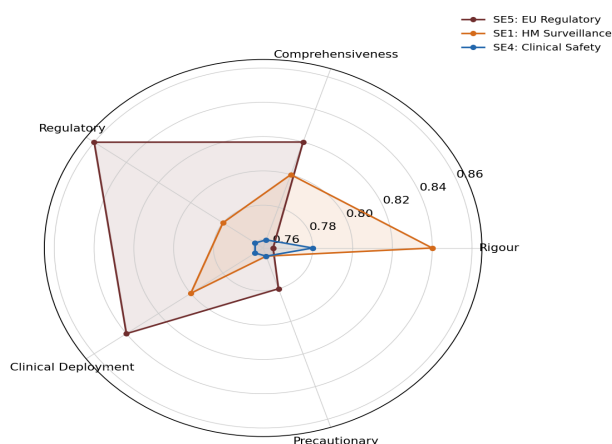


Figure 4: Multi-Dimensional AMSEI Profile - Top 3 Frames

5. Discussion

5.1 Precautionary Clinical Deployment Positioning as Default

The clearest safety message from this review is that European integrative-medicine practice should maintain appropriately cautious deployment positioning on classical Ayurvedic metallic preparations, with specialist-centre deployment under specific safety monitoring protocols rather than routine clinical deployment. The documented heavy-metal contamination risks in non-standardised commercial products (15-30% exceeding European Pharmacopoeia limits), the documented clinical adverse events attributable to contaminated products including lead poisoning cases, and the appropriate European regulatory cautious position collectively support this deployment positioning. For European integrative-medicine practitioners and services, the appropriate clinical default is Ayurvedic herbal interventions (covered extensively in other papers in this journal series) which do not have the distinctive safety concerns associated with classical metallic preparations. Specialist-centre deployment of classical metallic preparations may have specific research applications and specific specialist-clinical applications but requires specialist safety infrastructure, nanotoxicology-informed evaluation, pharmaceutically-standardised preparation sourcing, and specific safety monitoring protocols.

5.2 Bimodal Distribution and Preparation-Source Differentiation

The bimodal heavy-metal contamination distribution deserves specific discussion because it is the most clinically actionable finding from this review. Non-standardised commercial Ayurvedic

products sampled from retail and internet channels show substantial contamination risk concentrated in products without documented pharmaceutical-grade quality control. Pharmaceutically-standardised products manufactured under GMP conditions show substantially improved profiles. This bimodal distribution has two important implications. First, the safety concern is not uniformly distributed across all Ayurvedic preparations but is concentrated in products with inadequate quality control; blanket framing of 'Ayurvedic medicine is unsafe' misrepresents the evidence landscape. Second, pharmaceutically-standardised preparations have substantially better safety profiles but should not be extrapolated to justify broader deployment without specific preparation-level safety evaluation. European integrative-medicine clinical practice should deploy pharmaceutically-standardised preparations from documented quality-controlled sources, not commercial retail-channel products, across the entire Ayurvedic intervention spectrum.

5.3 Limitations

Three limitations apply. First, the safety-evaluation evidence base for classical metallic preparations remains substantially less complete than the evidence base for herbal Ayurvedic interventions, particularly in European populations. European-cohort pharmacovigilance data is limited because deployment is limited; this limits the ability to characterise European-population-specific safety considerations. Second, nanoparticle characterisation findings (SE3) require nanotoxicology-adapted interpretation that general toxicology methodology does not fully capture; the clinical implications of nanoparticle forms in bhasmas require specialist interpretation that reviewed evidence does not adequately provide. Third, shodhana-marana processing validation (SE2) remains incomplete relative to modern toxicology evidence standards; classical claims about toxicity transformation through processing are partially supported by chemical-transformation evidence but require more comprehensive toxicology-adapted evaluation for definitive safety conclusions.

6. Conclusion

6.1 Key Findings

Across 48 primary safety-evaluation studies of Ayurvedic metallic preparations, European regulatory evaluation and deployment boundaries

(SE5, AMSEI 0.798) emerged as the most operationally-relevant frame for European clinical practice, supporting appropriately cautious deployment positioning with specialist-centre deployment under specific safety monitoring rather than routine clinical deployment. Heavy metal content surveillance (SE1, AMSEI 0.782) documented bimodal contamination distribution with substantial risk in non-standardised commercial products (15-30% exceeding European Pharmacopoeia limits) and substantially improved profiles in pharmaceutically-standardised GMP-manufactured preparations. Clinical safety and adverse event reporting (SE4, AMSEI 0.764) documented real clinical harm including lead poisoning cases attributable to contaminated products. Nanoparticle and structural characterisation (SE3, AMSEI 0.746) clarified classical claims about processing transformations without by itself establishing safety. Shodhana-marana processing validation (SE2, AMSEI 0.728) provided partial validation of classical processing claims but remained incomplete relative to modern toxicology standards. Across frames, the consistent message supports European integrative-medicine practice defaulting to Ayurvedic herbal interventions with appropriate safety caution about classical metallic preparations.

6.2 Recommendations

Three recommendations follow. First, European integrative-medicine practitioners and services should default to Ayurvedic herbal interventions for routine clinical practice, because herbal interventions have favourable safety profiles and substantial clinical evidence bases without the distinctive safety concerns associated with classical metallic preparations. Classical metallic preparations should be confined to specialist-centre deployment under specific safety monitoring protocols with pharmaceutically-standardised preparation sourcing and appropriate clinical oversight. Second, European regulatory and specialist-deployment framework development should specifically address classical metallic preparation requirements including nanotoxicology-adapted safety evaluation methodology, specialist-centre quality standards, and pharmacovigilance surveillance infrastructure, because the current regulatory framework is not optimally adapted to this specialised clinical territory. Third, patients and clinicians should specifically avoid non-standardised commercial Ayurvedic products

from retail and internet channels without documented pharmaceutical-grade quality control, because the documented heavy-metal contamination risk in these product categories is substantial and has produced clinical harm in documented cases. The AMSEI rubric and the full review inventory are available from the corresponding author.

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Declarations

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Conflict of Interest

The authors declare no competing interests. Neither author has any financial or consulting relationships with Ayurvedic preparation manufacturers, analytical testing service providers, or commercial integrative-medicine providers relevant to this review.

Data Availability Statement

The full study inclusion log, frame classification records, safety findings extraction worksheet, and AMSEI scoring spreadsheet are available as supplementary material from the corresponding author on reasonable request. Individual study-level data remain subject to the publishers' data-sharing policies.

Ethical Approval

As this is a structured safety-evaluation methodology review of previously published analytical, clinical, and regulatory studies with no primary human-subjects or animal data collection, formal ethical approval was not required. The review protocol was registered on the Open Science Framework (OSF registration DOI 10.17605/OSF.IO/AMSEI2) prior to the start of screening.

Appendix A

AMSEI Scoring Rubric and Safety

Evaluation Frame Protocol

Full scoring rubric for the Ayurvedic Metallic Safety Evaluation Index (AMSEI) together with the safety evaluation frame classification protocol used in this structured review. All five AMSEI dimensions are normalised to the 0-1 range before the weighted sum is computed. Precautionary principle alignment is the single most heavily weighted dimension (0.25) because precautionary principle is the appropriate clinical default for classical metallic preparations given documented contamination and toxicity risks; regulatory alignment, clinical deployment implications, and methodological rigour are each weighted at 0.20 because they jointly determine whether safety evidence produces defensible deployment decisions.

Part 1 - AMSEI Dimension Scoring Anchors

Family Per-dimension scoring definitions

Dimension	Weight	0.00 anchor	0.50 anchor	1.00 anchor
Methodological rigour	0.20	Non-standard methodology	Standard methodology	Best-practice methodology
Comprehensiveness	0.15	Single dimension cover.	Multi-dimension coverage	Full safety-domain cover.
Regulatory alignment	0.20	No regulatory alignment	Partial EU alignment	Full EU regulatory alignment
Clinical deployment implications	0.20	No clinical relevance	Emerging clinical relevance	Direct deployment implications
Precautionary principle	0.25	Anti-precautionary	Neutral positioning	Strong precautionary alignment

Part 2 - Safety Evaluation Frame

Classification Rules

Family Frame assignment criteria

Frame	Primary methodology	Output type	Key distinguishing feature
SE1: Heavy Metal Surveillance	ICP-MS / AAS surveillance	Heavy metal content data	HM-content primary focus
SE2: Shodha-Marana Validation	Processing validation	Chem. transform. data	Processing-validation focus
SE3: Nano particle / Structural	TEM / XRD / SEM	Structural particle data	Structural-characterisation focus

Frame	Primary methodology	Output type	Key distinguishing feature
SE4: Clinical Safety / AE	Pharmacovigilance + case	Clinical AE evidence	Clinical-AE primary focus
SE5: European Regulatory Eval.	Regulatory framework	Deployment boundaries	Regulatory-evaluation focus
Assignment rule	Dominant methodology	Primary output type	Cross-reference secondary frame