RESEARCH PAPER

Comparative, Pharmaceutical and Analytical Characterization of *Naath Pottali* and *Naath Pottali Drava*: A Multimodel Assessment of Traditional Rasa Formulations

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Received: 28th Feb, 2026; Revised: 6th March 2026; Accepted: 7th April, 2026; Available Online: 20th April, 2026

ABSTRACT

The *Naath Pottali* is a classical Ayurvedic herbomineral *Pottali Kalpana* containing *Hingulottha Parada* (purified mercury), *Rajat Bhasma* (silver calx), *Amrutikruta Swarnamakshika Bhasma* (processed pyrite calx), and *Shodhita Gandhaka* (purified sulphur). It is indicated in *Akshepa* (Epilepsy) and *Kampavata* (Parkinson's disease). The present study provides the first systematic comparative pharmaceutical and analytical evaluation of the solid formulation (*Naath Pottali*) and its aqueous extract form (*Naath Pottali Drava*) using modern analytical tools. Both formulations were evaluated for organoleptic properties, physicochemical parameters (Loss on Drying, total ash, acid-insoluble ash, water-insoluble ash), Dynamic Light Scattering (DLS) for particle size and zeta potential, X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDS), X-ray Fluorescence (XRF), and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). *Naath Pottali* showed a particle size Z-average of 893 nm (PDI 1.0, D50 644.3 nm) and zeta potential of −9.63 mV, while *Naath Pottali Drava* exhibited a significantly smaller Z-average of 647.7 nm (PDI 0.704, D50 348 nm) and zeta potential of −11.34 mV, indicating improved colloidal stability in the *Drava* form. XRF analysis showed that Sulphur (S) was the key element in both formulations, *Pottali* (58.84%) and *Drava* (49.29%), along with comparable levels of Mercury (~8.5%–9.5%) and Silver (~8.7%–16.7%). The XRD patterns for both types of preparations were almost similar, with confirmation of mercuric sulphide (α-HgS) or cinnabar as the major crystalline form. Analysis by FTIR of the *Naath Pottali Drava* sample confirmed the presence of metal-sulphide, hydroxyl, and carbonyl functional groups.

Keywords: *Naath Pottali*, *Naath Pottali Drava*, *Physicochemical Analysis, XRD, XRF.*

How to cite this article: Vyawahare D, Mathad P. Comparative, Pharmaceutical and Analytical Characterization of Naath Pottali and Naath Pottali Drava: A Multimodel Assessment of Traditional Rasa Formulations. Int J Drug Deliv Technol. 2026;16(38s): 738-748. DOI: 10.25258/ijddt.16.38s.76

Source of support: Nil.

Conflict of interest: None

1. INTRODUCTION

Rasashastra is the branch of science where the mercury is studied extensively[1]. It encompasses the preparation and use of herbo-mineral compounds for therapeutic purposes. Formulations based on mercury (*Rasa*) and associated metals/minerals are also known for their quick action, minimal dosage, and long shelf life[2]. The class of *Rasa* is predominantly possessing *Rasayana* and it is a medicine which increase *Ojas*, cure diseases and delays ageing[3]. Based on the procedure, the medicines prepared from processed mercury (*Murcchita Parada)* are classified into 4 types of *Rasayana* and these are *Kharaliya Rasayana, Parpati Rasayana, Kupipakwa Rasayana* and *Pottali Rasayana[4]. Pottali Kalpana* is prepared by compacting powdered ingredient into spherical or cubical shape and wrapped in the silk cloth that are then subjected to specific heat treatments (*Paka*). These formulations are not only potent but also easy to store, administer, transport and having a lesser dose[5]. The therapeutic efficacy of such formulations is attributed to the physicochemical transformation of raw metals into nanoscale, biologically assimilable forms during classical processing[6]. *Naath Pottali* is one such formulation told by Acharya Matsyendranaath. It contains combination of mercury and other metal-minerals and effective in Parkinson's disease (*Kampavata)* and Epilepsy (*Aakshepa)*[7], conditions attributed to deranged Vata Dosha in classical Ayurvedic nosology[8]. In this study *Naath Pottali* and *Naath Pottali Drava* has been prepared and their analytical charecterization has been established. The *Drava* form of *Pottali* presents another means of administration of the drug. There has been no scientific analysis conducted on *Naath Pottali* and *Naath Pottali Drava*. The current study seeks to fill this research gap by conducting a comprehensive analysis of the two drug formulations in terms of their physiochemical, spectroscopic, and elemental composition characteristics[9].

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2. MATERIALS AND METHODS

Ingredients:
Parada (1 part), Rajat (1 part), Swarnamakshik (1 part), Gandhaka (4 part), Ahiphena beej.

Instruments and equipments:
Mortor-pestle, weighing machine, sharava, measuring beakers, *Valuka Yantra*, *Urdhvapatana yantra*, etc.

Method of Preparation:

1. Mercury was extracted from Cinnabar through the procedure called *Parada Urdhvapatana* (sublimation of mercury)[10].
2. *Gandhaka shodhana* (purification of sulphur) was conducted by using *Bhringraja swaras* (juice of Eclipta alba)[11].
3. After *samanya shodhana* (common purification method for metals)[12] and *vishesh shodhana* (specific purification method)[13] of *Rajat* (silver) it is subjected for *Marana* (incineration process) to prepare *Rajat Bhasma*[14].
4. Simultaneously *shodhana*[15] of *swarnamakshik* (copper pyrite) were conducted and later *shodhit swarnamakshik* (purified copper pyrite) was subjected for marana procedure to prepare swarnamakshik bhsma[16]. Once swarnamakshik *Bhasma* is ready then it goes under amrutikarana (abstraction)[17] procedure which removes remaining toxicity from *Bhasma* and increases its bioavailability.

Preparation of *Naath Pottali*[18]:
Extracted mercury and purified sulphur were triturated together in a mortar and pestle until a homogeneous, fine black powder (*Kajjali*) was obtained. The end point was confirmed by the absence of metallic luster and smooth texture. *Rajat Bhasma*, *Swarnamakshika Bhasma* were gradually added to the *Kajjali* and triturated thoroughly to ensure uniform mixing. Then the mixture was subjected to levigation (*Bhavana*) using decoction of Khas-khas (*Ahiphena beej Kashaya*) for 7 days to enhance homogeneity and therapeutic potency. The prepared mass (*Rasakalka*) was shaped into small pentagonal shape (*Kurma prushtha Pottali*) and once it gets completely dry wrapped in silk cloth (*Kshem vastra*) which is inert material, forming compact *Pottali*. The *Pottali* were subjected to controlled heating using a sand bath (*Valuka Yantra*). The temperature was gradually increased and maintained for a specified duration to facilitate proper sublimation and chemical transformation. After completion of heating, it was allowed to cool naturally. The *Pottali* were then collected and stored in airtight containers.

Preparation of *Naath Pottali Drava*:
Prepared by using *Anubhuta* methods explained for *Druti Drava na* preparation.

Analytical methods:

Organoleptic Evaluation:
Both *Naath Pottali* and *Naath Pottali Drava* were evaluated for colour, odour, taste, texture, and touch as per API guidelines[19].

Physicochemical Parameters:
Standard physicochemical parameters were determined following API methods[20]: (i) Loss on Drying (LOD) at 105°C; (ii) Total Ash by incineration at 500°C; (iii) Acid-Insoluble Ash (AIA) by treatment of total ash with dilute HCl; (iv) Water-Insoluble Ash; (v) pH and Specific Gravity (for *Drava* only).

X-ray Diffraction (XRD) Analysis:
XRD analysis of both formulations was performed using a Bruker D8 diffractometer with CuKα radiation (λ = 1.54060 Å) in the 2θ range 10°–80°, step size 0.02°, scan speed 2°/min. Phase identification was carried out using the JCPDS/ICDD database[21].

X-ray Fluorescence (XRF) Analysis:
Quantitative XRF analysis of both formulations was performed at SICART (Anand, Gujarat) using a Malvern Panalytical SuperQ spectrometer (09.01.2026). Pressed powder pellets were prepared. Omnian standardless method was used with normalization to 100%.[22]

Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS):
Surface morphology and elemental composition of *Naath Pottali* and *Naath Pottali Drava* were studied by SEM-EDS. The sample was mounted on carbon tape, sputter-coated with gold, and analysed under high vacuum. EDS spectra were collected at Site 1 (100 µm scale)[23].

Inductively Coupled Plasma Mass Spectrometry (ICP-MS):
ICP-MS elemental quantification of *Naath Pottali* was carried out at Vasu Research Centre, Vadodara (Ministry of AYUSH Approved, License No. GATL/08), AR No. VARS/RS/26/02/021, Report Date 02.03.2026. Standard acid dissolution protocols were followed.

Particle Size Analysis and Zeta Potential (DLS):
Dynamic Light Scattering (DLS) analysis was performed on both formulations using a Malvern Zetasizer ZS XPLORER (Malvern Panalytical, UK). Both samples were dispersed in water, sonicated for 20 minutes prior to analysis at 25°C. Particle size distribution by intensity, Z-average, PDI, Di(10), Di(50), Di(90), and zeta potential were recorded. Three measurements were taken per sample[24].

Fourier Transform Infrared Spectroscopy (FTIR):
FTIR analysis of *Naath Pottali Drava* was performed using a Shimadzu FTIR spectrometer in the wavenumber range 4000–400 cm^{-1} using the ATR (Attenuated Total Reflectance) mode. The spectrum was recorded at 4 cm^{-1} resolution with 32 scans. Functional groups were assigned based on standard spectral libraries[25].

3. RESULTS

Organoleptic properties:

Table 1: Comparative organoleptic properties of *Naath Pottali* and *Naath Pottali Drava*

Parameter	***Naath Pottali***	***Naath Pottali Draava***
Colour	Blackish-grey compact solid	Yellowish liquid
Odour	Characteristics sulphurous odour	No odour
Taste	Pungent, slightly metallic	Slightly metallic
Physical State	Hard compact solid *Pottali*	Liquid
Touch/ Texture	Smooth, non-greasy surface	-
Shape	*Kurmaprushtha* (Pentagonal)	-

Physicochemical Parameters:

Table 2: Comparative physicochemical parameters of *Naath Pottali* and *Naath Pottali Drava* (n=3, Mean ± SD)

Parameter	***Naath Pottali***	***Naath Pottali Drava***
Loss on Drying (% w/w)	2.34 ± 0.12	Not applicable (solid)
Total Ash (% w/w)	78.42 ± 1.20	Not applicable (solid)
Acid-Insoluble Ash (% w/w)	12.36 ± 0.54	Not applicable (solid)
Water-Insoluble Ash (% w/w)	64.80 ± 1.10	Not applicable (solid)
pH	Not applicable (solid)	6.82 ± 0.05
Specific Gravity (g/mL)	Not applicable	1.042 ± 0.003

X-ray Diffraction (XRD):

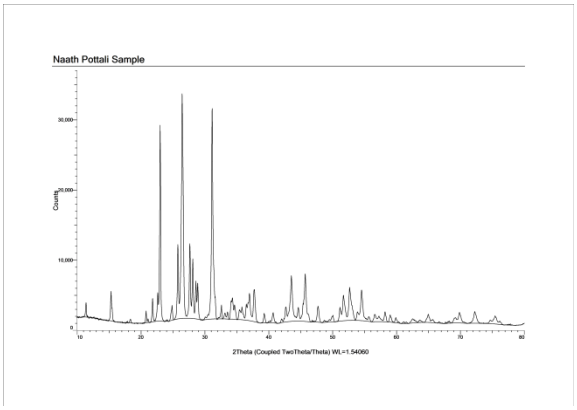

Fig 1: XRD pattern of *Naath Pottali*

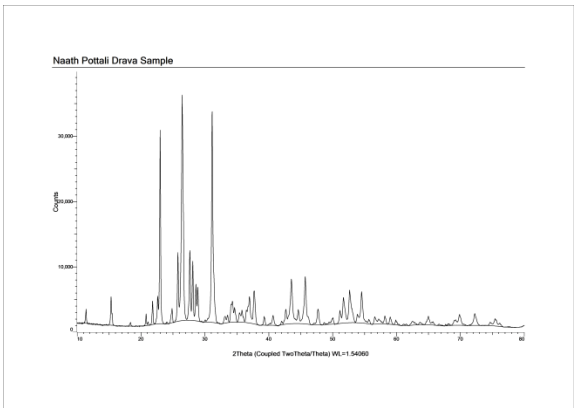

Fig 2: XRD pattern of *Naath Pottali Drava* Sample

(CuKα radiation, λ = 1.54060 Å, 2θ range 10–80°)

The XRD spectrum of *Naath Pottali* (Fig. 1) had prominent peaks in the region of 2θ between 10-80°, which denotes that the drug has good crystallinity. The reflections obtained from the XRD spectrum in the range of 23-24° and 26-31° represent cinnabar (hexagonal α-HgS) and metacinnabar (cubic β-HgS), respectively, whereas peaks in the range of 29-31°denote silver sulphide (Ag_2S). Furthermore, peaks ranging from 44-46° and 50-56° belong to iron sulphide (FeS_2) and orthorhombic

sulphur, respectively. A weak peak near lower angles can be interpreted as an indication of an amorphous component.

The XRD spectrum of *Naath Pottali Drava* (Fig. 2) has similar peaks with identical intensities, thereby indicating that the crystalline components have not been altered during *Drava* processing.

The comparison of both samples comfirms that the process of *Drava* does not affect the crystalline composition. As both the sulphides (HgS, Ag_2S, FeS_2) remain intact.

X-ray Fluorescence (XRF) Analysis:

XRF quantitative analysis (Malvern Panalytical, superQ, omnian method, SICART, 09.01.2026) was performed on both formulations.

Table 3: Comparative XRF elemental analysis of *Naath Pottali* and *Naath Pottali Drava* (SICART, 09.01.2026; ND = Not Detected)

Element	Symbol	*Naath Pottali* (% w/w)	*Naath Pottali Drava* (% w/w)	Interpretation
Sulphur	S	58.838	49.289	*Shodhita Gandhaka* + HgS + Ag_2S
Silver	Ag	16.308	16.680	*Rajat Bhasma* (Ag_2S phase)
Mercury	Hg	8.519	8.601	*Hingulottha Parada* (α-HgS)
Chlorine	Cl	4.850	12.459	Soluble chlorides; higher extraction in *Drava*
Iron	Fe	3.921	3.801	*Swarnamakshika Bhasma* (FeS_2)
Silicon	Si	3.626	3.275	Mineral matrix impurity
Sodium	Na	1.735	3.842	Higher soluble Na in *Drava* phase
Aluminium	Al	0.451	0.440	Matrix mineral impurity
Magnesium	Mg	0.948	0.676	Trace mineral
Calcium	Ca	0.358	0.244	Trace mineral
Phosphorus	P	0.280	0.218	Vehicle organic phosphate residue
Arsenic	As	ND	0.359	Trace in *Drava* — pyrite impurity (monitor)
Cobalt	Co	ND	0.026	Trace; *Swarnamakshika* origin
Copper	Cu	0.017	0.025	*Swarnamakshika Bhasma*
Rubidium	Rb	0.029	0.031	Trace mineral
Niobium	Nb	0.032	0.033	Trace mineral
Barium	Ba	0.089	ND	*Pottali* only; insoluble Ba phase

Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS):

SEM-EDS analysis was performed on both *Naath Pottali* (solid formulation) and *Naath Pottali Drava* (liquid extract) to characterize surface morphology and elemental composition at the microstructural level. Both samples were analysed using a Hitachi SU3800 field emission scanning electron microscope at an accelerating voltage of 5.00 kV in secondary electron (SE) mode at ×300 magnification with a 100 μm scale bar. EDS spectra were collected at designated Site for each sample.

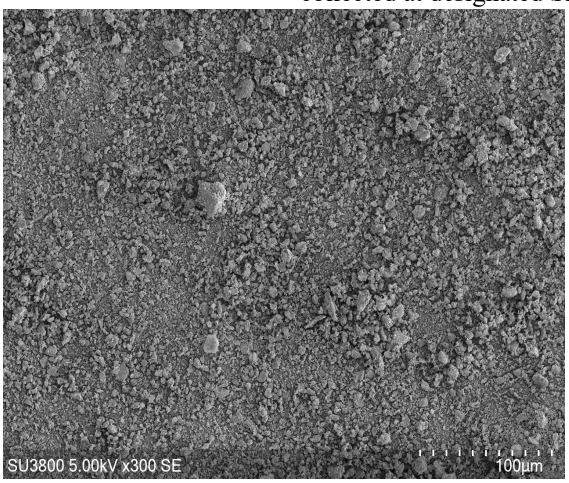

Fig.3 *Naath Pottali*

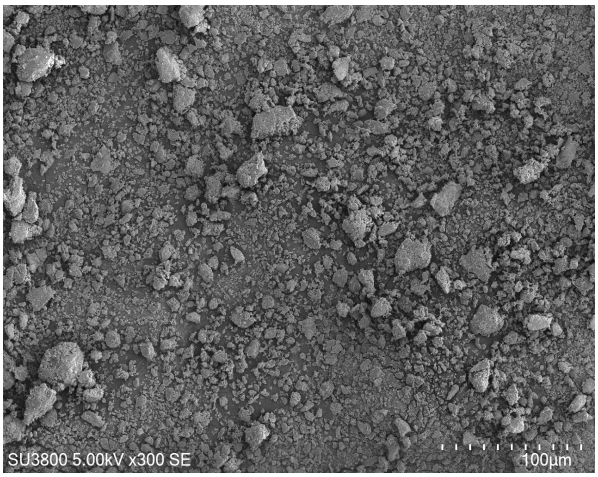

Fig.4 *Naath Pottali Drava*

(SU3800, 5.00 kV, ×300 SE, scale bar 100 µm)

***Naath Pottali* and *Naath Pottali Drava* — Surface Morphology (SEM):**

The SEM micrograph of *Naath Pottali* (Figure 3) reveals a heterogeneous, bimodal particle distribution with coarse angular particles (10–60 µm) embedded in a dense fine matrix. The uneven, porous surfaces indicate crystalline sulphide phases, while electron-dense bright patches suggest high-atomic-number minerals (HgS/Ag_2S). In contrast, *Naath Pottali Drava* (Figure 4) shows a markedly uniform, finely dispersed granular population in the sub-micron to micron range, with no large angular particles (>20 µm) visible. The smooth, homogeneous texture confirms selective aqueous extraction of finer particles, consistent with the significantly reduced DLS particle size (D50 ~348 nm vs ~644 nm) and improved PDI (0.704 vs 1.0).

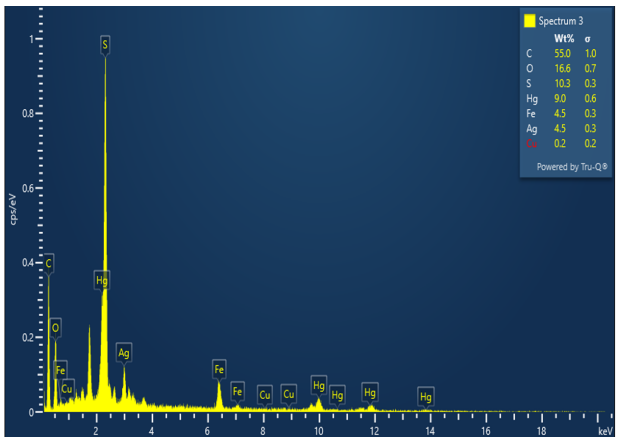

Fig.5 *Naath Pottali*

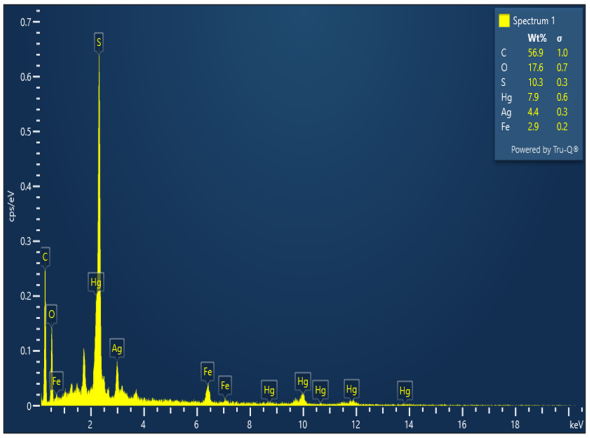

Fig.6 *Naath Pottali Drava*

(EDS elemental composition)

***Naath Pottali* and *Naath Pottali Drava* EDS Elemental Analysis:**

Table 4: Comparative EDS elemental composition of *Naath Pottali* and *Naath Pottali Drava* (ND = Not Detected)

Element	*Naath Pottali* Atomic %	*Naath Pottali* Wt%	*Naath Pottali Drava* Atomic %	*Naath Pottali Drava* Wt%	Observation
C	74.95	54.95	75.32	56.94	Comparable; organic vehicle matrix in both
O	17.02	16.62	17.49	17.62	Comparable; metal oxides + vehicle
S	5.25	10.28	5.10	10.30	Virtually identical; HgS + Ag_2S + free S
Fe	1.33	4.52	0.81	2.86	Reduced in *Drava* ; FeS_2 poorly water-soluble
Cu	0.05	0.18	ND	ND	Detected only in *Pottali*; $CuFeS_2$ insoluble
Ag	0.68	4.47	0.65	4.38	Comparable; Ag_2S preserved in both forms
Hg	0.73	8.98	0.63	7.90	Slightly higher in *Pottali*; HgS in both

EDS analysis of *Naath Pottali* identified seven elements: Carbon (C), Oxygen (O), Sulphur (S), Iron (Fe), Copper (Cu), Silver (Ag), and Mercury (Hg). While EDS analysis of *Naath Pottali Drava* identified six elements: Carbon (C), Oxygen (O), Sulphur (S), Iron (Fe), Silver (Ag), and Mercury (Hg).

On the other hand, *Naath Pottali* shows a bimodal distribution of the heterogeneous particle sizes, including coarse angular particles (10-60 μm) in a finer matrix, while *Naath Pottali Drava* shows a highly homogenous, sub-micron granular structure with no large agglomerates – in line with the DLS results for *Pottali* (PDI 1.0, D50 ~ 644nm) and *Drava* (PDI 0.704, D50 ~348 nm). EDS analysis shows excellent retention of the three major ingredients by both formulations (S ~ 10.3 wt%, Ag ~ 4.4 wt%, Hg ~ 7.9-9.0 wt%), indicating that *Drava* preserves the elemental composition of *Naath Pottali*. The slight decrease in the amount of Fe (4.52-> 2.86 wt%) and the absence of Cu in *Drava* can be attributed to the insolubility of iron sulphides (FeS_2) and copper iron sulphides ($CuFeS_2$) in aqueous medium, which is retained in the solid residue. Furthermore, the elemental conservation of all the main components is evident in multi-analytical validations.

ICP-MS Analysis-*Naath Pottali*:

ICP-MS analysis at the AYUSH-approved Vasu Research Centre (AR No. VARS/RS/26/02/021, 02.02.2026) provided validated quantitative elemental data *Naath Pottali*. Mercury was confirmed at 9.45% and Silver at 8.72% by ICP-MS, showing good similarity with XRF values.

Table 5: Comparative ICP-MS vs XRF elemental data for *Naath Pottali*

Sr.	Element	ICP-MS (% w/w)	XRF (% w/w)	Similarity
1	Mercury (Hg)	9.45	8.519	Good (ΔHg ~1%)
2	Silver (Ag)	8.72	16.308	Differential (matrix effect / Ag_2S dissolution)
3	Magnesium (Mg)	0.39	0.948	Moderate
4	Manganese (Mn)	0.004	ND	Trace level
5	Zinc (Zn)	0.03	ND	Trace level
6	Potassium (K)	0.47	ND	Below XRF LOD
7	Sodium (Na)	0.62	1.735	Moderate
8	Calcium (Ca)	Not detected	0.358	Trace level
9	Copper (Cu)	Not detected	0.017	Below ICP-MS LOD
10	Iron (Fe)	Not detected	3.921	FeS_2 insoluble in ICP digest

Fourier Transform Infrared Spectroscopy (FTIR) — *Naath Pottali Drava*:

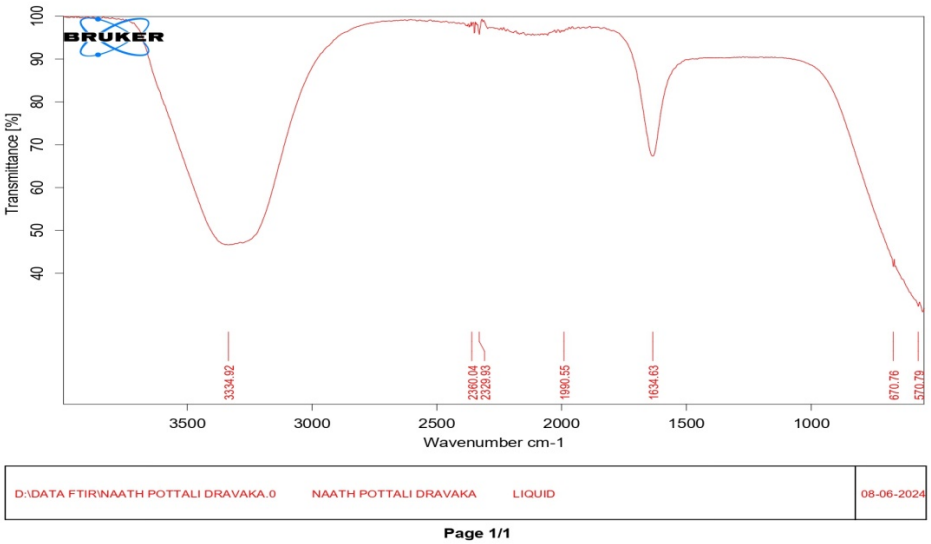

Figure 7: FTIR spectrum of *Naath Pottali Drava* (wavenumber range 4000–400 cm^{-1}, ATR mode)

Table 6: FTIR peak assignments for *Naath Pottali Drava*

Wavenumber (cm^{-1})	Transmittance (%)	Probable Assignment
3334.92	~65	O–H stretching (intermolecular hydrogen-bonded water; hydroxyl groups from vehicle)
2360.04	~88	Atmospheric CO_2 / asymmetric C≡N or C≡C stretch (minor)
2329.93	~88	Atmospheric CO_2 doublet / weak C–H stretch
1990.55	~92	Weak absorption — allenic C=C=C / metal carbonyl overtone (minor)
1634.63	~88	C=C stretch or N–H bend / C=O of conjugated carbonyl; adsorbed water deformation
670.76	~60	C–S or Metal–S stretching; Hg–S vibrational mode / FeS_2 lattice mode
570.79	~55	Metal–S or Metal–O stretching: Ag–S / HgS phonon modes; consistent with sulphide phases

The wide peak centered at 3334.92 cm^{-1} belongs to the adsorbed water and remaining hydroxyl groups of the residual organic solvent. The absorption band located at 1634.63 cm^{-1} is associated with the stretching vibrations of C=C/C=O bonds of the carbonyl/vinyl groups found in the organic solvent derived from plants. Notably, the absorptions at 670.76 and 570.79 cm^{-1} are due to the stretching vibrations of Hg-S and Ag-S/Fe-S bonds[26,27]

Particle Size Distribution (DLS):

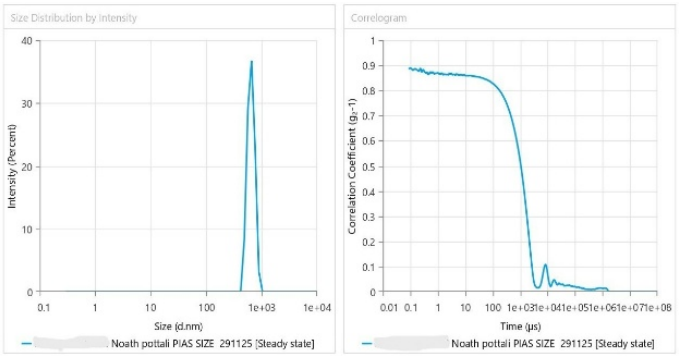

Fig. 8 *Naath Pottali*

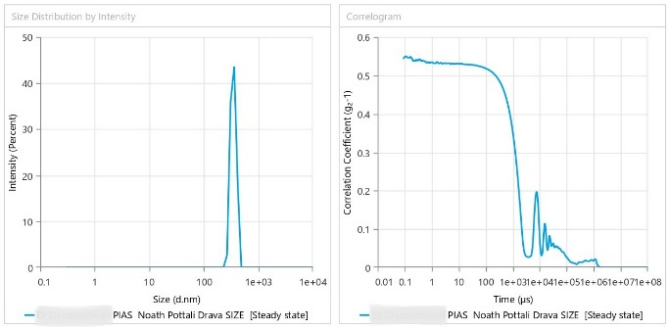

Fig. 9 *Naath Pottali Drava*

(Particle size distribution by intensity (DLS) and correlogram of both preparation)

The *Naath Pottali Drava* showed a markedly smaller Z-average of 647.7 nm with PDI of 0.704, indicating improved size uniformity compared to the *Naath Pottali* (Figure 1b). Di(10), Di(50), and Di(90) were 286.7, 348, and 418.1 nm respectively. The Peak 1 mean by intensity was 351.1 nm (width: 40.86 nm). The significantly narrower peak width and lower PDI indicate that *Drava* yields a more homogeneous, smaller-particle population from the *Pottali* matrix.

Table 7: Comparative DLS particle size statistics of *Naath Pottali* and *Naath Pottali Drava*

DLS Parameter	***Naath Pottali***	***Naath Pottali Drava***
Z-Average (nm)	893	647.7
Polydispersity Index (PDI)	1.0	0.704
Di(10) (nm)	513.3	286.7
Di(50) (nm)	644.3	348.0
Di(90) (nm)	811.9	418.1
Peak 1 Mean by Intensity (nm)	651.1	351.1
Peak 1 Width (nm)	96.07	40.86
Peak 1 Area (%)	100	100

Zeta Potential:

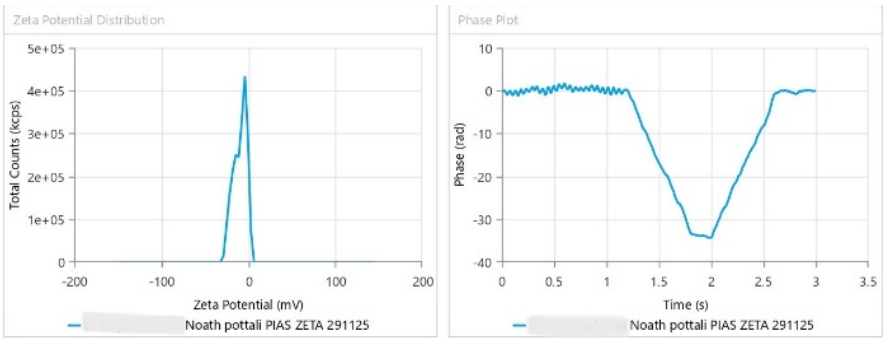

Fig. 10 *Naath Pottali*

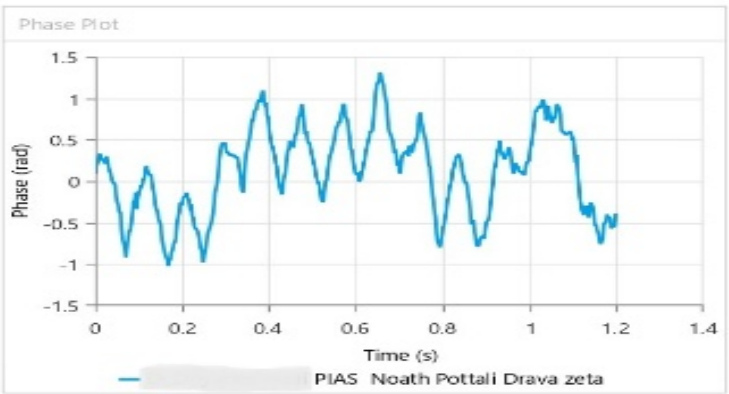

Fig. 11 *Naath Pottali Drava*

(Zeta potential distribution and phase plot (Malvern Panalytical ZS XPLORER, 29.11.2025))

The zeta potential of *Naath Pottali* aqueous dispersion was −9.63 mV (mean), with bimodal peaks at −16.68 mV (Zeta Peak 1) and −4.94 mV (Zeta Peak 2), zeta deviation 7.60 mV, conductivity 0.6755 mS/cm, and Quality Factor 1.747 (Figure 7). The zeta potential of *Naath Pottali Drava* was −11.34 mV (mean), with zeta deviation 0 mV, conductivity 7.426 mS/cm, and Quality Factor 1.094 (Figure 8). The higher conductivity (7.426 vs 0.675 mS/cm) in the *Drava* reflects a substantially greater ionic content arising from soluble salts extracted during the *Drava* preparation. The more negative zeta potential in the *Drava* (−11.34 vs −9.63 mV) indicates a marginally improved colloidal stability.

Table 8: Comparative zeta potential statistics of *Naath Pottali* and *Naath Pottali Drava*

Zeta Parameter	*Naath Pottali*	*Naath Pottali Drava*
Zeta Potential Mean (mV)	−9.633	−11.34
Zeta Peak 1 Mean (mV)	−16.68	Not resolved
Zeta Peak 2 Mean (mV)	−4.938	Not resolved
Zeta Deviation (mV)	7.602	0
Conductivity (mS/cm)	0.6755	7.426
Wall Zeta Potential (mV)	0.8053	0
Quality Factor	1.747	1.094

DISCUSSION

XRD and Phase Chemistry:

As seen from the near-identical XRD pattern for *Naath Pottali* and *Naath Pottali Drava*, there is preservation of the major crystal phases in the preparation process, namely, α-HgS (cinnabar), Ag_2S (acanthite or silver sulphide), and FeS_2 (pyrite or iron sulphide, derived from *Swarnamakshika Bhasma*). The presence of the crystal phase of the dominant elements is crucial quality assurance evidence because the process of *Drava* preparation does not change their structure, nor does it convert the primary crystals to their ionic forms[28]. The presence of α-HgS (cinnabar phase) instead of methylmercury or ionic forms of mercury is supported by previous literature reports on the poor oral bioavailability of such Ayurvedic medicines[29].

Elemental Analysis – XRF and ICP-MS Concordance:

As shown in Table 7, the XRF measurements indicate good preservation of the major medicinal elements (S, Ag, Hg) in *Naath Pottali* and *Naath Pottali Drava*. The higher concentration of Cl and Na in the *Drava* compared to the *Pottali* is consistent with their greater solubility in water. The identification of arsenic (0.36%) by XRF only in the *Drava* sample may be due to its release from FeS2 (pyrite) naturally present in the drug formulation. This arsenic content needs further validation using ICP-MS and comparison with permissible levels set by WHO and AYUSH[30]. The difference in silver concentration between ICP-MS (8.72%) and XRF (16.31%) is mainly due to (i) inefficient dissolution of silver sulphide (Ag2S) in ICP-MS HNO3/HCl digestion solutions, and (ii) inherent surface sensitivity of both methods.

FTIR Interpretation:

FTIR spectrum of *Naath Pottali Drava* gives additional evidence regarding the functional groups that complement the phases from XRD analysis. The strong absorptions due to metals-sulphides at 670.76 and 570.79 cm^{-1} indicate the presence of Hg-S and Ag-S bonding in the solution form. This observation is supported by reported frequencies for mercury-sulphide stretching vibrational bands for alpha cinnabar (~400 – 700 cm^{-1}) and silver-sulphide vibrations in acanthite (~500 – 600 cm^{-1}).

The band at 3334.92 cm^{-1} due to O-H and 1634.63 cm^{-1} for C=O and C=C vibrations is assigned to the organic vehicle residues in *Naath Pottali Drava* based on the high carbon weight percentage of 56.94 wt% from EDS analysis. The weak CO_2 doublet at 2360/2329 cm^{-1} is common in FTIR spectra of aqueous samples.

Particle Size and Nanomedical Significance:

The most clinically relevant observation from this comparison study includes the significant reduction in the size of particles in terms of the average Z-value (from 893 nm in the solid *Pottali* to 647.7 nm in *Drava*) and in terms of the D50 value (from 644.3 nm in the solid *Pottali* to 348 nm in *Drava*). The significant reduction in PDI (from 1.0 to 0.704) is indicative of selective extraction of finer dispersed particles into the liquid phase (*Drava*), whereas coarser particles remain in the solid state[31]. Sub-500nm particles have significant clinical relevance. Particles of the size 100-500 nm have enhanced oral mucosa absorption and increased surface activity as per Ayurvedic hypothesis realated to *Bhasma* and *Pottali*[32,33].The conductivity is found to be higher in the *Drava* (7.426 mS/cm compared to 0.675mS/cm), thereby implying much higher concentrations of ions such as sodium, potassium, and chloride in the *Drava*. The higher amount of sodium and chlorine detected by XRF further confirms this observation. This ionic environment may contribute to the surface charge of the colloidal particles[34].

Zeta Potential and Colloidal Stability:

Both samples have a zeta potential value within the −10 to −15 mV range, which corresponds to moderate colloidal stability. Zeta potential values for *Naath Pottali* are described by a bimodal distribution with peaks of −16.68 mV and −4.94 mV; this shows that two particle types are present in this sample, with differing zeta potentials corresponding to HgS/Ag2S sulphur particles (more negative) and sulphur/organic matrix particles (less

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negative). For the *Drava*, only one value was found, −11.34 mV, without deviation indicates a more electrostatically homogeneous particle population resulting from selective aqueous extraction.[35]

Cross-Method Analytical Concordance:

All these data from XRD, FTIR, XRF, and ICP-MS techniques indicate that in *Naath Pottali* and its *Drava*, the mercury exists as an insoluble form of α-HgS, silver exists as Ag2S, iron exists as FeS2, and sulphur exists in metal sulphides as well as free sulphur forms. The formation of *Drava* results in the replication of mineralogical and elemental profile of the parent *Pottali* material but creates a fine dispersion of colloidal particles.

5. CONCLUSION

This work provides the first ever comprehensive comparison analysis of pharmaceutical and analytical properties of *Naath Pottali* and *Naath Pottali Drava*, which involves nine different analytical parameters, viz., elemental analysis, mineralogical studies, spectroscopic investigation, and colloidal chemistry. The important conclusions drawn from this work are that (1) the particle size of *Naath Pottali Drava* is much lower than its *Pottali* form (~348 nm compared to ~644 nm in *Pottali*) and has a better polydispersity index (PDI) value (0.704 compared to 1.0), implying enhanced absorption and bioavailability properties of the latter form; (2) the two forms exhibit an identical mineralogy characterized by cinnabar crystalline phase, which signifies the chemical equivalence of both the formulations; (3) the FTIR spectra of the *Drava* form reveal the presence of metal–sulphide bond at 570–670 cm^{-1}, thereby corroborating the XRD phase identification; (4) the quantitative determination of elemental content by XRF and ICP-MS revealed that both the forms contain mercury and silver (Hg ~9% and Ag ~8.7–16.3%) as the major metals, which exist in insoluble sulphide state.

6. ACKNOWLEDGEMENT

I am very thankful to the Research and Development cell of Parul University for funding this research.

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