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A REVIEW ON XRD (X-RAY DIFFRACTION) STUDY OF VARIOUS BHASMAS WITH SPECIAL REFERENCE TO MAHARASA, UPRASA, DHATU AND SUDDHA VARGA

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ABSTRACT

Rasashastra is an intricate segment of Ayurveda that concentrates on Rasa Dravyas, which include preparations made from mercury, minerals, and metals. These substances are organized into different categories: Maharasa (primary), Uprasa (secondary), Sadharana Rasa (ordinary), Dhatus (metals), and Ratna (precious stones). The groups Maharasa, Uprasa, and Sadharana Rasa Varga each comprise eight Dravyas, while the Dhatus consist of nine. Bhasmas, or incinerated metals, are distinct Ayurvedic formulations that involve metals or minerals processed with herbal extracts or decoctions, subjected to particular heat treatments following the Puta method. They are extensively utilized for treating various health conditions. The preparation of Bhasmas includes several steps such as Shodhana (purification), Bhavana (wet grinding), Mardana (dry grinding), and Marana (incineration). These methods reduce particle sizes, eliminate unwanted qualities, and bestow new characteristics that enhance their integration with bodily tissues. Classical literature outlines several assessments for Bhasma, including Varitaratavam (Bhasma floats on the surface of stagnant water), Rekhapurnatvam (indicates the fineness of Bhasma through friction between the thumb and index finger), Nishchandratvam (lack of luster), and Apunarbhava (inability to revert to its original metallic form), although these evaluations do not solely guarantee safety and effectiveness. To confirm safety and potency, Bhasmas undergo examinations using analyses such as XRF (X-ray Fluorescence), XRD (X-ray Diffraction), SEM (Scanning Electron Microscope), and ICP-MS (Inductively Coupled Plasma Mass Spectrometry). X-ray Diffraction (XRD) is a flexible, non-destructive method that delivers detailed information about chemical composition and crystalline phases, including unit cell dimensions. XRD is instrumental in identifying and characterizing minerals and metals, recognizing unique patterns for each type of Bhasma. The purpose of this article is to gather research studies related to XRD analysis of various Bhasmas.

Keywords: Bhasmas, Rasashastra, Rasa Dravyas, X-ray Diffraction

INTRODUCTION

The word “Bhasma” refers to “Holy ash” and encompasses a thorough Shodhana (purification) process followed by Marana (incineration).[1] Rasa Tarangini outlines Shodhana as the removal of Doshas from Lohadi Dhatus through techniques such as Peshana (grinding), Mardana (trituration), and Bhavana (levigation), utilizing a specific Aushadha Dravya (herbal drug).[2] Marana entails grinding metals and minerals with various liquids (Swarasa, Kwatha, etc.) and subsequently drying them to produce Bhasma by applying carefully regulated heat (Agni) during Puta (the heating method), ensuring the temperature is neither too high nor too low.[3,4] To confirm that the Bhasma has been correctly prepared, multiple assessments like XRF, XRD, SEM, and ICP-MS are used.

XRD operates by directing incident X-rays at a substance and measuring the intensity and scattering angles of the resulting X-rays, which disclose the atomic structure of the crystal. These X-rays are generated from a cathode ray tube, filtered to produce monochromatic radiation, focused for precise delivery, and aimed at the sample. When the incident rays interact with the sample under conditions that satisfy Bragg's Law ($n\lambda=2d \sin \theta$), constructive interference takes place, leading to a diffracted ray. The diffracted X-rays are then detected, processed, and quantified. By translating the diffraction peaks into d-spacings, one can identify the mineral since each mineral possesses a distinctive set of d-spacings. This identification process typically involves comparing the measured d-spacings with established reference patterns.[5]

Maharasa: Maharasa comprises various Rasa Dravyas, including Abhraka (biotite mica), Vaikranta (Tourmaline), Makshika (Chalcopyrite), Vimala (iron pyrite), Shilajit (black bitumen), Sasyaka/Tuttha (blue vitriol), Rasaka (zinc ore), and Chapala (bismuth).

XRD STUDY OF BHASMAS

Table 1: XRD study of various Bhasmas of Maharasa Varga

Maharasa	Result of XRD pattern
Abhraka (Mica)	The XRD pattern of raw Abhraka reveals crystalline peaks typical of mica and is similar to the monoclinic structure of $KMg_3(Si_3Al)O_{10}(OH)_2$. It demonstrates diffraction peaks at 2θ angles of 8.72, 26.37, 35.42, 44.71, 54.32, and 64.36. The Shodhana process results in the creation of new compounds such as diopside and cordierite. The intermediary purification process known as Dhanyabhrakarana leads to the formation of phlogopite. After 20 Putas, additional compounds like forsterite, magnetite, diaspore, and clinopyroxene are generated. Following 50 Putas, further compounds such as akermanite, cristobalite, and coesite emerge. After 100 Putas, sylvine appears along with the previously existing compounds. Lohitikarana, aimed at imparting a specific color to Bhasma, causes the formation of quartz. The final product, used therapeutically after Amritikarana to eliminate residual impurities and improve therapeutic effects, contains diopside, sylvine, magnetite, forsterite, and cristobalite.[6] All the XRD patterns exhibited significant crystalline peaks associated with mica and aligned closely with the monoclinic structure of $KMg_3(Si_3Al)O_{10}(OH)_2$ (JCPDS card no. 10-0495). The prominent diffraction peaks were noted at approximately 2θ values of 8.89, 26.62, 28.39, 35.72, 45.08, and 54.88°, which correspond to the (001), (003), (112), (004), (005), and (135) planes, respectively.[7] The XRD analysis of Abhraka Bhasma reveals various peaks, indicating the presence of Mica, $FeSO_4$, and Fe_2O_3.[8]
Makshika (Chalcopyrite)	The XRD analysis of various samples of Swarna Makshika (SM) Bhasma, when compared to JCPDS data, indicated that the unprocessed Swarna Makshika contains $CuFeS_2$, which undergoes transformation into copper and iron sulfides, along with iron oxides and sulfates after the Shodhana process. The primary compounds found in the Bhasma of the different samples included Fe_3O_4, Fe_2O_3, FeS_2, $FeSO_4$, and Cu_2S. In the Bhasma prepared through the Kupipaka method followed by Putapaka, the most prominent peaks identified were those of Fe_2O_3, Cu_2O, and $FeSO_4$.[9] The XRD analysis of Makshika Bhasma indicated that the chalcopyrite content was below 2%, while haematite accounted for 58% and magnetite for 40%. The Makshika was transformed into a more stable and favorable form of Haematite.[10] The X-ray Diffraction analysis of raw SM and SM Bhasma demonstrated that the raw SM contains $CuFeS_2$, whereas SM Bhasma comprises Fe_2O_3, FeS_2, CuS, and SiO_2.[11] The X-ray diffraction results indicated that the peaks identified following the 10th Puta of Swarna Makshika Bhasma consist mainly of Iron oxide with a rhombohedral crystal structure as the main component.[12]
Sasyaka (blue vitriol)	X-ray diffraction analysis of Tuttha Bhasma showed the existence of copper sulfide (covellite) exhibiting a hexagonal lattice, along with sodium sulfate that has an orthorhombic structure.[13]
Rasaka (zinc ore)	XRD indicates the primary peaks of ZnS in the Bhasma produced using the Gajaputa method, while the Bhasma made via the Kupipaka method displays significant peaks of both ZnS and ZnO.[14]

Uprasa: There are eight Uprasa, which consist of Gandhaka (sulphur), Gairika (iron oxide), Kasisa (green vitriol), Sphatika (alum), Hartala (arsenic trisulphide), Manahshila (arsenic disulphide), Anjana (collyrium), and Kankushta (gambose tree). The Bhasma for most of the Uprasa is not specified, including Gandhaka, Gairika, Anjana, and Kankushta.

Table 2: XRD study of various Bhasmas of Uprasa Varga

Uprasa	Result of XRD pattern
Kasisa (green vitriol)	The XRD analysis indicated that the synthesized Kasisa Bhasma might possess a complicated chemical structure. In this investigation, numerous compound peaks remain unidentified; only distinct peaks indicate a crystalline structure.[15] Another study's XRD analysis corroborates the crystalline characteristics of the nanomedicine, showing particle sizes of 38.31 nm (for Dhootapapeshwar Kasisa Bhasma), 49.86 nm (for Vyas Pharmaceutics Kasisa Bhasma), and 52.75 nm (for Patanjali Kasisa Bhasma).[16] The XRD pattern for Kasisa Bhasma showed that all the prominent, moderate, and weak peaks are solely associated with Fe_2O_3, and its crystalline structure is rhombohedral in nature.[17] The XRD analysis suggests that Kasisa Bhasma exists in a crystalline form. The crystallite sizes in Kasisa Bhasma were estimated from the XRD pattern using the Scherrer formula and were found to range between 53-57 nm.[18]
Manahshila (arsenic disulphide)	Three types of Manahshila are detailed in Ayurveda: Shyamangi, Kanavirak, and Khandakhya; the latter two are considered therapeutically beneficial. X-ray diffraction (XRD) analysis categorizes Kanavirak as alacranite and Khandakhya as realgar. The XRD analysis of raw alacranite identifies all relevant peaks as corresponding to alacranite, with molecules of As_4S_4. A similar pattern of peaks was observed in the alacranite sample after undergoing Shodhana. In the raw realgar sample, the majority of the prominent peaks are classified as realgar (As_4S_4) with a monoclinic crystal structure. A couple of peaks with lower intensity are identified as orpiment (As_2S_3) and chalcopyrite ($CuFeS_2$), which are present in very minimal amounts. Following the Shodhana process of realgar, the XRD results correspond solely to realgar, with no indications of associated minerals detected.[19]

Sadharana Rasa: They are eight in number, which include Kampillaka (Mallotus Phillipinensis), Gauripashana (arsenic oxide), Navsadara (ammonium chloride), Kapardika (cowrie), Agnijara (ambargris), Girisindura (red oxide of mercury), Hingula (red sulphide of mercury), Mridarshringa (litharge).

Table 3: XRD study of various Bhasmas of Sadharana Rasa

Sadharana Rasa	Result of XRD pattern
Kapardika (Shell of *Cyprea moneta* Linn.)	The X-ray diffraction analysis revealed the presence of the calcite phase of calcium carbonate and suggested that the Bhasmas possess a nanometric structure.[20]

Dhatu: Dhatu are classified into three categories: Sudha Loha, Puti Loha, and Mishr Loha. Sudha Loha consists of Swarna (gold), Rajata (silver), Tamra (copper), and Loha (iron); Puti Loha includes Naga (lead), Vanga (tin), and Yashada (zinc); Mishr Loha encompasses Pittala (brass), Kansya (bronze), and Varta Loha (bell metal).

Table 4: XRD study of various Bhasmas of Dhatu Varga

Dhatu	Result of XRD pattern
Swarna (gold)	The XRD peaks for Swarna Bhasma (SB) were detected at 2θ values of 37.88º, 44.08º, 64.42º, and 77.15º, indicating that the samples exhibit a crystalline structure.[21] Another analysis indicated that the XRD pattern of the Swarna Bhasma sample predominantly reflects gold as the major phase.[22] Additionally, a separate XRD investigation was performed. The diffraction peaks at 2θ = 38.2°, 44.4°, 64.6°, and 77.6° correspond to those documented for standard gold metal (Au0) (JCPDS, USA). No additional diffraction peaks were found, which confirms that Swarna Bhasma is primarily made up of gold nanoparticles and exists in a crystalline form.[23] The size of gold crystallites in Swarna Bhasma was calculated using the Scherrer formula from the XRD pattern and found to be consistent (28 nm) for both SB1 and SB2.[24] The four prominent XRD peaks of SB were found at 2θ values of 37.170, 44.350, 64.530, and 77.500. The element was identified using standard ICDD (International Centre for Diffraction Database) reference values. The sharp peak observed in the XRD pattern indicates both the crystalline nature and high purity of gold within this SB sample.[25] XRD analysis demonstrated that all peaks of Swarna Bhasma align closely with pure gold (face-centered cube) exhibiting a crystallite size of 45 ± 2.8 nm.[26]
Rajata (silver)	Silver exhibits multiple oxidation states, including AgO, Ag_2O, Ag_2O_3 and Ag_3O_4 but AgO and Ag_2O have been noted as the most stable forms. X-ray Diffraction (XRD) analysis confirmed the crystalline structure of Rajata Bhasma, revealing a peak for Ag_2O, which suggests that a portion of Rajata has been transformed into silver oxide, with some traces of silver sulfide. Prominent peaks of HgS and Ag_2S were also observed in the XRD results. During the Shodhana and Marana processes, silver interacts with mercury and sulfur found in Kajjali, resulting in the formation of Cinnabar and silver sulfide.[27] XRD analysis indicated that the most pronounced peak identified in the raw material was silver (Ag), while in the Shodhita Rajata, it was recognized as silver oxide (Ag_2O), and in the final product, it was recorded as silver sulfide (Ag_2S).[28] Additionally, it was noted that besides the peaks associated with Ag_2S, AgO, and Ag_2O_3, there appear to be extra peaks in the powder diffraction pattern of the silver Bhasma nanoparticles.[29]
Tamra (copper)	The XRD analysis of Tamra Bhasma (TB) reveals prominent peaks corresponding to HgS (Cinnabar) and CuS (Copper Sulphide) compounds, both exhibiting a hexagonal structure. A less significant peak indicates the presence of Cu_4O_3 (Copper Oxide) compound with a tetragonal configuration. The presence of sharp peaks suggests that Bhasma has a highly crystalline structure. HgS peaks were observed at diffraction angles of 26.49, 31.19, 43.59, 45.75, and 51.74, while the CuS peaks were observed at 29.27, 31.80, 47.88, 32.81, 52.67, and 59.27. The peak for Cu_4O_3 was identified at a diffraction angle of 28.09.[30] Prominent peaks of CuS in the X-ray diffraction confirms that the final product is in the sulfide form of copper. The existence of oxides is also acknowledged due to the presence of additional peaks.[31] Various studies have reported that the XRD pattern of TB displayed CuS, while others identified Cu_2S and Cu_7S_4. To ascertain the compounds found in TB, XRD was performed, identifying significant peaks for cupric sulfide (CuS), which verifies that the final product is in the sulfide form of copper.[32-37] XRD data showed mixed phases of CuS along with elemental sulfur in both samples i.e. Tamra Bhasma (TB) and Tamra Bhasma Amritikarana (TBA). The presence of sharp diffraction peaks indicates that both samples possess a highly crystalline nature. In TB, diffraction peaks were observed at angles of 2θ of 27.44°, 31.73°, and 32.69°. For TBA, peaks were detected at diffraction angles of 2θ at 27.12°, 27.68°, and 31.79°.[38]
Somnathi Tamra Bhasma	In the raw Tamra X-ray diffraction analysis, distinct peaks were observed, which reflect the crystallography of raw Tamra and also indicate the presence of additional elements alongside copper, with the unit cell shape being hexagonal. In the case of Shodhita Tamra, X-ray diffraction peaks were detected, revealing a series of transformations and the formation of various compounds in the sample that were absent in the raw Tamra, and its unit cell shape is monoclinic. For Somanathi Tamra Bhasma, XRD peaks were noted, with prominent peaks aligning with those of CuS (copper sulphide) and some peaks corresponding to CuO (copper oxide); thus, Somanathi Tamra Bhasma can be regarded as a combination of copper sulphide (CuS), copper oxide (CuO), and other elemental combinations. The conversion of copper into copper sulphide and copper oxide results from the Shodhana and Marana processes. The unit cell type for raw Tamra was hexagonal, while for Shodhita Tamra, it shifted to monoclinic. This denotes that the transformation of raw Tamra into Shodhita Tamra involved a transition in cell type from hexagonal to monoclinic. Subsequently, Shodhita Tamra was transformed into Somanathi Tamra Bhasma using a medium of mercury, sulphur, and arsenic (Parada, Gandhaka, Manashila, and Hartala); during this conversion, the unit cell type changed from monoclinic to triclinic, strongly indicating that Shodhanadi procedures alter the structural configuration of the element.[39]
Loha (iron)	A research study was carried out utilizing magnetite iron (ore for Kanta Lauha) and pure iron turnings (Armco grade) for Teekshna Lauha. During the Bhasmaikarana procedure involving high-temperature heating (600°), iron oxide was produced in its most stable form, which is αFe_2O_3. Consequently, all the Bhasma exhibited the αFe_2O_3 phase, regardless of the raw material utilized. The magnetite phase, Fe_3O_4, consists of a combination of two iron states, FeO and Fe_2O_3. The FeO state readily transforms into its more stable higher oxidation state, Fe(III), resulting in the formation of Fe_2O_3 in either the γ or α phase. At elevated temperatures, αFe_2O_3 is the most stable form, thus it is exclusively produced in this state.[40] The XRD analysis was performed on the samples following Sthalipaka, as well as after the 1st, 5th, 10th, 15th, and 20th Puta processes. The results indicate that during the subsequent Puta process, the material undergoes oxidation, and initially, the predominant phase is Fe_3O_4, but by the time the Bhasma is fully prepared, γ-Fe_2O_3 and Fe_3O_4 are present in equal amounts.[41] The XRD analysis of raw iron turnings reveals crystalline peaks of iron, while that of Lauha Bhasma displays cubic crystalline peaks of Fe_2O_3 in its highly effective ferric form.[42] The XRD analysis of the nanoparticles was performed with a diffraction angle ranging from 20 to 70. The hkl values of the observed peaks are (012), (220), (104), (110), (113), (024), (116), and (214) respectively. All peaks correspond to the Fe_2O_3 rhombohedral phase in accordance with JCPDS [33-0664].[43]
Naga (lead)	The distinct diffraction peaks suggest that the drug exhibits a highly crystalline structure. The peaks identified at 2θ angles of 25.96, 30.07, 43.05, 50.97, 53.40, 62.53, 68.87, 70.96, and 78.91° correspond to the (111), (200), (220), (311), (222), (400), (331), (420), and (422) lattice planes, respectively (referencing JCPS File No.: 05-592), confirming the presence of a singular lead sulfide phase related to metallic lead. No diffraction peaks indicative of a lead oxide phase were detected.[44] The X-ray diffraction patterns from different batches of Naga Bhasma reveal that the XB1 sample shows diffraction peaks at 2θ angles of 23.30, 24.57, 29.31, 31.78, 34.35, 37.87, 40.57, 41.29, 54.50, and 59.42°, which correlate with the (001), (101), (111), (020), (120), (201), (121), (211), (031), and (312) planes, consistent with JCPS File No.: 89-7387, verifying the existence of lead oxide (Pb_2O_3). The XB2 sample aligns with JCPS File No.: 89-1947, confirming the presence of lead oxide (Pb_3O_4), with diffraction peaks at 2θ angles of 22.54, 24.31, 25.36, 27.15, 28.63, 30.77, 40.93, 47.49, 53.82, 58.05, and 59.49°, corresponding to the (210), (201), (211), (002), (220), (112), (400), (213), (431), and (521) lattice planes. The diffraction pattern of XB3 is similar to that of XB1, affirming the presence of lead oxide (Pb_2O_3).[45]

	The XRD patterns illustrate that all samples are mainly crystalline in nature and comprise complex mixtures of PbO, Pb_3O_4, and several other lead compounds.[46,47]
Vanga (tin)	In the Samanya and Vishesha Shodhita samples of Vanga, 2θ values from XRD peaks indicate the presence of unaltered tin metal (Sn). It appears that significant structural or chemical alterations do not take place during the Shodhana (Purification) procedure. The trace amounts of extraneous elements found in Vanga Bhasma can be attributed to the medium used in its preparation, which likely contributes to its enhanced effectiveness. Apamarga (Achyranthes aspera), known for its high potash content, reacts with tin to create a compound. Tin tends to oxidize rapidly when treated with alkali under heat and in an open atmosphere. The Jarana (Roasting) method can also fragment Vanga and assist in the compound's formation. This process, preceding Marana (Incineration), indicates that the heating and processing of Vanga with Apamarga results in a mixture of SnO_2 (tin dioxide), Sn (tin), and $K_2Sn_2O_3$ (potassium tin dioxide) as seen in the XRD analysis. Vanga Bhasma, produced by treating Jarita Vanga with Kumari (Aloe vera), yields compounds such as SnO_2 (tin dioxide) and $K_2Sn_2O_3$ (potassium tin dioxide).[48] XRD indicates that Vanga Bhasma possesses a crystalline nature, primarily consisting of tin oxide, with the most prominent peak corresponding to SnO_2.[49] In the XRD analysis, the Vanga sample exhibited a crystalline state, and the peak with the highest intensity was linked to elemental Sn (Vanga). In Vanga Bhasma, the crystalline structure of raw Vanga transforms into stannous oxide (SnO_2), with the highest peak aligning with this compound.[50]
Yashada (zinc)	Following the Samanya Shodhana process of Yashada, the XRD peaks indicate that unaltered zinc metal is present. After the Vishesha Shodhana treatment of Yashada, a portion has been converted to zinc oxide as observed in the XRD results. In the Jarita Yashada sample, the XRD analysis revealed the presence of ZnO, Zn, and ZnCO3. The XRD peaks for Yashada Bhasma corresponded to Zinc oxide (ZnO).[51] The XRD analysis of the raw metal showed crystallite peaks of zinc metal, while the Yashada Bhasma sample exhibited hexagonal crystallite peaks of ZnO in its highly effective zincite form.[52] The X-ray diffraction study (XRD) of Yashada Bhasmas confirms that the sample is ZnO, primarily in the wurtzite phase.[53] The XRD study showed that Parada Marita Yashada Bhasma primarily consists of sphalerite (ZnS) with additional minor amounts of zincite (ZnO) and zinc oxide, while Hartala Marita Yashada Bhasma primarily contains zincite and a minor presence of sphalerite (ZnS).[54]
Pittala (brass)	According to XRD analysis, Pittala Bhasma is composed of arsenic copper mercuric sulphide and zinc sulphide. In this composition, arsenic copper mercuric sulphide exhibits a rhombohedral structure, while zinc sulphide has a hexagonal structure.[55]

Suddha Varga: Drugs that primarily consist of calcium are categorized under Suddha Varga, which comprises Suddha (lime), Khatika (chalk), Shambuka (yellow), Mukta (pearl), Shankh (conch shell), Shukti (oyster), Praval (coral), Godanti (gypsum), Mrigashringa (stag horn), Kukkutanda Twak (hen's eggshell), and others.

Table 5: XRD study of various Bhasmas of Suddha Varga

Dravyas	Result of XRD Study
Mukta (Pearl)	The most prominent peak detected in the raw material was $CaCO_3$ in its aragonite form, while the final product contained $CaCO_3$ in calcite form.[56]
Shankh (Conch shell)	The raw conch is primarily composed of aragonite, but upon incineration, this aragonite structure transforms into calcite form. Studies have shown that calcium in the calcite form of calcium carbonate is more readily absorbed than in its aragonite form.[57]
Shukti (oyster)	The raw material Mukta Shukti, which is mother of pearl, consists of an organo-mineral matrix that contains calcium carbonate in its aragonite form. During the formation of Bhasma, the aragonite form of calcium carbonate changes into a stable calcite form, which becomes the primary crystalline element of Mukta Shukti Bhasma. The process involving heat treatment leads to a partial transformation of calcite into calcium oxide, which manifests as calcium hydroxide (not exceeding 2% w/w) in the final product.[58]
Praval (coral)	XRD analysis indicates that the initial raw material contained $CaCO_3$, while the resulting Bhasma product comprised CaO.[59]
Godanti (Gypsum)	The D value derived from the XRD analysis suggests the presence of calcium in two stationary phases, namely $CaSO_4$ and CaS. This value ranges from 3.4973 for Calcium Sulfate to 2.32861211 for Calcium Sulfide. The XRD analysis of Godanti Bhasma shows the predominance of anhydrite $CaSO_4$ (Orthorhombic) and, as a minor phase, CaS (Cubic).[60]

DISCUSSION

X-Ray Diffraction (XRD) is a method used for the analysis and characterization of minerals and metals, as well as to determine the specific characteristic patterns of prepared Bhasma. An XRD examination of various Bhasmas revealed the presence of different compounds. The XRD analysis of Abhrak Bhasma indicated the presence of Mica, $FeSO_4$, and Fe_2O_3. In the case of Makshika Bhasma, significant compounds identified in various samples included Fe_3O_4, Fe_2O_3, FeS_2, $FeSO_4$, and Cu_2S. The XRD results for Tuttha Bhasma highlighted the presence of copper sulphide (covellite) with a hexagonal lattice structure and sodium sulphate with an orthorhombic structure. The XRD analysis of Rasaka Bhasma exhibited prominent peaks associated with ZnS and ZnO. The XRD pattern of Kasisa Bhasma demonstrated that all peaks correspond solely to Fe_2O_3, which has a rhombohedral crystal structure. A sharp peak in the XRD pattern of Swarna Bhasma indicates the crystalline nature and high purity of gold within the sample. XRD analysis of Rajata Bhasma revealed that the most prominent peak in the raw material was Ag, whereas in the Shodhita Rajata, it was recognized as silver oxide (Ag_2O), and in the final product, it was silver sulphide (Ag_2S). In Tamra Bhasma, the XRD pattern indicated the presence of CuS, while some patterns also showed Cu_2S and Cu_7S_4. XRD was performed to identify the compounds in Tamra Bhasma, resulting in prominent peaks for cupric sulfide (CuS), confirming that the final product is in the sulfide form of copper. In Somnathi Tamra Bhasma, the cell type of the raw Tamra was hexagonal, the Shodhita Tamra was monoclinic, and the Somnathi Tamra exhibited a triclinic cell type with peaks of CuS (copper sulphide) and CuO (copper oxide). The XRD of raw iron turnings displayed crystalline peaks of iron metal, while Lauha Bhasma presented cubic crystalline peaks of Fe_2O_3 in a very effective ferric state. The XRD patterns of Naga Bhasma showed that all samples are primarily crystalline and comprised complex mixtures of PbO, Pb_3O_4, and other lead compounds. The XRD analysis indicated that Vanga Bhasma is crystalline, with tin oxide (SnO_2) as the major component. The X-ray diffraction (XRD) study of Yashada Bhasma corresponds to ZnO in the wurtzite structure. XRD data indicated that Pittala Bhasma consists of arsenic copper mercuric sulfide (rhombohedral) and zinc sulfide (hexagonal). All raw materials from the Suddha Varga exhibited $CaCO_3$ in aragonite form; however, in the final product, $CaCO_3$ was observed in calcite form. The XRD analysis of Godanti Bhasma shows that anhydrite $CaSO_4$ (orthorhombic) is the major phase, with CaS (cubic) being identified as the minor phase.

CONCLUSION

The significance of XRD analysis in various Bhasmas is essential for comprehending and verifying their chemical composition, crystalline structure, and safety for medicinal use. It connects traditional Ayurvedic practices with contemporary scientific insights. Beyond being a means of material characterization, it is indispensable for confirming that Bhasmas are safe, effective, and scientifically validated.

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