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Exploring the Nanomedicinal Features of *Ayurvedic Bhasmas*: Insights from Traditional Medicine

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Abstract

Ayurveda is a traditional and scholarly medical system practiced in South Asia since the *Vedic* period. It integrates science and philosophy to promote a healthy, happy and prosperous life. *Ayurvedic bhasmas* are classical formulations that contain non-toxic forms of metals and minerals, enriched with therapeutic metabolites. These *bhasmas* are produced through repeated trituration of metals and minerals with the extracts from potent *Ayurvedic* herbs, followed by intense heating at temperatures above 650 °C. The preparation process of *bhasmas* closely resemble top-down approach in nanoparticle synthesis, resulting in very fine calcined nano-powders. These powders are used effectively in *Ayurvedic* treatments for various ailments, particularly chronic diseases. Recent studies have highlighted that *bhasmas* possess antioxidant, anti-inflammatory, antibacterial, antiviral and antitumor properties and may serve as potential carriers for drug delivery. This paper aims to compare bhasma particles prepared by traditional and modern methods, explore the therapeutic benefits of different bhasmas, and investigate the nanomedicinal features of various *Ayurvedic bhasmas*.

Introduction

Ayurveda, with its diverse range of therapies and a holistic approach to health and well-being has a history spanning around 5,000 years. It merges ancient *Vedic* science with a life-centred philosophy aimed at promoting a healthier, happier, and more fulfilling existence [1, 2]. This principle is succinctly expressed in a *Sanskrit* verse found in *Charaka Samhita Sutra* 30/26 as "*Swasthasya swaasthya rakshyanam Aaturasya vikara prasamanam*", which translates to "Protecting the health of the healthy and treating the ailments of the sick."

The *Ayurvedic* philosophy holds that the universe in composed of five fundamental elements, known as *Pancha Mahabhootas.* These elements are air (*vayu*), water (*jala*), earth (*prithvi*), fire (*teja or agni*), and space or ether (*aakash*). The combination of these elements in varying proportions forms three fundamental energies (called *tridoshas*) and seven bodily tissues (called *sapta dhatus*) in the human body. The three energies are *vata dosha* (a blend of air and space), *pitta dosha* (a mix of fire and water), and *kapha dosha* (a combination of water and earth). The seven tissues include *rakta* (blood), *asthi* (bones), *mamsa*

(muscles), *majja* (marrow), *meda* (fats and connectives), *shukra* (semen), and *rasa* (fluids or plasma).

According to *Ayurveda,* imbalance in *doshas* and *dhatus,* often caused by an imbalance of metals and minerals in the body, lead to health issues. These abnormalities are addressed by administering appropriate doses of *Ayurvedic* medicines to restore balance[3]. *Ayurvedic bhasmas,* known for their extended shelf life and nanoscale dimensions, are traditional *Vedic* medicines and are highly effective in their action[2]. Their therapeutic potency is derived from the careful selection of medicinal herbs, herbal extracts, oils, metals and minerals, as well as a meticulous preparation process involving detoxification, trituration, and incineration, which enhances their quality and medicinal value[1]. Modern analysis of these medicines has revealed that they contain non-toxic forms of metals and minerals, along with essential phytochemicals and carbonaceous particles[4]. Additionally, a detailed examination of their preparation and composition highlights the connection between *Ayurveda* and nanotechnology [5].

This article aims to explore the history, fundamental preparation methods, composition, properties, therapeutic significance, and nanomedicinal aspects of *Ayurvedic bhasmas*.

History of Ayurvedic Bhasmas

Traditional medicinal approaches

Despite significant advancements in allopathic medicine, over 80% of WHO member countries continue to utilize traditional medicinal practices in various forms to address a wide range of health issues [6]. These practices are referred to as 'non-conventional medicine', or 'complementary medicine', or 'alternative medicine', depending on whether they rely solely on local and indigenous knowledge or are combined with modern medical practices, varying by region across the world [7]. The World Health Organization defines traditional medicine as an indigenous practice used for maintaining health and for preventing, diagnosing, and treating physical and mental illness. It differs from allopathic medicine in its reliance on specific theories, beliefs, and experiences." Many people worldwide rely heavily on traditional medicine for their health management, with Southeast Asian countries being particularly noted for their diverse traditional medicine systems [8, 9]. In East Asia, traditional medicine was the primary medical approach for treating various disorders before Western influences began in the 19th century [10].

Traditional medicine encompasses a broad range of therapies and practices that vary from culture to culture and country to country. Each nation has developed its own system of traditional medicine, influenced by its unique culture, history, resources, social structures, economic conditions, and international interactions [11]. Table 1 illustrates the various traditional medical systems practiced around the world and their primary approaches. Despite the different names and systems, traditional medicine can generally be categorized into three types: Scholarly medical systems, Folk medical systems, and Shamanistic medical systems [7].

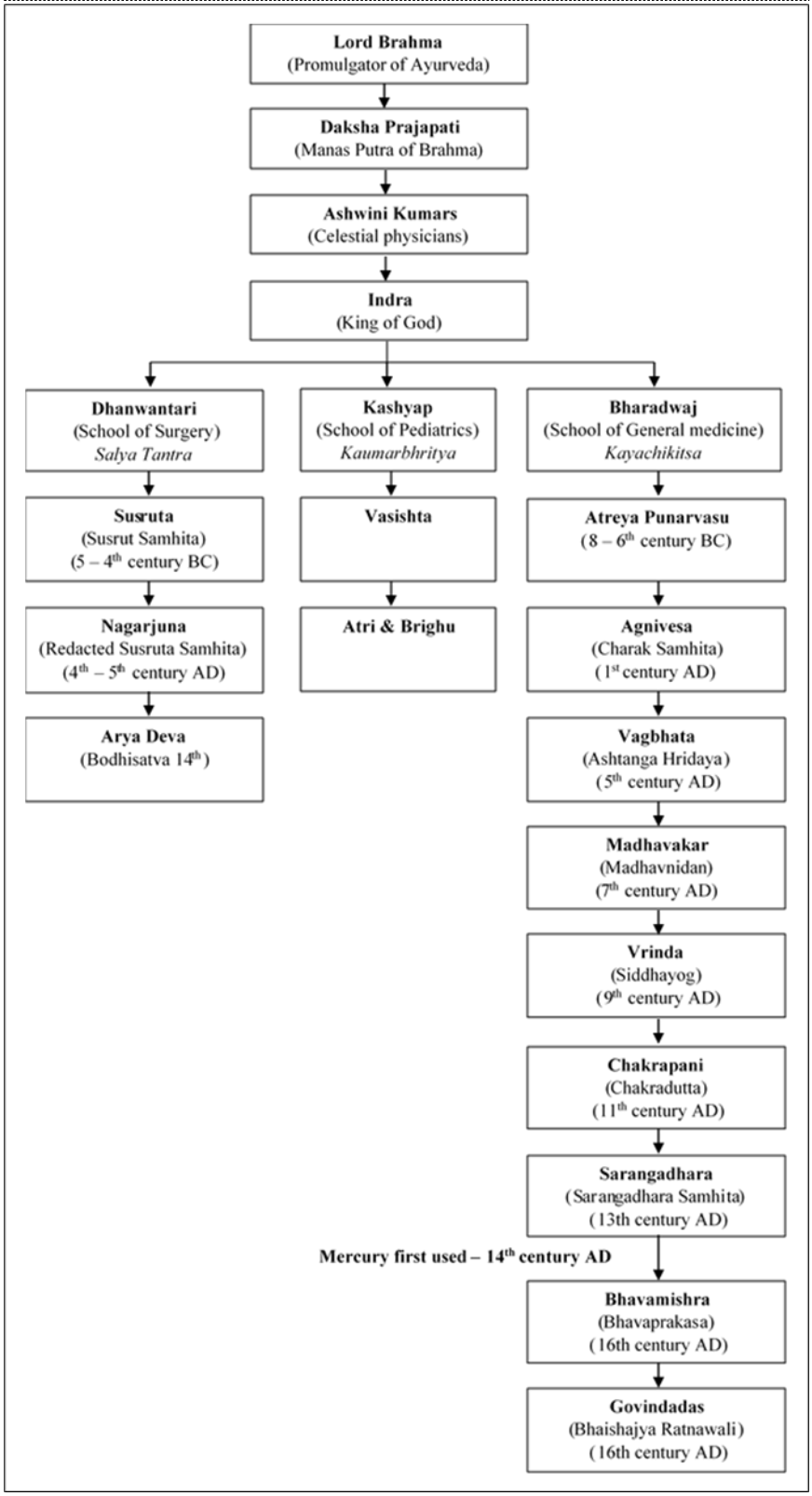
Ayurveda: a scholarly medical system

A medical system that has a long-standing therapeutic history, established theories and principles, and a rigorous academic discourse is referred as a scholarly medical system. *Ayurveda*, believed to have originated during *Vedic* period (1500-900 BC), encompasses a vast body of scriptures detailing principles and practices in internal medicine and surgery, along with both informal and formal methods of education. Therefore, *Ayurveda* is considered one of the scholarly medical systems within the traditional medicine framework [7, 30]. *Ayurveda*, known as the 'science of life', extends beyond medical

Table 1. Traditional medicine system and their principal approaches

Traditional Medicine System	Origin	Principal Approach	Reference
Acupuncture	China	Specific points on the body are stimulated, usually by inserting thin needles into the skin and underlying tissues.	12, 13
Amchi (Sowa-Rigpa)	Tibet	Disorders result from the imbalance of five Cosmo-physical elements in the body. Proper regulation of diet, behaviour, medication and accessory therapies help restore the balance.	14, 15
Ayurveda	Indian sub-continent	Disorders result from an imbalance of the body's life force (*Prana*). Balance is restored by making equilibrium among three body qualities (*Doshas*): *Vata*, *Pitta* and *Kapha*.	1, 16
Homeopathy	Germany	Based on the principle that 'like cures like'. A substance that, when given in large doses, causes set of symptoms is believed to cure the same symptoms when it is given in minute to non-existent doses. The minute dose is thought to stimulate the body's healing mechanisms.	17, 18
Jamu	Indonesia	Roots in *Ayurvedic* principles. Uses naturally occurring herbs, spices and other botanicals to bring the body back into balance.	19
Naturopathy	Europe	Emphasizes prevention and treatment of disease through a healthy life style by stimulating body's natural healing abilities	20
Reiki	Japan	Practitioners intend to channel energy through their hands and transfer it into the patient's body to promote healing.	21
Siddha	South India	Similar to *Ayurvedic* principles. Five natural elements are balanced to treat disorders.	22, 23
Traditional Chinese Medicine	China	Uses medicinal herbs, Acupuncture, diet plan, massage and meditative exercise to balance life force (qi).	24, 25
Unani	Greece	Disease results from deviation in normal temperament of individual which is balanced by using four humour theory of Hippocrates.	26, 27
Yoga	North India	Believes that spiritual ignorance creates suffering and binds us to the wheel of Samsara (cycle of rebirth). The removal of any ignorance can take many different paths and techniques of yoga.	28, 29

Figure 1. Timeline of Ayurveda showing its mythological origin from Lord Brahma and inheritance to disciples of different era[33].



care to encompass the art of living a happy and prosperous life [31]. It takes a holistic approach, offering a unique blend of science and philosophy that integrates physical, psychological, emotional and spiritual aspects of health [32]. Although the exact origin and history of *Ayurveda* remain unclear and shrouded in the passage of time, it is mythologically believed that the original verses of *Ayurveda* originated from the consciousness of Lord Brahma (the creator) and were passed down to various disciples who compiled them into large texts called *Samhitas* (compendiums). Over time, these works were revised by numerous scholars, leading to the modern form of *Ayurveda.* A timeline of *Ayurveda,* as outlined in literature is depicted in Figure 1.

Ayurvedic formulations

Ayurvedic formulations are medicines derived from plants, animals, and minerals, available as both single-ingredient and compound preparations. These formulations have been used to treat different disorders like acne, allergies, asthma, anxiety, arthritis, chronic fatigue syndrome, cold, colitis, constipation, depression, diabetes, flu, heart disease, hypertension, immune problem, inflammation, insomnia, nervous disorders, obesity, skin problems, and ulcers. They are administered in various ways within the body, and there are essentially two main types of *Ayurvedic* formulations: classical and proprietary [34, 35].

Classical *Ayurvedic* formulations are made using the exact methods outlined in ancient *Ayurvedic* texts such as the *Charaka Samhita*, and *Sushruta Samhita*. Examples of these formulations are mentioned in Table 2.

Proprietary or Patent formulations are those whose recipes are patented by the manufacturer and are not found in traditional *Ayurvedic* scriptures.

Panta *et al.* (2018) reported that certain *Ayurvedic* formulations with an amorphous texture and higher water solubility in water exhibit antibacterial properties, whereas formulations with a crystalline texture

Table 2. Different types of classical Ayurvedic Formulations[35]

Formulation	**Category**	**Examples**
Ark	Distillate of herbs	Ajwain Ark, Tulsi Ark
Arista	Fermented liquid	Ashokarishta, Dashamularishta
Avaleh	Jam or paste	Amalakavaleha, Chyawanprashavaaleha
Bhasma	Purified calcinations	Abhrak *Bhasma*, Swarna *Bhasma*
Churna	Powders	Triphala Churna, Sitopaldi Churna
Ghrita	Medicated clarified butters	Brahmi Ghrita, Triphala Ghrita
Guggulu	Resins	Yograj Guggulu, Kanchanar Guggulu
Kwath or Kashya	Decoctions	Rasnadi Kwath, Triphala Kwath
Pak	Herbal granules	Ashwagandha Pak, Musali Pak
Ras Rasayan	Herbal mineral medicine	Yakuti Rasayan, Chandrakala Ras
Taila	Medicated oils	Neem Taila, Anu Taila
Vati	Tablets or pills	Agni Tundhi Vati, Sarpagandha ghan Vati

and lower solubility in water show no effect against bacterial strains [36].

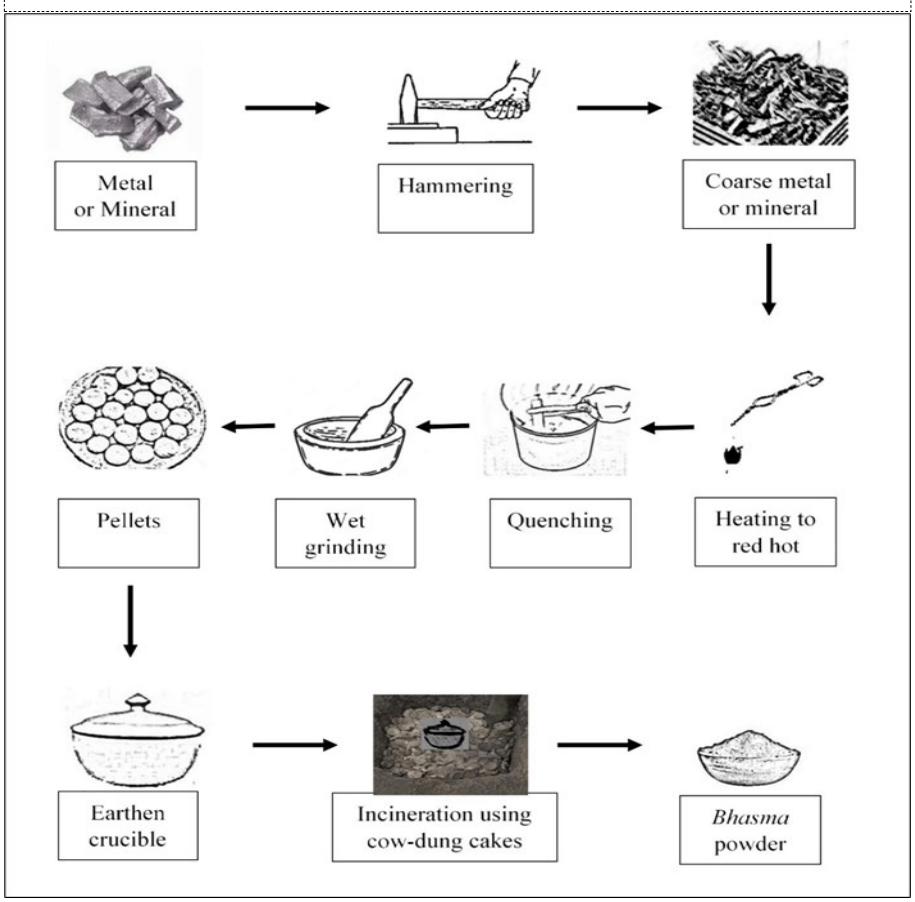
Ayurveda is thus a scholarly traditional medicine system widely practiced in the Indian subcontinent, including Nepal. With a history spanning over 5,000 years, its precise origins remain unclear. *Ayurveda* focusses on achieving balance and harmony between the body, mind, and spirit to promote optimal health. It takes a holistic approach to wellness by addressing the underlying causes of imbalances rather than just alleviating symptoms. A significant portion of the population in India and Nepal continues to trust in *Ayurvedic* principles and uses various *Ayurvedic* formulations to treat various health disorders.

Ayurvedic Bhasmas

Ayurvedic bhasmas are classical formulations that uses non-toxic form of metals and minerals as key therapeutic ingredients. These are actually very finely powdered, purified calcinations of metals and minerals, enriched with herbal ingredients. The systematic and stepwise procedure for *bhasma* preparation is well described in the traditional *Ayurvedic* scripture '*Rasashastra*' where the process, known as '*Bhasmikaran*' or 'Calcination', is outlined. The major objective of '*Bhasmikaran*' is to reduce the particle size and transform the toxic nature of metals and minerals into a non-toxic form with enhanced therapeutic effectiveness [3]. Two primary methods are used for *bhasma* preparation, though modifications may be needed based on the specific type of *bhasma*: the '*Putapaka*' method and the '*Kupipakwa*' method [37].

Putapaka (Calcination) method

Figure 2. Schematic diagram of *Putapaka* method for preparation of *Bhasma*

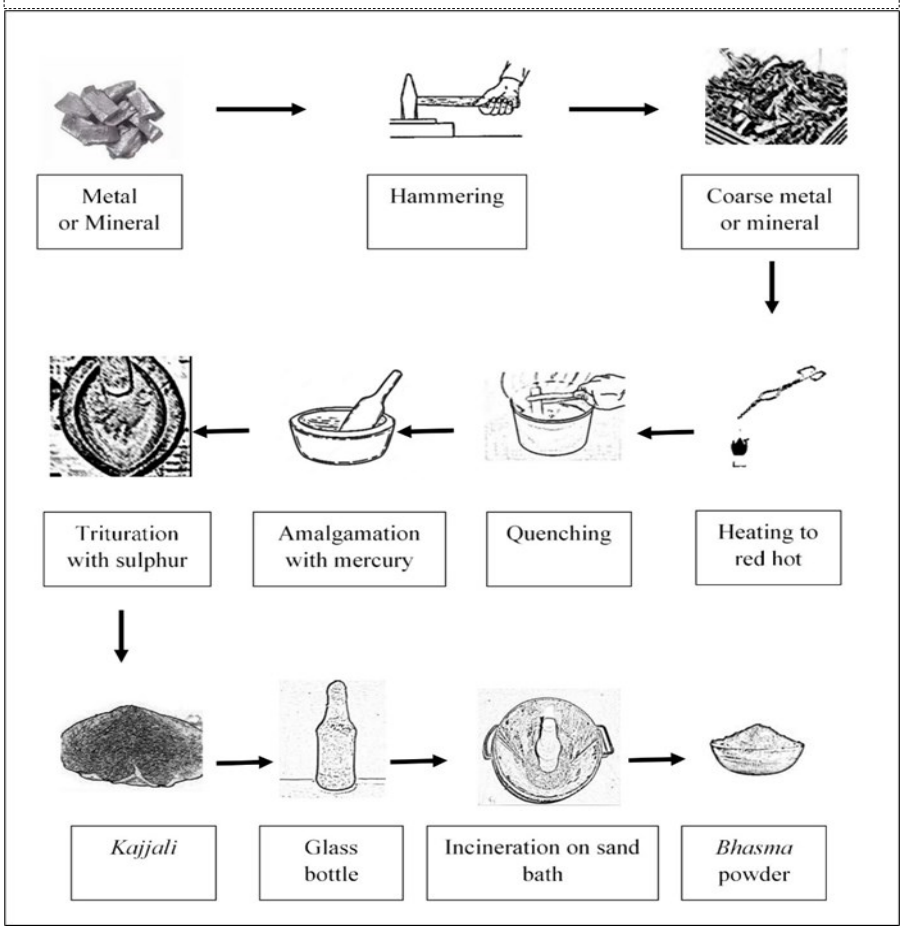


In the '*Putapaka*' method, illustrated in Figure 2, metals or minerals are first hammered into a coarse form. This coarse material is then repeatedly heated until red hot and quenched in a suitable liquid medium (such as oil, milk, or cow's urine) several times. This is called '*Shodan*' (purification) process. After purification, the metal or mineral is ground with a specific herbal extract for a set period in a mortar, called a '*Khal*', to form a dough-like mass. This process is called '*Bhavan*' (Levigation or wet trituration). The dough is shaped into pellets (called '*Chakrikas*') and placed into an earthen crucible (called a '*Sharav*'). The crucible is then covered with a lid (or another crucible), and the joint is sealed with multiple layers (typically seven) of mud smeared clothes. This sealed setup is referred to as '*Sharav Samputa*'. Finally, the assembly is repeatedly heated in a limited air supply in a calcination furnace, or '*Puta Bhatti*', using cow dung cakes as fuel, until a fine, homogeneous powder called *bhasma* is produced. This process is known as '*Maran*' (calcination) [38].

Kupipakwa method

In the '*Kupipakwa*' method, illustrated in Figure 3, metals or minerals are first purified through the '*Sodhan*' process and then amalgamated with mercury. The amalgam is triturated with sulphur in a mortar until it becomes black, lustreless, fine and smooth mass is obtained. This process is called '*Kajjali*' preparation. Once the '*Kajjali*' is ready, it is shade-dried and placed in a glass bottle known as '*Kachkupi*'. The glass bottle is then sealed and wrapped with seven layers of mud smeared cloth. This assembly is placed in a sand bath and heated repeatedly for a specific period until the *bhasma* is formed [38].

Figure 3. Schematic diagram of *Kupipakwa* method for preparation of *Bhasma*



Ayurvedic bhasmas are herbo-mineral or metallic formulations used as potent medicines in *Ayurvedic* treatments. These drugs are prepared by repeated grinding of minerals or metals with extracts from *Ayurvedic* herbs, followed by calcination at temperature above 650 °C. This preparation process closely resembles the top-down approach used in nanoparticle synthesis, and *bhasma* is regarded as a form of biologically produced nanomedicine.

Composition and Characteristics of Bhasma

Traditional methods

Traditional methods for assessing the quality of bhasmas are straightforward and primarily rely on physical characteristics. Several of these traditional characterization techniques for *Ayurvedic bhasmas* are detailed in Table 3.

Table 3. Traditional methods of characterization of bhasmas [39].

Test	Process	Results
A. Physical parameters		
***Varna* (Colour)**	Presence of single or multi-colour is noted.	Each bhasma has a specific colour.
***Nishchandratva* (luster)**	Bhasma is observed under bright sun light.	Bhasma does not possess metallic luster.
***Rekhapurnatvam* (Fineness)**	Small amount of bhasma is rubbed between index finger and thumb.	Bhasma particle enters the creases of these fingers.
***Varitara* (Lightness)**	Small amount of bhasma is sprinkled on stagnant water surface.	Bhasma particles float on water surface
***Unama* (Uniformity)**	A grain of rice is carefully kept on the layer of bhasma floated on water surface	Rice grain remain on the layer of bhasma without sinking.
***Niswadutam* (Taste)**	A pinch of bhasma is placed on the tongue.	Absence of metallic taste.
B. Chemical Parameters		
***Apunarbhava* (Metal recovery)**	Certain quantity of bhasma is mixed with equal quantity of seeds of *Abrus precatorius*, *guda*, *gunja*, *madhu*, ghee and *tankana*, enclosed in *musha* (crucible), heated strongly, and self-cooled.	Absence of free metals
***Niruttha* (Silver test)**	Definite quantity of bhasma is mixed with equal quantity of silver in musha (Crucible), strongly heated, and self-cooled.	No change in weight of silver.

Modern Analytical methods

Modern analytical methods, including XRD, EDX, FTIR, DLS, SEM, and TEM, are used to analyze the chemical composition and properties of *bhasma* particles. X-ray diffraction (XRD) is a non-destructive technique that characterizes crystalline materials. It provides detailed information on structures, phases, preferred crystal orientations, and several other structural parameters such as average grain size, degree of crystallinity, strain, and crystal defects in the particles [40]. Energy Dispersive X-ray (EDX) microanalysis is a technique specifically used to determine the quantitative elemental composition of particles. It allows for the identification of major, minor and trace elements within a sample [41]. This method detects the X-rays emitted as a result of the interaction between an electron beam and the sample. Fourier-Transform Infrared (FTIR) spectroscopy is a rapid, non-destructive optical technique that measures the vibrations of excited molecules using IR radiation within a specific wavelength range. It is used to identify various types of organic and some inorganic materials, molecular species, and molecular orientations [42]. FTIR spectroscopy can be employed to detect organic moieties in *bhasma* particles that may have been introduced during its preparation. Dynamic Light Scattering (DLS), also referred to as Photon Correlation Spectroscopy (PCS) is a rapid spectroscopic technique used to determine the size distribution of particles in solution or suspension [43]. This technique provides information on the effective diameter and polydispersity of *bhasma* particles. Scanning Electron Microscopy (SEM) produces detailed three dimensional images of particles at very high magnifications, offering insights into their topography, morphology, composition, and crystallographic nature [44]. SEM can be used to examine the size, shape and structure of *bhasma* particles.

For the purpose of illustrating structure and properties in the following sections, three metal based *bhasmas* – *Tamra* (Copper based), *Vanga* (Tin based), and *Yashad* (Zinc based) – as well as three mineral-based *bhasmas* – *Abhrak* (mica based), *Mandura* (Haematite based), and *Godanti* (Gypsum based) – are selected as representative examples. These *bhasmas* are chosen because their raw materials are relatively inexpensive and readily available, and they have broad applications beyond medicinal use, making them commonly recommended by practitioners.

Tamra (Copper based) Bhasma

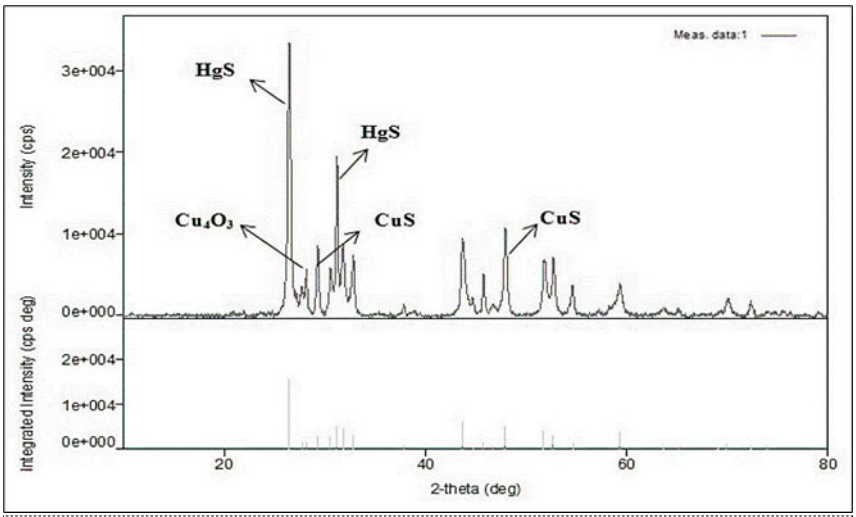


Figure 4. XRD image of Tamra (Copper based) Bhasma showing HgS and CuS as major crystalline phase and Cu_4O_3 as minor crystalline phase [47].

Tamra bhasma prepared using the '*kupipakwa*' method shows a notable presence of elements such as oxygen (O), sulphur (S), copper (Cu), and mercury (Hg), with mercuric sulphide (HgS) and cupric sulphide (CuS) as the main crystalline phases, and Cu_4O_3 as a minor crystalline phase (Figure 4). FTIR analysis confirmed the presence of organic groups containing O-H, N-H, C=C, C=O and C-H bonds. SEM images reveal the particles are clustered with irregularly shaped flakes. The average particle size is 2.2 nm, and the zeta potential of – 44.2mV indicates strong colloidal stability [45–47].

Vanga (Tin based) Bhasma

Vanga bhasma is crystalline in nature and contains elements such as carbon (C), oxygen (O), calcium (Ca), magnesium (Mg), Copper (Cu), and tin (Sn), with tin oxide (SnO_2) being the major component (Figure 5). It also contains organic groups like CH_3, OCH_3, C=O, C=C. Using an electric muffle furnace during the incineration process results in 100% nanoparticles within the 50-100 nm range and a uniform particle size distribution, whereas the traditional method produces only 50% nanoparticles within 150-300 nm range, exhibiting a trimodal distribution. SEM images show spherical granules smaller than 100 nm [48, 49].

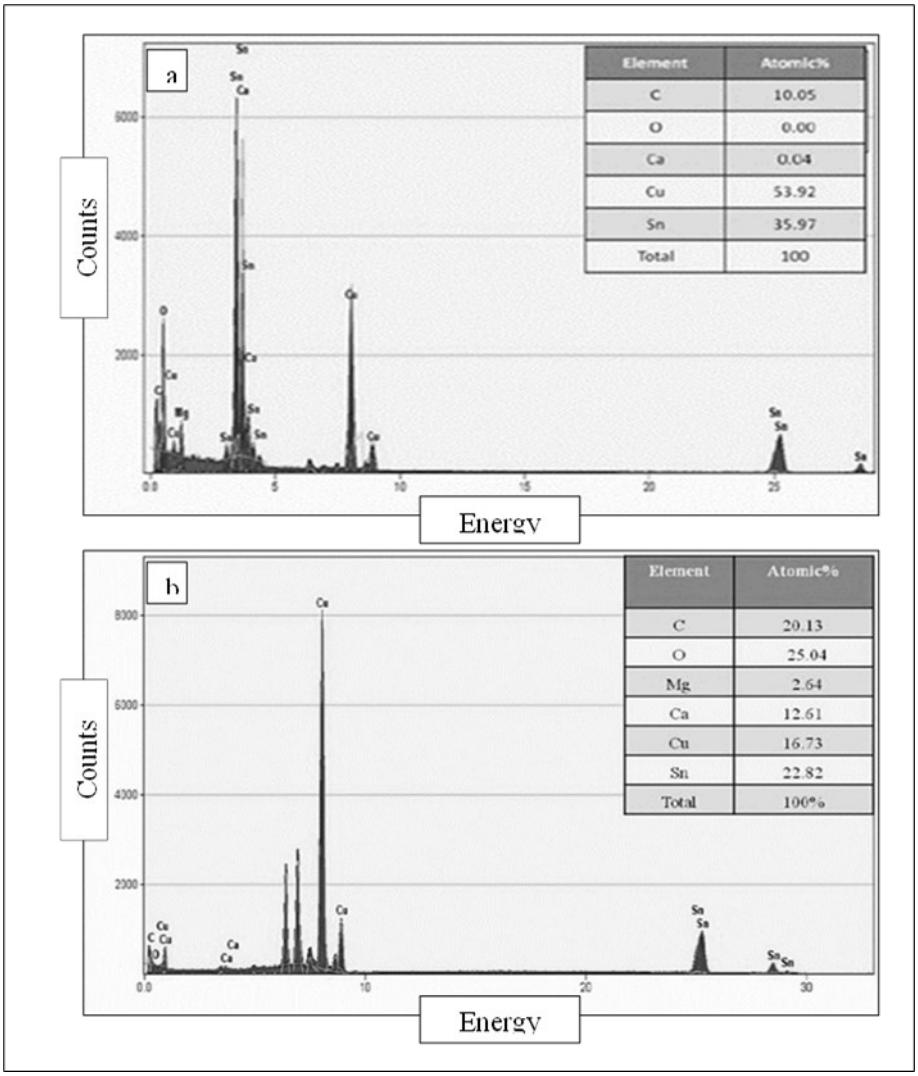


Figure 5. EDX spectra of *Vanga* (Tin based) *bhasma* (a) prepared by traditional method of heating and (b) prepared by using electric muffle furnace showing major elements present and their percentage composition [48, 49].

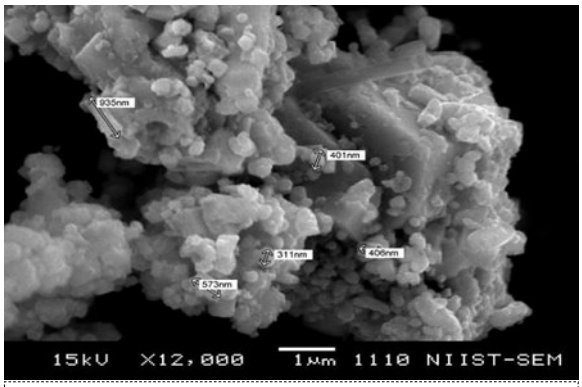


Figure 6. SEM image of *Yashad* (Zinc based) *bhasma* showing particles of nanoscale dimensions [52].

Yashad (Zinc based) Bhasma

Yashad bhasma contains elements such as carbon (C), oxygen (O), sodium (Na), sulphur (S), calcium (Ca), and zinc (Zn), with zinc oxide (ZnO) in a hexagonal crystalline phase as its primary component. Organic groups containing C=C, C=O and C-H bonds, introduced during the levigation process, are also present. SEM images (Figure 6) show the presence of nanometer-sized particles. *Yashad bhasma* produced using an electric muffle furnace contains 70% nanoparticles in the 250-750 nm range, while the traditional heating method yields 35% nanoparticles, mostly around 500 nm, with a trimodal distribution [50–52].

Abhrak (Mica based) Bhasma

XRD analysis of *Abhrak bhasma* reveals peaks indicating the presence of mica, ferrous sulphate ($FeSO_4$), and ferric oxide (Fe_2O_3). EDX results show that the major elements in *Abhrak bhasma* are oxygen (O), silicon (Si), aluminium (Al), magnesium (Mg), potassium (K), sodium (Na), calcium (Ca), and iron (Fe). SEM images display nanoparticles with sizes ranging from 50 nm to 1mm. The FTIR spectrum shows prominent bands between 2700 cm^{-1} and 3700 cm^{-1}, indicating the presence of -OH groups, along with bands for O=C=O and Si-O stretching bonds (Figure 7). DLS spectra reveal bimodal particle distribution with 50 – 90% of the particles in the 50-500 nm range [53, 54].

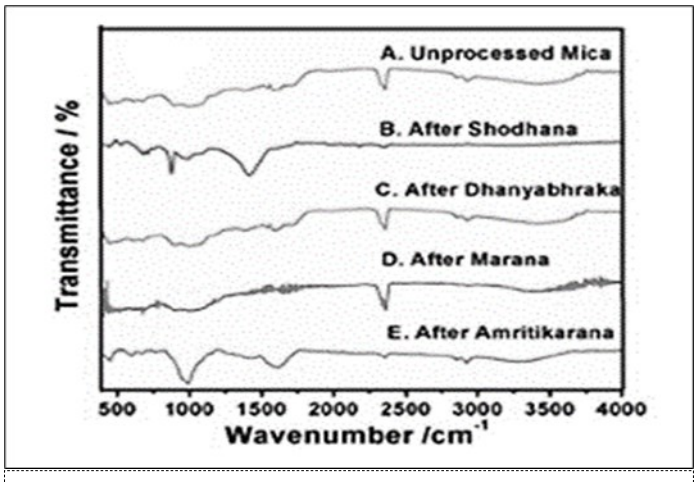


Figure 7. FTIR spectra of *Abhrak* (Mica based) *Bhasma* at different stages of preparation [54].

Mandura (Haematite based) Bhasma

XRD analysis of *Mandura bhasma* shows major peaks corresponding to ferric oxide (Fe_2O_3) with a rhombohedral structure and minor peaks of potassium sulphate (K_2SO_4) (Figure **8**). EDX results indicate the presence of elements such as carbon (C), oxygen (O), aluminium (Al), silicon (Si), chlorine (Cl), potassium (K), calcium (Ca), and iron (Fe). SEM images reveal an irregular distribution of particles, mostly with a rhombohedral shape (Figure **9**). FTIR analysis confirms the presence of organic groups with O-H, N-H, C-H, C-C and C-X bonds. The average particle size is 3.2 nm, with a zeta potential of – 32.7 mV, indicating high colloidal stability. The UV spectrum shows maximum absorbance at 300 nm in UV region [55, 56].

Godanti (Gypsum based) Bhasma

XRD analysis of *Godanti bhasma* shows that calcium sulphate ($CaSO_4$) with orthorhombic structure is the major phase, while calcium sulphide (CaS) with a cubic structure is present as a minor phase. EDX analysis confirms the presence of calcium (Ca), sulphur (S), oxygen (O), and carbon (C). The FTIR spectrum shows bands corresponding to O-H bending and SO_4 stretching vibrations. SEM images depict a mixture of rod-shaped and rhombohedral particles with sizes ranging from 14 to 33 nm [57].

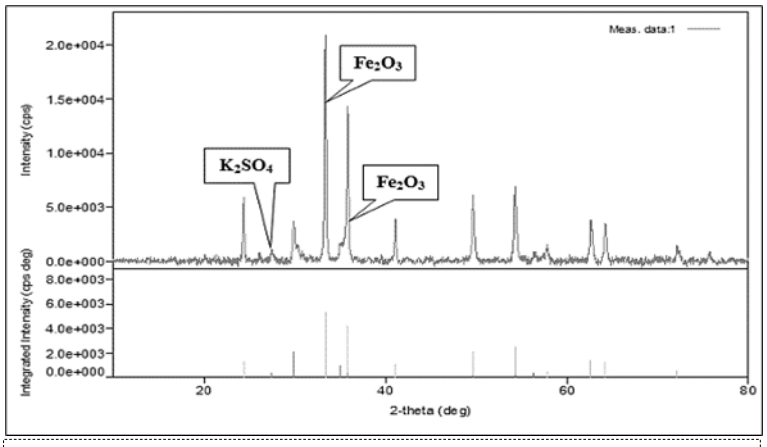


Figure 8. XRD image of *Mandura* (Haematite based) *Bhasma* showing major peaks of Fe_2O_3 and minor peak of K_2SO_4 [56].

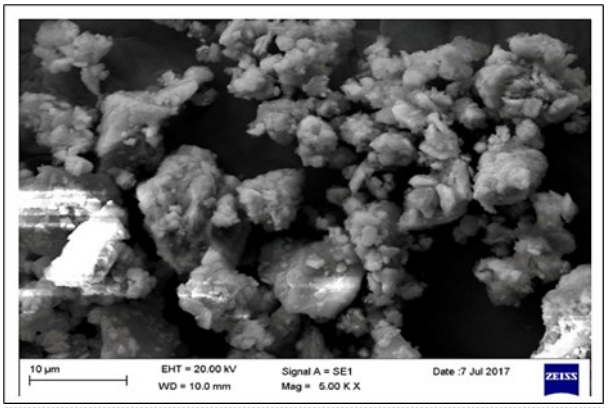


Figure 9. SEM image of Mandura (Haematite based) Bhasma showing irregular distribution of nanometer sized particles [55].

Findings

Instrumental analysis of various *bhasmas* using different techniques has shown that the particles are crystalline and fall within the nanoscale size range. These particles primarily consist of metal oxides or metal sulphides, along with other elements and organic compounds derived from *Ayurvedic* herbs used during preparation. The size, shape, and distribution of the particles are influenced by factors such as the preparation steps, heating methods, equipment used, temperature, and duration of heating. *Bhasmas* prepared using modern muffle furnace heating tend to have a higher percentage of smaller particles with uniform distribution compared to those produced with traditional cow dung cake heating. In the traditional method, the particle fineness increases with the number of *puta* cycles (processing rounds). The particles exhibit various shapes, including spherical, irregular flakes, rhombohedra, and rod-like forms. Their high colloidal stability suggests they disperse easily and are quickly absorbed into body fluids.

Therapeutic Importance of Ayurvedic Bhasmas

Bhasmas are metal- or mineral-based preparations that undergo specific purification and calcination processes to enhance their therapeutic properties. The reduction of particle size to the nanometer scale, along with the incorporation of various herbal ingredients during synthesis, enriches these particles with medicinal value. For centuries, they have been used to treat various human ailments[58]. Practitioners of *bhasma* believe that these preparations promote healing, balance the body's doshas (energy principles), and improve overall well-being [31, 32]. Recent studies have shown that *bhasmas* possess antioxidant, anti-inflammatory, antibacterial, antiviral and antitumor properties and may serve as potential carriers for drug delivery [37, 59, 60]. The therapeutic uses of some *Ayurvedic bhasmas* are listed in the Table 4.

Recent studies have highlighted the therapeutic potential of various *bhasma* particles. *Swarna Bhasma* has been shown to be effective in treating malignant tumors in the lungs, liver, pancreas, gall bladder, colon, and rectum. *Yashad Bhasma* has demonstrated effectiveness as a cytostatic drug in human pancreatic ductal adenocarcinoma. *Abhrak Bhasma* has exhibited anti-cancer activity, particularly in cases of breast cancer and leukemia. *Tamra Bhasma,* synthesized using *Acalypha indica* extract, has shown cytotoxic potential against human breast cancer cells. *Heerak Bhasma* has been found to possess immunostimulatory and tumoricidal properties, particularly against highly metastatic and aggressive murine lymphoma [62, 68–71].

Ayurvedic bhasmas have been an integral part of traditional *Ayurvedic* medicine, used for therapeutic purposes over centuries. According to *Ayurvedic* principles, *bhasmas* are believed to enhance the medicinal properties of the substances from which they are made. They are thought to have unique healing abilities and are used to treat various ailments. Advocates of *Ayurvedic* medicine suggest that *bhasmas* can help restore balance, support overall health, provide nourishment, improve digestion and metabolism, and stimulate the body's natural healing processes. However, due to a lack of sufficient scientific evidence, research, and rigorous clinical trials, it is important to use *bhasmas* with caution and under the guidance of a qualified practitioner.

Bhasma as Nanomedicine

Nanotechnology and Nanomedicine

A nanometer one billionth of a meter. The concept of nanotechnology was first introduced by Richard Feynman in his 1959 lecture titled "There is Plenty of Room at the Bottom" given at an American

Table 4. Therapeutic potential of some *Ayurvedic bhasmas*.

Bhasma	**Raw materials**	**Typical examples of therapeutic uses**	**References**
Abhrak Bhasma	Mica (Biotite)	In treatment of asthma, urinary disorders and skin diseases.	53, 54, 61
Heerak Bhasma	Diamond	Effective in cancers, rheumatoid arthritis, bone marrow depression and immune disorders.	38, 59, 62
Kasisa Bhasma	Green vitriol	In treatment of eye diseases, leukoderma, helminthiasis.	38, 59, 63
Lauha Bhasma	Iron fillings	In cardiovascular diseases, eye disorders, obesity, diabetes, asthma, bronchitis, herpes, chronic respiratory disorders, liver disorders, piles and fistula.	38, 59
Mandura Bhasma	Ferric oxide	Natural diuretic, improve blood count, remove toxins from blood, hepatitis and edema.	38, 55, 56, 59
Muktashouktic Bhasma	$CaCO_3$ (Aragonite)	Abdominal colic gastritis, cardiac diseases, urinary calculi.	38, 59
Naga Bhasma	Lead	Diabetes, piles, diarrhoea, jaundice, skin diseases, cough, asthma, whooping cough, bronchitis, obesity, anaemia, gonorrhoea, epilepsy.	38, 59
Praval Bhasma	Coral	Bloating, splenic disorders, cough, asthma, anorexia, indigestion, diarrhoea, urinary tract disorders.	38, 59
Rajat Bhasma	Silver	Irritable bowel syndrome, acidity	38, 59, 64, 65
Swarna Bhasma	Gold	Improve immunity, treat weakness and anaemia	59, 66, 67
Swarna Makshika *Bhasma*	Copper and Iron pyrite	Boost immunity, lungs disease, nervous system diseases, bone joint diseases and heart diseases.	59, 66, 67
Tamra Bhasma	Pure copper	Peptic ulcer, anaemia, skin diseases, dyspnea.	38, 45, 46, 59
Trivanga Bhasma	Lead, zinc and tin	Urinary tract disease, UTI, diabetes, female infertility.	38, 59
Vanga Bhasma	Tin and associated minerals	Vomiting, anorexia, premature ejaculation, cough, cold, bronchitis, asthma, weight loss, urinary disorders.	38, 48, 59
Yashad Bhasma	Zinc	Eye disorders, anaemia, diabetes, cough, cold, bronchitis, asthma, gonorrhoea, urinary constraints.	38, 50, 51, 59

Physical Society meeting. The term 'nanotechnology' was coined by Norio Taniguchi in 1974. Nanotechnology involves the innovative application of science and technology to design, synthesize, characterize, and apply materials at the molecular level, specifically within the range of a few to several hundred nanometers [72]. This field has opened up new possibilities in various domains, including medicine, electronics and communication, energy and environment, transportation, food and agriculture, and space exploration [73, 74].

Nanomedicine is a field of medicine that makes advanced nanotechnology techniques for the prevention, diagnosis and treatment of diseases. It has had a transformative effect on health care in the twenty-first century. Nanomedicine employs nanoparticles, including polymeric micelles, liposomes, and lipid nanoparticles, to improve disease prevention and treatment within living organisms. It provides opportunities for earlier disease detection, more effective and personalized therapies with minimal side effects, and reduced health care costs. Additionally, nanomedicine proves valuable in drug delivery systems, cancer therapy, tissue engineering, and holds potential for future applications in molecular nanotechnology [75–81].

Principle of Nanomedicine

The principles of nanomedicine revolve around integrating nanotechnology into medicine. This field focusses on developing and applying nanoscale tools, devices and materials for various medical purposes. The core principle of nanomedicine is the manipulation and control of materials at the nanoscale to achieve specific therapeutic or research outcome. The basic principles of nanomedicine include [75, 80–83]

Targeted delivery: Nanoparticles can be engineered to specifically target diseased cells or tissues. By attaching ligands or antibodies that bind to particular cell surface markers, these particles can deliver drugs or therapeutic agents directly to the intended location, minimizing side effects and enhancing treatment effectiveness.

Enhanced drug delivery: Nanoparticles can improve drug delivery and release by being chemically modified to protect against corrosion, enhanced solubility, and sustain their effects over time. This allows better drug bioavailability and longer therapeutic periods.

Imaging and diagnosis: Nanoparticles can be designed with unique imaging properties, making them valuable for various diagnostic techniques. They can serve as high- resolution contrast agents in imaging techniques such as magnetic resonance imaging (MRI), computed tomography (CT), or fluorescence imaging.

Regenerative medicine: Nanotechnology contributes to tissue engineering and regenerative medicine by providing nanoscale scaffolds and materials that mimic the extracellular matrix, supporting cell growth and tissue regeneration.

Nanomedicinal features of Ayurvedic bhasmas

Studies have demonstrated that the methods used in the preparation of *bhasmas* closely align with the top down approach in nanoparticle synthesis[77]. In *Ayurveda,* various pharmaceutical techniques such as *Sodhana* (Purification), *Bhavana* (Trituration), and *Marana* (Intense heating) are used in the manufacture of *bhasmas.* These processes are aimed at reducing particle size and transforming minerals and metals into non-toxic forms with therapeutic properties [32]. During the *Sodhana* process, the metal or mineral is subjected to increasing tension during heating and decreasing tension during cooling, making the material more brittle and easier to process further. In the *Bhavana* process, the metal or

mineral particles endure high stress when ground between a pestle and mortar, which helps to reduce their size. Additionally, levigation with appropriate herbal extracts or decoctions during this process integrates herbal metabolites into the preparation. The *Marana* process involves exposing the particles to high temperatures, which reduces their size to the nanometer range and endows them with various beneficial qualities [84].

It is worth mentioning that various modern analytical techniques have been employed to investigate and characterize the physicochemical properties of *Ayurvedic bhasmas*. These analyses have examined particle size, elemental composition, and surface characteristics. Research has identified the presence of nanoparticles or nanocrystals, as well as therapeutically significant herbal ingredients in certain *bhasmas*, indicating their potential for nanoscale properties [38]. *Ayurvedic bhasmas* are used in the treatment of various diseases, including chronic diseases such as cancer, asthma, and gastritis. Recent studies have highlighted that *bhasmas* possess antioxidant, anti-inflammatory, immunomodulatory, antibacterial, antiviral and antitumor properties, along with the capability to target drug delivery to specific sites in the body with fewer side effects. Thus, *Ayurvedic bhasmas* are nanoparticles with considerable medicinal value [85].

Nanomedicine generally refers to the deliberate design and use of nanoscale materials for specific therapeutic applications in modern medicine. It involves meticulous control over the size, shape, surface properties, and targeting abilities of nanoparticles to improve drug delivery, imaging, and diagnostics [81]. *Ayurvedic bhasmas* are prepared by following *Ayurvedic* principles with the aim of reducing particle size, extending shelf life, transforming toxic nature of metals or minerals into non-toxic forms, and enriching them with medically important herbal metabolites. In this regard, *Ayurvedic bhasmas* can be considered a form of nanomedicine [59]. However, the precise control of particle size, shape, and properties, as well as the mechanisms and specific features related to nanoscale interactions or effects, have not been thoroughly documented or scientifically explored in the context of *Ayurvedic bhasmas*.

Conclusion

Ayurveda is a traditional and scholarly medical system that originated during the *Vedic* period (1500-900 BC). Despite its ancient roots, its principles and approaches can be closely aligned with modern nanotechnology. *Ayurvedic bhasmas* serve as a key example of how nanotechnology is applied within *Ayurveda*. The pharmaceutical techniques described in *Ayurveda* for making *bhasmas* closely resemble the top down approach used in nanoparticle synthesis, aiming to reduce particle size, extend shelf life, remove toxicity, and enhance therapeutic value. Research has shown that *bhasmas* are calcined powders with nanoscale dimensions that are effective in treating various health disorders, particularly chronic ailments. These powders have a long shelf life and feature non-toxic metals or minerals combined with potent herbal metabolites. However, the lack of scientific standardization, systematic research, and significant clinical trials has obscured their medical relevance. Therefore, it can be concluded that *Ayurvedic bhasmas* are biocompatible traditional nanomedicines that need revival, reinvention and advancement to meet contemporary medical standards.

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