

LEVERAGING PLANT AND MINERAL DATABASES IN ADVANCING AYURVEDIC RESEARCH, AND INTEGRATION WITH BIOMEDICINE

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ABSTRACT

Background: Ayurveda, which forms the basis of AYUSH systems of medicine, employs phytochemical drugs/medicines, such as Tulsi (*Ocimum sanctum*) and Neem (*Azadirachta indica*), and herbo-mineral drugs/medicines, e.g., Bhasmas, which are generated by processing minerals/metals, e.g., mica (*Abhraka*) and mercury (*Parad*). In the face of the threat of ethnobotanical erosion and toxicity facing modern science, databases are important to the solution of knowledge preservation, standardization, pharmacovigilance, and integration with modern science.

Methods: This review will review over 7,000 Indian medicinal plants and important minerals (mercury, gold, iron), the features, sources of the data and limitations of the databases with the help of narrative synthesis.

Results: IMPPAT (4,010 plants, 17,967 phytochemicals, ADMET predictions) and OSADHI (6,959 unique species, 27,440 phytochemicals, ML classification) are the important databases on plants that assist in drug discovery and therapeutic suitability. The identification and conservation is facilitated by the use of taxonomic tools such as WFO (1.6M names), IPNI (1.4M names), POWO (1.4M names), BSI (1,915 species), and Indian Medicinal Plants DB (7,263 names). Safety and processing Compositional and structural data on minerals is available in mineral databases like Rasa shastra Portal (79 metals, 45 texts), Mindat.org (300,000 entries), Web Mineral (4,714 species), and WWW-MINCRYST (5,000 entries). These are limited to data silos and partial herbo-mineral connectivity as well as access problems.

Conclusion: These databases augment Ayurvedic studies which have weaknesses of loss of biodiversity and regulation gaps. The next steps include AI/ blockchain to validate and open it further to develop sustainable AYUSH.

KEYWORDS: Ayurveda, Medicinal Plants, Herbo-Mineral Formulations, Databases, Phytochemistry, Rasa Shastra.

INTRODUCTION

The AYUSH systems rely on Ayurveda which is an ancient traditional balancing of the doshas through natural remedies (>3,000 years)(1). The therapy is based on herbo-mineral preparations such as mica (Abhraka) and Mercury (Parad) in Bhasmas, Tulsi (*Ocimum sanctum*) as an immunity-promoting plant, and Neem (*Azadirachta indica*) as an antimicrobial, herb(2). Untreated Gynecology Phytochemicals (e.g.- eugenol Treat inflammation, detoxication).

Databases are essential in conserving knowledge of Ayurveda, standardising of plant and mineral data, pharmacovigilance as well as incorporation with modern science. These make bioinformatics driven drug discovery by standardizing phytochemicals and herbo-mineral formulations to aid research and safety evaluations. This review aims at databases that are publicly available recording medicinal plant species and minerals/metals such as mercury, gold, and iron when used in Ayurveda.

OBJECTIVES: The objectives are to engage with well-known databases, including OSADHI, IMPPAT, and the Rasashastra Portal, to determine their strengths, weaknesses, and how they can help in herbo-mineral study through incorporating the knowledge of ayurveda with the modern scientific methods.

Significance of Databases in Ayurveda

- Data bases facilitate curing and computerizing the traditional knowledge of Ayurveda herbs and minerals, which is accurate, safe, and reproducible(3,4).
- They include classical literature such as. why nearly 150,000 trademarks such as, preserve cultural heritage(5,6).
- The databases promote the standardization by the quality control via verified taxonomy and chemical profiling (7,8).
- They contribute to increased safety as they track the adverse reactions and the ADMET risks(9,10).
- Biological and machine learning contribute to the development and progress of modern research, implementation, and connection with databases worldwide(11,12)

Databases for Medicinal Plants

Ayurveda gives high appeal to medicinal plants which are valued as they have therapeutic qualities. The Ayurveda professionals and students are empowered by digital databases that catalogue significant information overall such as taxonomy, phytochemistry, medicinal uses, and geographical distribution. These repositories which were constructed on relational databases or web platforms make navigation of complex data easier and ensures the conservation of the Indian ethnobotanical heritage. They augment research, contribute to drug discovery, pharmacovigilance, and cooperation so that AYUSH practitioners and scholars can develop the heritage of medicinal plants.

IMPPAT: *Indian Medicinal Plants, Phytochemistry And Therapeutics*

1. **Development:** IMSc, Chennai under the leadership of researcher Areejit Samal. (2018; v2.0: 2022).(13)
2. **Data Sources:** PubMed (1,200+), ethnobotany, PubChem, TKDL.
The *Indian Medicinal Plants, Phytochemistry And Therapeutics (IMPPAT)* database, updated to version 2.0 on June 17, 2022, serves as a pivotal resource for researchers, practitioners, and students in Ayurveda, Siddha, and Unani systems of AYUSH medicine.

IMPPAT has grown remarkably since the time of its first release on January 25, 2018, providing a strong source to provide the scientific and therapeutic aspects of Indian medicinal plants. This promotes co- relation of plant phytoconstituents, enhances drug discovery as well as assists in validating Ayurvedic claims by clarifying therapeutic interactions between Ayurvedic phytochemicals and pharmacological impacts.(13)

3. **Extensive Plant Documentation:** It has now added the detailed information about the 4,010 Indian medicinal plants into the database which will be increased by twice the number of those that existed in 1.0 version and furthermore covers the species that is of importance in AYUSH systems.(13)

 - **Detailed Phytochemical Profiles:** It has in total of 17967 list of phytochemicals that are near 2018 and has 2D, 3D chemical structure and molecular analysis to ensure that the study is valid.
 - **Therapeutic Applications:** Documented therapeutic uses are of the order of 1,095 and are evidently associated with certain parts of the plant including roots or leaves.
 - **Enhanced Data Associations:** There is a 5-fold augmentation in data associations between plants and their 5,069 formulations and their therapeutic applications and 5,069 phytochemicals, which are documented in the Traditional Knowledge Digital Library (TKDL).
 - **Advanced Cheminformatics:** It additionally provides some advanced data on chemicals including physicochemical properties, some scores indicative of a drug-likeness, and predictive values of ADMET to determine safety and effectiveness.
 - **Research and Innovation Support:** It facilitates research and innovation research through studies about the mechanisms action of phytochemicals to induce healing action.(13)

1. **Significance:** It promotes information standardization of medicinal plants and makes ayurvedic researches feasible.(13)

OSADHI (Online Structural and Analytics-based Database for Herbs of India)

1. **Development:** CSIR-NEIST CSIR-North East Institute of Science and Technology.(14)

2. **Data Sources:** 800 or more articles, NAPRALERT.(14)

OSADHI, which is launched in the frame of the **4Ds** paradigm Documentation, Digitization, Deposition, and Data Science, integrates geographical knowledge with new cheminformatics to help in drug discovery and validate AYUSH therapeutic claims by phytochemical-therapeutic relationships.(14)

3. Key features include:

- **Extensive Plant Documentation:** Documents 21,238 medicinal plants distributing in India including 6,959 distinct species that represent 343 plant families.
- **Detailed Phytochemical Profiles:** Search 27,440 phytochemicals having 2D chemical structures, SMILES, InChIKeys and IUPAC names as well as physicochemical characteristics to research them illustrated accurately.
- **Therapeutic Applications:** Describes 2,477 therapeutic uses, stipulated by parts of the plant (as, roots, leaves).
- **Geographical Classification:** Maps distribution of plant in Union Territories and Indian states.
- **Advanced Cheminformatics:** Provides drug-likeness scores, ADMET (Absorption, Distribution, Metabolism, Excretion, Toxicity) predictions, and NP Classifier-based categorization of phytochemicals by classes, super classes, and pathways.
- **Research and Innovation Support:** Employs machine learning models to classify plants by therapeutic uses, enabling systems-level studies to explore mechanistic links between phytochemicals and therapeutic effects, aligning with AYUSH research goals.

4. Significance: helps in Validation of geographical distribution data.(14,15)**Global and National Taxonomic Databases****1. World Flora Online (WFO)**

The World Flora Online (WFO) is an official online system that contains all the taxonomic information on known vascular plants (flowering plants, conifers, ferns, and allies) and bryophytes (mosses and liverworts). WFO was started by the Secretariat of the Convention on Biological Diversity (CBD) and major botanical institutions, including the Royal botanic Gardens, Kew, the Missouri Botanical Garden and the New York botanical Garden, in 2017 to meet Target 1 of the Global Strategy of Plant conservation (GSPC). This goal will develop a functional checklist of known plant species by 2020, enhance conservation of plants on Earth, biodiversity documentation and availability of scientific research. Based on the philosophy of The Plant List (TPL) a static 2013 partnership between Kew and Missouri Botanical garden that offered accepted Latin names and synonyms of more than 1 million species, WFO is its dynamic successor with renewed backbones in taxonomy and contributions currently ongoing through global partners.(15)

Key features: It is characterized by key attributes of 1,632,731 plant names, 379,950 accepted names, 633,987 description records, 56,356 images, 1,937,160 distribution records and 8,981,917 references that allow searching by name, distribution or content.(15)

In the case of AYUSH, WFO contributes to facilitate the work of researchers and students in verifying scientific nomenclature of medicinal plants, getting proper identification in ethnobotanical studies, thereby facilitating the overlap of the Ayurvedic knowledge and the contemporary system of taxonomy.

2. International Plant Names Index (IPNI)

The International Plant Names Index (IPNI) is a joint database with intensive nomenclatural information on the name of a scientific and scientific rank of vascular plants, including a range of family (and infraspecific) rank. IPNI was established in 1999, by a merger of three historic indices; Index Kewensis (Royal Botanic Gardens, Kew, began 1893), Gray Herbarium Index (Harvard University Herbaria) and Australian Plant Names Index (Australian national Herbarium), to bring about the elimination of the necessity to consult original literature repeatedly, and standardisation of nomenclature of plants, in response to the increasing demands of botanical research. It is hosted by the Royal Botanic Gardens, Kew with donations by Harvard University Herbaria and Australian National Herbarium to ensure accuracy is maintained by adding new records day by day.(16)

Key features: Some of these main features include spelling, authors, types and first publication details of 1,433,000 plant names in 18,500 publications of 55,100 authors, to which protologues are linked via the Biodiversity Heritage Library and taxonomic applications, such as Plants of the World Online, which provide synonymy and distributions. It equally enables new names to be registered in order to encourage scientific work. (16)

The IPNI is used to aid practitioners and researchers in AYUSH systems, to ensure that nomenclatural and nomenclatural identifications in research activities are accurate, precise, and timely recording of herbal preparations for avoiding misidentification, and pharmacovigilance by means of standardised references.

3. Plants of the World Online (POWO)

Plants of the World Online (POWO) is an active resource with variable and user friendly portal supplying taxonomic and distributional information about vascular plants in the whole world, with accepted names, synonyms, descriptions and multimedia. Established by and with the Royal Botanic Gardens, Kew (Kew Science), in collaboration with other institutions,

such as the Missouri Botanical Garden and Botanic Gardens Conservation International POWO was developed in 2017 as a component of the mission of the Kew to promote the science and conservation of plants. It was created to solve the increasingly fragmentary nature of botanical information after The Plant List period, to offer an open-source and constantly updated virtual resource to facilitate research, teaching, and policy-making regarding it as per the Global Strategy for Plant Conservation. (17)

Key Features: Its Main Features are browsing 1,442,000 global plant names, 531,700 in-depth descriptions, and 502,700 images, and Distribution, Threat and Reference search tools. Confirmed statistics can be compared with site data with more focus on full coverage.(17)

In the case of AYUSH medicine, POWO enables students and practitioners to keep pace with provision of certified taxonomy of medicinal species to assist in authentication of herbs in formulations, ethnopharmacological research as well as connecting with databases such as IMPPAT or OSADHI to approve traditional uses, based on current scientific nomenclature.

4. Botanical Survey of India (BSI) Medicinal Plant Database

The Botanical Survey of India (BSI) Medicinal Plant Database which is run by the Ministry of Environment, forest and climate change is an important source of AYUSH researchers, practitioners and students. Introduced to conserve the rich Indian ethnobotanical heritage it is now indexing 1915 medicinal plant species and the next phase of the project will document another 1000 species of plant life. The database contains comprehensive data on scientific names, family names, common names, medical use, geographical location and high resolutions of herbarium images. It aids in the conservation work since it maps the locations of species and records ethnomedicinal uses, which is available to botanists, conservationists, and AYUSH scholars. Its easy to use system adds value on its standardisation of plant-based remedies and promotion of ethnopharmacological research in AYUSH systems.(18)

5. The Indian Medicinal Plants Database

The Foundation of Revitalisation of Local Health Traditions (FRLHT) in partnership with the National Medicinal Plants Board (NMPB) at the ministry of AYUSH funded the Indian Medicinal Plants Database. It draws its data on classical Ayurveda, Unani, Siddha, Homeopathy, and Sowa-Rigpa literature, and compares it with vernacular knowledge with modern scientific publications in books and journals. Indian Medicinal Plants Database, an open resource portal, was introduced in 2010, and it provides a central point of researchers, practitioners, and students of Ayurveda, Siddha, and Unani systems of AYUSH medicine. It

has been used to enhance a strong platform to study the taxonomic and ethnomedicinal aspects of Indian medicinal plants since its first publication. This aids in standardizing the identification of the plant itself, facilitates preservation of the plant, and aids in validating claims on AYUSH in elucidating connections between botanical material and traditional usage.(19)

- The database contains 7263 names of plants used in AYUSH systems with their author names and synonyms given in the database to be easily identified.
- It also gives above 150,000 local names in 10 Indian languages and a little over 5,000 clear images to understand.
- The medicinal uses of plants are described based on the parts of plants and among the traditional systems such as Ayurveda, Siddha, Unani, Folk and the Sowa- Rigpa.
- The user is able to either do a search using botanical name, local name, part of the body, or medicinal use to find associated information.
- It relates information of six conventional medicine systems and 20 classical texts.
- The resource promotes the investigation, preservation and sustainable market of herbal drugs.(19)

3.2.4 Comparative Table (13,15–20)

Aspect	IMPPAT	OSADHI	WFO	IPNI	POWO	BSI	Indian Med Plants DB
Launch Year	2018	2023	2017	1999	2017	Ongoing	2010
Coverage	4,010 plants	6,959 spp.	379,950 spp.	1.43M names	1.44M names	1,915 spp.	7,263 names
Key Features	Phytochem., ADMET	ML, Geo-maps	Taxonomy, Images	Nomenclature	Distributions	Uses, Images	Vernaculars, Texts
AYUSH Relevance	Therapeutic	Discovery	Identification	Standardization	Authentication	Conservation	Ethno-medicinal

MINERAL DATABASE

1. Rasashastra Portal (rasashastra.tdu.edu.in)

1. **Development:** TDU/Metastring (2020).(22)

2. **Data Sources:** 45 Rasagranthas.(22)

Rasashastra Portal is an extremely essential tool to undergraduate/ post-graduate students, pharmaceutical companies, research workers of Ayurveda. It has presented a solid platform since launch to find out ancient knowledge on herbo-mineral medications, assisting in standardization of formulations such as Bhasmas, easing development of medications, and fact-checking of ancient claims by use of digitized classical knowledge.

3. Key features:-

- **Extensive Mineral Documentation:** It contains the information about 79 Ayurvedic metals and minerals such as Swarna (gold), Parada (mercury), and Loha (iron), relevant in the practice of Rasa Shastra.
- **Detailed Property Profiles:** It gives them a clear understanding of their types, purification and use.
- **Therapeutic Applications:** Each mineral is discussed in terms of the single and combined medications based on the dosha balance and treatment of the disease.
- **Enhanced Data Associations:** It indexes to 45 Rasagranthas. It has features like rule of name search, category search, and processing method search.
- **Advanced Accessibility Tools:** The site is user friendly among students and researchers.
- **Research and Innovation Support:** It helps in researching the new avenues by relating the conventional process to the contemporary requirements of the safety concern, in order to bring in the evidence based herb-mineral use in therapy.

2. **Significance:** Classical education.

2.Mindat.org

1. **Development:** Hudson Institute (2000).(21)

2. **Data Sources:** Crowd-sourced, literature.

It was the work of a single person, Jolyon Ralph, on a personal project, to design Mindat.org, which was publicly released in 2000 and currently operated by the nonprofit Hudson Institute of Mineralogy.

The Mindat.org database acts as a key source of knowledge to the researchers, practitioners, and students of mineralogy and traditional medicine system such as Rasa Shastra in Ayurveda. Since its first publication, it has grown to be the largest open database in the world, which provides a solid foundation on which to investigate the identification, properties, and events of minerals utilized in herbo-mineral preparations. This helps in the aid of standardization of the sources of minerals, assists in safety assessment.(21)

3. Key features:-

- **Extensive Mineral Documentation:** It has more than 300,000 minerals and one million locales in the different parts of the world including mercury, gold or iron.

- **Detailed Property Profiles:** It includes a comprehensive reveal of chemical structure, composition, and physical properties, pictures and localization map of each mineral, which could be examined in a thorough way.
- **Identification Applications:** It gives mineral names, origins and sources by area which is useful in locating and acquiring materials used in Ayurvedic bhasma preparation.
- **Enhanced Data Associations:** The system interrelated the minerals, fossils and rocks, where one can easily compare mineral, fossil and rock through search tools and classification filters.
- **Advanced Search and Tools:** Interactive maps, image galleries, and data that can be exported are available to the users and checked by experts to ensure accuracy.
- **Research and Conservation Support:** It helps in the study of rare minerals, fosters sustainability and the shallower herbo-mineral ethics in Rasa Shastra.(21)

4. **Significance:** Sourcing (e.g., mercury).

3. Web Mineral

1. **Development:** David Barthelmy (1995).

2. **Data Sources:** IMA, International Mineralogical Association, literature.(23)

The Web Mineral database acts as a central venue of scholars, practitioners and scholars in mineralogy and systems of ayurvedic medicine such as Rasa Shastra. It has expanded since the first publication to comprise specifications of species, providing a strong site on which to look at crystallographic and physical properties of minerals used in herbo-mineral preparations. This facilitates standardization of mineral characterization, ease of quality control and aid in the validation of Rasa Shastra assertions through detailed chemical and optical characterization of minerals to be used as medicine.

3. Key features:-

- **Extensive Mineral Documentation:** The database has a limited description of 4,714 types of the mineral, in some detail.
- **Detailed Property Profiles:** On every mineral, one can find all the information about its structure, chemical composition, physical, and optical characteristics and well-defined images.
- **Identification Applications:** The classification systems of minerals are Dana and Strunz, and the minerals are easily selected in formulas by readily readable tables.

- **Enhanced Data Associations:** All data item types (property, synonym, related mineral) are interrelated in terms of their links, and one is able to search by formula or feature.
- **Advanced Search and Tools:** It provides such sophisticated features as A-Z, or property-based searches, or interactive structure viewers via the jPOWD applet to correctly study it.
- **Research and Innovation Support:** The resource facilitates mineral identification research, comparisons and analog research. It may serve in particular the research of Rasa Shastra, which allows to increase the purification process and make the mineral-based formulation more effective.(23)

4. Significance: QC characterization.

4. WWW-MINCRYST

1. Development: The Institute of Experimental Mineralogy, Russian Academy (1996; Oct 2025 update).(24)

2. Data Sources: Structure DBs, calculated polycrystal standards

The WWW-MINCRYST database is an essential resource to both the researchers and practitioners of mineralogy. It has provided a strong platform to investigate analogues of structures of minerals utilized as a constituent of herbo-mineral preparations since its release online, that facilitates crystallographic analysis, validation of synthesis, and validation of claims using accurate structural data.(24)

3. Key Features:

- **Extensive Mineral Documentation:** It contains some of the largest mineral records that contains 2400 mineral names, 2600 species among which, one among them, quartz and feldspar, was employed in Ayurveda.
- **Detailed Structural Profiles:** Both records include a description of structural profiles to describe, crystal structures, cell parameters, atomic positions, and diffraction patterns which could potentially be utilized to learn about the minerals on lengths.
- **Therapeutic and Identification Applications:** It assists in the context of identifying minerals and it goes further to locate structural analogue, which could be key in herbo-mineral preparations.
- **Enhanced Data Associations:** It allows providing search by chemical formula, space group or volume of cells, and displaying similar minerals.

- **Advanced Crystallochemical Tools:** There are also polycrystal standards and collaborative research tools which are in the database.
- **Research and Innovation Support:** It aids research and innovation because it allows comparative studies on mineral structures with respect to incineration process and enhances bioavailability of mineral in Ayurvedic preparations.(24)

4. Significance: Bioavailability.

CHALLENGES AND LIMITATIONS

Transformative yet struggling with a broad array of issues grounded in resource failure, technological and regulatory gaps, especially between 2023-2025 with the increasing global interest in herbal therapeutics.(5) The main problem is the shortage of raw materials (medicinal plants and minerals) that have been certified according to quality standards due to the loss of biodiversity, overexploitation, and the effects of climate on the habitat; as an example, more than 20 percent of 7500 plus medicinal species in India face the threat of extinction, which makes it difficult to update databases with verified ethnobotanical information(25). Another obstacle is associated with accessibility, particularly in the rural AYUSH environment where digital disparities restrict the activities of the practitioners; survey found that less than 40 percent of non-urban clinics (poor internet and multilingual differences) use it(3). There are still gaps in pharmacovigilance data with unfinished ADMET on herbo-minerals (only a quarter of formulations have been modeled to study toxicity) increasing ADR underreporting(9).

Those problems are further exacerbated by constraints: Over-use of peer-reviewed sources gives preference to city-curated information, ignoring indigenous folk knowledge and non-English vernacular languages, and scalability also fails to support real-time updates due to the large-scale classical texts (e.g., 68,000+ slokas in APTA)(6). Without stronger IP network connectors such as TKDL, the inherent risks of biopiracy are high, and reproducibility implosion due to non-standardized metadata standards is a problem (Esber et al., 2025).

FUTURE DIRECTIONS

The future directions provide potential remediation avenues of AI/ML-powered predictive analytics, e.g. SAPPHIRE how-to-phytochemical-identification guidelines to enable automated cross-validation of 1,000(4) and more herbo-mineral interactions Blockchain integration into pharmacovigilance has the potential to secure ADR tracking and provenance of 1,000 and more herbo-mineral interactions Blockchain integration should secure the

ethical sourcing of minerals like gold.(11) International partnerships, where TKDL interconnects with the WHO databases, will increase the coverage of endangered species and unionized screening of high-throughput of Bhasmas.(12) These will be exploited through innovative formulations through network pharmacology such as immunomodulatory herbo-minerals like IMMBO to promote precision Ayurveda and SDGs of sustainable health by 2030 Hybrid AI-classical models are likely to be able to standardize 80% of formulations, promoting evidence-based global implementation.(26)

CONCLUSION

Plant and mineral databases are holding the key positions in the paradigm shift by which the ancient empirical knowledge of Ayurveda, developed in ancient texts such as Charaka Samhita and Granthas, is matched to the demands of modern science. The cataloguing (and taxonomic verification, phytochemical profiling and mapping) of over 7,000 Indian medicinal plants and the most common herbo-mineral ingredients, including mercury, gold, and iron, enables conservation of ethnobotanical heritage by overcoming erosion forces as well as providing control over standardization, such as through IMPPAT, OSADHI and the Rasashastra Portal. Adding ADMET simulations and machine learning nulls and linebreaks have transformed pharmacovigilance to reduce the risk of toxicity in Bhasmas and expedite drug discovery hundreds of new therapeutic targets to chronic conditions, for example. However, with the development of these platforms, they reinforce the idea of Ayurveda as a solution to the world in terms of metabolic disorders or antimicrobial resistance, by confirming the classical arguments with current data such as PubChem connectivity and TKDL preparancies. Its real importance is that they spur innovation by catalyzing systems level research that unravels polyherbal interactions and doshic adjustments, which increases a high degree of efficacy and safety in clinical practice. Nevertheless, the realization of this potential will require the concerted action. The stakeholders of the AYUSH including researchers, practitioners, policymakers, and industry leaders should focus on the open-access contributions to increase the volume of coverage of vernacular data, endangered species, and invest in AI-blockchain hybrids to be able to operate on a real-time scale and provide ethical IP protection. International agreements such as WHO alignment could be used to democratize access, rural-urban divisions and biopiracy. These data bases are innately not merely a locality of storage but a beginning act of active development and advancement of therapeutic technologies. Hence,they placed Ayurveda in important position medical care of the world.

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