Annexure – 1

Semi-Structured Questionnaire for
Ethnomedicinal Field Survey
Data Acquisition Questionnaire for documenting use of ethnomedicinal plants in North East India.

Part I : Detail of Informant

Name:
Sex: Male/Female Age: ............. Years
Profession:
Knowledge on Medicinal Plant: Healer/User/Research Scholar/Other
Address:
• Village:
• Sub-division:
• District:
• State:
Level of education: Training, if any:
Name of community:
Religion:
Language:
Contact No.:
How knowledge is acquired:

Part II : Informant’s Consent Agreement

I, ........................................................................................................... hereby agree to participate in this study with my full consent and conscience to disclose the details of Traditional Health Practices for documentation of medicinal plants. I declare that to the best of my knowledge, the information provided here is true, accurate and complete.

Place:
Date:

Signature/Thumb Impression

Part III : Researcher’s Declaration
The information collected will be used only for the research purpose and not in any undisclosed intention. We will not under any circumstances edit or tamper the information provided by the informant.

Signature of the Researcher
Part IV: Information on Ethnomedicinal Plant (Polyherbal Preparation)

Preparation Reference No.: 

1. Name of the Polyherbal Preparation: 
2. Name of the Disease in local language: 
3. Name of Traditional Medicine applied: 
4. Equivalent Medical Terminology (if any): 
5. Category of the patient: Men/Women/Children/All 
6. Symptoms: 

7. Diagnosis Process: 

8. Details of the Plant(s): 

<table>
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<tr>
<th>Name of the Plant in local language</th>
<th>General Description of the Plant</th>
<th>Part of the Plant Used</th>
<th>Stage of the plant part</th>
<th>Availability</th>
<th>Method of Collection</th>
<th>Ecology of the Collection Area</th>
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9. Other ingredients (if any): 

10. Mode of Preparation: 

11. Storage: 

12. Mode of Administration: 

13. Characteristics: 

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<th>Flavour:</th>
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14. Main symptoms after administration: 

15. Dosage: 

16. Advice on Diet and Regimen: 

17. Precaution on Application: 

18. Recommended for future use by the patient: 

19. Recommendation by the Healer, if any: 
Preparation Reference No. : :

1. Name of the Polyherbal Preparation : 
2. Name of the Disease in local language : 
3. Name of Traditional Medicine applied : 
4. Equivalent Medical Terminology (if any) : 
5. Category of the patient : Men/Women/Children/All
6. Symptoms : 

7. Diagnosis Process :

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19. Recommendation by the Healer, if any :
**Preparation Reference No.**

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4. Equivalent Medical Terminology (if any) : 
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6. Symptoms :

7. Diagnosis Process :

8. Details of the Plant(s) :

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11. Storage :

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13. Characteristics :

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14. Main symptoms after administration :

15. Dosage :

16. Advice on Diet and Regimen :

17. Precaution on Application :

18. Recommended for future use by the patient :

19. Recommendation by the Healer, if any :
## Part V: Information on Ethnomedicinal Plant (Monoherbal Preparation)

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<th>Language or Dialect</th>
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<th>Availability</th>
<th>Disease</th>
<th>Part of Plant</th>
<th>Stage of Plant</th>
<th>Method of Collection</th>
<th>Other Ingredients (if any)</th>
<th>Mode of Preparation</th>
<th>Storage</th>
<th>Mode of Administration</th>
<th>Dosage</th>
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Annexure – 2

Published Article

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Review

Challenges in developing medicinal plant databases for sharing ethnopharmacological knowledge

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ARTICLE INFO

Article history:
Received 4 November 2011
Received in revised form 19 February 2012
Accepted 25 February 2012
Available online 6 March 2012

Keywords:
Medicinal plant database
Ethnopharmacology
Ethnomedicine
Phytochemical information
Traditional knowledge
Minimum methodological standard

ABSTRACT

Ethnopharmacological relevance: Major research contributions in ethnopharmacology have generated vast amount of data associated with medicinal plants. Computerized databases facilitate data management and analysis making coherent information available to researchers, planners and other users. Web-based databases also facilitate knowledge transmission and feed the circle of information exchange between the ethnopharmacological studies and public audience. However, despite the development of many medicinal plant databases, a lack of uniformity is still discernible. Therefore, it calls for a common standard to achieve the common objectives of ethnopharmacology.

Aim of the study: The aim of the study is to review the diversity of approaches in storing ethnopharmacological information in databases and to provide some minimal standards for these databases.

Materials and methods: Survey for articles on medicinal plant databases was done on the Internet by using selective keywords. Grey literatures and printed materials were also searched for information. Listed resources were critically analyzed for their approaches in content type, focus area and software technology.

Results: Necessity for rapid incorporation of traditional knowledge by compiling primary data has been felt. While citation collection is common approach for information compilation, it could not fully assimilate local literatures which reflect traditional knowledge. Need for defining standards for systematic evaluation, checking quality and authenticity of the data is felt. Databases focusing on thematic areas, viz., traditional medicine system, regional aspect, disease and phytochemical information are analyzed. Issues pertaining to data standard, data linking and unique identification need to be addressed in addition to general issues like lack of update and sustainability. In the background of the present study, suggestions have been made on some minimum standards for development of medicinal plant database.

Conclusion: In spite of variations in approaches, existence of many overlapping features indicates redundancy of resources and efforts. As the development of global data in a single database may not be possible in view of the culture-specific differences, efforts can be given to specific regional areas. Existing scenario calls for collaborative approach for defining a common standard in medicinal plant database for knowledge sharing and scientific advancement.

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0378-8741/$ – see front matter © 2012 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.jep.2012.02.042
1. Introduction

From the ancient time, plants are used as an essential component of traditional medicine systems (Fang et al., 2005). Still today medicinal plants remain significant as natural alternatives to synthetic drugs (Kettner et al., 2005) with about 80% of the world population depending upon plants for their primary health care according to WHO estimation (Akerele, 1993). These past and current dependence on plants as a source for medicines gives impetus to the ethnopharmacological studies for studying their efficacy, safety and drug-discovery potentials (Karou et al., 2007). Ethnopharmacology is a multidisciplinary area of research (Etkin and Elisabetsky, 2005) concerned with the observation, description, and experimental investigation of indigenous drugs and their biological activity. The approach of stressing on the importance of plant-derived drugs (Ortega, 2006), assimilation of ethical aspects and anthropological oriented research as well as introduction of historical perspectives of indigenous knowledge systems, thereby makes this field a rich area of multidisciplinary science.

Current view on ethnopharmacology also contextualizes ecology and addresses perception of plants, their use, pharmacology and physiology in human communities (Etkin and Elisabetsky, 2005; Leonti, 2011) all of which are based on traditional medicinal plant use (Heinrich et al., 2006) and natural products. Documenting indigenous medical knowledge and scientific study of indigenous medicines and sharing this knowledge are some of the priorities for the current ethnopharmacological research (http://www.ethnopharmacology.org/ISE/journal.htm). Such efforts of intellectual discovery process require access to all sorts of information and organizing them into systematized knowledge (Chung and Wooley, 2003). Formerly, the process of sharing knowledge was helped by making corresponding journals, manuals and textbooks available in the scientific library (Boehm et al., 2010). Nowadays, application of computerized databases has supplemented new methods for information dissemination. This innovative change in scientific research method has been initiated by the application of Information Technology (Buneman, 2005) which has served a “quiet revolution of Information Technology and bioinformatics” (Risky, 2000). In view of the quantity and frequency of data generated by the combination of chemical, biological and pharmacological sciences (Reyes-Garcia, 2010), computerized database can provide efficient solution for data management. Database can also contribute towards ethnopharmacological research by facilitating the process of analysis and interpretations (Farnsworth and Louh, 1983; Heinrich et al., 2009).

It also brings information generated from diverse fields into a coherent whole (Syne and Heywood, 1988) making them available to researchers, planners and other users. Moreover, web-based databases facilitate knowledge transmission and feed the circle of information exchange between the ethnopharmacological studies and public audience (Leonti, 2011). With the growing popularity of Internet this becomes more significant also for healthcare systems (Fysenbach et al., 2002).

Nowadays, information stored in electronic medium has remarkably increased (Bhat, 1997; Thomas, 2003) with medicinal plant database emerging as one of the trends (Dighe et al., 2010). These databases compiled a wide range of information on plant characteristics, medicinal properties and bioactive compounds along with their images (Deng et al., 2010). Similar to many public, commercial and supplier databases available for natural products (Fulbeck et al., 2006), many medicinal plant databases, diverse in contents and in representations (Allais et al., 2000; Gaikwad et al., 2008; Liu and Sun, 2004; Skoczen and Bussmann, 2006; TradiMed, 2011) have been developed relating this field to information science, such as other disciplines in biology (Morgan et al., 2004).

In spite of the wide use of plants in ethnopharmacology and in modern pharmaceuticals (Farnsworth and Bingel, 1977; Rates, 2001), traditional knowledge of medicinal plant in many communities is yet to be explored. Though there is growing awareness on the role of ontology for shared conceptualizations of the traditional knowledge based systems, where these medicinal plants operate (Jang et al., 2010; Vadvu and Hooper, 2010), the vocabularies of many traditional medicine systems are yet to be standardized and integrated into the database. Consensus is yet to be made for developing database models for integrating and facilitating collaborative ethnopharmacological research (Stepp and Thomas, 2006). Because of the multidisciplinary nature of ethnopharmacology, information compiled by different workers may have diversified perspectives. Establishment of a common standard can help in integrating these subsets into a common pool. In view of this background, need for developing and maintaining a common standard for medicinal plant databases is felt for achieving the objective of representing the complex ethnopharmacological knowledge.

In this review paper, computerized databases developed for compiling ethnopharmacological information of the plants are analyzed with an attempt to address the challenges faced in developing such databases. The broad objective of this review is to gather information on state of the art on medicinal plant databases with reference to their diversity in content and approaches as well as software design so as to suggest minimum methodological standards.

2. Search strategy

An extensive search for articles on the development of databases on medicinal plants was done in the Google Scholar, PUBMED and SCIRUS. The keywords “ethnobotany”, “ethnopharmacology”,

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“ethnomedicine”, “ethnomedicinal plant”, “ethnobotanical database”, “botanical database”; “ethnopharmacological database”, “herbal database”, “traditional medicine database”; “ethnmedicinal plant database” and “database” were used independently and in combination. Literatures related with databases were also searched from the printed materials. The grey literature not listed in the above-mentioned databases was also searched using Google and Yahoo search engines. Bibliographies of the retrieved articles were also searched for additional information and other relevant references. Listed resources were rechecked and updated URLs had been incorporated.

Herbal information resources available in the web have been differentiated by Wootton (2005) into monograph series and databases that are dynamically created and updated using multiple fields. In view of the importance of the interpreted information, both types of resources were collected for this review. In the preliminary survey, 148 records were obtained. After excluding offline databases and websites no longer available, a total of 83 online information resources were listed in Table 1. Selected resources were analyzed according to content type and source, accessibility, language, country, focus area, software technology used, status of the URL, sustainability, update information and compiler information. Information from the unlisted resources was also analyzed to comprehend the challenges.

3. Diversity of databases

The diversity in development and deployment has been reflected by databases like Drug herb interaction database (Cohall et al., 2010), Traditional Medicine Collection Tracking System (Harris et al., 2011), Traditional Chinese medicine information database (Ji et al., 2006), etc. It reveals the diversity in expertise and interests of the groups that maintain them (Stein, 2003). There are several attempts to categorize biological databases including those dealt with medicinal plant following different criteria. Some of them are classification into reference centric or compound centric databases on the basis of design of the database systems (Jagapalupdi and Kishan, 2009); primary, secondary or tertiary information databases on the basis of data source (Bhat, 1997); bibliographic databases or databases combining bibliographic information with numerical and textual information (Loub et al., 1985) on the basis of content type; large-scale public repositories, community-specific database resources and project-specific databases (Rhee and Crosby, 2005) on the basis of scale of the database project, etc. In most cases the demarcating line between these categories is not clear.

In this analysis, major variations in approaches of database development have been observed in source of content, selection of focus area and software technology used. A critical assessment of the approaches adopted and challenges encountered are presented in the following sections.

3.1. Source of content

The content of the databases is derived from either traditional knowledge, scientific research or both, representing the intellectual wealth produced by research and societal investment (Shanmughavel, 2007). Documents reporting current works or reviews provide the content of the primary information databases (Bhat, 1997). Databases like International Ethnobotany database (eBDR) (Skoczen and Bussmann, 2006) and Customary Medicinal Knowledgebase (CMKB) (Gaikwad et al., 2008), Traditional Medicines in the Islands (TRAMIL) (http://www.tramil.net) fall in this category, to some extent, as they can integrate primary data by the users and researchers. On the other hand, contents of the secondary and tertiary information databases depend upon information compiled from published primary information or common knowledge. However, the two differ as secondary information databases reflect original publication (http://www.embase.com; http://www.nlm.nih.gov), while tertiary information databases may or may not indicate the source literature and may also incorporate information from unpublished sources, compiler’s comments and graphic materials (http://www.thenewtree.com; http://www.proseanet.org). There are instances of websites displaying online versions of printed books, e.g. A Modern Herbal (Owen, 2002), Botanical Dermatology Database (Schmidt, 2001), International Directory of Specialists in Herbs, Spices and Medicinal Plants (Bhat, 1997), etc.

In this review, it was observed that one of the major approaches for collecting information is bibliographic source (Bothmer et al., 1997; Liu and Sun, 2004; Roberts, 1995; Schoonbaert, 1996). Bibliographic source as the most frequently encountered category has been reported by other researchers also (Bhat, 1997; Loub et al., 1985). Databases specified on related areas also serve as important resource for ethnopharmacological knowledge, e.g. Agricultural Online Access (http://agricola.nal.usda.gov/), International Information System for Agricultural Sciences and Technology (http://agris.fao.org/), Allied and Complementary Medicine Database (http://www.bi.uk/services/stb/amed.html), Chemical Abstracts Service (http://www.cas.org), etc. Bibliographic resource is usually the preferred source for reaffirming the properties of the medicinal plants before any analytical works. Although large numbers of collection are there in such databases, the content remains still inadequate. It is because they represent a regressive view which can only be updated by regular revision (Kettner et al., 2005). Literatures from local or regional publications, etc. highlight the immense contribution to conserving traditional knowledge, could not be fully assimilated in many of the global level bibliographic databases. There had been some attempts to retrieve information on medicinal plants from regional publications and non-indexed journals (Manha et al., 2008; Soetjipto and Rosario, 2003).

In addition to bibliographic databases, the necessity for primary source from users and healers is felt for compiling information on traditional knowledge. It is because practice of traditional knowledge is usually encountered in remote areas rich in biodiversity but poor in modern scientific amenities (Edwards and Heinrich, 2006). The necessity is also compounded when certain lab-based biomedical researchers tried to obtain data from secondary sources thereby raising the chance of distortion of the original information from primary source (Andrade-Cetto and Heinrich, 2011). As the traditional knowledge system contained within a particular culture is changing under the impact of globalization and urbanization, the situation calls for rapid incorporation of available knowledge in addition to articles from peer-reviewed journals or findings from lab-based research. Approaches in this line have been noticed in development of Native American Ethnobotany Database (Moerman, 1998) through systematic exploration of scientific literature, ethnographic accounts and historical documents. Similarly, Historical Estonian Herbal Medical Database (Hiirola and Kukk 2000) and Eesti Rahvamedititsiini Botaniikline Andmebaas) came into existence by digitizing handwritten pages of folklore that include local plant knowledge and plant lore (Sõukand et al., 2010).

Collection and incorporation of primary data demand rigorous methodologies for systematic evaluation, checking quality and authenticity of the data. Secondary and tertiary information, also, are not free from the problem of data quality. Occurrence of unreliable data and questionable research methodology without detailed reference (Thomas, 2003) make some online resources unsuitable for sound scientific research. For instance, presence of
### Table 1
List of the online databases providing information on medicinal plants.

<table>
<thead>
<tr>
<th>Name of the database</th>
<th>Compiler</th>
<th>Country</th>
<th>Language</th>
<th>Website</th>
<th>Year of launch</th>
<th>Comments</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADONIS</td>
<td>Group of European Publisher</td>
<td>UK</td>
<td>English</td>
<td></td>
<td>1992</td>
<td>Organized into two datasets—NAL Public Online Access Catalog and Article Citation Database; does not contain the text of articles cited; URL changed; provides information on agriculture and related fields. Records from 1975; contains citations from scientific journals; URL changed; efforts are given for better interlinked information collection and services</td>
<td>Botheuer et al. (1997)</td>
</tr>
<tr>
<td>AMED (Allied and Complementary Medicine Database)</td>
<td>Health Care Information Service, British Library</td>
<td>UK</td>
<td>English</td>
<td><a href="http://www.bl.uk/services/sth/amed.html">http://www.bl.uk/services/sth/amed.html</a></td>
<td>1985</td>
<td>Bibliographic database of complementary medicine; URL changed; subscription based. Project began from 1974; covers all aspects of northern Canada including life-science; emphasizes on grey literature; however could not cover all publications on northern Canada. Downloadeable</td>
<td>Roberts (1995)</td>
</tr>
<tr>
<td><strong>BiGCI—Plants for the Planet</strong></td>
<td>Botanic Gardens Conservation International</td>
<td>UK/International</td>
<td>English, Spanish, Japanese</td>
<td><a href="http://www.bgc.org">http://www.bgc.org</a></td>
<td>1987</td>
<td>Documented plants in cultivation in botanic gardens including 12,000 threatened plants; linked with other resources.</td>
<td></td>
</tr>
<tr>
<td><strong>Biosis Previews</strong></td>
<td>Thomson Reuters</td>
<td>USA</td>
<td>English</td>
<td><a href="http://thomsonreuters.com/products/services/science/science_products_sciencescope/biosis/">http://thomsonreuters.com/products/services/science/science_products_sciencescope/biosis/</a></td>
<td>1926</td>
<td>Now part of Thomson Reuters; information on published literatures and non-journal coverage including reports, reviews, meetings, etc.; updated weekly. Online version of the book—Botanical Dermatology. URL changed; updated frequently.</td>
<td></td>
</tr>
<tr>
<td><strong>CAB Direct</strong></td>
<td>CAB International</td>
<td>UK</td>
<td>English</td>
<td><a href="http://www.cabi.org">www.cabi.org</a></td>
<td>2003</td>
<td>Computerized since 1973; runs online in 2003; bibliographic records with news articles, reports; covers CAB Abstract and CAB global health.</td>
<td></td>
</tr>
<tr>
<td><strong>Chemical Abstracts Service</strong></td>
<td>American Chemical Society, Columbus</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.cas.org">www.cas.org</a></td>
<td>NA</td>
<td>Chemical information; also contains biochemical information. Information for different disciplines; also includes medicinal plant information.</td>
<td></td>
</tr>
<tr>
<td><strong>China National Knowledge Infrastructure Database</strong></td>
<td>Tsinghua University</td>
<td>China</td>
<td>English, Russian, German, Chinese</td>
<td><a href="http://www.cnki.net">http://www.cnki.net</a></td>
<td>1988</td>
<td>Chemical information; also contains biochemical information. Information for different disciplines; also includes medicinal plant information.</td>
<td></td>
</tr>
<tr>
<td><strong>CHMS-C</strong></td>
<td>University of Michigan</td>
<td>USA</td>
<td>English</td>
<td><a href="http://jsw16im.med.umich.edu/chms-c/">http://jsw16im.med.umich.edu/chms-c/</a></td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CIEER</strong></td>
<td>Centre for International Ethnomedicinal Education and Research</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.cieer.org">http://www.cieer.org</a></td>
<td>NA</td>
<td></td>
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<tr>
<td>Name of the database</td>
<td>Compiler</td>
<td>Country</td>
<td>Language</td>
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<td>Comments</td>
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<tr>
<td>Cochrane Library</td>
<td>Cochrane Collaboration</td>
<td>International</td>
<td>English</td>
<td><a href="http://www.cochranelibrary.com">http://www.cochranelibrary.com</a></td>
<td>1996</td>
<td>Collection of databases in medicine and other healthcare specialties; originally published by Update Software, now part of Wiley Online System; subscription-based, pay/try-free.</td>
<td>Chalmers (1993);</td>
</tr>
<tr>
<td>CMB (Customary Medicinal Knowledge Base)</td>
<td>Macquarie University</td>
<td>Australia</td>
<td>English</td>
<td><a href="http://biolinfo.org/cmb/index.php">http://biolinfo.org/cmb/index.php</a></td>
<td>NA</td>
<td>Online relational database; focuses on customary medicinal plants; linked to other online resources; contains disclaimers. Emphasizes on medicinal aspect; began as a flat html text website; now reorganized into structured database; contact required for data accessibility.</td>
<td>Galkowd et al. (2008);</td>
</tr>
<tr>
<td>Datadiwan</td>
<td>Bernhard Harzer Wissentransfer</td>
<td>Germany</td>
<td>English, German</td>
<td><a href="http://www.datadiwan.de/index_e.htm">www.datadiwan.de/index_e.htm</a></td>
<td>1995</td>
<td></td>
<td>Allais et al. (2000);</td>
</tr>
<tr>
<td>Dr. Duke’s Rhythmical and Ethnobotanical Database</td>
<td>Dr. Jim Duke</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.as-grinev/duke/">http://www.as-grinev/duke/</a></td>
<td>NA</td>
<td>Phytochemical information; new website at <a href="http://www.greenpharmacy.com">www.greenpharmacy.com</a>; old website still exists; data gathered from the literature.</td>
<td>Duke (2011);</td>
</tr>
<tr>
<td>Dr. G. Madaus Medicinal Plant Database</td>
<td>Dr. G. Madaus</td>
<td>Germany</td>
<td>English, German</td>
<td><a href="http://www.madaus.de/Plants-Database-82.0.html">http://www.madaus.de/Plants-Database-82.0.html</a></td>
<td>NA</td>
<td>Contains information collected from 1938; updated regularly. Replaces three separate web resources.</td>
<td></td>
</tr>
<tr>
<td>EBBD (Economic Botany Bibliographic Database)</td>
<td>Centre for Economic Botany, Royal Botanic Gardens, Kew</td>
<td>UK</td>
<td>English</td>
<td><a href="http://kbd.kew.org/kbd/searchpage.do">http://kbd.kew.org/kbd/searchpage.do</a></td>
<td>NA</td>
<td>Multilingual; ethnographic information; covers Ecuador, Peru, Kenya and Hawaii; location information; non-commercial.</td>
<td></td>
</tr>
<tr>
<td>eBBD (International Ethnobotany Database)</td>
<td>Foundation for Open Ethnobotanical Research</td>
<td>USA</td>
<td>English</td>
<td><a href="http://ebbd.org">http://ebbd.org</a></td>
<td>NA</td>
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<td>Database</td>
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<tr>
<td>ETHMED</td>
<td>Based on traditional medicine; URL changed; now under the supervision of the Institute of Natural Medicine.</td>
<td><a href="http://ethmed.u-toyama.ac.jp/search,Eng/">http://ethmed.u-toyama.ac.jp/search,Eng/</a></td>
<td></td>
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<tr>
<td>Ethnobotany of the Peruvian Amazon</td>
<td>Flat text; information on medicinal and useful plants in the Amazonian region of Peru; with bibliographic inputs.</td>
<td><a href="http://www.biopark.org/Plants-Amazon.html">http://www.biopark.org/Plants-Amazon.html</a></td>
<td></td>
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<tr>
<td>Ethnomedicinals for Research and Development EXTRACT Database</td>
<td>Background information not available.</td>
<td><a href="http://www.ethnomedicinals.com">http://www.ethnomedicinals.com</a></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Fomocicins Base de Dates</td>
<td>Focusses on medicinal plants and phytomedicines in Latin America; subscription based; Advocate of data standard provides information publishing, integrating and using data.</td>
<td><a href="http://www.plantasmedicinales.org">http://www.plantasmedicinales.org</a></td>
<td></td>
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<tr>
<td>GBIF (Global Biodiversity Information Facility)</td>
<td>Advocate of data standard provides information publishing, integrating and using data.</td>
<td><a href="http://www.gbif.org">http://www.gbif.org</a></td>
<td></td>
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<tr>
<td>Database</td>
<td>Adminstrator/Institution</td>
<td>Country</td>
<td>Language(s)</td>
<td>Website</td>
<td>Notes</td>
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<tr>
<td>Medicinal and Poisonous Plant Database</td>
<td>Michael C. Tims</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.biologie.uni-hamburg.de/b-online/ltc99/poison">http://www.biologie.uni-hamburg.de/b-online/ltc99/poison</a></td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEDPHYT</td>
<td>Institute of Pharmacy Sciences for Medicinal Plants</td>
<td>Austria, Germany</td>
<td>English, German</td>
<td><a href="http://www-it.boku-uni-berlin.de/medphyt/">http://www-it.boku-uni-berlin.de/medphyt/</a></td>
<td>2003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPBD (Medicinal Plants Database of Bangladesh)</td>
<td>Dr. Naikib Dohil (Bokheer)</td>
<td>Bangladesh</td>
<td>English</td>
<td><a href="http://www.mpbd.info">www.mpbd.info</a></td>
<td>NA</td>
<td></td>
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<tr>
<td>MMPD (Myanmar Medicinal Plant Database)</td>
<td>Tun Institute of Medical Learning</td>
<td>Myanmar</td>
<td>English</td>
<td><a href="http://www.tinninst.net">www.tinninst.net</a></td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAPRAERT (Natural Product Alert)</td>
<td>Department of Medicinal Chemistry and Pharmacognosy, University of Illinois, Chicago</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.napralert.org">www.napralert.org</a></td>
<td>1975</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native American Ethnobotany Database</td>
<td>Museum of Anthropology, University of Michigan</td>
<td>USA</td>
<td>English</td>
<td><a href="http://herb.umich.edu/">http://herb.umich.edu/</a></td>
<td>1977</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Medicines Comprehensive Database</td>
<td>Therapeutic Research Faculty</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.naturaldatabase.com">www.naturaldatabase.com</a></td>
<td>1999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern Ontario Plant Database</td>
<td>Algoma University College</td>
<td>Canada</td>
<td>English</td>
<td><a href="http://www.northernontarioflora.ca">www.northernontarioflora.ca</a></td>
<td>2002</td>
<td></td>
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<td>Name of the database</td>
<td>Compiler</td>
<td>Country</td>
<td>Language</td>
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<tr>
<td>PAM (Plantas Aromáticas e Medicinais)</td>
<td>Universidade de Trás-os-Montes e Alto Douro</td>
<td>Portugal</td>
<td>Portuguese</td>
<td><a href="http://www.infoherbs.com/frontend.html">http://www.infoherbs.com/frontend.html</a></td>
<td>NA</td>
<td>Searchable by plant name; uses medicinal properties and active compounds.</td>
<td>WIPO (2011)</td>
</tr>
<tr>
<td>PFAE (Plants For A Future)</td>
<td>Plants For A Future</td>
<td>UK</td>
<td>English</td>
<td><a href="http://www.pfae.org/user/default.aspx">http://www.pfae.org/user/default.aspx</a></td>
<td>NA</td>
<td>Online free; download fee based; regional focus on edible and useful plants of temperate regions.</td>
<td>WIPO (2011)</td>
</tr>
<tr>
<td>PHARMEL</td>
<td>Université Libre de Bruxelles</td>
<td>Belgium</td>
<td>French</td>
<td><a href="http://www.ub.ac.be/sciences/bot/Pharmel.htm">http://www.ub.ac.be/sciences/bot/Pharmel.htm</a></td>
<td>1994</td>
<td>Subscription based; emphasized on phytochemicals; targeting the herbalists for relevant information;</td>
<td>Lejoly (1995)</td>
</tr>
<tr>
<td>Phytotherapies</td>
<td>Herborist Corporation, Australia</td>
<td>Australia</td>
<td>English</td>
<td><a href="http://www.phytotherapies.org">www.phytotherapies.org</a></td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant-antivenom</td>
<td>Universidade de São Paulo—Faculdade de Medicina de Ribeirão Preto—Departamento de Genética</td>
<td></td>
<td></td>
<td><a href="http://phi.fmr.pus.pbb/plantantivenom">http://phi.fmr.pus.pbb/plantantivenom</a></td>
<td>NA</td>
<td>Disease-specific; information from scientific literatures; features amino acid sequence;</td>
<td>Amui et al. (2011)</td>
</tr>
<tr>
<td>PLANTS Database</td>
<td>United States Department of Agriculture</td>
<td>USA</td>
<td>English</td>
<td><a href="http://plants.usda.gov/java/">http://plants.usda.gov/java/</a></td>
<td>NA</td>
<td>Advanced search with boolean logic; new feature compatible with Geographic Information System; information confined to US and its territories.</td>
<td>WIPO (2011)</td>
</tr>
<tr>
<td>PRELUDE</td>
<td>Catholic University of Louvain</td>
<td>Belgium</td>
<td>English, French</td>
<td><a href="http://www.metafor.be/prelude">http://www.metafor.be/prelude</a></td>
<td>1996</td>
<td>Plants used in traditional veterinary and human medicines in Africa; data collected from scientific literatures including grey literatures or directly by the Prelude Sub-Network.</td>
<td></td>
</tr>
<tr>
<td>PROSEA (Plant Resources of South East Asia)</td>
<td>PROSEA Network</td>
<td>Indonesia, Netherlands,</td>
<td>English</td>
<td><a href="http://www.proseanet.org">www.proseanet.org</a></td>
<td>1991</td>
<td>Regional focus on South East Asia; URL changed; data from published literature, photo and compilation by experts; online version through E-Prosea.</td>
<td>Danimihardja (1995)</td>
</tr>
<tr>
<td>Database Name</td>
<td>Location</td>
<td>Language(s)</td>
<td>Website</td>
<td>Year</td>
<td>Description</td>
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<tr>
<td>PROTA Databank</td>
<td>International</td>
<td>English</td>
<td><a href="http://www.prota.org.uk/">http://www.prota.org.uk/</a></td>
<td>2000</td>
<td>Regional focus; primary data of priority species; secondary data from literatures; bilingual features; current phase involves changing static webpages to interactive ones.</td>
<td></td>
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</tr>
<tr>
<td>Rainforest Tropical Plant Database</td>
<td>USA</td>
<td>English, French, German, Italian, Norwegian, Portuguese, Spanish</td>
<td><a href="http://www.rain-tee.com">http://www.rain-tee.com</a></td>
<td>1996</td>
<td>Focus on Amazon rainforest; information from independent sources and publications; HTML based; include disclaimers; last updated in 2010. Provides information wild and semidomesticated tropical and subtropical plants; target species for germplasm collection and storage for research, biodiversity conservation and utilization; remote data entry facility through Global Editing software; Though project was initiated in 1981, PC version of database began in 1990s. URL changed; includes downloadable software with feature of e-content.</td>
<td>WIPO (2011)</td>
<td></td>
</tr>
<tr>
<td>SEPASAL (Survey of Economic Plants for Arid and Semi-Arid Lands)</td>
<td>UK</td>
<td>English</td>
<td><a href="http://www.kew.org/cebjepasal">www.kew.org/cebjepasal</a></td>
<td>1990s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCM Herb Database</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.rmhherbal.org/ai/pharmmo.html">www.rmhherbal.org/ai/pharmmo.html</a></td>
<td>NA</td>
<td></td>
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<td>Name of the database</td>
<td>Compiler</td>
<td>Country</td>
<td>Language</td>
<td>Website</td>
<td>Year of launch</td>
<td>Comments</td>
<td>Citation</td>
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<tr>
<td>TCMP (Taiwan’s Compendium on Medicinal Plants)</td>
<td>Department of Industrial Technology, Ministry of Economic Affairs, Taiwan</td>
<td>Taiwan</td>
<td>English</td>
<td><a href="http://www.icmp.com.tw/index.asp">http://www.icmp.com.tw/index.asp</a></td>
<td>2005†</td>
<td>Both subscription and open access to limited information; focuses on Chinese herbal medicine; Based on Chinese and Korean traditional medicine; information on prescription, chemistry and image of medicinal plants; subscription based; free preview for selected plants; now under company TradiMed Inc.</td>
<td>Chang (2001)</td>
</tr>
<tr>
<td>Traditional Medicinal Plants of Samoa</td>
<td>Centre for International Ethnomedical Education and Research</td>
<td>Germany</td>
<td>English, German</td>
<td><a href="http://www.dittmar.dusnet.de/english/ESamoan.html">www.dittmar.dusnet.de/english/ESamoan.html</a></td>
<td>NA</td>
<td>Regional focus; information provided by Samoan healers; plants without known scientific names are also included; HTML with search script; vernacular name included.</td>
<td>WIPO (2011)</td>
</tr>
<tr>
<td>TRAMED (South African Traditional Medicines Database)</td>
<td>University of Cape Town</td>
<td>South Africa</td>
<td>English</td>
<td><a href="http://www.mrc.ac.za/Tramed3/">http://www.mrc.ac.za/Tramed3/</a></td>
<td>NA</td>
<td>URL changed; regional focus on Africa; contains disclaimers; capability of boolean search; Primary data through participatory ethnopharmacological survey: qualitative and quantitative approach; voucher specimen collection; regional focus on medicinal plants of Caribbean.</td>
<td>Sharma et al. (2011)</td>
</tr>
<tr>
<td>TRAMIL (Traditional Medicines in the Islands)</td>
<td>TRAMIL Network</td>
<td>Latin America, Caribbean</td>
<td>English, French, Spanish</td>
<td><a href="http://www.tramil.net/">http://www.tramil.net/</a></td>
<td>1984</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA–Iowa State Database of the Isoflavone Content of Foods</td>
<td>U.S. Department of Agriculture, Agricultural Research Service</td>
<td>USA</td>
<td>English</td>
<td><a href="http://www.nal.usda.gov/fsic/foodcomp/Data/Isoflav/isoflav.html">http://www.nal.usda.gov/fsic/foodcomp/Data/Isoflav/isoflav.html</a></td>
<td></td>
<td>Database downloadable as ZIP file; phytochemical database; primary data from laboratory analysis; secondary data from refereed journal; updated periodically; open access.</td>
<td></td>
</tr>
</tbody>
</table>

URL—uniform resource locator, NA—not available.  
† Year of copyright.
incomplete, incorrect and irregular data was reported in the data source of Chinese Materiam Medica (Lin et al., 2008). Such situations demand authentication for standardization of Chinese medicines (Zhao et al., 2006).

Website providing information on quality evaluation is very limited. The CAM on PubMed (http://ncam.nih.gov/research/camnpubmed) shows compliance with evaluation standard of the Health on the Net Foundation (HON, 2011). Selection of credible herbal Internet sites had been done by Owen (2002) using criteria consisting of source, accuracy, referenced information, content, currency, depth, uniqueness, bias, design, audience, stability, reputation and interactivity of the database. The World Health Organization (WHO) has also provided efforts for defining the minimum standards for evaluations that can be achieved by information-gathering on efficacy and safety, observational studies, standard clinical and sharing of the information with traditional healers and other stakeholders (Homsy et al., 2004). More efforts can be given for development of standard criteria for evaluation and their applications.

Since the emergence of the Internet as powerful medium for health communication (Casel et al., 1998; Eysenbach et al., 2002), there is a chance of applying online information as a guide for personal healthcare. As such, segregation of ethnomedicinal information without proper validation from medical prescription has become more than an ethical issue. Posting Disclaimers stating that the data should not be seen as medical tool but intended only for exchange of scientific views is a means to overcome the problem. This mechanism has been applied in few databases such as FDA Poisonous Plant Database (FDAPPD, 2011), Customary Medicinal Knowledge Base (Gaikwad et al., 2008), Rainforest Tropical Plant Database (http://www.rain-tree.com).

Herbal treatment may be associated with some adverse reactions (Elvin-Lewis, 2001) that may arise from various factors such as toxic constituents (Calixto, 2000), dose (De Smet, 1995), age (Ernst, 1999), drug-use etc. In view of the scope of the problem and to bring the issue forward to public, proposals for conducting herbal surveillance service (De Smet, 1995) are there. Such efforts can be fully achieved by collaborative works of health-care officials, pharmacologists, industry and other stakeholders (Winslow and Kroll, 1998). Cross linking or integrating information elicited from Internet resources like the National Centre for Complementary and Alternative Medicine (http://ncam.nih.gov/), American Botanical Council (http://www.herbalgram.org), US Food and Drug Administration (http://www.fda.gov), US Pharmacopeia (http://www.usp.org) (Elvin-Lewis, 2001; Murphy, 1999) could contribute immensely in such endeavour.

3.2 Thematic databases

Many databases were found to be providing attention to specialized content. In this section, databases focused on specialized area such as traditional medicine system, regional aspect, disease-specific and phytochemical information are analyzed. Specialized databases have some advantages as compared to comprehensive approaches. One of the comprehensive approaches as suggested by a meeting convened by UNIDO recommended that medicinal plant databases should contain information such as botanical aspects, ethnopharmacological aspects, chemical aspects, agrotechnological aspects, chemotaxonomic aspects, market aspects and other relevant aspects (Syne and Heywood, 1988). Except in public-funded large database project, such comprehensive approaches have limitations (Syne and Heywood, 1988), because data collection from a wide geographical area and different disciplines in a single database is impractical (Gaikwad et al., 2011) with the chance of inconsistencies and compromises (Stein, 2003). Many of the existing independent databases, thus developed, are variable in their content and quality with regional or cultural focus (Thomas, 2003). In the following sub-sections, databases differing in thematic content are assessed.

3.2.1 Databases on traditional medicine system

Many drugs have entered the international pharmacopoeia through the study of ethnopharmacology and traditional medicine (Patwardhan, 2009). Importance of plants in traditional medicine is reflected in Ayurveda and other indigenous medicines in Asia with a record of about 1800 plant species (Kumar and Gupta, 2004). Likewise, the Chinese Materiam Medica also has described many prescriptions, with the first record dating from about 1100 BC followed by works such as the Shennong Herbal and the Tang Herbal (Newman et al., 2000). Thus, databases targeting traditional medicine system provide a good chance for storing and archiving information on medicinal plant. Examples can be cited from the database on Oriental Medicine derived from the knowledge of TCM (TradiMed, 2011), Traditional Medicine in the Island database (TRAMIL, 2011), CMbK (Gaikwad et al., 2008) and many others.

Medicinal plant databases based on traditional knowledge system have various objectives like archiving of traditional knowledge (Gonzalez-Tejero et al., 2008; Upadhye et al., 2010), application of herbal knowledge for screening (Ye et al., 2010) and protection of intellectual property rights (Liu and Sun, 2004; Upadhye et al., 2010). Codified and non-codified knowledge on traditional medicinal systems (WHO, 2002) disappeared with the experts and could not be carried forward from generation to generation (Anami et al., 2008). Gradual loss of indigenous knowledge of medicinal plants from demographic changes (McCarthy, 1992) demands urgent need to preserve the existing traditional medicine (Upadhye et al., 2010). Development of medicinal plant database, apart from other methods, serves as a tool for archiving traditional knowledge on medicinal plants (Gonzalez-Tejero et al., 2008). When the databases are based on a specific cultural context, they can contribute towards conserving traditional knowledge and also serve as medium for complementing transmission of the knowledge (Edwards and Heinrich, 2006; Leonti, 2011).

Providing information on traditional knowledge through databases is one of the approaches for protection of traditional knowledge. Databases like Traditional Knowledge Digital Library (TKDL) of India (Das et al., 2007) and the China TCM Patent Database (Liu and Sun, 2004) act as a bridge between the traditional knowledge of the respective countries and the patent examiners at the International Patent Offices. EthnoMedicinal Plants of Western Ghats (EMPWG) database project in India safeguards the claims of the local community on Intellectual Property Right issues (Upadhye et al., 2010). From these aspects, databases storing traditional knowledge are seen as medium for legal protection. However, archiving of medicinal information needs to be looked beyond the legal framework as the prime objective of such databases is to put traditional knowledge in the service of humanity. Databases on traditional knowledge therefore, should be the medium for hybridization of scientific and indigenous knowledge (Edwards and Heinrich, 2006) for sustainable use of bioresources.

Medicinal efficacies of biological organisms and minerals are well understood if studied within broad domain of cultural knowledge of the community or group concerned (Reyes-Garcia, 2010). Databases, also, should have the capability to represent ethnographic information and associated traditional knowledge. Attempts in this aspect have been observed in databases like eBBD (Skoczen and Bussmann, 2006) and MEDFLOR (Beecher and Gyllenhaal, 1993). At the same time, segregation of valid practices and remedies from ineffective and unsafe practices (Akerel, 1984) is also necessary. As the traditional medicine system has two universal categories of disease aetiology namely natural and unnatural (supernatural) causes (Williams, 2006), magico-religious
practices remain part and parcel of practice in many of these systems. Whether these aspects of traditional knowledge should be incorporated, distilled or rejected depends on the nature of the study. From the perspective of the social sciences, these practices represent a significant component of the culture of the society. Some scholars have advocated inclusion of spiritual healing for HIV/AIDS prevention initiative by defining it as entirely distinct from witchcraft, however, based on certain criteria, such as, the acceptable ethnomedicinal community, absence of negative social or physical connotations (Hosny et al., 2004). If the objective of a particular project is inclined more towards the drug discovery, emphasis may be given on plants having psychoactive drug inducing properties.

3.2.2. Regional level databases

In this category, information of the databases has been exclusively based on traditional usage confined to a particular geographical area, though the information can be accessed globally. Several attempts have been made to develop information systems for collecting and managing ethnomedicinal plant knowledge at different geographical areas (Babac, 2004; Manha et al., 2008; Natale et al., 2009).

In the Asian countries where traditional medicinal systems with rich legacy of plant medicines (Dighe et al., 2010), many national level database such as Medicinal Plants Database of Bangladesh (MPDB, 2011), Myanmar Medicinal Plant Database (MMPDB, 2011), Medicinal and Aromatic Plants Database of Nepal (http://www.forestryrnepal.org/website/), databases of Foundation for Revitalisation of Local Health Tradition (FRHIT) in India etc. have compiled widely dispersed data along with their vernacular names and associated literature. Regional Networks such as the Asian Pacific Information Network on Medicinal and Aromatic Plants (APIMP) (Dayao, 1995; McCarthy, 1992) and the Plant Resources of South East Asia (PROSEA) Foundation (Soetjipto and Rosario, 2003) have contributed to the sharing of medicinal plant data. In other regions, efforts like the Database for North African Medicinal and Aromatic Plant (http://data.ucn.org/places/medoffice/nabp/database/NA_Piant.htm), MEDUSA (Skoula et al., 2003), Rubia Project (Pieroni et al., 2006) etc. have contributed to the collection and dissemination of traditional knowledge.

Selection of plants for medicinal usage by the indigenous population followed their own criteria as culturally specific plants in one community may not be significant in another (Edwards and Heinrich, 2006). Apart from tendency to use native and perennial resources (Alburquerque, 2010), indigenous people also incorporate many exotic and weeds (Stepp and Moerman, 2001) in their traditional medicinal systems. Locally developed databases based on a country or a district’s need (Deng et al., 2010) have greater advantage in compiling the local and culture-specific knowledge systems and the newly introduced medicinal plants through field-based studies.

From the perspective of scientific knowledge sharing, sharing of information in regional database is of utmost importance (Heinrich et al., 2009). It can be achieved by aggregating the data at different levels by employing standard meta-data, appropriate protocol and technology. A conceptualized framework for developing and sharing local data with the global database repository is depicted here (Fig. 1).

Lack of unified system for recording ethnopharmacological data in regional databases is discernible. Many of regional databases exist as stand-alone applications (Bhattacharyya et al., 2006; Upadhyaya et al., 2010) following their own customized technical standard. Content of many of these databases could not be accessible on the Internet, e.g., AFlora (Ichiikawa et al., 2001), Indian Medicinal Plants National Network of Distributed Databases (Chander, 1995; Geevan, 1995), Medicinal Plants of Malta (Bhat, 1997), Plants for Life Database (Gachathi, 1995), etc. Linguistic barrier in the regional database also restricts sharing of information with the large scientific community. For instance, dominance of Chinese language in most of the medicinal plant databases developed in China (Deng et al., 2010) hinders information sharing at global level. For making data interoperability and sharing of information with large scientific community, development of regional database needs to adhere to common unified standard as discussed in the later sections.

3.2.3. Disease-specific databases

In the last few years, some of the medicinal plant databases are found to be dedicated only to a particular disease (Jarayaman, 2000). In this review, many disease-specific databases are observed. Databases for storing medicinal plant information used in asthma (Kasirajan et al., 2007), in diabetes (Arulrajan et al., 2007; Babu et al., 2006; Middha et al., 2009; Singh et al., 2009), in cancer (AAMD, 2011; Fang et al., 2005; Vetriev et al., 2009), in anti-arthritis plants ( Siddiqui et al., 2011) are some of the examples.

Approaches for targeting a particular disease thrived as a convenient means for study of recipes, ingredients and individual compounds. However, approach of prioritization of the most effective species through quantitative methods is yet to be applied in many of the databases observed even though this approach has become an emerging trend in ethnobotany (Hoft et al., 1999). Though descriptive listing also finds its relevance in recording traditional knowledge (Verpoorte, 2008), quantification methods such as disease-consensus index (Andrade-Cetto et al., 2006) are equally important for studying the nature of information collection and analysis for disease-specific studies. Mere listing of plants used in a particular disease is not a sufficient way for selecting potentially effective plants, because indigenous people may use plants in remedies according to their beliefs other than biochemical activity (McClutchey et al., 2009; Williams, 2006). Therefore, expected potential of the disease-specific databases include providing sufficient ethnopharmacological knowledge for searching clues to bioactivity from the traditional medicine.

For classification of disease, ethnopharmacological databases need to look beyond the disease aetiology of the western medicine system. The International Classification of Diseases (ICD) of the WHO, which is globally recognized standard for generating statistics on morbidity (Heinrich et al., 2009), has the potential for applicability in ethnopharmacological databases. However, inconsistencies are observed between ICD and traditional medicine system as knowledge between these two systems differ (Jang et al., 2010). While the modern western medicine attempts to identify the individual factors contributing to illness, the TCM views disease as the result of abnormal interactions or imbalances in human systems (Lukman et al., 2007). In Ayurveda, harmonious state of three doshas (forces) creates balance and health, while an imbalance manifests as a sign or symptom of a disease (Patwardhan et al., 2005). In spite of these different viewpoints, symptoms are practically identical in both the medicine systems from the perspectives of patient. By selecting such common feature, different medicine systems can be interlinked through development of ontology (Jang et al., 2010). An initiative has been set to bridge the traditional medicine and modern pharmaceutical research by using open linked data for depressive disorders (Samwald et al., 2010).

3.2.4. Phytochemical databases

Some of the databases under review are observed to focus on the phytochemical information of the medicinal plants, e.g., database on pharmacophore analysis of active principles from medicinal plants (Pitchai et al., 2010), the Indian Medicinal Plants Protein Dataset (IMPPDS) (Anandakumar et al., 2008) and herbal
constituents and bioactive plant compounds with known target specificities (Ehrman et al., 2007a, etc.

Effectiveness of a herbal medicine may be attributed to one or a few bioactive compounds or synergistic effects of all of its constituents (Ehrman et al., 2007b). It has been argued that lack of these phytochemical information has prevented wide acceptance of medicinal plants (Fang et al., 2005). Databases providing phytochemical information are acting as the medium for filling these lacunae. However, despite presence of lot of interest in pharmaceutical databases (Horace, 1985), many of them are found providing very basic information on medicinal plants and tend to focus on drug discovery (Kettner et al., 2005).

A commendable work on phytochemical database is observed in Dr. Duke’s database (Duke, 2011). The main feature of this database is the compilation of the chemical information of the plants along with bibliographic records. However, Dr. Duke’s database has limited support for a variety of ethnobotanical data (Skoczen and Busmann, 2006) and could not encompass all the phytochemical data in spite of its global perspective.

Problems of trivial names for biochemical compounds are not free in biological databases also. These problems are encountered when comparing biochemical data from different sources or automatically parsing chemical compound names (Aguilar et al., 2003). Inconsistencies can be minimized by checking the
IUPAC names with resources like Dictionary of Natural Products (http://dnp.chemnetbase.com) or other resources along with the CAS Registry Number.

Plants of the same species collected from different locations are known to possess different chemical compositions. Traditional healers also put geographical location as important criterion for efficacy of the medicinal plant. Tibetan healers believed that presence of bioactive compounds differ according to altitude (Liu et al., 2009). Traditional healers in Nigeria prefer the mistletoe growing on cocoa tree for treatment of hypertension as opposed to the same plant growing on oil palm or any other tree (Mafimisebi and Oguntade, 2010). Such ‘apparently insignificant’ information is very critical from the point of ethnopharmacology. Moreover, approaches like incorporating datasets about structure, nomenclature, compound class, chirality, pharmacology, targets, traditional medicine categories, botanical name along with vernacular name etc. (Ehrman et al., 2007a) could contribute immensely in our understanding of herbal medicine.

Genetic and genomics information of the concerned species also have the potentiality for utilization in developing medicinal plant databases (Deng et al., 2010), e.g. the Medicinal Materials DNA Barcode Database (MMDRD) incorporating the DNA sequences of medicinal plants (Lou et al., 2010) and Plant Antivirnom database incorporating amino acid sequences of the compound (Amul et al., 2011). Integration of sequence data into the database for proper identification of the medicinal plant is a feature that needs to be stimulated having a lot of potential.

4. Design of DBMS

Online resources on medicinal plants are found to be represented either as (a) flat HTML texts, e.g. A Modern Herbal (Owen, 2002), Botanical Dermatology Database (Schmidt, 2001), (b) downloadable databases, e.g. Boeins Aroma Chemical Information Service (http://leffingwell.com/bacis/bacispdf.html), TCM Herb Database (http://www.rnhiherbal.org/ai/phantintro.html), (c) relational databases, e.g. CMDB (Gaikwad et al., 2008), MEDPyr (Kettner et al., 2005) and NAPRALERT (Cyllenhaal et al., 1993), or (d) object-oriented databases (Thomas et al., 2001). Databases specially designed for mobile computing environment are also there (Clausen et al., 2008; Reynolds and Strayer, 2005). Wide ranging variation of online resources from simple file directories to object-oriented database software (Rhee et al., 2006; Thomas et al., 2001) indicates lack of benchmark database available for researchers or practitioners in medicinal plant (Anami et al., 2008).

Issues pertaining to general bioinformatics community in designing databases also exist in designing information system for medicinal plants. One of the problems in computer-aided biology is difficulty in communication between life scientists and computer scientists (Lacroix, 2003). Most of the papers on databases describe the content and user functionality with little information on the design and implementation of the software (Nelson et al., 2003; Rhee and Crosby, 2005). Only a few guidelines (Chadha, 1990; Frost-Olsen and Holm-Nielsen, 1986) are there to direct database development. Guideline proposed by Frost-Olsen and Holm-Nielsen (1986) and extended by Syne and Heywood (1988) provides the following recommendations for developing databases: keep it simple, design it first, build up the expert knowledge needed, work out the objectives and scope of the database before choosing the hardware, use standard hardware and software, allow for future expansion, let the machine do the hard work, plan for good quality output, plan for networking and follow the data standards that have been agreed upon.

Basically, objectives of a database management system (DBMS) are to provide means to store and retrieve information that is both convenient and efficient (Silberschatz et al., 2006). For achieving these objectives, these systems need to be well designed (Nelson et al., 2003). Unlike sequence-centric databases used in molecular biology (Galperin, 2006), in which queries are based on nucleic acid or amino acid sequences, medicinal plant databases would need to handle disparate types of data. Designing of a perfect DBMS requires systematic analysis and consideration of characteristics of the plants such as taxonomy, phytochemistry, medicinal usage etc. which will form the basic components of information system. Data structures should be customized for each data type and overall schema should be made flexible and scalable. As required in nutrition databases (Lernay et al., 2007), the database structure must be able to handle meta-data for enhancing integration of various databases (Tan et al., 1995).

Development of biological database, including ethnobotanical database, is complex because such applications differ significantly from the commercial software applications both in their modelling and processing requirements (Vidy and Haritza, 1996). Software development process needs to address the ground reality of the traditional knowledge and practices of indigenous people that are working to ensure intergenerational transmission of knowledge traditions (Christie, 2006).

4.1. Unique identification of plants

Most of the databases reviewed in this paper employed taxonomic name as unique identification of plants. The core of any medicinal plant database should include a shared identifier to serve as the natural link between different databases for sharing information (Patterson et al., 2006). The approach of representing taxonomic names as identifiers in databases (Sarkar, 2007; Syne and Heywood, 1988) has serious limitations as they are not completely stable, nor they are globally unique (Kennedy et al., 2005). Occurrence of different classification systems and several alternate names make development of single, common reference taxonomy difficult. Chances are there that software using Linnean binomial may aggregate data about different taxonomic concepts (Berendsohn, 1995). DBMS should have the capability of handling multiple taxonomies arising from the combination of legacy data, newly described taxa, modern revisions and conflicting opinions (Ragunaud et al., 1999).

Application of globally unique identifiers (GUI) is one of the methods for integration of biological information from diverse source (Fig. 2). These identifiers are valuable because they expose information in a standard way to other software (Godfray et al., 2007). Though there are numerous schemes for generating such identifiers, current focus is given mainly on three alternatives, HTTP URIs (Uniform Resource Identifiers), Digital Object Identifiers (DOIs) and Life Science Identifiers (LSIDs) (Page, 2008). Software clients can access the data associated with the LSIDs using a protocol called Simple Object Access Protocol (Box et al., 2000).
Need for a global ethnobotanical plant name index that can capture scientific names from primary and secondary ethnobotanical datasets (Gaikwad et al., 2011) has been felt by many researchers. Such index will serve as a catalogue for determining the plant species having medicinal value while assisting in the validation of the scientific names and in biodiversity conservation (Sarkar, 2007).

Another problem that needs attention is inaccurate identification (Syng and Heywood, 1988) which is one of the problems in ethnobotanical works (Lucas, 2010). Even in conservative and easily distinguishable plants high proportion of misidentification is found when identifications are done by non-taxonomists. Obvious misidentification problem is compounded by the prevalence of variation in vernacular name (Lawrence and Hawthorne, 2006). Misidentification problems are reflected in many journals (Khola and Fraser-Jenkins, 2011) and databases along with outdated taxonomy (Soberon and Peterson, 2004). Traditional knowledge is usually associated with vernacular name known to the particular culture. When misidentified species have been rectified, the associated ethnobotanical attributes need to be assigned to the correct scientific taxon. Such flexibility in the database structure can be implemented by application of unique identifiers as the reference point.

4.2. Data aggregation

Growth of Internet and the availability of biological data sources on the Web have opened up tremendous opportunity for biological research (Chung and Wooley, 2003) including ethnopharmacological research. Ability to access data from many different databases (Jagadish and Olken, 2004) is one of the requirements of the biomedical database. Integrating diverse sources of digital information as a single resource is important (Fagi, 2006; Stein, 2003). There are different approaches of data aggregation. Websites like EcoPort (Ecoport, 2011) integrate different data sources through meta-search engine. The Natural Product Alert (NAPRALERT) compiles information on natural products including medicinal properties by survey of the current literature and selective retrospective indexing (Gyllenhaal et al., 1993; Stepp and Thomas, 2006). The electronic Plant Information Centre (ePIC) of the Kew provides a single point of search across all Kew’s major specimen, bibliographic and taxonomic databases on the Internet (ePIC, 2011). The TCMGeneDIT integrates information about TCMs, genes, diseases, effects and ingredients by using text mining approaches (Fang et al., 2008). Heterogeneous origin of web-assembled databases makes quality control an important exercise to be followed (Soberon and Peterson, 2004).

Integration of biological databases can be achieved by link integration, view integration and data warehousing approaches (Stein, 2003). In the link integration query from one database can follow hypertext links to related information in other data sources. This type of integration has been observed in some of the online resources (http://www.hort.purdue.edu/newcrop/medaro/default.html; http://www.bgc.org). View integration which builds an environment for viewing data from other sources is resource intensive and can be implemented by large-scale project. Data warehousing approach brings all the data in a single database, an effort which is very difficult to create. Probability of depositing standardized ethnopharmacological survey data into a common repository for future comparison in the line of metabolomics databases (Verpoorte, 2008) for future reference also has been discussed.

One of the approaches to harness available ethnopharmacological resources is incorporation of primary data by the users into the database. Contributors may belong to either research scholars, traditional knowledge holders or common users (Skoczyn and Bussmann, 2006). If the databases have multilingual features (http://www.plantnames.unimelb.edu.au; http://www.prota.org/uk/; http://www.tradimex.com/index.asp) data sharing will be more effective.

A different model for collaborative authoring of taxonomic work is done through community-based projects called the wikis (Godfray et al., 2007). Remote data entry by registered users is implemented in SEPALAS database (http://www.kew.org/ceb/sepasal) through Global Editing software. Collaborative and community-based model implemented in sharing the medicinal plant databases can accelerate the data aggregation process. Probable insertion of false information in the wiki type of database is minimized by using the Captcha module (Completely Automated Public Turing test to tell Computers and Humans Apart) in Plant antivenom database (Amar et al., 2011).

Heterogeneity in data formats and structures, lack of standard terminology along with cultural and linguistic differences complicated the data integration (Cheung and Chen, 2010). For developing a system that enables biological data sharing, the fundamental prerequisites are compatibility of data definitions and a common access protocol.

4.3. Data standard

Only a few databases emphasized the application in data standard e.g. AGRICOLA (http://agricola.nal.usda.gov), Global Biodiversity Information Facility (http://www.gbif.org), etc. Standardization and nomenclature are important so as to provide a consistent view of data available in a particular field (Brusic et al., 2000) as the lack of uniform data standard creates problems in data mining and integration of data (Ehrman et al., 2007b; Schloman, 2006). Standardization of terms to describe medicinal plant can and community-based model implemented in sharing data content. For interchange of data between databases, obstacles of data compilation standards (Cao et al., 1995) and compatibility of data definitions should be addressed. Compatibility of data definitions includes both structural compatibility and semantic compatibility (Berendsohn, 2003). Full structural compatibility i.e. the use of the same fields and relations, the same database schema etc. is impossible to achieve in most of the cases. Semantic compatibility i.e. adherence to a definition of the contents of a data element needs to describe and define data elements for the entire domain. There are efforts to provide a common standard of data at global level. The Economic Botany Data Collection Standard (EBDCS) developed by the International Working Group on Taxonomic Databases for Plant Sciences (TDWG) is one of such efforts. The objective of the TDWG (now Biodiversity Information Standards) is to promote common use and interpretation of terminology, data fields, dictionaries and common logical rules (Bisby, 1994). During implementation, EBDCS was found to lack flexibility as the standard does not translate into relational structure easily (Cook, 1996) and it also contains many inconsistencies. It also lacks option to incorporate local terminologies (Heinrich et al., 2009). The standard was designed with the emphasis on development of independent databases (Thomas, 2003).

At present, the data standards endorsed by the TDWG include Plant Names in Botanical Databases, and Authors of Plant Names and World Geographical Scheme for Recording Plant Distributions. Access to Biological Collections Data (ABCD), another standard for support exchange and integration of data on living specimens, preserved specimens and observations, was ratified by TDWG in 2005, and is under constant review by the ABCD Task Group (ABCD, 2011). Current work of the TDWG includes Applicability of the GUID and Life Sciences Identifiers, Darwin Core, TAIPR (TDWG Access protocol for Information Retrieval), etc. On the other hand, the CEEB (Collections for Ethno- and Economic Botany) Project, a joint initiative of the Missouri Botanical Garden, the New York
Botanical Garden, the Field Museum of Chicago and the Society for Economic Botany, is working to develop and publish curatorial standards (CEEB, 2011) on its website (http://ceeb.econbot.org). Advances in these fields could contribute immensely in sharing data.

4.4. Ontology

Ontology has become the backbone technology for knowledge-based systems. It has been defined as ‘specification of a conceptualization’ (Gruber, 1995). Ontologies applied to the online resources create semantic web (Vadivu and Hooper, 2010), the architecture of which consists of machine understandable languages such as XML (Extensible Markup Language), RDF (Resource Description Framework) and OWL (Web Ontology Language).

Ontologies can be applied in data selection, data aggregation, decision support, natural language processing and knowledge discovery (Bodenreider, 2008). Ontologies support data integration in two ways: warehousing and mediation (Hernandez and Kambhampati, 2004). Initiative to create, maintain and facilitate the use of a controlled vocabulary for plants has been started by the Plant Ontology Consortium (Avramah et al., 2008).

As compared to classical technologies (e.g. non-semantic web pages, SQL databases, SOAP application interface), several advantages of semantic web technology and ontologies are there (Samweld et al., 2010) in ethnompharmacology in the way data and knowledge are accessed and exchanged (Heinrich et al., 2009). As non-codified traditional medicine is transmitted orally through generations, the knowledge may become adulterated or deteriorated, thus changing meaning and concept. Standardization of disease concept is of utmost importance for preserving and validating the information. Ontology is a means to reduce or eliminate the conceptual inconsistencies and to achieve a shared understanding so as to improve communication, sharing, interoperability and reusability.

Conceptualization of disease knowledge through ontologies can enable representation of knowledge in a computer comprehensible way as well as interoperability across databases. As different ontologies can be mapped on each other and interlinked to develop an ontological network, a user working in one area can access information from another different area (Baird and Rhee, 2004). For example, a user having knowledge of TCM can access information about a particular disease, say diabetes, from another knowledge domain represented by western medicine or Ayurveda. Initiative for application of ontology in traditional medicine system has been started with the development of the Unified Traditional Chinese Medical Language System (UTCMS) (Zhou et al., 2004), ontology for Traditional Korean Medicine (TKM) (Jang et al., 2010), ontology for African Traditional Medicine (ATM) (Atemezing and Pavon, 2008).

Success of applicability of ontology depends on the quality, installed base and governance (Bodenreider, 2008). Knowledge presented in the ontology has to be interpreted with an understanding of the concerned medicine system (Jang et al., 2010). Ontologies do not by themselves lead to the integration of biological databases. They serve as facilitators. In the absence of organized common hierarchy of common concepts, integration through ontology becomes a tedious and error-prone work (Stein, 2003).

The potentials and capabilities of ontology and semantic web will need to be explored in the ethnompharmacological databases for exchanging domain-specific ideas between different fields. This endeavour can be achieved through community-based efforts from different sections of the ethnompharmacological researchers and knowledge holders.

5. Applications

Medicinal plant databases allows quick recovery of multidisciplinary information (Chen et al., 2011; Manha et al., 2008) making them information bank (Upadhya et al., 2010) for future research in ethnopharmacology. Expected potentials of such databases include capability of analysis (Kumar and Gupta, 2004) and exporting relevant data for analysis (Skoczen and Bussmann, 2006), irrespective of the amount of information contributed by different parts of the databases are illustrated by the applicability of the analysis in different parameters. Application of the NAPRALERT database for searching information related to human reproduction (Farnsworth et al., 1981), application of database for computational screening of medicinal plants (Vyas et al., 2008), application of Random Forest for virtual screening of Chinese herbs (Ehrman et al., 2007c), docking methods for screening against hepatitis C virus (Srinivasan et al., 2011), screening of bioactive molecules utilizing information of medicinal and aromatic plants database in India (Masood and Shaft, 2005) and validation of prescription of TCM by developing artificial intelligence (Chen et al., 2006) are examples of the different applications.

The applications are not limited to providing information for drug discovery and conserving traditional knowledge. A unique application has been observed in the Aurukun Ethnobiology Database, where Wik community used the database as a means of promoting traditional knowledge in eco-tourism initiative (Edwards and Heinrich, 2006).

Another important utility of medicinal plant database is its contribution towards plant conservation research (Bhattacharyya et al., 2006). Information collated in databases may become relevant for influencing decision makers at any level, but the quality and efficiency of this documentation is directly associated with the amount of the available information (Pupulin, 2007; Smith et al., 2000).

Though different types of applications of medicinal plant databases have been reported, full applicability and potentiality of these databases are yet to be explored.

6. Challenges

Challenges encountered in developing medicinal plant databases include issues related to ethnobotanical issues and technical issues as represented in Fig. 3.

Similar to other biological databases, sustainability issue is observed with many websites become inaccessible or relocated to other sites (Galperin, 2006; Wren and Bateman, 2008). It has been commented that such issue is common in many project-funded databases specified for project data during the funding period (Rhee and Crosby, 2005). However, some changes in websites have been associated with evolution of the databases when they are absorbed into other services, e.g. ADONIS, BIOSIS Previews, (Table 1) etc. Other limitations like lack of frequent update (Wren and Bateman, 2008) and non-disclosure of year of creation are also noticed. Maintenance of digital data in long term basis is associated with many challenges including evolution of hardware and software, and the risk of systems becoming obsolete (Canhos, 2004). Since maintenance in long-term basis is costly (WHO, 1993) and possible only in major institutions and government agencies (Hussey et al., 2006), aggregation of information stored in different databases will become one of the options.

Consideration of open accessibility of traditional knowledge is usually encountered in sharing medicinal plant data. Restriction on using biodiversity data is common mainly in developing countries, based on interpretations of Convention on Biological Diversity with regard to access and benefit-sharing (Chavan and Krishnan, 2003). When the traditional knowledge is openly accessible, there
Challenges and Issues in developing Medicinal Plant Databases

- Data Integration Issues (e.g. common protocol, metadata engine etc.)
- Location Data Issues (e.g. Conservation Strategies, Biopiracy, etc.)
- Data Accuracy Issue (e.g. Phytochemical information, therapeutic validation, misidentification of specimen etc.)
- Data Heterogeneity
- Lack of benchmark model
- Need for Globally Unique Identifier (e.g. multiple taxonomies, linking primary and secondary data etc.)
- Intellectual Property Rights (e.g. Patents, Traditional Knowledge, etc.)
- Maintenance of Data (e.g. sustainability of website, regular update, data provenance, etc.)

Fig. 3. Challenges facing the utilization of databases for medicinal plant research.

are arguments that it may be used as a modern commodity like any form of intellectual property (Brush, 1993). However, commodification of the traditionally used plants have occurred even in spite of limited or negative scientific information to support to their use, e.g. Euterpe oleracea (Heinrich et al., 2011), Salvia hispanica (http://naturalstandard.com/monographs/herbsupplements/chia.asp). While the databases can prove useful in preventing patents from being granted on the assets of traditional communities, unrestricted access to these databases may well give rise to biopiracy (Duffield, 2002). All the academic research based on traditional knowledge does not lead to patent filings and commercial exploitation. However, there are arguments that such research are not free from biopiracy realm and get benefitted from the scientific use of traditionally used plant material (Mahop and Mayet, 2007). Another view is that the existence of sensitive data should not be used as an excuse for restriction of data (Canhós, 2004). Indigenous community needs to adapt to novel methods for protecting the traditional knowledge (Aguilar, 2001) and associated plant materials.

In view of the occurrence of diversified approaches and associated issues, need for development of common standards for application of database technology in ethnomedicinal research is felt. Need for such standards and conceptual contributions had also been expressed in many papers (Heinrich et al., 2009; Homysy et al., 2004; Moshiuzzaman and Choudhary, 2008). Standardization can be achieved by collective, integrative and collaborative approaches from many sectors. In the light of the above analyses and existing trends, some of the issues that need to be addressed for the development of a sound approach are discussed here.

- Botanical nomenclature: It can be checked through internationally recognized databases like the International Plant Name Index (http://www.ipni.org) which is considered as ‘authority data server’ for plant names (Lughadha, 2004), the W3TROPICOS (http://www.mobot.org), the Index Nominum Genericus (http://botany.si.edu/ing/), the Species 2000 (http://www.sp2000.org), the International Organization for Plant Information (http://plantnet.rbgsyd.nsw.gov.au/iopi/iopihome.htm) and the Planta List (http://www.theplantlist.org). To achieve “minimum standard for names in botanical databases”, the standard of “Plant Names in Botanical Databases” endorsed by the TDWG (TDWG, 1994) can be referred.
- Identification: Accurate identification of the botanical species can be achieved by collecting voucher specimens and depositing them in herbaria (Heinrich et al., 2009) and making them available for future comparisons. Inclusion of separate field for Voucher Number in the database table is a practicable approach in field-based studies. However, this field could not be mandatory when the information is retrieved from published literature, historical texts or published pharmacopeia. There have been discussions about the deposit of the plant materials in the germplasm banks (Cordell and Colvard, 2005) and application of DNA barcoding of the collected species (Newmaster and Ragupathy, 2010) for proper identification of the plant.
- Geographical location: Standard for representing geographical location has been provided by TDWG under the title of World Geographical Scheme for Recording Plant Distributions, and can be downloaded from the website (http://www.tdwg.org). But incorporation of this data should be in accordance with the Convention of Biological Diversity which recognizes national and international regulations.
- Ethnographic information: Collection of ethnographic information is essential as the traditional usage of the plant is usually culture-specific. Methodologies for ethnographic and ecological information collection have been discussed in several papers. Since qualitative research can produce culturally specific and contextually rich data (Mack et al., 2005), greater flexibility in database design is demanded.
- Ethnic taxonomy: Apart from scientific taxonomy, traditional taxonomy including vernacular name (Heinrich et al., 2009) is important because it is the connecting link between the traditional knowledge holders and the plant specimen.
- Personal information: Collection of information about the knowledge holders also becomes relevant. It will allow the scholars in conducting quantitative methods such as consensus index, user value indices, relative cultural importance, etc. (Hoffman and Gallaher, 2007). For ensuring respect for persons (NCPHSBBR,
1979) and respect for communities (Weijer et al., 1999), the mechanism of prior informed consent should be incorporated.

• Traditional medicine system: It is important to mention the type of medicinal system along with the source of the traditional knowledge, for instance whether the knowledge is transmitted knowledge, or acquired from some other sources. Such information is relevant in countries like India where different traditional medicine systems (e.g. Ayurveda, Unani, Siddha etc.) exist. Integration of traditional knowledge for medicinal system can be done by following published pharmacopelia or standardized publication. This approach may not be applicable in non-codified traditional medicine. In view of difference in cultural context, a common standard for describing traditional medicine can be attempted for integration into the databases.

• Disease classification: In addition to traditional classification, modern classification of disease should be followed for sharing information at global level. The current version of International Classification of Diseases (ICD-10) which is available on WHO website (http://www.who.int/classifications/icd10) can be used as a reference for the ethnopharmacological works.

• Ontology: With many tools available for ontological development in the web, development and sharing of concept and vocabularies through ontology will become common feature in the coming years. Collaborative efforts of the Plant Ontology Consortium (http://www.plantontology.org) have developed controlled vocabulary that describes anatomical and morphological structures along with growth and developmental stages for all plants. Biomedical ontologies can be accessed from resources like Open Biological and Biomedical Ontology (http://www.obofoundry.org), Gene Ontology (http://www.geneontology.org), RxNorm (http://www.nlm.nih.gov/research/umls/rxnorm), the Medical Subject Headings (MeSH) (http://www.ncbi.nlm.nih.gov/mesh), etc. Along with these efforts, development of standard ethnopharmacological ontology at global level can contribute a lot in sharing knowledge.

• Collection information: Plant parts used, stage of the collection, storage condition, drying process should be highlighted. The WHO has provided guidelines on Good Agricultural and Collection Practices (GACP) to individual countries, which has been applied in countries like India (NMPB, 2009). Regional level databases need to be made conformed to the guidelines prescribed by the respective countries.

• Non-botanical components: Chemical constituents can be referred to by correct IUPAC along with CAS Registry Number(s) that can be implemented by cross-checking from resources such as LiGAND (www.genome.jp/kegg/ligand.html), UM-BBD databases (http://umbbd.msi.umn.edu), etc. Biochemical reactions, if required, can be checked and integrated from different databases such as BREND A (www.brenda-enzymes.org), MetaCyc (http://metacyc.org), etc. as reaction data differs among the databases (Lang et al., 2011). When zoological names have to be cited, it can be done by checking through resources like Index to Organism Names (http://www.organisnamin es.com/), Nomenclator Zoologicus Online Information (http://ulo.mbl.edu), etc.

• Pharmacological information: For ethnopharmacological research, characterization of the range of pharmacological actions of herbal medicines and determination of the chemical characteristics of bioactive compounds are relevant. So, data generated from pharmacodynamics, general pharmacological and toxicological investigations need to be incorporated in the database. Guidelines for conducting these studies have been provided by the WHO (WHO, 1993), and can also be a source of database designers to determine type of information to cover.

• Authenticity of information: One of the functionality of the databases should be towards evaluation of traditional medicine. While collating the information some standard should be maintained by the curator for incorporating the authentic knowledge. Use of certificate of authenticity (Moshuzzaman and Choudhary, 2008) and information extraction from reputed peer-review journals are some of the methods.

• Informatics: Type of database (whether offline or online), software platform to be used and database schema to be followed will depend on the objective of the project. As discussed above, strict adherence to standardized protocol is demanded when the need of data sharing arises. It can be implemented through either including capability to export datasets in a standard common format or following standard database schema. With Economic Botany Data Collection Standard could not fully comprehend the expectancy from ethnopharmacological research, development of more specialized standard is required. Some other efforts of the TDWG can be studied for applicability. For instance, Darwin Core intending for sharing information about biological diversity by providing reference, definitions, examples, and commentaries, and TAIPR (TDWG Access Protocol for Information Retrieval) need to be analyzed in view of their applicability in ethnopharmacological research. Apart from these aspects, applicability of the CUIs and Semantic Web Technologies need to be considered for data sharing and interoperability. While disseminating scientific data, evaluation from the legislative perspective is also relevant. Proposal set by the International Council for Science (ICSU) and the Committee on Data for Science and Technology (CODATA) is an approach towards setting principles (http://www.codata.org). Collaborative and community-based approaches are required for setting the trends and standard in this area.

7. Conclusion

In this review electronic databases on medicinal plants are identified and categorized according to different criteria. Even when a particular database is focussing on a particular area, features and characteristics of other types of databases are also observed. For avoiding unnecessary duplication of research and for efficient utilization of resources, sharing of content of medicinal plant databases is necessary. It can be achieved by optimization of data and development of common minimum standard for sharing such resources.

As the development of global data in a single database may not be possible in view of the culture-specific differences, efforts can be given to specific regional areas. However, the compiler should address the issues of authenticity and validation of the data, multilingual and semantic issues as well as the applicability of the data for further medicinal plant research. Adopting and incorporating similar and parallel techniques and methodology already implemented in allied and interrelated disciplines can provide a dimension in the medicinal plant research.

For the integrative and scalable potential of the database, thorough understanding of the discipline of ethnopharmacology along with its current scenario and future vision becomes relevant. In spite of many efforts, still there is no standard protocol for developing medicinal plant database that caters to a specialized area. Such endeavour can be fulfilled by collaborative works of institutes concerned, international organizations, academicians and stakeholders. A continuous critical assessment in this field and dialogue among the academicians and programmers will contribute immensely in knowledge sharing and scientific advancement.

Acknowledgements

We are indebted to the numerous authors and programmers who have spent their precious time developing medicinal plant databases which now serve as a basis for this analysis. The authors
Annexure – 3

Published Article

Traditional uses of herbal vapour therapy in Manipur, North East India: An ethnomedical survey

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A R T I C L E  I N F O

Article history:
Received 5 September 2012
Received in revised form 10 November 2012
Accepted 25 December 2012
Available online 6 March 2013

Keywords:
Traditional medicine
Medicinal plant
Medicinal smoke
North East India
Vapour inhalation

A B S T R A C T

Ethnomedical relevance: Vapour-based medicines are an aspect of traditional medicine in North East India. However, no collective studies on this therapy in the region have been attempted. With the changing perception of traditional knowledge, documenting these herbal preparations and the subsequent development of baseline data for applications in further ethnomedical research are needed.

Aims of the study: To survey and document the plant species associated with vapour therapy in Manipur, North East India, and to evaluate these traditional practices.

Materials and methods: Semi-structured questionnaires were used to collect information from the Meitei community in the Imphal valley and the Jiribam area in Manipur. Traditional disease concepts were studied along with their corresponding medical terminologies. Plant samples collected from fields, healers’ private collections and home gardens were identified. Evaluation of the ethnomedical data was performed with a modified fidelity level index.

Results: In the study, 41 traditional disease complexes were treated by 13 different routes of administration using 48 mono-ingredient and 17 multi-ingredient compositions. Preparation methods included boiling in water (28%), burning the materials (48%), crushing the materials to release the aroma (21%) and slight heating of the materials (3%). Some of the ingredients were not reported in the study observed to have similar uses in other parts of the world, whereas polyherbal remedies were found to be unique without any similar report.

Conclusion: Many compositions mentioned in the paper are still used by the Meitei community. Traditional healers follow their own criteria for selecting medicinal plants. Plants recorded in this ethnomedical study can suggest methods for selecting and identifying potentially effective plants for future drug candidates. Scientific characterisation of the herbal remedies can contribute to the endorsement of traditional vapour-based therapies in the modern health care systems. Findings from these “new usage” reports of plants and unique combinations of polyherbal compositions indicate the importance of such documentation efforts.

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1. Introduction

Traditional medicines are prepared in liquid, solid, semi-solid or gas states (Mafimisebi and Oguntade, 2010). The use of medicines in the form of powders, vapours, smokes or volatile oils for treatment of many types of ailments (Shehata, 2006) has made administration of gaseous medicine a popular therapy in traditional medicine (Mohagheghzadeh et al., 2006). Vapour-based therapies have been reported in many cultures and form an integral part of health care systems all over the world (Kokwaro, 2009; Pennacchio et al., 2010). With respect to plant-derived medicinal smoke alone, there are more than 1000 use reports from over 737 plants throughout the world (Pennacchio et al., 2010). Application of vapour-based medicine as part of traditional medicine has been reported in Africa (Kokwaro, 2009; Togola et al., 2005), Australia (Devanesen, 2000), America (Luziati et al., 2010; Ross, 2002), Europe (Pieroni et al., 2002) and Asia (Gilm and Zhou, 2004; WHO, 2007).

Various types of ailments, including respiratory diseases (Pennacchio et al., 2010), reproductive problems (Collective, 2008), dermatological problems (Mohagheghzadeh et al., 2006), psychopharmacological problems (Dannaway, 2010; de Smet, 1985), and orthopaedic remedies (Mohagheghzadeh et al., 2006), are treated with vapour-based medicines. Common routes of administration of these medicines include either internal or
external fumigation, steam or aroma inhalation and steam sauna. External fumigation may be directed at specific body parts or the whole body. Internal application may be through oral, vaginal or rectal pathways. Steam inhalation is the process whereby the steam released from boiling water containing the herbal products is inhaled by the patient, and vapour inhalation is the suction of volatile substances produced at ordinary room temperatures (Fantus, 1926). Ayurvedic therapies such as dhrumrapana (aerosol), nasu (nasal medications) and dhupanarthaa (fumigation) (AYUSH, 2006; Kajaria et al., 2011) emphasise these fumigation and inhalation therapies for specialised ailments. Steam sauna or vapour bath is a specialised form of heat treatment that is therapeutically used for various types of ailments as well as for ceremonial and hygienic purposes (Fisher, 1951). Steam sauna using decoction of plants is still a tradition in many parts of South-East Asia (de Boer et al., 2011; Lamxay et al., 2011), Africa (Titanji et al., 2008) and South America (Luziatielli et al., 2010).

Vapour-based herbal medicines may be prepared as either mono-ingredient or multi-ingredient recipes (Mohagheghzadeh et al., 2006). As most ethnomedicinal works have been limited to documenting the use of single species (Bussmann et al., 2010), limited literature refers to polyherbal compositions used in vapour-based therapies. In view of this limitation, documentation of the polyherbal compositions of vapour-based medicines by investigating separate mono-ingredient compositions may yield important information for further research.

North East India has a rich tradition of ethnomedicinal practices, with its abundant flora and fauna and diverse communities (Chakraborty et al., 2012). Manipur is one of the states of North East India, bordering Myanmar. It lies at latitude 23°83’N to 25°68’N and longitude 93°03’E to 94°78’E, covering an area of 22,347 sq km. The floristic composition of Manipur falls in the Indo-Burma global biodiversity hotspot (Myers et al., 2000). Various types of forests, ranging from tropical and sub-tropical to temperate deciduous forests, provide rich floral diversity with many medicinal plants. Because of its position at the gateway between South Asia and South-East Asia, Manipur has been influenced by both Indian and South East Asian culture. Traditional medicine in the state has incorporated knowledge from Indian medicinal system, primarily Ayurveda and Unani. At the same time, many traditional practices prevalent in Manipur are similar to those of South-East Asian countries. For instance, practices similar to mother roasting and steam bath using decoction of plant observed in many of South-East Asian countries (de Boer et al., 2011) were also observed in Manipur. Although some ethnobotanical works had been taken up in Manipur (Khan and Yadava, 2010; Khumbongmayum et al., 2005; Singh et al., 2010; Srivastav et al., 2009) extensive documentation is not available except for some efforts (Singh et al., 2003; Singh, 2009; Sinha, 1996).

Vapour-based medicines are part of traditional medicine practices in North East India. Usage of vapour-based medicines has been reported in Assam (Sikdar and Dutta, 2008), Arunachal Pradesh (Srivastava et al., 2010), Manipur (Singh, 2009), Meghalaya (Hynmiewtta and Kumar, 2008), Mizoram (Rai and Lalramnungha, 2011; Sharma et al., 2001), Sikkim (Pradhan and Badola, 2008) and Tripura (Majumdar et al., 2006). However, no collective study on the medicinal use of smoke and vapour in this region had been attempted. With rapid urbanisation and popularisation of modern medicine in the region, a changing perception of traditional medicine in the region was expected. Because of this, documenting these herbal preparations and subsequent development of baseline data for applications in further ethnomedicinal research are needed. To fill this gap, an attempt was made to document the traditional application of vapour-based medicine in Manipur.
Table 1
Traditional disease concepts with matching modern medicine terminologies.

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Traditional disease or symptom complex</th>
<th>Equivalent modern medicine concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Amanhpa yelhatpaya</td>
<td>Constipation</td>
</tr>
<tr>
<td>2</td>
<td>Arum lahou</td>
<td>Malaria</td>
</tr>
<tr>
<td>3</td>
<td>Asimba jaba</td>
<td>Acidity</td>
</tr>
<tr>
<td>4</td>
<td>Bhukuri (Khulai lahou)</td>
<td>Pneumonia</td>
</tr>
<tr>
<td>5</td>
<td>Dhatu nai tuba</td>
<td>Gonorrhea</td>
</tr>
<tr>
<td>6</td>
<td>Er nungsit na chikpa</td>
<td>Dysmenorrhoea</td>
</tr>
<tr>
<td>7</td>
<td>Er-nungit</td>
<td>Irregular menstruation</td>
</tr>
<tr>
<td>8</td>
<td>Hara thungba</td>
<td>Asthma</td>
</tr>
<tr>
<td>9</td>
<td>Khirai</td>
<td>Migraine</td>
</tr>
<tr>
<td>10</td>
<td>Khou naba</td>
<td>Tonsilitis</td>
</tr>
<tr>
<td>11</td>
<td>Khouri naba</td>
<td>Pharyngitis</td>
</tr>
<tr>
<td>12</td>
<td>Kok chikpa</td>
<td>Headache</td>
</tr>
<tr>
<td>13</td>
<td>Kokta e nungsit haigutpa</td>
<td>Menstrual migraine</td>
</tr>
<tr>
<td>14</td>
<td>Lai thokpa</td>
<td>Small pox</td>
</tr>
<tr>
<td>15</td>
<td>Lok kungkha</td>
<td>Cough (Dry)</td>
</tr>
<tr>
<td>16</td>
<td>Lok kthubha</td>
<td>Cough</td>
</tr>
<tr>
<td>17</td>
<td>Lok khatra</td>
<td>Influenza</td>
</tr>
<tr>
<td>18</td>
<td>Lok na nakong yeisimba</td>
<td>Eustachian tube dysfunction by Cold</td>
</tr>
<tr>
<td>19</td>
<td>Lok rhungba</td>
<td>Common cold</td>
</tr>
<tr>
<td>20</td>
<td>Mening kumbb</td>
<td>Post partum</td>
</tr>
<tr>
<td>21</td>
<td>Nahi tuba</td>
<td>Nose bleed</td>
</tr>
<tr>
<td>22</td>
<td>Nakong luikhal</td>
<td>Otitis</td>
</tr>
<tr>
<td>23</td>
<td>Nipu ruba</td>
<td>Rhinorrhoea</td>
</tr>
<tr>
<td>24</td>
<td>Naton da til leba</td>
<td>Nasal myiasis</td>
</tr>
<tr>
<td>25</td>
<td>Naton mukhun gi laina</td>
<td>Sinusitis</td>
</tr>
<tr>
<td>26</td>
<td>Natschabi</td>
<td>Relapsing polychondritis</td>
</tr>
<tr>
<td>27</td>
<td>Naton phumba</td>
<td>Nasal catarrh</td>
</tr>
<tr>
<td>28</td>
<td>Nungsang</td>
<td>Hemorrhoids</td>
</tr>
<tr>
<td>29</td>
<td>Nungsang pere khaoraba</td>
<td>Internal hemorrhoids with rectal prolapse</td>
</tr>
<tr>
<td>30</td>
<td>Nungsang pere nai chaba</td>
<td>Internal hemorrhoids with suppuration</td>
</tr>
<tr>
<td>31</td>
<td>Putpu</td>
<td>Ulcerous lesion</td>
</tr>
<tr>
<td>32</td>
<td>Phugri</td>
<td>Pustules</td>
</tr>
<tr>
<td>33</td>
<td>Salmat</td>
<td>Nasal schistosomiasis (in Cow)</td>
</tr>
<tr>
<td>34</td>
<td>Sareri hruaba</td>
<td>Epilepsy</td>
</tr>
<tr>
<td>35</td>
<td>Sauje da mareng mareng chapatra</td>
<td>Fructus anii</td>
</tr>
<tr>
<td>36</td>
<td>Taiki</td>
<td>Syphilis</td>
</tr>
<tr>
<td>37</td>
<td>Thabek phumba khueba</td>
<td>Wheezing</td>
</tr>
<tr>
<td>38</td>
<td>Thabek tu lok leba</td>
<td>Bronchitis</td>
</tr>
<tr>
<td>39</td>
<td>Thagokpa</td>
<td>Hiccough</td>
</tr>
<tr>
<td>40</td>
<td>Umsagi laina</td>
<td>Skin disease</td>
</tr>
<tr>
<td>41</td>
<td>Ya til chabu</td>
<td>Dental caries</td>
</tr>
</tbody>
</table>

* Protective application in postpartum stage.

2. Aims of the study

This study aimed to survey and document the plant species used in vapour therapies in Manipur, North East India, and to evaluate these traditional practices for further ethnopharmacological studies.

3. Materials and methods

3.1. Study area

The study was conducted in the two geographically distinct areas of Manipur viz., Imphal valley area and Jiribam area (Fig. 1). Studies in the Imphal valley areas were conducted in the villages of the Imphal East District (Wangkhei, Kongba, Naharup and Sanjenham). Jiribam is a subdivision of the Imphal East District and is located at the western part of Manipur, bordering Cachar (a district of Assam). It is considered to be an extension of the Cachar valley of Assam, with many similarities in floristic compositions between the two regions. Studies in Jiribam areas were conducted in the villages of Nongshingkhul, Ucharol and Harinagar. The study was confined to the Meitei community, also referred to as Manipuris. Meiteis belong to mongoloid stock and form a major ethnic group of Manipur. Their language is Manipuri, which is a subgroup of the Kuki-Chin group of the Tibeto-Burman branch of linguistic division. Their main religions are Hinduism, Sanamahism and Christianity.

3.2. Interviews

Semi-structured questionnaires were administered to collect ethnobotanical data from the informants. Information was collected from 45 informants from the Jiribam areas and 65 informants from the Imphal valley areas. All of the informants belonged to the Meitei community and were born and reared in their respective villages. Prior informed consent was obtained before collecting the information.

3.3. Specimen collection

On the basis of information provided by the informants, plant samples were collected from fields. Some specimens were collected from the healers’ private collections and home gardens. Plants collected from the fields were checked for their vernacular name by the healers. Herbarium specimens were identified and deposited at the herbarium of the Department of Life Sciences, Manipur University. Scientific names were cross-checked with the IPNI (www.ipni.org) and the Plant List (www.theplantlist.org) databases.
3.4. Disease concepts

As the ethnomedicinal applications were linked with the traditional concepts of the disease, traditional terminologies were used in collecting the information. Symptoms associated with the diseases were studied, and the corresponding medical terminologies were matched accordingly. Diseases were categorised according to the Economic Botany Data Collection Standard (EBDCS) (Cook, 1995). Some of the disease concepts that could not be categorised according to EBDCS were grouped based on the organ system involved.

3.5. Quantitative methods

In the present work, evaluation of the ethnomedicinal data was performed with a fidelity level index (Friedman et al., 1986) with certain modifications (Bruni et al., 1997). The primary use of the recipe was used as a fidelity index and expressed as a percentage of the citation for that recipe (%Cm). A specialised index called the “Index of Specialisation by the main use” (ISm) was used to evaluate the consensus for the specific medical uses along with type of preparation and application. This index can be represented by the following formula:

\[ ISm = \left( \frac{SCm}{SC} \right) \times 100 \]

where, ISm is the Index of Specialisation by the main use, \( SCm \) is the percentage of citation for a particular drug, and \( SC \) is the percentage of the total citations. In the present work, monoherbals and polyherbal compositions containing same species were treated as distinct entities.

4. Results

Traditional healers applied their own concept and disease classification system while treating various ailments. Traditional concepts recorded in the study were matched with the Western medicinal systems on the basis of signs and symptoms supplemented with the inputs provided by the traditional healers (Table 1). Some of the traditional diseases reported in the study were found to be symptoms and signs of other main diseases under modern medicine concepts. For example, rhinorrhea is a symptom of the common cold from the perspective of modern medicine. However, traditional healers in Manipur provide specific treatment of rhinorrhea, which is different from the general treatment for the common cold. Traditional concepts of headache (Kok chikpa) and migraine (Khorial) are different with respect to their cause and treatment. In view of these specificities, signs and symptoms of traditional medicine were treated separately in the study, although these ailments may belong to same category under the modern medicine system.

In all, 41 traditional disease complexes that fall under different categories of ailments were reported (Fig. 2). Diseases associated with infections and infestations were most prevalent (24%), whereas diseases associated with muscular–skeletal system disorders recorded the lowest percentage (2%). Almost all of the recorded traditional treatments belonged to human disease, with the exception of one ethnoveterinary disease. One particular citation of Meining Kumbu was associated with postpartum treatment for preventing antimicrobial infections.

Ethnomedicinal data were divided into two groups—mono-ingredient and multi-ingredient herbal remedies. In the present study, 48 mono-ingredient (Table 2) and 17 multi-ingredient compositions (Table 3) were reported with 69 and 18 therapeutic applications respectively.

4.1. Mono-ingredient herbal remedies

In the present study, 48 mono-ingredient herbal remedies were prepared from 42 species. Their therapeutic applications, route of administration and index of specialisation were provided in Table 2 along with similar use reports from other parts of the world. Altogether 69 applications were associated with these recipes. The Index of Specialisation for mono-ingredient herbal compositions ranged from 6.80 (Steam inhalation using Justicia adhatoda for treating nasal catarrh) to 0.38 (vapour inhalation using Blumeopsis flava for treating colds). Many mono-ingredient herbal remedies reported in this study had similar use descriptions from other parts of the world. Plant parts used for the remedies included the bulb, bark, branch, fruit, flower, inflorescence, leaf, oleoresin, petal, root, rhizome, shoot and stem.

4.2. Multi-ingredient herbal remedies

In the present study, 17 multi-ingredient herbal remedies were reported in 18 therapeutic applications (Table 3). Among the multi-ingredient compositions, the most commonly cited recipe was the combination of hoodon termifolius and Goniothalamus sesquipedalis with an ISm index of 5.10. These two species were also used in combination with other species for treating the same ailment. Compared to the mono-ingredient herbal compositions, remedies in multi-herbal ingredients had no reported similar use descriptions.

4.3. Types of use

Vapour-based medicines were prepared by boiling in water (28%), burning the materials (48%), crushing the materials to release the aroma (21%) or slightly heating the materials (3%). These medicines were applied through 13 routes of administration. Therapeutic applications were categorised into inhalation therapy, smoke or steam directed at body parts or organs, steam bath and ambient smoke (Fig. 3). Inhalation therapies were found to be the primary forms of administration (60%), which included smoke inhalation (29%), steam inhalation (3%) and aroma inhalation (22%). Smoke inhalation included using cigars or cigarettes made from leaves of the plants. Sometimes, smoke released from burning materials was inhaled with deep inspiration. Steam inhalation from boiling materials was performed by placing one’s head over the boiling pan and covering the head with a thick
<table>
<thead>
<tr>
<th>Sl no</th>
<th>Scientific name and family</th>
<th>Local name</th>
<th>Parts used</th>
<th>Preparation</th>
<th>Cre</th>
<th>U B</th>
<th>Main therapeutic use, disease condition and route of administration</th>
<th>Cre</th>
<th>U B</th>
<th>Other uses, disease condition and routes of administration</th>
<th>Evidence for local use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aristolochiaceae</td>
<td>Nongnanggha angulosa</td>
<td>Leaf</td>
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<td>21</td>
<td>1.66</td>
<td>Asthma, chronic (smoke inhalation)</td>
<td>21</td>
<td>100</td>
<td>1.08</td>
<td>SUD in Sri Lanka (Jayasena and Sivaruntha, 2006): smoke from Aristolochia is used for creating asthma in Anuradha Pradesh, India (Rao and Henry, 1996). Steam from boiling leaves is used in cough and cold in Nepal (Bhattacharya et al., 2005). Determination of leaves is used for scabies in Pakistan (Qureshi et al., 2008).</td>
</tr>
<tr>
<td>2</td>
<td>Phlogacanthus rohitphuran Nees</td>
<td>Leaf</td>
<td>Boiled in water</td>
<td>46</td>
<td>4.34</td>
<td>Dry Cough, acute (steam inhalation)</td>
<td>32</td>
<td>70</td>
<td>3.02</td>
<td>Paroxysm, acute (steam inhalation); cold, acute (steam collected with cloth and fumigated on the nose)</td>
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<tr>
<td>3</td>
<td>Anacardiaceae</td>
<td>Edhah Rai</td>
<td>Leaf</td>
<td>Boiled in water</td>
<td>7</td>
<td>0.66</td>
<td>Haemorrhoids, chronic (steam directed at the anal region)</td>
<td>7</td>
<td>100</td>
<td>0.66</td>
<td>SUD in other parts of India (Bhawan, 2005).</td>
</tr>
<tr>
<td>4</td>
<td>Anacardiaceae</td>
<td>Khajjum pori</td>
<td>Leaf</td>
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<td>10</td>
<td>0.94</td>
<td>Nasal catarrh, acute (aroma inhalation)</td>
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<td>100</td>
<td>0.94</td>
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</tr>
<tr>
<td>5</td>
<td>Alkanna tomentosa</td>
<td>Leaf</td>
<td>Crushed</td>
<td>34</td>
<td>3.21</td>
<td>Epilepsy, chronic (aroma inhalation)</td>
<td>24</td>
<td>71</td>
<td>2.27</td>
<td>None bleeding, chronic (aroma inhalation)</td>
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<td>6</td>
<td>Alkanna tomentosa</td>
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<td>21</td>
<td>1.58</td>
<td>Epilepsy, chronic (aroma inhalation)</td>
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<td>100</td>
<td>1.08</td>
<td></td>
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<td>7</td>
<td>Apocynaceae</td>
<td>Cenelle andrewsii</td>
<td>Leaf</td>
<td>Boiled in water</td>
<td>6</td>
<td>0.57</td>
<td>Constipation, chronic (steam directed at the anal region)</td>
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<td>100</td>
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<td>Fumaria asplenoides L.</td>
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<td>Crushed</td>
<td>8</td>
<td>0.76</td>
<td>Epilepsy, chronic (aroma inhalation)</td>
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<td>100</td>
<td>0.76</td>
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<tr>
<td>9</td>
<td>Apocynaceae</td>
<td>Celerinum giganteum (L.)</td>
<td>Stalk</td>
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<td>8</td>
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<td>Headache, chronic (aroma inhalation)</td>
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<td>11</td>
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<td>Butea monosperma</td>
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<td>22</td>
<td>2.08</td>
<td>Haemorrhoids, chronic (steam directed at the anal region)</td>
<td>14</td>
<td>100</td>
<td>1.32</td>
<td>Bacterial proctitis chronic; Pruritis ani, chronic (smoke directed at the anal region)</td>
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<tr>
<td>12</td>
<td>Apocynaceae</td>
<td>Calotropis gigantea</td>
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<td>Crushed</td>
<td>24</td>
<td>2.27</td>
<td>Migraine, chronic (smoke inhalation)</td>
<td>16</td>
<td>100</td>
<td>0.04</td>
<td>Bartholm tube dysfunction by cold, acute; Irregular menstruation cycle, chronic (vapor inhalation)</td>
</tr>
<tr>
<td>13</td>
<td>Apocynaceae</td>
<td>Cassia fistula</td>
<td>Leaf</td>
<td>Crushed</td>
<td>22</td>
<td>2.08</td>
<td>Sinuses, chronic (steam inhalation)</td>
<td>22</td>
<td>100</td>
<td>2.08</td>
<td>Vapour from heated plant material is inhaled for treating sinusitis in Sudan, India (Alberg et al., 2015).</td>
</tr>
</tbody>
</table>

**Notes:**
- Cre: Cretaceous
- U B: U and B
- SUD: Sudden Urinary Dilation
- Crept: Creptosis
<table>
<thead>
<tr>
<th>No.</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Habitat</th>
<th>Place of Harvest</th>
<th>Uses</th>
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<tbody>
<tr>
<td>34</td>
<td>Mitragyna pudica L.</td>
<td>Kangphal</td>
<td>Sh</td>
<td>Burnt</td>
<td>9.05 1 Haemorrhoids, chronic (smoke directed at the anal region); Gastrointestinal; acute (smoke inhalation); 9 100 0.05</td>
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<tr>
<td>35</td>
<td>Vigna unguiculata (L.)</td>
<td>Sagol bayi</td>
<td>St</td>
<td>Burnt</td>
<td>5.047 1 Herpes, chronic; Acute; 5 100 0.47</td>
</tr>
<tr>
<td>36</td>
<td>Clerodendrum indicum (L.)</td>
<td>Lonkrize</td>
<td>Churundong</td>
<td>Burnt</td>
<td>24 2.277 4 Arthrosis, chronic (smoke inhalation); 12 50 1.13 Bronchitis, acute; Sinusitis, Tonsillitis (smoke inhalation); 5 100 0.47</td>
</tr>
<tr>
<td>37</td>
<td>Sesamum indicum (Walt. &amp; Link)</td>
<td>Mustard</td>
<td>Pcr</td>
<td>Crushed</td>
<td>22 2.081 1 Sinusitis, chronic (smoke inhalation); 22 100 2.08</td>
</tr>
<tr>
<td>38</td>
<td>Moringa oleifera (L.)</td>
<td>Barm Tutli</td>
<td>Lfr</td>
<td>Crushed</td>
<td>19 1.792 2 Sinusitis, chronic (smoke inhalation); 10 51 0.04 Herprous, acute (smoke inhalation); 10 01 0.04 Nasal Mynitis, acute (smoke inhalation);</td>
</tr>
<tr>
<td>39</td>
<td>Chlorophyllum coriacea (L.)</td>
<td>Kalmi</td>
<td>Lfr</td>
<td>Crushed</td>
<td>16 1.512 2 Haemorrhoids, chronic (smoke inhalation); 34 3.213 3 Cold, acute (smoke inhalation); 34 100 3.21</td>
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<tr>
<td>40</td>
<td>Euphorbia schweinfurthii (L.)</td>
<td>Senna &amp; Maneh.</td>
<td>Moisand</td>
<td>Burnt</td>
<td>9 0.85 2 Arthrosis, chronic (smoke inhalation); 9 100 0.85</td>
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<tr>
<td>41</td>
<td>Vicia sieberi L.</td>
<td>Srikhitli</td>
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<td>15 1.421 1 Cough, acute (smoke inhalation); 15 100 1.42</td>
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<tr>
<td>42</td>
<td>Cinnamomum camphora (L.)</td>
<td>Kopyser</td>
<td>Lfr</td>
<td>Crushed</td>
<td>21 1.088 1 Epilepsy, chronic (smoke inhalation); 11 52 1.04 Influenza, acute (smoke inhalation);</td>
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<tr>
<td>43</td>
<td>Cinnamomum zoanth (Buch.-Ham.)</td>
<td>Terpat</td>
<td>Lfr</td>
<td>Crushed</td>
<td>7 0.661 1 Nasal catarrh, acute (smoke inhalation); 7 100 0.66</td>
</tr>
<tr>
<td>44</td>
<td>Aegle marmelos (L.)</td>
<td>Harangkhlo</td>
<td>Lfr</td>
<td>Burnt</td>
<td>7 0.661 1 Arthrosis, chronic (smoke inhalation); 7 100 0.66</td>
</tr>
<tr>
<td>45</td>
<td>Annona squamosa (L.)</td>
<td>Neem</td>
<td>Lfr</td>
<td>Boiled in water</td>
<td>24 2.277 2 Pneumonia, acute (smoke inhalation); 14 58 1.52 Skin diseases, acute (steam bath); 9 100 0.85</td>
</tr>
<tr>
<td>46</td>
<td>Moringa oleifera (L.)</td>
<td>Sizard</td>
<td>Lfr</td>
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<td>9 0.851 1 Pneumonia, acute (smoke inhalation); 9 100 0.85</td>
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<tr>
<td>47</td>
<td>Ficus religiosa L.</td>
<td>Khongnang</td>
<td>Bfr</td>
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<td>7 0.661 1 Haemorrhoids, chronic (steam directed at the anal region); 7 100 0.66</td>
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<tr>
<td>48</td>
<td>Neolamarckia nudiflora Gaertn.</td>
<td>Thambol</td>
<td>Pr</td>
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<td>8 0.761 1 Nasal Schistemias; acute (smoke directed at the nose); 8 100 0.76</td>
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<tr>
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<td>Nymphaea arka-misih (L.)</td>
<td>Univangoni</td>
<td>Rf</td>
<td>Crushed</td>
<td>7 0.661 1 Malaria, acute (smoke inhalation); 7 100 0.66</td>
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<tr>
<td>50</td>
<td>Polygonum hydropiper (L.)</td>
<td>Delafio</td>
<td>Lfr</td>
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<td>9 0.851 1 Haemorrhoids, chronic (steam directed at the anal region); 9 100 0.85</td>
</tr>
<tr>
<td>51</td>
<td>Polygonum afra (DC.)</td>
<td>U-babyo</td>
<td>Bfr</td>
<td>Boiled in water</td>
<td>6 0.571 1 Haemorrhoids, chronic (smoke directed at the anal region); 6 100 0.57</td>
</tr>
</tbody>
</table>

*Note: Uses are based on traditional practices and may vary in efficacy and safety.*

- Smoke from the leaves is used for treatment of asthma in Orissa, India (Seetharam, 2006).
- Vapour is inhaled to clear nasal passages in Bomi, Canada (Uppery et al., 2012).
- Vapour from boiling leaves is inhaled for treating cold, cough and fever in Tamil Nadu, India (Srinivasulu et al., 2000).
- Bath with leaves in hot water for treating skin diseases is a practice in India (Conrick, 2001).
- Aquous extraction of bark is used for treating haemorrhoids in India (Warrier et al., 1994).
<table>
<thead>
<tr>
<th>Sl no</th>
<th>Scientific name and family</th>
<th>Local name</th>
<th>Parts used</th>
<th>Preparation</th>
<th>T.G.</th>
<th>U.T.</th>
<th>Main therapeutic use, disease condition and route of administration</th>
<th>Ca</th>
<th>T.G.</th>
<th>IL</th>
<th>Other uses, disease condition and routes of administration</th>
<th>Evidence for local use</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>M. spinosum (L.) Druce</td>
<td>Herba</td>
<td>Leave</td>
<td>Boiled in water</td>
<td>7</td>
<td>0.66</td>
<td>Gastritis, acute (steam bath)</td>
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<td>100</td>
<td>0.06</td>
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<td>Aegle marmelos (L.) Corr</td>
<td>Herba</td>
<td>Leave</td>
<td>Boiled in water</td>
<td>10</td>
<td>0.04</td>
<td>Acidity, acute (steam bath)</td>
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<td>100</td>
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<td>35</td>
<td>Citrus auranti</td>
<td>Fruits</td>
<td>Crushed</td>
<td></td>
<td>11</td>
<td>1.04</td>
<td>Pharyngitis, acute (steam inhalation)</td>
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<td>100</td>
<td>0.04</td>
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<td>36</td>
<td>Xylopia longifolia (L.) T. &amp; G.</td>
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<td>23</td>
<td>2.17</td>
<td>Pneumonia, acute (steam bath)</td>
<td>23</td>
<td>100</td>
<td>2.17</td>
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<td>Neolitsea cortex Thwaites</td>
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<td></td>
<td>15</td>
<td>1.42</td>
<td>Hepatitis, acute (steam inhalation)</td>
<td>15</td>
<td>100</td>
<td>1.42</td>
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<td>38</td>
<td>S. rotundifolia</td>
<td>Fruits</td>
<td>Leave</td>
<td></td>
<td>19</td>
<td>1.79</td>
<td>Asthma, chronic (smoke inhalation)</td>
<td>15</td>
<td>79</td>
<td>1.42</td>
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<td></td>
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<td>39</td>
<td>D. stramonium L.</td>
<td>Herba</td>
<td>Leaf</td>
<td></td>
<td>22</td>
<td>2.98</td>
<td>Asthma, chronic (smoke inhalation)</td>
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<td>77</td>
<td>1.61</td>
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<td>40</td>
<td>S. suffruticosum Desv.</td>
<td>Fruits</td>
<td>Leave</td>
<td></td>
<td>12</td>
<td>1.11</td>
<td>Cough, acute (smoke inhalation)</td>
<td>12</td>
<td>100</td>
<td>1.11</td>
<td></td>
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<tr>
<td>41</td>
<td>C. zeylanicum</td>
<td>Fruits</td>
<td>Leave</td>
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<td>62</td>
<td>5.85</td>
<td>Bronchitis, acute (smoke directed at the mouth)</td>
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<td>Zingiber officinalis</td>
<td>Herba</td>
<td>Leave</td>
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<td>19</td>
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<td>Arthritis, chronic (smoke inhalation)</td>
<td>11</td>
<td>58</td>
<td>1.04</td>
<td></td>
<td></td>
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</tbody>
</table>

**SUD—Similar Uses Descriptions:** Plant parts: Bl—Bark, Br—Bud, Br—Branch, Fr—Fruit, Pw—Flower, In—Inflorescence, Le—Leaf, OB—Oleoresin, Pr—Pedal, Re—Root, Rh—Rhizome, Sh—Shoot, St—Stem.
<table>
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<tr>
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<th>Parts used</th>
<th>Preparation</th>
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<th>$C_2$</th>
<th>No. of use</th>
<th>Main use, disease condition and room of administration</th>
<th>$C_3$</th>
<th>$C_4$</th>
<th>$B_1$</th>
<th>Other use</th>
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<tbody>
<tr>
<td>1</td>
<td>Achyranthes aspera L. (Amaranthaceae)</td>
<td>Khajur Puri</td>
<td>Rs</td>
<td>Crushed together</td>
<td>10</td>
<td>0.84</td>
<td>1</td>
<td>Headache, chronic (arthritis, inhalation)</td>
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<td>100</td>
<td>0.84</td>
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<tr>
<td>2</td>
<td>Calotropis gigantea (L.) Drueke (Apocynaceae)</td>
<td>Pongamalam (Makaram, L. C.)</td>
<td>Rs</td>
<td>Burn</td>
<td>6</td>
<td>0.57</td>
<td>1</td>
<td>Haemorrhoids, chronic (smoke directed at the anal region)</td>
<td>6</td>
<td>100</td>
<td>0.57</td>
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<tr>
<td>3</td>
<td>Calliandra dimeritaria Linnaeus*</td>
<td>Yen amukti</td>
<td>F</td>
<td>Boil in water</td>
<td>8</td>
<td>0.76</td>
<td>1</td>
<td>Haemorrhoids with rectum prolapse, chronic (steam directed at the anal region)</td>
<td>8</td>
<td>100</td>
<td>0.76</td>
<td></td>
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</tbody>
</table>

*Authors: personal copy
<table>
<thead>
<tr>
<th>No.</th>
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<th>Parts used</th>
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<th>C_{M}</th>
<th>C_{N}</th>
<th>D_{P}</th>
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<td>14</td>
<td><em>Azadirachta indica</em> (Mull.) (Meliaceae)</td>
<td>Hindi</td>
<td>Bark</td>
<td>Burnt</td>
<td>1</td>
<td>0.28</td>
<td>1</td>
<td>Genitourinary, acute (smoke directed at the perineal region)</td>
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<td>100</td>
<td>0.28</td>
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<td>15</td>
<td><em>Neem</em>, <em>Azadirachta indica</em> (Meliaceae)</td>
<td>Hindi</td>
<td>Bark</td>
<td>Burnt</td>
<td>1</td>
<td>0.47</td>
<td>1</td>
<td>Rheumatism, chronic (steam directed at the perineal region)</td>
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<td>100</td>
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<tr>
<td>16</td>
<td><em>Aurum santalum</em> (Santalaceae)</td>
<td>Sanu</td>
<td>Bark</td>
<td>Burnt</td>
<td>1</td>
<td>0.57</td>
<td>1</td>
<td>Syphilis, acute (smoke inhalation)</td>
<td>6</td>
<td>100</td>
<td>0.57</td>
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<tr>
<td>17</td>
<td><em>Boswellia papyrifera</em> (Burseraceae)</td>
<td>Bhai</td>
<td>Bark</td>
<td>Burnt</td>
<td>2</td>
<td>0.07</td>
<td>2</td>
<td>Post-partum (ambient smoke)</td>
<td>54</td>
<td>54</td>
<td>5.10</td>
<td>Small piece (ambient smoke)</td>
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</tbody>
</table>

Plant Parts used: Bl-Brush, Br-Bark, Fb-Fibre, Fr-Fruit, Gr-Grain, In-Infermariam, Lf-Leaf, Ol-Oil, Rs-Resin, Rf-Root, Rr-Rhizome, Sl-Seed, Sh-Shoot, St-Stem, Wd-Wood, and Wp-Whole Plant.

Animal Parts used: *Amar*—Feather, *Gai*—Elastic, and *Chemical*.

Plant: Parts used: Bl-Brush, Br-Bark, Fb-Fibre, Fr-Fruit, Gr-Grain, In-Infermariam, Lf-Leaf, Ol-Oil, Rs-Resin, Rf-Root, Rr-Rhizome, Sl-Seed, Sh-Shoot, St-Stem, Wd-Wood, and Wp-Whole Plant.

Animal: Parts used: *Amar*—Feather, *Gai*—Elastic, and *Chemical*.

Fig. 2. Various types of therapeutic applications.

4.4. Dangers and safety

Dosage of these applications varied based on the type of disease. When leaves were used for producing smoke, whole leaves were completely burnt. Duration of the steam bath was specific for a particular patient. It was strictly practised that the smoke should not be suitable for the patient. For patients who were severely ill or had fever, the duration of steam bath should be extended.

Adverse reactions of steam bathing involved components contained in the smoke. Skin irritation and cough were observed in some patients. The use of steam or steam directed at a specific body part or the use of smoke inhalation in deep inspiration caused cough, sneezing, and other respiratory symptoms. In some cases, patients developed skin irritation and cough. Adverse reactions were common in patients who were allergic to smoke. Steam bathing was not recommended for patients with respiratory problems.

Steam bathing was not recommended for patients with respiratory problems.
made for pregnant women for smoke treatment in their anal and urogenital regions. Aside from these exceptions, the remaining therapies were used by the people at various stages of ailments. For treating the same ailment, the multi-ingredients were recommended in more serious conditions.

5. Discussion

Though the therapeutic applications observed in this study had many similarities to those in other parts of the world, exceptions were observed in the formulations of the herbal components. Most of the inhalation therapies reported in this study were associated with respiratory diseases. These therapies had been practised for centuries (Pandey and Khuller, 2005), and their benefits in medication of the affected respiratory organs were well known (Sanders, 2007). It is the most convenient and effective direct means of administration of drugs into blood and is also the only means applicable for treating the lower respiratory tract (Fantus, 1926). Moreover, studies on South African medicinal plants revealed that combustion produced superior antimicrobial activity, thus giving inhalation as an efficient mode of administration in traditional healing (Braithwaite et al., 2008).

Traditional healers considered the dosage of application important. In inhalation therapies, the amount and absorption rate of substance from the air depended on the relative concentration of the substance in the air, air vesicles and blood as well as the duration of administration. When the air is more saturated with vapour compared to the blood, the substance passes into the blood, and vice versa (Fantus, 1926). As such, dosage can be controlled not only through concentration but also through duration of administration.

All over the world, respiratory diseases such as coughs, colds, influenza, catarrh, nasal congestion and tuberculosis are treated with plant-derived smoke (Pennacchio et al., 2010) with significant usage reported for asthma. In the present study, Datura stramonium and Datura metel were observed to be used in the treatment of asthma, which also been reported over the world (Gilman and Zhou, 2004; Pennacchio et al., 2010). The medicinal properties of Datura were considered to be due to the paralysing action of atropine on the pulmonary branches of the lungs, which eliminates the spasms during asthma attacks. These effects serve as an alternative treatment to the symptom without a cure (Pennacchio et al., 2010).

One of the important species used in inhalation therapies was J. adulata, which had high Index of Specialisation for application in respiratory problems. Applications of this species in respiratory problems through oral administration were well known. However, compared to oral administration, application of steam released from J. adulata as remedies for respiratory problems were less common. Studies on the bioactive compounds present in the steam could contribute to a better understanding of the medicinal properties of this plant.

Fumigation of specific body parts for treating various ailments is one of the therapeutic methods of traditional medicine system. In the present study, fumigation of anal region with either steam or smoke was reported for treating ailments associated with haemorrhoids. In the Western medicinal concept, haemorrhoids are considered to be vascular cushions of thin submucosa containing blood vessels, muscle and elastic connective tissue (Thomson, 1973) that are independent of intestinal worms. However, traditional healers in Manipur associate intestinal worms with nungsom. Thus, most of the fumigation methods for treating haemorrhoids included anti-helminthic medication. Application of vapour therapy for treating haemorrhoids were also observed in China and other parts of India (Gilman and Zhou, 2004) and one apparatus using this method had been filed for a patent (Taraglia, 2010). Occasionally, treatment for rectal prolapse through fumigation may include measures to stabilise the body organs, not for disinfection only. In Traditional Chinese Medicine, fumigation therapy was applied utilising both the medicinal and heat effects to open the interstices and promote the flow of qi and blood for reducing swelling, alleviating pain, dispelling wind and relieving itching (WHO, 2007). As such, the purpose of fumigation varied according to the disease concepts.

Contrary, to the mono-ingredient remedies, multi-ingredient compositions had no similar user reports from other areas. In most cases, complex formulation and tedious processes associated with multi-ingredient compositions were closely guarded secrets of the traditional healers. Some species used in multi-ingredient remedies might be used independently as monotheral remedies for the same treatment in the state or in other parts of the world. In the present study Acorus calamus, which was used as a component of polyherbal remedies for treating haemorrhoids, was found to be used as a monotheral recipe for the same ailment. Combination of this species with Fumaria parviflora was reported for treating the same ailment in Iran (Hooper and Field, 1937). Such species that are common in both mono-ingredient and multi-ingredient remedies might have a higher potential for treating the particular disease.

Among the multi-ingredient compositions, the combination of L. termifolius and G. sesquipedalis had the highest index of specialisation. This combination is still used by most of the Meitei people at different stages of rites de passage. At the post-partum stage, this recipe was used as ambient smoke during mother roasting. Smoke from this combination is believed to possess curative properties for various skin diseases for both the mother and new born babies. In the magico-psychological realm, this recipe was also used for thwarting evil eyes and avoiding spirits. Because of this cultural significance, this combination is currently used in the commercial production of incense sticks. Although the chemical properties of these two species were studied separately, to our knowledge, the combined effects of these two species have not been analysed. Combustion of the two species together could contribute to the synergistic or antagonistic reactions of the chemicals present, thus inducing anti-microbial effects or medicinal properties. Some studies have reported that medicinal smokes generated by burning different plant species reduce airborne bacteria (Chen, 2004; Nautiyal et al., 2007).

Plant selection for use in steam bath is based on their organoleptic properties. Traditional healers recommend only bitter plants for such applications. Evidence of sauna therapy as an effective treatment for cardiovascular problems was observed (Crinion, 2011). In the present study, steam baths were mainly used for dermatological and other infectious diseases.

Even though smokes and steam baths have been used for treating various ailments in the neighbouring states of North East India, the context of use and plant species differ. Leaves of Brugmansia suaveolens (Humb. & Bonpl. ex Willd.) Bercht. & J.Presl (syn. Datura suaveolens Humb. & Bonpl. ex Willd.) were burned and inhaled to provide relief from asthma in Mizoram (Rai and Lilamanghinglova, 2011), another state in North-East India. Smoke from burning G. sesquipedalis was used to treat asthma and to induce sleep in Mizoram (Rai and Lilamanghinglova, 2011).

One of the species used in fumigation therapies is Canarium resiniferum which is used as a monotheral remedy and as one of the components in multiple-ingredient recipes for the treatment of haemorrhoids. Burning of the oleoresin obtained from this plant is not only used in medicinal purposes but also for religious purposes as incense. Resins obtained from related species of Canarium have been used for incense purposes in other countries (Pennacchio et al., 2010). In the multi-ingredient compositions,
any species present in more than one composition for treating a particular disease (as found in combination of *I. ternifolia* and *G. sesquipedalis*) may be effective for the disease.

The presence of similar use descriptions (SUD) from other areas is significant for the validation of the medicinal properties from the species in question. Plants that are used to treat a particular disease in several different areas are more likely to be effective (Leaman et al., 1995). Similar user reports have indicated independent discoveries of the effective properties of the plant by the communities studied. Even when parallel observations are present through the exchange of plant use knowledge (Heinrich et al., 1998; Leonti, 2011), the presence of SUD is still relevant. In most cases, people would convey and acquire only the effective species for treating a particular ailment.

However, toxicological aspects of herbal smoke and vapor are an important side to consider in determining the efficacy of the methods. The probability of emphysema caused by smoke from herbal asthma remedies was reported in some studies (Freilich et al., 2010). Some medicinal smoke might have unwanted effects, such as damage to respiratory system, skin and eyes (Duke et al., 2002; Mohagheghzadeh et al., 2006). Complications arising out of vapour-based therapies are also reported in Ayurvedic medicine (Rao, 2008). In view of such complications, the probability of adverse effects from the long term use of certain medicine cannot be ruled out. Interestingly it is recorded that (Tables 2 and 3) most of the vapour applications are used in both acute and chronic cases. However, such applications are restricted to pregnant women with an idea that use of these vapours may create some adverse effect. Reports of using herbal vapour as an abortifacient (Hooper and Field, 1937; Moerman, 1998), contraceptive (Jain and Bharathi, 2011) or correct for gynaecological problems (Mohagheghzadeh et al., 2006) described specialities of the medicines used. Restrictions imposed on weak patients in steam bath are another indication of such unwanted effects. Thus, detailed pharmacological studies are needed for characterising the medicinal properties before incorporating them into the health care system.

**6. Conclusion**

Vapour therapies that use herbal and non-herbal ingredients are important components of the traditional medicine of the Meitei community in Manipur. This paper has documented the application of medicinal smoke, steam and aromas for treating various ailments in Manipur. Some of the recipes mentioned in this paper are still used by the Meitei community. Many mono-ingredient herbal applications have yielded similar use reports from other parts of the world, whereas multi-ingredient herbal remedies are unique because no similar reports have been collected to date. These recipes are associated with the cultural heritage of the people and might possess many medicinal properties. Chemical analyses of these multi-herbal ingredients as well as mono-herbal ingredients may provide new insights into the medicinal properties of these plants and allow for the integration of these findings into primary health care systems. The existence of the association between the different attributes indicates that the plant selection for treatment of a particular disease is not performed randomly, but rather based on some criteria. Plants recorded in this ethnobotanical study may provide leads for selecting and identifying potentially effective plants for future drug candidates. At the same time, scientific characterisation of herbal remedies can contribute to the endorsement of traditional vapour-based therapies in modern health care systems. The findings of new use reports of plants and the unique combination of polyherbal compositions indicate the importance of such documentation efforts.

**Acknowledgements**

We are indebted to the people of Manipur for cooperating and sharing their traditional knowledge, which formed the basis for this study. The authors are also grateful to Dr. Waikhom Shashi Singh, Regional Institute of Medical Sciences, Imphal, and Dr. Sydney Moirangthem, Chettinad Health City, Chennai, for providing suggestions in the identification of traditional disease concepts. We thank Dr. Naoribam Bhubaneshwar Singh, Department of Veterinary and Animal Husbandry, Government of Manipur, for helping in the identification of veterinary diseases. We also express our gratitude to Thingujam Bhogen Singh and Nambam Chandrakumar Singh of the Department of Environment, Government of Manipur, for their extensive cooperation during our field studies. Our compliments are also owed to Bioinformatics Centre, Assam University, Silchar, sponsored by Department of Biotechnology, Government of India, New Delhi for providing literature support.

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Annexure – 4

Published Article

NoSQL Data Model for Semi-automatic Integration of Ethnomedicinal Plant Data from Multiple Sources

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ABSTRACT:
Introduction – Sharing traditional knowledge with the scientific community could refine scientific approaches to phytochemical investigation and conservation of ethnomedical plants. As such, integration of traditional knowledge with scientific data using a single platform for sharing is greatly needed. However, ethnomedicinal data are available in heterogeneous formats, which depend on cultural aspects, survey methodology and focus of the study. Phytochemical and bioassay data are also available from many open sources in various standards and customised formats.

Objective – To design a flexible data model that could integrate both primary and curated ethnomedicinal plant data from multiple sources.

Materials and methods – The current model is based on MongoDB, one of the Not only Structured Query Language (NoSQL) databases. Although it does not contain schema, modifications were made so that the model could incorporate both standard and customised ethnomedicinal plant data format from different sources.

Results – The model presented can integrate both primary and secondary data related to ethnomedicinal plants. Accommodation of disparate data was accomplished by a feature of this database that supported a different set of fields for each document. It also allowed storage of similar data having different properties.

Conclusion – The model presented is scalable to a highly complex level with continuing maturation of the database, and is applicable for storing, retrieving and sharing ethnomedicinal plant data. It can also serve as a flexible alternative to a relational and normalised database. Copyright © 2014 John Wiley & Sons, Ltd.

Keywords: MongoDB; NoSQL databases; ethnomedicinal plants

Introduction

Medicinal plants are integral parts of traditional medicine systems (TMS) worldwide. Ethnomedicine-guided medicinal plants research has opened up a new vista in understanding bioactivity, as well as the isolation of many bioactive compounds. Understanding and sharing the hidden knowledge of traditional medicine could enhance scientific approaches to therapeutic investigation and conservation efforts. However, the domain of knowledge of ethnomedicinal plants still remains fragmented and is rapidly disappearing because of lack of appropriate attention.

During the past decade, various attempts have been made to integrate ethnomedicinal data from plants, which are based on a relational data model (RDM) as well as a few flat-file approaches. Earlier approaches to store ethnopharmacological data in a RDM suffer from certain limitations. Although it is the most common and reliable approach for storing and querying data in various forms, this approach needs pre-designing of the exact field structure of the data for normalisation processes (Lee et al., 2013). One of the important hurdles in RDMs is the complexity in establishing relationships between entities. Ethnomedicinal plant research is associated with complex relationships between botanical nomenclature, geographical distribution, disease concept, phytochemical information and ethnographic data (Ningthoujam et al., 2012). Establishment of all these relationships in a RDM is a complex process. Moreover, available ethnobotanical and ethnopharmacological data exist in heterogeneous data format, ranging from textual narratives in ancient texts, scientific literature, oral tradition and practical knowledge. Even in the published scientific literature, the

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representation of field data may be quantitative through provi-
sion of ethnomedical indices, sometimes supplemented by
dosage and routes of administration, while some are purely de-
scriptive (McClatchey, 2006). Integration of these divergent data
from various sources along with user-generated primary data in
a single database demands a flexible schema. Integration of
such heterogeneous data formats requires tedious and complex
pre-processing and data cleaning methodologies.

Over the past few decades, NoSQL (Not only Structured Query
Language) databases have become popular, with many devel-
opers and users turning towards this non-relational approach.
The current trend is partially motivated by the needs of data-
bases in search of large storage capacities (Hecht and Jablonski,
2011). As the name indicates, document databases store data in
the form of documents. Attribute names can be generated
during run times and storing values in nested documents is also
allowed (Cattell, 2011). Because of these properties, a document
database can be a more flexible storage alternative to a
relational standard, normalised database.

MongoDB is a document-oriented database developed in C++
that stores data in field and value pairs. Data are stored in binary
JavaScript object notation (BSON) format. All documents are stored
in collections having a shared common index. In tradi-
tional RDM, such as MySQL, designing the data model involves
normalisation to remove redundancy from a set of tables.
MongoDB departs from the relational model by storing data in
documents rather than in fixed tables. The major difference is
that whereas the first normal form in a relational database de-
mands that each row–column intersection contains exactly one
value, MongoDB allows storing of an array of values if desired
(Copeland, 2013). Although NoSQL databases have been used in
various projects, to the best of our knowledge, no ethnomedical
database has been created in MongoDB. How-
ever, there have been some attempts made using other NoSQL
approaches in biological collection databases. The potential of
NoSQL and XML approaches as alternatives to a relational data-
based for storing clinical data has been highlighted in some stud-
ies (Lee et al., 2013). The capability of importing phytochemical
data from the PubChem Data (Bolton et al., 2008) into MongoDB
has been shown in one Internet blog (Swain, 2013). We now
report on the development of a flexible data model, based on
MongoDB (a NoSQL database), for integrating both primary
and curated ethnomedical plant knowledge with scientific
data from multiple sources.

Experimental

Technology

The systems were developed using a personal computer equipped with
2.93 GHz Intel(R) Core(TM) Duo CPU 4.00 GB RAM and 298.09 GB hard
drive. MongoDB Version 2.4.5 was installed in the 64-bit Microsoft
Windows 7. Pentaho Data Integration Community Edition 5.0 was used for
data integration. Data preparation and editing were performed in
Microsoft Office Excel® 2013 and R Studio Version 0.98.501. Data manipu-
lation and administration were carried out in Rockmongo Version 1.1.6,
Apache Version 2.2.22 and PHP (Hypertext Pre-processor) Version 5.4.16.

NoSQL data designing

Schema Design in MongoDB is different to a relational database system.
Although MongoDB does not contain schema in principle, in this work,
some structural modelling was performed. The presented MongoDB
data model for an ethnomedical plants database relies on the flex-
ibility of the rich document model of MongoDB, while maintaining the relation-
ship between related objects. Key challenges to data modelling were to
balance the needs of the application, the performance characteristics
of the database engine and the data retrieval patterns. The application
usage of the data, such as queries, updates and processing, were taken
into account while designing the data models.

Design pattern. There were two options for representing the data
presentation and their logical relationship. Selection of a design pattern,
whether to chose embedding or reference through unique identifier,
depends on the type of data to be retrieved. The first option was to
put everything into a single document (Figure 1), whereas in the second
option the data were partly normalised.

The first option was to embed the related data as subdocuments in
a nested array, and this was a comparatively easier approach. This
approach also favoured maintaining locality, atomicity and isolation
(Copeland, 2013). Embedding everything in a single document had a
limitation in the present model though, because there were many
common fields shared by different documents. In other words, there
were many-to-many relations between different documents. For
instance, two or more plants might have many similar phytochemicals;
a single literature source might publish use-reports for many plants.
Moreover, herbal recipes in many countries might be polyherbal,
containing various information regarding dosage, preparation and con-
traindications. In view of these conditions, a second option (Figure 2)
was selected, where multiple collections were proposed, each having a
similar set of documents. Semi-normalisation of the data was undertaken
for optimising the query processing. Relationships between documents
were maintained by linking through references.

Allocation of documents in different collections was a pragmatic ap-
proach in view of the document growth. Integration of rapidly increasing
bioassay or chemical data in dedicated collections for phytochemicals
would be easier than to push the data in a single plant document under
one, or many, arrays.

The proposed model is a semi-relational model, the fields of which
were based on our previous paper (Ningthoujam et al., 2012). The general-
ised representation of the document data for ethnomedical plants is
depicted in Figure 2. In the MongoDB, relations could be established
through two options, embedded and references, the choice of which
depended on the type of data to be represented in the database. Three ba-
sic forms of relations, that is, one-to-one, one-to-many and many-to-many,
have been represented in the current model. Referencing was by linking between the documents, not by relationship establishment between a pair of collections.

In the current model, some data were denormalised for performance benefits (Copeland, 2013). Denormalisation is the copying of the same record into multiple documents or tables in order to simplify or optimise query processing or for convenience of data representation according to the user’s choice.

Controlled vocabulary. For the present modelling, controlled vocabulary was incorporated as much as possible. For taxonomic and plant distribution collections, field names were inspired by the term references of the Darwin Core (Wiekorek et al., 2012). Disease concepts, classification and symptoms were based on the World Health Organization’s International Classification of Diseases (ICD) Version 10, Cook’s (1995) Economic Botany Data Collection Standard and Medical Subject Heading (MeSH) of the US National Centre of Biotechnology Information.

Reusing resources. Instead of developing a new data model, reusing a suitable data model was considered to be a pragmatic approach. Considering the infrastructure and manpower cost that may arise when developing a project-specific software module, our approach tried to incorporate and reuse well-established protocols, standards and software as much as possible. Although a perfect document data model for the ethnomedicinal plants is still lacking, there are many related-data models that are related to the ethnopharmacological data. In the current model, chemical collections and bibliography collections were heading on an existing data model of the MongoDB and Bib/SON format (Jones et al., 2011) for data compatibility and linking open data.

Collections

As the data model specifically focused on a particular field, that is, ethnopharmacology, collections could be mandatory or optional. In the present model, eight collections could be categorised as:

1. mandatory collections – plants, recipe and bibliography;
2. optional collections – disease concepts, phytochemicals, ethnopharmacy, geographical and location.

In addition to these collections, others could be incorporated to provide more meaningful inputs. As there was no pre-design creation of the relationship between the collections, more collections could be created afterwards or during run-time. The choice of the collection depended on the focus of the database.

Plants collection. This collection category was meant for storing basic taxonomic information, along with phytochemical data and geographical distribution (not to be confused with location data). This collection contained a master list of plants known for their ethnomedicinal properties.

Each document (Figure 3) consisted of customised taxon identity, optional fields (slug (a short label containing only letters and underscores for use in uniform resource locators (URLs) in the address bar of the browser), full name), family, scientific names, vernacular names and distribution, as well as phytochemical, toxicological and pharmacological arrays, if available. The standard MongoDB object identity was stored in the ’_id’ field: a slug (Django, 2014). In this model, the slug was incorporated into the plant and other collections to provide a meaningful human-readable URL and to avoid the appearance of object identifiers in the URLs (Banerker, 2011).
Scientific names consist of different components and were presented in the plant collection, as the user name for each taxonomic unit was represented in the field. For example, the scientific name for a particular plant could be represented as 'Acacia nilotica' for the genus, 'Acacia' for the species, and 'nilotica' for the variety. Each species was linked with its corresponding taxonomic information, which included habitat, distribution, and geographical location.

The plant collection was a valuable resource for taxonomic studies, as it contained a wide range of plant species, each with its unique characteristics and ecological requirements. The collection served as a reference for researchers and students who were interested in the study of plant biodiversity and its conservation.

The plant collection was also an excellent tool for educational purposes. It allowed students to learn about the diversity of plant species and their habitats, as well as the importance of preserving such diversity for the benefit of ecosystems and human societies. The collection provided a practical way to teach the principles of taxonomy and the importance of biodiversity conservation.

In conclusion, the plant collection was a significant asset for scientific research and educational purposes. It allowed researchers and students to study the diversity of plant species and their habitats, and to learn about the importance of biodiversity conservation. The collection provided a practical way to teach the principles of taxonomy and the importance of preserving plant diversity.
be stored in the arrays as shown in the ‘plants’ collection. Data for each plant were designed to be manually curated, based on published literature. In the second, detailed information of each compound can be represented in a separate collection called ‘phytochemicals’.

In this collection, data from online resources such as PubChem (Bolton et al., 2008), Chemical Entity of Biological Interest (ChEBI) (Degtyarenko et al., 2008) and the European Bioinformatics Institute’s ChEMBL database can be integrated in order to avoid redundant efforts. In the current model, second option was selected.

The phytochemical array in the ‘plants’ collection data adopts referencing to point to the respective compound in the phytochemical collection. The purpose of this was to avoid repetition of phytochemical data as embedded fields in each plant containing that particular compound. If the references were kept in the phytochemical documents, this would lead to mutable, growing arrays. To avoid this, references are kept in the plant document. References in the ‘plant’ document use the International Union of Pure and Applied Chemistry’s International Chemical Identifier key (InChIkey) to point to a particular chemical, because the hashed InChIkey is unique and can be employed to search web resources for chemical data. The same key provides a unique identifier when integrating chemical data from different sources. The document produced (Figure 6) is a combination of ChEBI source and MongoChem (http://wiki.openchemistry.org/MongoChem) of the Open Chemistry Project.

**Disease concept model.** Representation of disease concepts published in the ethnomedical literature is a challenging task. In some papers, diseases were rejected in equivalent western medicinal concepts, whereas in other papers, traditional disease concepts were also included. As traditional knowledge transmission occurs through traditional disease concepts, it sometimes may be necessary to include the original concepts in order to avoid ambiguity. In the following example of representing Ayurvedic Jwara, considered to be equivalent to allopatic fever, there are conflicting concepts. In the Ayurvedic concept, Jwara is considered as one of the important diseases, whereas in the allopathic concept fever is a common symptom of many ailments.

![Figure 4](https://example.com/fig4.png) **Figure 4.** Documents showing location data.
Considering the significance of traditional concepts, an array was included to represent traditional concepts, if available in the published literature. Information present in this collection can be populated with data obtained from ontological mapping of traditional knowledge with western medicine (Figure 7).

**Geographical collection.** For representation in the 'geographical' collection, the possibility of hierarchical relationships was taken into account because, country, state, district and locality could be represented in hierarchical tree relationships. In MongoDB there are some possibilities available for representing these relationships; in the present model...
'child relationship' was used for representing the data, whereby child nodes form subdocuments (Figure 8).

**Ethnography collection.** Ethnopharmacological plants are associated with the culture and context of the community concerned, thus making ethnographic data an inseparable component of an ethnopharmacological database. In the current model, only basic information on the community concerned is represented in the 'ethnography' collection, in the format depicted in Figure 9. Information present in this collection is not adequate to represent the whole community, but can be extended by incorporating more fields and more data. In the integration of primary data, this collection can store ethnographic data for one informant or respondent.

**Recipe collection.** In this model, only the traditional recipe component of the ethnopharmacology is stored. The object relationships of traditional recipes are classified as many-to-many because a particular disease can be treated by many species; likewise, a species can be used for many diseases. It is considered that this type of relationships can be represented efficiently by linking through reference identifiers (Copeland, 2013). Figure 10 represents a document for a polyherbal formulation. In this collection, the mandatory fields are plants, disease and survey area. Inclusion of the field 'dataSource' was to differentiate between primary and secondary data, although the same could be achieved by using certain codes in the prefix of the recipe code. Preparation, dosage, routes of administration, contraindication, diet and regimens, associated with the traditional recipe, can be incorporated when these data are available in the published literature. From ethnobotanical surveys, such information was presented in many publications in a concise descriptive manner. It would take extra effort to segregate the components from such descriptions, but they could be integrated by providing an appropriate key and allocating the description later on to their respective fields.

```
"state": "Aasam",
```

**Figure 8.** A document representing a level of geographical entity.

```
"_id": ObjectId("527e6a2799884b9408000001"),
"communityName": "Meitei",
"religion": {"Hinduism","Meiteism","Christian"},
"languageName": "Manipuri",
"langISO": "MNI",
"locality": {
  "village": "Jiribam",
  "districtCounty": "Imphal East",
  "stateProvince": "Manipur",
  "country": "India",
  "region": "South and South East Asia"
}
```

**Figure 9.** A document containing ethnographic data for one community.
Bibliographical collection. There are different formats possible for representing bibliographical data. Although the default keysets in the present model are based on the BibJSON, different types of keysets can be incorporated, as shown in Figure 11. Keyword search features can be used in bibliographic collections.

Dataset

For evaluation of the present data model, some data for ethnomedical plants of the Northeast India were integrated with data from other sources. In the initial stage, a master list containing accepted names and synonyms was prepared. The basic purpose was to maintain uniformity in plant names according to accepted taxonomic concepts. The field of taxonStatus (taxonomic status) in the 'plants' collection represents the current taxonomic level of the taxon based on the international taxonomic databases associated with botanical resources, such as The Plant List (www.theplantlist.org), the International Plant Name Index (www.ipni.org), Encyclopædia of Life (www.eol.org) and Taxonomic Name Resolution Service (http://tnrs.iplantcollaborative.org). Even then, there was still a mismatch between the different data sources with regards to taxonomic status and concepts. In the present dataset, resolutions of the taxonomic names and status, and subsequent development of a master list were achieved according to the workflow as depicted in Figure 12.

Preparation of the provisional master list was based on the scientific names published in ethnomedical literature. However, many of these published names included synonyms, informal names and unresolved names, along with orthographic errors. All these ambiguities were resolved through bulk checking and interactive process. In the first instance, the Taxonomic Name Resolution Service of iPlant Collaboratory was used for bulk checking of plants names, by cross-checking with records in the Plant Database of the US Department of Agriculture, Missouri Botanical Garden’s Tropicos Database, the Global Compositae Checklist database and the National Center for Biotechnology Information’s Taxonomy database (Boyle et al., 2013). In a second step, ‘Taxonstand’ and ‘taxize’ packages of ‘R’ software were used to check plants recorded in The Plant List database and other resources such as Encyclopædia of Life, Catalogue of Life, IUCN Red List and uBio (Cayuela et al., 2012; Chamberlain and Szöcs, 2013). When there was still inconsistency in the authority name, as a matter of policy names recorded in the International Plant Name Index (www.ipni.org) database were manually assessed for correction. However, this strategy can be modified according to the policy of database choice.

Properties of phytochemicals associated with medicinal plants were downloaded from the ChEBI website (Degtyarenko et al., 2008) and also from the MongoChem application of the Open Chemistry Project. These data also can be supplemented with chemical data from other sources, such as PubChem data.

Data integration

There were various options for importing primary and secondary data for the present model, but two options for large-scale data integration were selected.

Figure 10. A document showing a polyherbal recipe.
NoSQL Data Model for Integration of Ethnomedicinal Plant Data

Phytochemical Analysis

{  
  "id": "object1Id(527e7a9988b8404000000)",  
  "title": "Challenges in developing medicinal plant databases for sharing ethnopharmacological knowledge",  
  "authors": [{"name": "Sanjoy Singh Ningthoujam"},  
              {"name": "Anupam Das Talukdar"},  
              {"name": "Kumar Singh Potsangbam"},  
              {"name": "Manabendra Dutta Choudhury"}],  
  "year": "2012",  
  "journal": {"name": "Journal of Ethnopharmacology",  
               "id": "J Ethnopharmacol"},  
  "volume": "141",  
  "issue": "1",  
  "pages": "9-32",  
  "identifier": {"type": "doi", "id": "10.1016/j.jep.2012.02.042"},  
  "type": "PMID", "id": "22401841"}
}

{  
  "id": "object1Id(50e8548c9f30644b80b8a96f)",  
  "articleType": "Journal Article",  
  "authors": [{"name": "B K Acharya"}, {"name": "H K Sharma"}],  
  "year": "2004",  
  "title": "Folklore medicinal plants of Mahmora area, Sivasagar district, Assam",  
  "journal": {"name": "Indian Journal of Traditional Knowledge"},  
  "volume": "3",  
  "issue": "4",  
  "pages": "365-372",  
  "ISSN": "0972-6938, 0975-1088",  
  "keywords": ["Folk medicine", "Traditional medicine", "Sivasagar", "Ethnomedicine"],  
  "abstract": "Traditional methods of treatment using plants and animals are followed in Mahmora region of Sivasagar district, Assam. The plants, either single or as multi component preparations are used to treat various ailments. An attempt has been made to study 35 plant species, from 35 genera belonging to 30 families along with the method of preparation and mode of use."
}

Figure 11. Bibliography collection containing different document formats.

Pentaho data integration tool. The Pentaho Data Integration (PDI) tool, also known as Kettle, is a tool for extraction, transformation and load (ETL) solution. This tool includes a data integration server, design tool, utilities and several plug-ins. With the release of Pentaho Community Edition 5.0, native integration of MongoDB is supported, which has simplified data integration and analysis using MongoDB and other traditional data resources. In the present model, Pentaho Community Edition 5.0 is used for data integration and report design.

Mongosaicimport tool. There are many resources already stored as legacy data in various formats such as tab-delimited or comma-separated files, or simply Microsoft Excel files. Comma-separated value (CSV) files, tab-separated value (TSV) files and JavaScript object notation (JSON) files can be directly imported into the MongoDB using the ‘mongosaicimport’ tool. When arrays are involved in such files, some modifications are required. Microsoft Excel, TSV and CSV fields cannot be nested as in the Extensible Markup Language (XML) or in JSON, thus the need for an alternative pathway to integrate the legacy data in MongoDB.

At the initial step, a nested XML was created for Excel files (also CSV files after importing into Excel files) by using an XSD (XML schema definition) file. Then, the nested XML were converted to JSON format through an XML conversion plug-in in R software. Import of JSON files in MongoDB was enabled through the mongosaicimport tool. However, this tool, by default assumes a special MongoDB-specific JSON format for a file to import. If there are few documents, manual editing is possible. When the number of documents runs into hundreds or thousands, manual manipulation would be cumbersome. In this case, ‘mongosaicimport’ can be made to import the data as a JSON array using the ‘jsonArray’ parameter. In addition to these two options for large data integration, individual data can be incorporated through conventional webpage forms or through open-source administration tools, such as Rockmongo and phpMyAdmin, by hardcoding in JSON format.

Testing the database

For the analysis of the performance of the data model, baseline and load tests were performed. Baseline tests were carried out on the data model without any optimisation in order to determine the baseline of performance. Load tests were performed after the initial tests had been established and necessary actions taken.
Results and discussion

For the present work, MongoDB was selected for a variety of reasons: it is an open source and supports most of the features of the NoSQL; other aspects are user-friendly installation, replication and automatic sharding (i.e. partitioning a collection of data and splitting them through machines, called shards) and presence of good documentation support; it is supported by official drivers in various languages, such as Ruby, Python and PHP. In the traditional relational database management systems, the data model usually operates hand in hand with object-mapping by using object-relational mapping, such as Java’s Hibernate framework or Ruby’s ActiveRecord (Banker, 2011). However, these mappers are less necessary in MongoDB because the document is already an object-like representation. There are many drivers for various languages that provide a high-level interface to MongoDB, so that entire applications on MongoDB can be built using the drivers’ interface alone (Banker, 2011). Another consideration for using MongoDB is its potential as a linked open data network. As the data are stored in JSON-compatible format they can be exported as JSON-LD (linked data) for consumption in linked open data on the web.

When it comes to designing a NoSQL schema, there are many variations because such a design pattern depends on the application’s user requirements. Despite MongoDB being schema-less in principle, some modellings needs to be established in view of the expected outputs. The model should be able to retrieve the medicinal plant data, particularly related to ethnopharmacological research. In preparing a medicinal plant database, particularly for ethnopharmacological research, minimum methodological standards are expected (Ningthoujam et al., 2012). Development of a data model reflecting this intricate relationship needs conceptual planning beforehand.

In the current work, the data model was populated with model datasets. From the perspective of data preparation, data can be integrated with different fields, as it was in the collection process. However, the present model comprises some basic uniform fields along with optional fields. Transformation to these schemas does not involve the preparatory steps required in a conventional relational database, such as data normalisation and inner and outer joins. With the availability of various tools such as Pentaho Data Integration and Mongoimport, various data formats can be easily integrated into the database.

In the plants collection, there is one key slug. If this field is a unique index, insert operations will fail when a duplicate slug is inserted (Banker, 2011). In the proposed model, the slug was derived from the genus and specific epithet of the accepted scientific name without the authority of the plant. Combination of genus and species only is not unique in certain cases. In such cases, the slug cannot be a unique index. To make it a unique index, it can be implemented by incorporating ‘authorString’ in the slug. In other collections also, the slug can be incorporated according to the data curator’s policy.
For representing plant names with associated phytochemicals, representing accepted names and synonyms as separate documents might create redundancy, that is, accepted names and synonyms, being the same entity, will contain the same phytochemicals. This information need not to be incorporated in each document; for instance, it is not necessary to include the phytochemicals of *Acacia nilotica* in the *Acacia araboica* also.

Instead, accepted names and synonyms can be presented as an embedded array of the same document representing a plant entity. As for plant names, the relationship between accepted names and synonyms is a one-to-one relationship and can be represented by embedded documents. One of the advantages of such representation is better performance in ‘read’ operations, in which it is possible to update data in a single operation. All the related data can be requested and retrieved in a single operation. However, it is not free from the problem of document growth, which produces document fragmentation at different disk locations.

Incorporation of detailed phytochemical data is based on the type of data usage. One option would be to redirect to other web resources such as PubChem, ChEMBL, and ChEBI for the information by providing links. However, for some resources run at dedicated data centres, it would be more appropriate to host this information as separate collections for viewing in offline mode.

The recipe collection could store traditional formulation and usage compiled from different sources. For the primary data, detailed classification is possible. However, in secondary data there is variation in the types of fields, ranging from detailed classified information to concise narratives. All of these variations can be stored in the same collection by keeping plant name (with unique identifier), disease name and survey area as common parameters.

Data in the ‘location’ collection are capable of geo-spatial indexing of medicinal plants. Modelling in this collection is designed to enable two-dimensional sphere indexing. This indexing type is appropriate for calculating geometry about plant distribution in a spherical body.

Linking to bibliographical documents can be made unique by using the document object identifier (DOIs) of each paper. However, such identifiers are not available for every piece of literature, hence a customised key was assigned for each bibliographic document. As observed in the bibliographical collection, documents containing different fields can be stored depending on the data available.

**Query time**

The query time of the developed database was evaluated by using different queries with varied complexities. The query time was determined through Rockmongo admin console. A set of eight queries were run, which are detailed in Table 1.

For testing, the phytochemical collection was populated with 73390 documents and plants collections with 667 documents. In each setting, the query was repeated for 10 times to determine the mean query time with standard deviations. In MongoDB the query time was enhanced by indexing the documents and the

<table>
<thead>
<tr>
<th>Table 1. Queries with different complexities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Query</strong></td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>V</td>
</tr>
<tr>
<td>VI</td>
</tr>
<tr>
<td>VII</td>
</tr>
<tr>
<td>VIII</td>
</tr>
</tbody>
</table>
impact was determined by exact matching of query types, for example Queries I, II and III only (Table 2).

With regard to the querying of taxonomic data from the plants collection, there were variations in the time to retrieve various results (Table 3). Optimisation of the data model depended on the data-use pattern. As the applications in the current model were mainly intended for read queries, additional indexes can be created to enhance quick accessibility. On the basis of the expected targeted search, prior assessment of the expected query could easily be designed and query results could be enhanced.

**Scalability**

In the present model, a large amount of text data can be incorporated in a single document while maintaining the structure of the original format. Moreover, scalability can be achieved by updating (Insert and Update) new key fields in already existing documents without affecting the existing structure.

**Flexibility**

In a RDM, the permissible number of columns and tables restricts the data modelling. It calls for pre-defining the fields, tables and their relationships. Contrary to such an approach, pre-defining of fields is not needed in the NoSQL approach, making it more flexible. In MongoDB, a ‘collection’ can be created during the run time if not present in the initial stage. Different types of contents can be gathered together in a single collection. The proposed model can be refined or modified during run time to adapt to the situation and demands.

**Extensibility**

The MongoDB store data in BSON (binary JSON) format, which can be exported in either traditional JSON format or XML format, are independent of platform and are portable. At the same time, both formats are human understandable and machine processable. These data can be exported to other systems.

**Replication**

Like any other database system, MongoDB deployment needs to consider availability, consistency and recovery of data, which can be achieved either by using replica-sets or applying backup methods. In MongoDB, a replica-set is a group of ‘mongod’ (primary daemon process for the MongoDB system) instances for replication. One ‘mongod’ acts as the primary member, which can accept ‘write’ operations. As only one primary is permitted per replica-set at a given moment, only one member can accept ‘write’ operations. Then, the data are synchronised to all the secondary members of the set. If the primary member became inaccessible or failed, a new primary is selected from the secondary members automatically. In other words, when one individual machine fails or undergoes servicing, datasets remain available to the clients from the other machines. Storing multiple copies of data on different servers protects a database from the loss of a single server. Moreover, members can be removed or integrated seamlessly. As such, replica sets ensure redundancy and availability of data when one node fails.

The data backup method is crucial for disaster recovery. In the eventuality of catastrophic failure (such as fire, accidents, etc.), entire replica sets might be destroyed. Considering such scenarios, a prior data backup insulated from the production system is the best precautionary measure. Data backup can be achieved through the MongoDB Management Service (MMS), by copying data files or using the ‘mongodump’ tool. This backup system takes a snapshot of the dataset at a particular moment, which are physically, logically and administratively stored far from the production system. Restoring the backup snapshot rolls back the data to the failure event.

### Table 2. Results of different query parameters for the phytochemical collection

<table>
<thead>
<tr>
<th>Query type</th>
<th>Total documents</th>
<th>Document(s) found</th>
<th>Query time in millisecondsa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Default</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ascending sort</td>
</tr>
<tr>
<td>I</td>
<td>7390</td>
<td>1</td>
<td>171.61 ± 10.43ab</td>
</tr>
<tr>
<td>II</td>
<td>7390</td>
<td>217</td>
<td>7.30 ± 0.48bc</td>
</tr>
<tr>
<td>III</td>
<td>7390</td>
<td>265</td>
<td>5.00 ± 0.47bc</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>158.21 ± 9.81cd</td>
</tr>
</tbody>
</table>

* Different letters represent significant difference at the 0.05 level.

### Table 3. Variation in query time in plants collection

<table>
<thead>
<tr>
<th>Query</th>
<th>Query type</th>
<th>Document(s) found out of 667 documents</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>Nested query</td>
<td>4</td>
<td>4.5002</td>
<td>1.080021</td>
</tr>
<tr>
<td>V</td>
<td>OR in nested query</td>
<td>12</td>
<td>4.0001</td>
<td>1.414449</td>
</tr>
<tr>
<td>VI</td>
<td>AND in nested query</td>
<td>1</td>
<td>3.6</td>
<td>0.966092</td>
</tr>
<tr>
<td>VII</td>
<td>OR query in simple and nested array</td>
<td>252</td>
<td>2.3</td>
<td>0.674949</td>
</tr>
<tr>
<td>VIII</td>
<td>AND query in simple and nested array</td>
<td>52</td>
<td>2.3</td>
<td>0.674949</td>
</tr>
</tbody>
</table>
NoSQL Data Model for Integration of Ethnomedicinal Plant Data

Phytochemical Analysis

One of the unique features of MongoDB is sharding. This process was implemented by splitting the MongoDB server into a set of front-end routing servers (mongos) that routed operations to a set of back-end data servers (mongod) (Dede et al., 2013).

Limitation

One of the concerns in most database systems is security. However, security was not a primary concern of MongoDB with its inherent gaps in design, such as encryption of MongoDB files, potential for injection attacks, use of TCP port 27017 port (which was ubiquitous) and absence of an auditing facility and authorisation. These limitations could be managed at the server-side administration levels. The most effective way to reduce risk is to deploy the data, inclusive of all components, in a trusted environment. Such an environment can be created by using a network firewall such as a firewall, binding MongoDB components to specific IP (Internet Protocol) addresses and limiting MongoDB programs to non-public local networks and virtual private networks. Data encryption can be carried out through third-party tools to secure sensitive data within MongoDB in real time.

In addition to these, there are other limitations in the MongoDB system, such as the size of the BSON document, which is restricted to 16 megabytes. Storage of larger documents, such as graphic images, illustrations, etc., is possible through GridFS. Use of this system depends on the MongoDB driver and also requires a comparatively steep learning curve. Another limitation is the inability of ‘mongod’ to manage data sets that exceed the maximum virtual memory provided by the operating system. Other limitations include restriction of replica sets to 12 members and naming restrictions, such as case sensitivity in the database name, restriction on the use of special characters and restriction on the length of the database name.

It is worth mentioning that some limitations observed in earlier versions are solved by evolution and strengthening of later versions. In spite of the limitations mentioned above, the MongoDB data model presented herein can be applied for efficient storage of datasets in different platforms.

Finally, schema design in MongoDB is a combination of art and science with regards to embedding and referencing type. The ultimate decision is generally based on the access pattern of the database. Advantage of the MongoDB data model is that it is highly flexible and the data storage strategy can be changed at will. Because of its flexibility, the MongoDB data model is appropriate for storing ethnomedicinal data, compiled from multidisciplinary sources. A simple model can be scalable to a highly complex model with the maturation of the database. The present model is designed to receive various data format related to ethnomedicinal plant data from multiple sources. The current effort shows the applicability of the NoSQL database for storing, retrieving and sharing ethnomedicinal plant data among the scientific community.

Acknowledgement

The authors would like to thank the Bioinformatics Centre, Assam University, Silchar, India for providing the necessary infrastructure for data integration and testing the data model.

References


Django. 2014. Django Documentation Release 1.7a2. Django Software Foundation: Lawrence, KS.


Annexure – 5

Certificates for participation in Seminar and Conference
National Conference
On
Contemporary Bioinformatics Researches in India
10th November, 2013
Organized by
Bioinformatics Centre (DBT-BIF)
Assam University, Silchar - 788 011
Sponsored by
DBT (Govt. of India), CSIR, ICMR, DEITY (Govt. of India)

CERTIFICATE

This is to certify that Prof. / Dr. / Mr. / Ms. N. Sanjoy participated / presented a paper in the form of Invited Lecture / Oral presentation in the National Conference on Contemporary Bioinformatics Researches in India, organised by Bioinformatics Centre, Assam University, Silchar - 788 011 on 10th November, 2013.

(Prof. M Dutta Choudhury)
Organising Secretary, CBRI
INTERNATIONAL CONFERENCE ON

BIODIVERSITY CONSERVATION AND ENVIRONMENTAL HEALTH

16-17 March 2012

Organised by
Department of Life Science and Bioinformatics
Assam University, Silchar - 788 011, India

(SUPPORTED BY UGC-SPECIAL ASSISTANCE PROGRAMME)

Certificate

This is to certify that Ningthoujam Sanjoy Singh
of Department of Life Science and Bioinformatics, Assam University, Silchar
has participated/presented a paper entitled "Antibacterial Medicinal Plants..."
by the Meitei community of Manipur during the International Conference
on Biodiversity Conservation & Environmental Health from 16-17
March 2012 at Assam University, Silchar.

Prof. G.D. Sharma
Chairman,
BCEH-12

Prof. S. Giri
Organising Secretary,
BCEH-12
Certification of Participation

This is to certify that

Prof. Dr. J.B. Singh

Participated in the Two days seminar on

SCIENCE FOR SHAPING THE FUTURE OF INDIA

organized by Indian Science Congress Association - Imphal Chapter

27-28 August, 2012

She chaired the technical session, delivered keynote or invited lecture on

Entomological Engineering for Ethnomedicinal plants of North East India.