

# PALM-LEAF MANUSCRIPT PROFILING INITIATIVE

## MISSION TO PONDICHERY 2022 - 2025



Cluster of Excellence Understanding Written Artefacts (DFG EXC 2176)

Centre for the Study of Manuscript Cultures  
Universität Hamburg



Funded by



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## ABOUT THE PROJECT

### Understanding Written Artefacts (UWA)

The Cluster of Excellence 'Understanding Written Artefacts' (UWA), is part of the Centre for the Study of Manuscript Cultures (CSMC), a research centre within the Universität Hamburg at the Faculty of the Humanities and the Faculty of Mathematics, Informatics and Natural Sciences. It brings together researchers from more than 40 academic disciplines with the aim to develop a global framework for the study of all written artefacts from the beginning of writing to the present day and from all regions that have produced such artefacts. Funded by the German Research Foundation (DFG), the Cluster is being carried out in cooperation with Helmut Schmidt Universität, Technische Universität Hamburg (TUHH), and Deutsches Elektronen-Synchrotron (DESY).

### Palm-Leaf Manuscript Profiling Initiative (PLMPI)

UWA and CSMC have established the project Palm-Leaf Manuscript Profiling Initiative (PLMPI), which aims to develop an innovative, comprehensive and integrated approach to studying Indian palm-leaf manuscripts. These include material analyses of both fresh palm-leaves and palm-leaf used in manuscripts, in order to investigate the material properties of those written artefacts and thus better appreciate their historical and cultural value.

### Project Concept

Palm-leaf manuscripts constitute one of the major formats for knowledge transfer in writing besides the Western codex, the predecessor of the modern printed book. They are one of the world's most important and numerous handwritten artefacts, found in yet uncounted millions. Geographically, their production and use span an area that reaches from the oases of the Silk Road over the Indian subcontinent to both mainland and maritime South-East Asia. Today their production has dwindled, with the exception of a few monasteries and workshops for tourist handicrafts. Very little is generally known about palm-leaf manuscripts in terms of their material features. This is even more true for those hailing from South India. In recent years UWA and CSMC have been at the forefront of this research, achieving significant results.



*Amarakośa with Tamil meaning (IFP RE37121, 38v), c. 19th century, Palmyra leaf (© Institut Français de Pondichéry).*

Reconstructing the history of production and circulation of written knowledge in historical Tamil Nadu and South India by integrating information from the study of manuscript texts (Humanities) with analysis of their material features (Applied Sciences) will allow creating a frame of reference for their study. Furthermore, such a reference study and database will provide a solid foundation for the study of palm-leaf manuscripts in Tamil Nadu and represent a pilot model for similar studies on palm-leaf manuscripts from other cultural areas both inside and outside India.

### Project Funding

The PLMPI Mission to Pondicherry (2022–2024) is funded by the German Research Foundation (DFG), under the auspices of the Cluster of Excellence "Understanding Written Artefacts", hosted by the Centre for the Study of Manuscript Cultures (CSMC), University of Hamburg.

### Goals of the PLMPI Mission to Pondicherry (2022–2025)

- Investigating the history of palm-leaf manuscripts from historical Tamil Nadu and South India,
- Gaining insight into the craftsmanship of the production of palm-leaves for writing,
- Testing the applicability of a number of analytic techniques to the study of palm-leaf manuscripts,
- Demonstrating the functionality of CSMC's novel Container Lab for overseas deployment.



## MANUSCRIPT COLLECTIONS PROPOSED FOR STUDY

Two large private collections of palm-leaf manuscripts that transmit principally Sanskrit, Tamil, and Manipravalam texts are preserved in French research institutions in Pondicherry. The first major collection is that of the French Institute of Pondicherry (IFP), which comprises 8,187 palm-leaf bundles collected from every area of the Tamil-speaking South of India and contains texts of every branch of pre-colonial Indian learning. Nearly half of the material relates to Saivism, the worship of the God Siva. It is in fact the largest collection in the world of manuscripts of texts of the Saiva Siddhanta, a religious tradition that in the 10th century CE was spread across the Indian subcontinent and beyond, as far as Cambodia in the East, and still represents the major form of Saivism practised in Tamil Nadu.

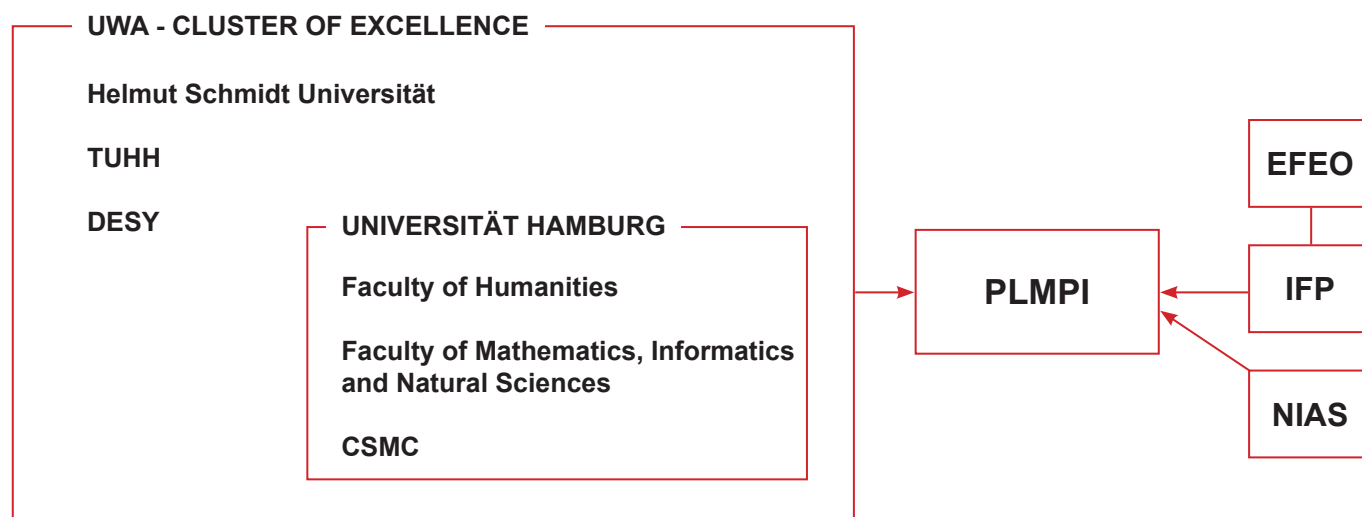


*Palm-leaf manuscripts in the collection of the IFP (© Institut Français de Pondichéry).*

The second collection is housed in the Pondicherry Centre of the École française d'Extrême-Orient (EFEO), a French research institution under the aegis of the French Ministry of Higher Education, Research and Innovation. This is a collection of 1,662 palm-leaf manuscripts, mostly related to Vaiṣṇavism, donated by their owner from the Tirunelveli District in Tamil Nadu.

In 2005, the “Manuscript Holdings of French Research Institutions in Pondicherry” were entered into the UNESCO Memory of the World Register at the joint request of EFEO, IFP, and the Government of India’s National Mission for Manuscripts. (<https://en.unesco.org/memoryoftheworld/registry/535>).

## ARCHITECTURE OF PLMPI



## PROFILES OF INSTITUTIONAL PARTNERS IN INDIA



### **French Institute of Pondicherry (IFP), Pondicherry (MoU signed)**

Director: Dr Blandine Ripert

The French Institute of Pondicherry (IFP), UMIFRE 21 CNRS-MEAE, is a research institution under the joint supervision of the French Ministry of Foreign Affairs and the French National Centre for Scientific Research (CNRS). It is the largest of the 26 research centres under these umbrellas. It is also part of the Research Unit USR 3330 "Savoirs et Mondes Indiens" of the CNRS, along with the Centre de Sciences Humaines (CSH) in New Delhi. The Indology Department, which administers the IFP manuscript archive, will be the most direct collaborator of the project, providing philological expertise on the manuscripts in the collections of the IFP and the EFEO. IFP's Ecology Department will anchor the 'Silica project' and the fieldwork to create the modern-analogue of palm-leaf varieties.



### **Ecole française d'Extrême-Orient, Pondicherry Centre (Letter of Intent signed)**

Head, Pondicherry Centre: Prof Dr Dominic Goodall

The French School of Asian Studies (EFEO), headquartered in Paris, is a public institution under the aegis of the French Ministry of Higher Education and Research. Its mission is interdisciplinary research on the civilizations of Asia, extending from India to Japan and maintains a network of eighteen research centres in twelve Asian countries. EFEO's Pondicherry Centre provides a setting for the Library of Indology (about 11,000 titles), and houses a collection of maps and drawings, as well as manuscript texts on palm-leaves in Sanskrit, Tamil, and Manipravalam.



### **National Institute of Advanced Studies (NIAS), Bangalore (MoU signed)**

Programme Head, Heritage Science and Society: Prof Dr Sharada Srinivasan

National Institute of Advanced Studies (NIAS) is an autonomous research organisation, nested within the Indian Institute of Sciences (IISc), Bangalore, a public, deemed, research university for higher education and research in science, engineering, design, and management and recognized as an Institute of Eminence. NIAS conducts advanced multidisciplinary research across natural and social sciences, humanities, and arts. The NIAS collaboration will draw on their expertise in archaeometry.

## OVERVIEW OF PAST AND ONGOING EFFORTS

Although a few descriptive catalogues are available for the main public and private collections of palm-leaf manuscripts of Tamil Nadu, the general degree of precision of the records does not yet allow us to undertake serious quantitative codicological studies for reconstructing the history of the artefacts. The in-depth study of the codicological features of palm-leaf manuscript from Tamil Nadu is still in its infancy, with just a few specialised publications, most of which published by scholars who are either working for the CSMC or are actively collaborating with it.

### PHILOLOGY & CODICOLOGY

Deciphering and interpreting Tamil and Sanskrit paratexts of manuscripts written in Tamilian Grantha and Tamil scripts

Preceding projects:

2019-2022 '*Texts Surrounding Texts*', co-funded by the French Agence Nationale de la Recherche (ANR) and the DFG, has catalogued the collection of some 500 palm-leaf manuscripts from Southern India held by the State and University Library of Hamburg and at the Bibliothèque Nationale de France in Paris.

### PALAEOGRAPHY & CODICOLOGY

Describing the evolution of scripts and other scribal features of manuscripts

Preceding projects:

2014-2019 '*NETamil - Going From Hand to Hand: Networks of Intellectual Exchange in the Tamil Learned Traditions*', funded by an European Research Council (ERC) Advanced Grant, with CSMC Hamburg and EFEO

2019-2022 '*Texts Surrounding Texts*'

### MULTI-SPECTRAL IMAGING

Using multi-spectral imaging equipment aimed at experimenting on difficult-to-read passages

Preceding projects:

2015, '*Bringing back to a legible condition manuscripts with the Cilappatikāram, belonging to Tiruvāṇṭūṭurai Mutt, one of the oldest active monasteries of the region*', with CSMC Hamburg and EFEO

### COMPUTER SCIENCE

Applying informational tools for the automatic detection of patterns in, among others, palm-leaf manuscripts from Tamil Nadu, which offers researchers a new tool for the study of the history of palm-leaf manuscripts.

Developing a customised XML-based Text Encoding Initiative (TEI) strategy for tagging the content (words and syntactic patterns) of colophons found in Indic manuscripts.

Ongoing project:

'*XML TEI Encoding Strategies for Indic Colophons*', in collaboration with independent TEI expert Dr Giulia Buriola Meneghin.

Preceding projects:

2022, '*Pattern Recognition in 2D Data from Digitised Images and Advanced Acquisition Techniques*', in collaboration with Dr Hussein Adnan Mohammed at CSMC Hamburg.

## TAMIL MANUSCRIPT CULTURE

***Who was copying and reading which texts, when, and where?***

### **Paratext**

*Material (prefaces, annotations, titles, etc.) associated with but distinct from the main body of a book, film, game, etc., typically produced by someone other than the original author or creator*

### **Colophon**

*-An inscription at the end of a book or manuscript usually with facts about its production*

*-An identifying mark used by a printer or a publisher*



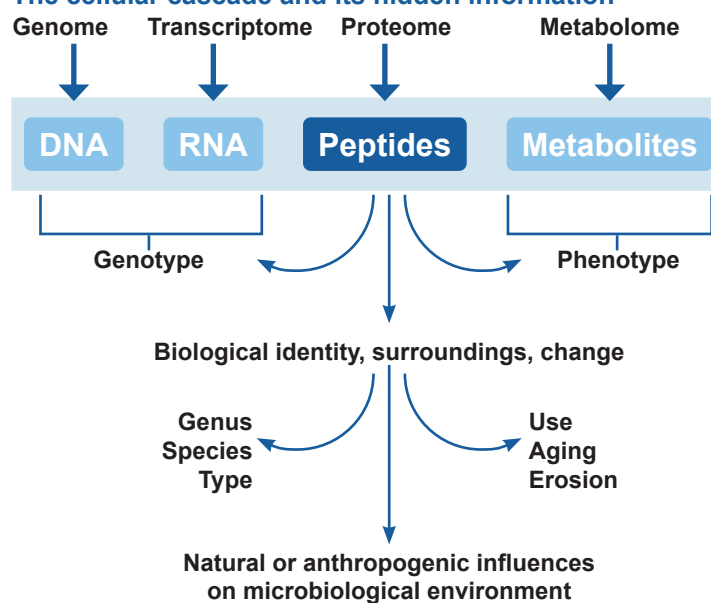
## STATE OF THE ART

Observing the bewildering diversity of sizes, colours, textures, etc., it is clear that a number of unknown factors affect the outlook of manuscripts; the selection of raw material, the methods for production of written supports, writing techniques, and the practices of storage. Information retrieved from paratexts can fruitfully be matched with other data obtained from material analysis. The results generated by the PLMPI activities can be accessed on the Research Data Repository of the University of Hamburg ( <https://www.fdr.uni-hamburg.de/>, search-word "PLMPI").

### MOLECULAR ANALYSIS

Each material is characterised by a unique molecular imprint that depends on its origin (animal or vegetal), storage history and bio-deterioration, and is reflected in its DNA molecules, proteins, lipids, and cells.

#### The cellular cascade and its hidden information



A nylon swab used for DNA analysis of a palm-leaf manuscript from Sri Lanka (© Karsten Helmholtz for CSMC)



XRF spectrometer (© CSMC)

### ELEMENTAL ANALYSIS

The study of the elemental composition of (inorganic) materials can be applied to the study of ink (soot + binder) and to elements that may occur on the surface of the manuscripts' leaves. In addition to X-ray Fluorescence (XRF) and Fourier Transform Infrared Spectroscopy (FTIR), Wide Angle X-ray Scattering (WAXS) is being tested in Hamburg at DESY.

### MECHANICAL ANALYSIS

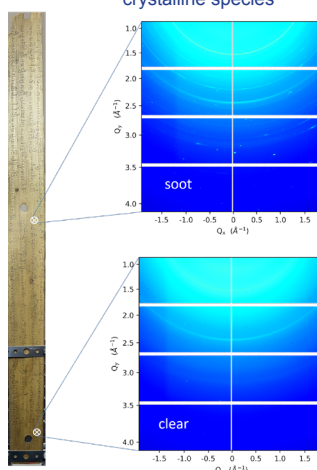
Mechanical properties of palm leaves, such as hardness and elasticity, that depend on the type of leaf and its preparation for hosting writing can be studied through microscopic techniques, such as Atomic Force Microscopy (AFM) and Small Angle X-ray Scattering (SAXS), both carried out at DESY.

### BIO-INFORMATICS

Introducing chemometric data analysis, such as the unsupervised Principal Component Analysis (PCA) and the machine learning method random forest to comprehensively exploit complex data, e.g. generated for the profiling of written artefacts.

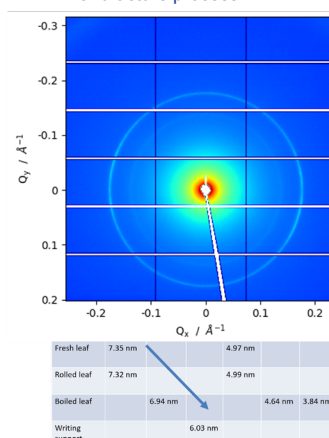
#### WAXS-Composition

Rings indicating different crystalline species



#### SAXS-Fiber Size

Possible decreasing fiber size with manufacture process



Leaves in different stages of preparation and PLM are measured with small and wide angle incident X-rays to investigate their fibre and molecular structures. (© Laura Gallardo Dominguez, AG Huber)

## MISSION TO INDIA (2022 - 2024)

Since April 2022, CSMC and IFP researchers have worked together towards contextualising and articulating the PLMPI project to Indian and specifically Pondicherry ground conditions, building partnerships with Indian research institutions, and obtaining the necessary permits required to undertake the various scientific work. As a result, PLMPI now comprises a number of sub-projects and activities that, thanks the experience already gained to this date (summer 2023), work towards an integrated and focused approach to the analyses of palm-leaf manuscripts in general and those belonging to the collections hosted by IFP and EFEO in particular.

### 1. Online Seminars at IFP

#### April 2022 onwards

Since April 2022, members of the PLMPI team have presented their ongoing work at the IFP to familiarise IFP researchers across all departments with the multiple analytical tools and techniques of the PLMPI project. The aims are to explain in detail how each technique will be useful to the material study of palm-leaf manuscripts, and discuss how they could be used by IFP researchers and students to develop small parallel projects using these techniques.

- |            |   |
|------------|---|
| April '22  | "Palm-Leaf Manuscript Profiling Initiative (PLMPI) and the Study of South Indian Palm-Leaf Manuscripts" - <i>Dr Giovanni Ciotti</i>   |
| May '22    | "Colophons to Material Analysis: A Comprehensive Approach to The Study of Palm-Leaf Manuscripts from Tamil Nadu" - <i>Dr Giovanni Ciotti &amp; Prof Dr Marco Franceschini</i> |
| July '22   | "Metabolite Profiling of Wood and Plant Food by non-targeted high-resolution Mass Spectrometry" - <i>Dr Marina Creydt</i>   |
| August '22 | "Classification and characterization of complex data with chemometric approaches" - <i>Prof Dr Stephan Seifert</i>  |
| Feb '23    | "Non-/minimally invasive on-site analysis of palm-leaf manuscripts" - <i>Dr Sebastian Bosch</i>   |

### 2. Silica Project and Sampling Fieldwork

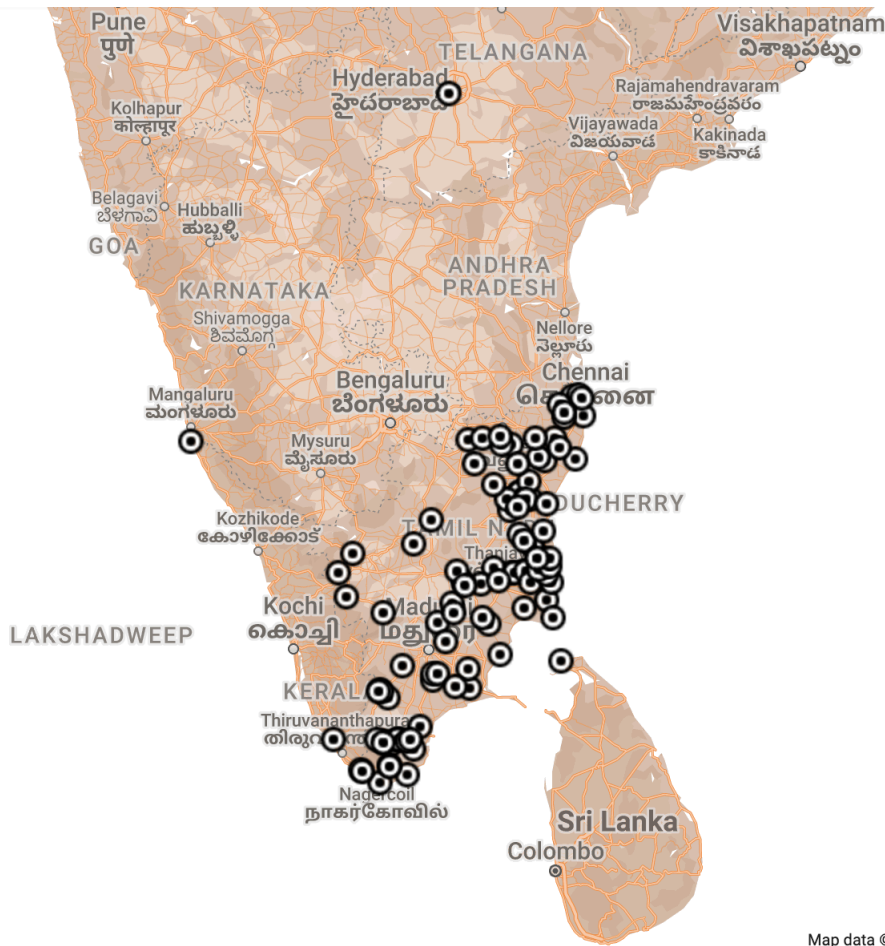
#### July 2023 - July 2024

The objective of the 'Silica Project' is two-fold; First, it aims at testing if phytolith composition and silica concentration play a role in the quality of a palm-leaf as writing support, and if some regions of Peninsular India, rather than others, may have been preferred suppliers of this material. Second, this study will investigate the potential impact of the preparation of palm leaves in the quality of the final manuscript. What are the harvest periods, methods and recipes for palm leaves preparations and how does this impact the quality of a manuscript?

Fieldwork to carry out sampling of living palms in peninsular India will be undertaken in order to provide a modern benchmark against which ancient palm leaves (i.e. manuscripts) could be compared in terms of silica content and composition. Sampling locations (villages) will be determined from geographical origins indicated in each manuscript. These locations are spread across Tamil Nadu, Kerala, Puducherry, Andhra Pradesh, Telangana, and Karnataka. The focus will be on the two species *Borassus flabellifer* (Palmyra) and *Corypha umbraculifera* (Talipot).

This sampling could be used for other studies (DNA, proteomics, etc.) involved in the PLMPI, which also require a modern reference frame. The results should help to provide another set of evidence on the geographical provenance of palm leaves, provided that the leaves do mark regional differences between soils and climatic domains, as expected from our knowledge of previous studies on silica in plants.

*Note: National Biodiversity Authority application in process. Fieldwork will begin once all approvals have been granted.*



Map data ©2023 Google

*Preliminary mapping of colophons to plan sampling fieldwork*

#### Researchers

##### CSMC, Hamburg

Prof Dr Markus Fischer

Dr Marina Creydt

Dr Anastasia Poliakova

##### IFP-Ecology

Dr Doris Barboni, (co-PI)

Dr Ayyappan Narayanan

Dr Balachandran Natesan

Ms. Kokilavani Vengatesan

### 3. Building a Database of Tamil Colophons / Protocol for Handling Manuscripts

July 2023 - December 2023

IFP's Indology Department will undertake two key activities during the PLMPI mission. First, expand on the work done by CSMC to extract and transcribe colophons from Tamil manuscripts; place names, scribe names, and all information relevant to the provenance of the manuscripts. The search will include nearly 300 Tamil manuscripts listed as 'medical' and critical editions of Sanskrit and Tamil texts from the IFP collections, and manuscript descriptions established by Pt. Varadadesikan and R. Sathyanarayanan from EFEO's collection. The objective is to identify as many 'locations' as possible to provide a wide sampling area for fresh palm-leaves.

Second, set up a protocol for the 2024 Container Lab mission, in particular how to safely handle the transport of manuscripts from the premises of the IFP and EFEO to and from the Container Lab's location.

#### Researchers

##### CSMC, Hamburg

Dr Giovanni Ciotti (PI)

Prof Dr Marco Franceschini

##### IFP-Indology, EFEO

Dr Hugo David (co-PI)

Dr Borayin Larios

Dr Deviprasad Mishra

Dr Babu Gunasekaran

#### 4. Archaeometric Analysis of Manuscripts (*Tentative*)

January 2024 - October 2024

Chemical elements other than carbon that can be found on the leaves of the manuscripts or in their ink (usually made of soot and an organic binder) can be indicative of specific methods for the preparation of the ink itself. Therefore, they may be used to divide manuscripts in sub-groups that are pertinent to their geographical and artisanal origin. In this respect, it is proposed to study the elemental composition of both leaves' surfaces and inks using spectrographic techniques, such as X-ray fluorescence (XRF-JET) and Fourier-transform infrared spectroscopy (FTIR).

Depending on the space and technical considerations, these two machines may be housed at either the IFP or the EFEO premises concurrent to the Container Lab mission.

##### Researchers

###### CSMC, Hamburg

Dr Sebastian Bosch  
Dr Olivier Bonnerot  
Prof Dr Stephan Seifert  
Lucas F. Voges

###### NIAS, Bangalore

###### Prof Dr Sharada Srinivasan, (co-PI)

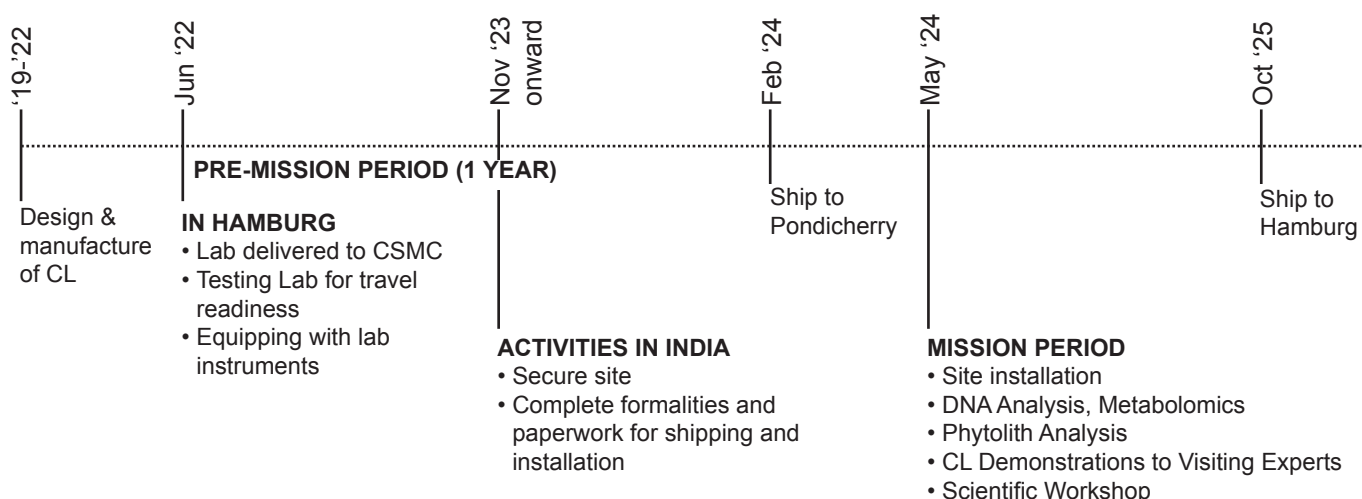
Madan S.  
Dr S. Udayakumar  
Diya Mukherjee

#### 5. Container Laboratory Pilot Mission

January - October 2024

CSMC has developed a state-of-the-art Container Laboratory to bridge the gap between site-based, high-performance analysis and mobile, hand-held in-situ analysis. It has been designed to be shipped anywhere in the world in order to carry out scientific analyses of written artefacts (manuscripts, inscriptions, etc.), in particular to areas where scientific instrumentation is not available or only partly available. The Lab will make its pilot mission to Pondicherry in 2024.

##### TIMELINE OF ACTIVITIES



##### Researchers

###### CSMC, Hamburg

Prof Dr Markus Fischer  
Dr Marina Creydt  
Dr Anastasia Poliakova

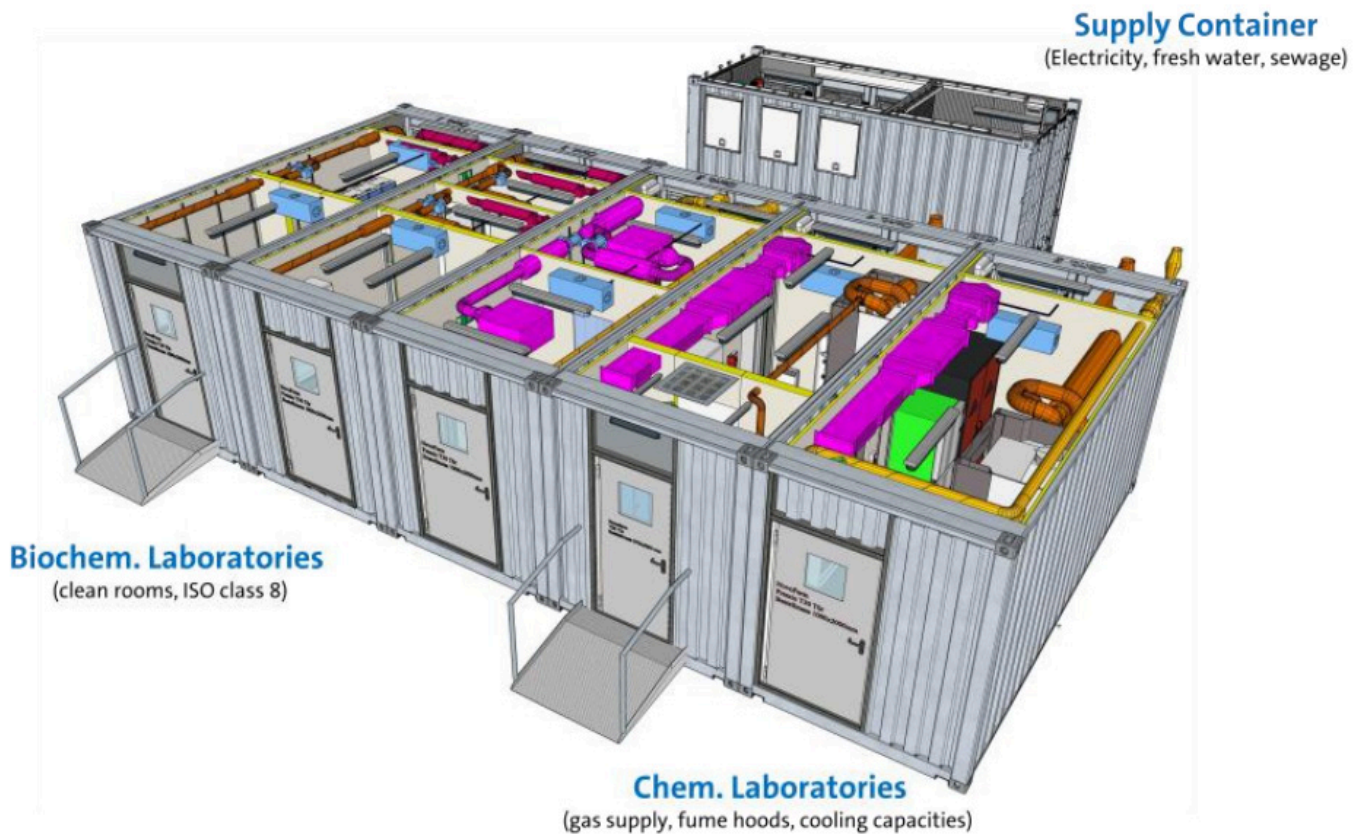
###### IFP-Ecology

Dr Doris Barboni, (co-PI)  
Ms. Kokilavani Vengatesan



## CSMC CONTAINER LAB

The Container Lab (CL) consists of five interconnected and inter-locked high-cube sea containers, air-conditioned and equipped with instruments for molecular biology, wet chemistry, and spectrography. A sixth Energy Container is fitted with utilities and infrastructure connections. A seventh Supply Container will be placed nearby. The Container Lab is intended for worldwide use and transportation by ship and truck with Convention for Safe Containers (CSC) safety approval, i.e. the containers can be transported on container ships without restriction.



*As seen from service side of Container Lab*



## SITE REQUIREMENTS

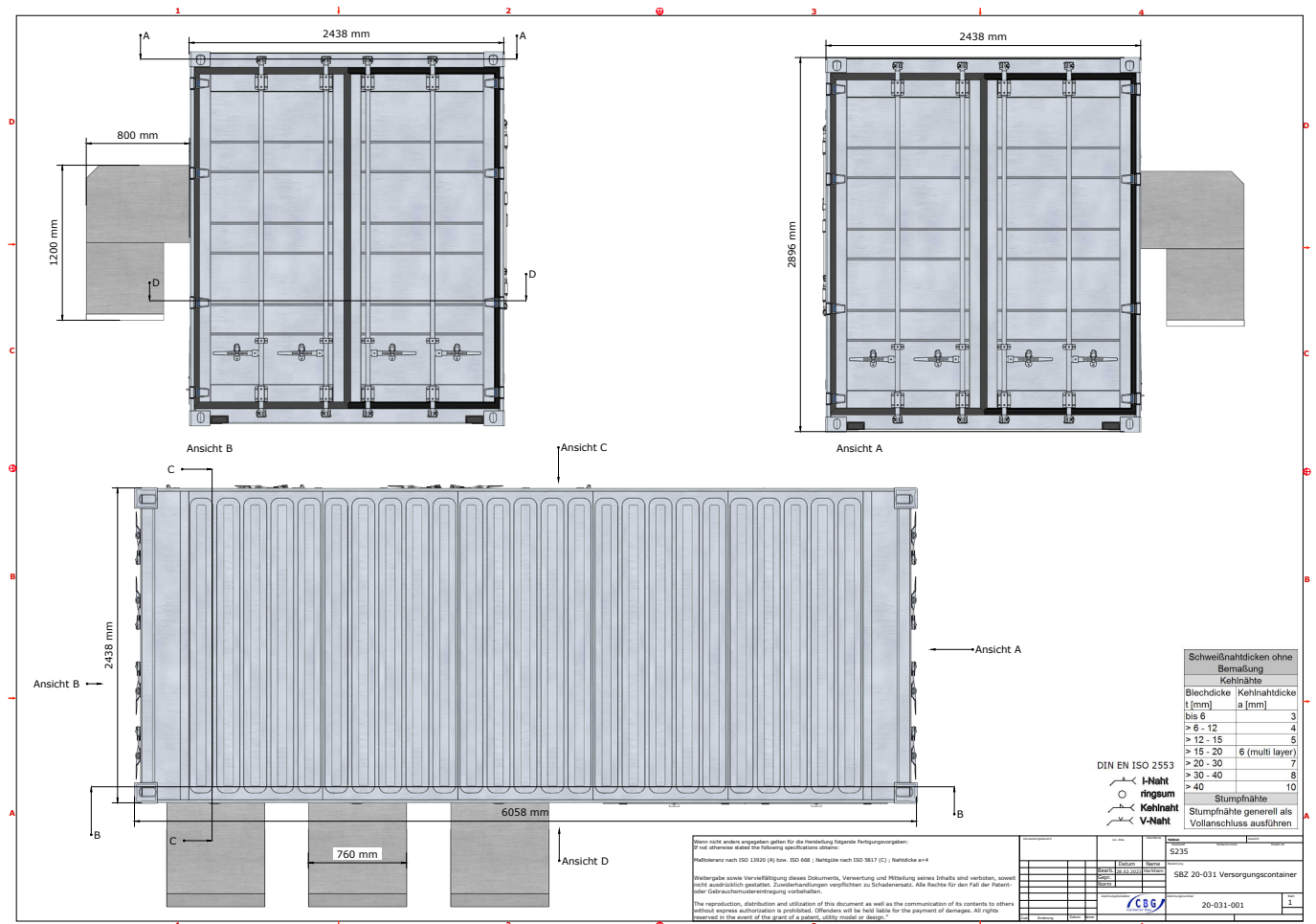
The Container Lab requires a secured space in the vicinity of the IFP for the duration of its pilot mission to Pondicherry. Wide entry and height clearance are required to enable lifting and manoeuvring the containers into place. In addition, access to on-site electricity and water will enable uninterrupted laboratory work during the mission.

The assembly will consist of:

**Laboratory Container (High Cube):** 5 Piece - 6.058 x 2.438 x 2.896 mm (L x B x H)

**Energy Container (High Cube):** 1 Piece - 6.058 x 2.438 x 2.896 mm (L x B x H)

**Material Container:** 1 Piece - 6.058 x 2.438 x 2.591 mm (L x B x H)



**Site Area: approx. 18m x 18m**  
**Entrance width: Minimum 3.2m**

### Requisites:

- Proximity to IFP
- Adequate open space for tractor bed and forklift
- On-site water and electricity supply
- The Energy Container must stay within 2.5m to the Container Lab, to connect electrical cables, water pipes and supply/exhaust air for cooling
- Adequate space to ensure rear side doors of the Container Lab can stay open

## UTILITIES & INFRASTRUCTURE

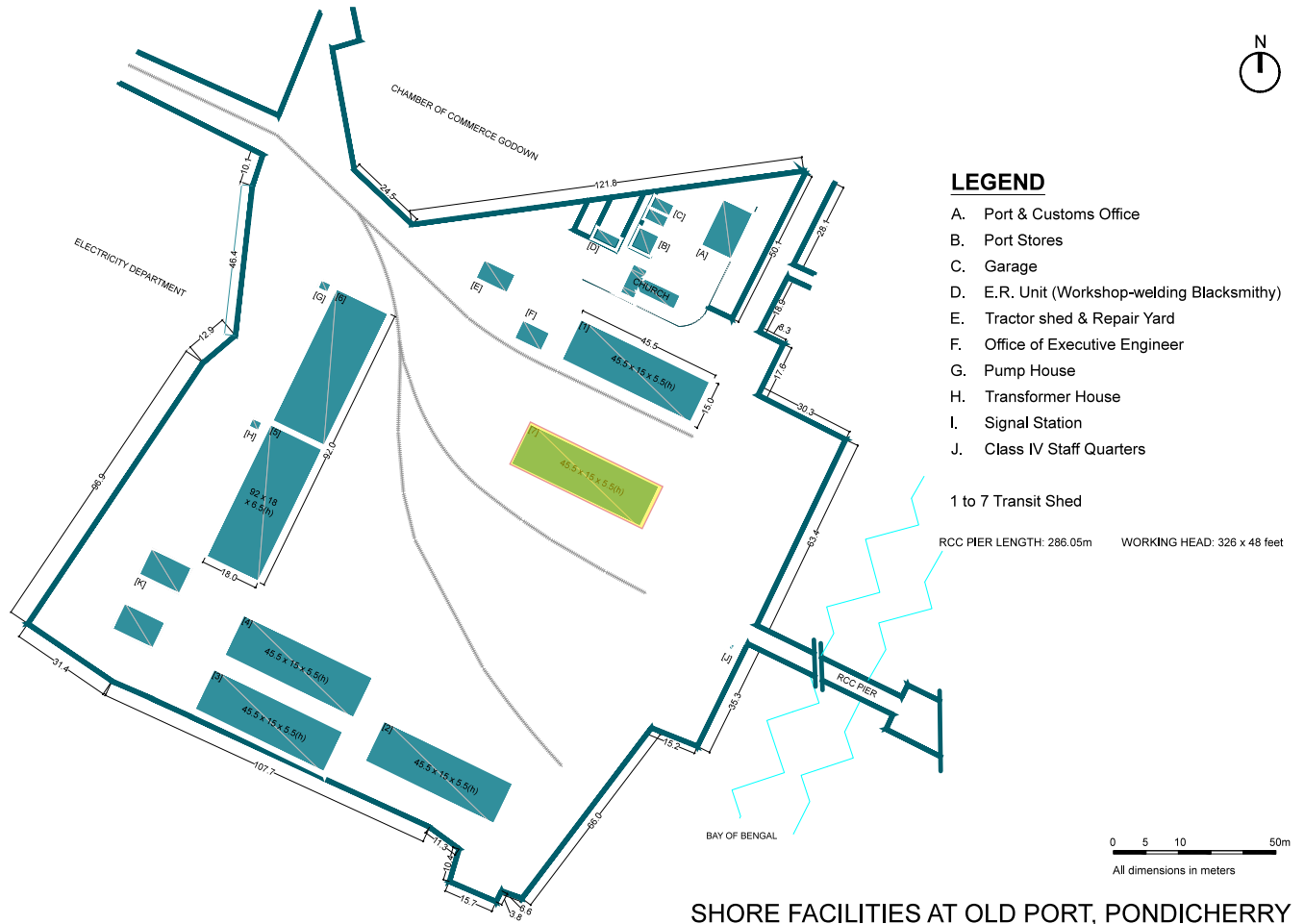
Type	Consumption	Supply	Disposal
<b>Electricity</b>	Power consumption: Total 75 kW/h i.e. 15 kW/h per container  Air conditioning Hot water Lighting Water Filtration Lab machines	<b>Supply Option 1:</b> Direct supply from electrical grid, complemented by stabiliser and standby generator  5 connections x 400 Volt / 3-phase current / 32 Ampere / (100A 3-phase current (400V) per day)  <b>Supply Option 2:</b> 85kVA Diesel Generator	NA
<b>Gas</b>	Nitrogen gas	<b>Supply Option 1:</b> Nitrogen generator installed inside container  <b>Supply Option 2:</b> Nitrogen tanks purchased locally	NA
<b>Water</b>	Uninterrupted continuous supply Drinking water filter Lab Sinks	Municipal water supply ↓ Connected to RO+UV water filtration system installed in the Utility Shed/ Lab.	Waste water pipe connected to existing drainage line on-site
<b>Distilled Water</b>  <b>DNase/RNase Free Millipore Water</b>	Approx. 20L daily	Canisters	Disposal Option 1: Direct connection to existing drainage line on-site  Disposal Option 2: Collected in 1000 litre tank and disposed off-site
<b>Organic Chemicals</b>	Small quantities of reagents - organic solvents, acids and alkalis  <i>Note: No explosive or radioactive materials will be used.</i>	Proteomic grade chemicals will be purchased locally and stored in canisters within the lab	A local company certified to carry out safe disposal will be engaged for the duration of the mission.
<b>Internet</b>	Uninterrupted supply	Broadband or Fibre Optic net will be locally installed	NA
<b>Toilets</b>	24x7 for mission duration	<b>Option 1:</b> Access to on-site facilities  <b>Option 2:</b> Install portable toilets	As needed
<b>Security</b>	24x7 for mission duration	Will be engaged locally	NA



**CONTAINER LAB SITE: OLD PORT COMPOUND - GODOWN NO. 7**  
*(PLANNED URBAN ENTERTAINMENT VILLAGE)*









**TRANSPORT AND INSTALLATION**  
(REFERENCE IMAGES FROM INSTALLATION IN HAMBURG)



*Containers being transported to site*



*40-tonne crane unloads each container and places it into position*





*Floor clamps of 8m span provide stability during lifting*



*The assembled Container Lab at Science City Bahrenfeld*

## SCIENTIFIC OUTPUT AND PUBLIC OUTREACH

### DOCUMENTARY FILM

A documentary film is in the making by the Berlin based media company Hoppenhaus & Grunze Medien (<https://hgmedien.com/>). This film will present to the interested public the construction and deployment to South India of the UWA/CSMC Container Lab.

Length:	Approx. 25 minutes
Language:	English
Shooting days:	4 days in Bremerhaven (construction site of the Container Lab); 2 days in Hamburg at CSMC (research and testing of the Lab in Germany); 6 days in Pondicherry, India (deployment of the Lab abroad)
Shooting period:	2022-2025

### SCIENTIFIC CONFERENCE AND WORKSHOPS AT IFP/EFE0

Key outputs of the PLMPI project will consist of publishing scientific results, and public and academic publications co-authored with project partners from Germany and India.

During the deployment of the Container Lab to Pondicherry, an international conference will be organised for scholars and scientists from all disciplines involved in PLMPI to present and share the state of the art of their researches and advance hypotheses on how to implement future sustainable investigations. The aim is to showcase advances in the field and foster interdisciplinary exchange among the humanities, natural sciences, and computer sciences.

Duration:	3 days
Programme:	Min. 10 presentations and 2 two hands-on workshops
Output:	Publication of the proceedings



## INSTITUTIONS WHERE ANALYSIS WILL BE CARRIED OUT

Material analysis will focus on two types of material

**Palm-leaf manuscripts:** Non-invasive investigation, as well as minimally invasive techniques (retrieval of a few molecules of leaf materials on an inscribed leaf by nylon swabbing) will be applied on inscribed folios. Invasive analysis will be carried out only on non-written fragments that have naturally detached from the manuscript.

**Fresh palm leaves:** Two palm tree species endemic to South and South-east Asia are identified for use as manuscript folios; *Borassus flabellifer* (Palmyra) and *Corypha umbraculifera* (Talipot). Leaves from living Palmyra and Talipot trees are required to establish a modern reference system for evaluating the results of analyses carried out on manuscripts.

In addition to the analyses that will be carried out in the Container Lab, further analyses will also be carried out at UWA partner institutions in Germany and at IFP.

### GERMANY

#### (i) DNA analysis, Phytolith analysis, Mass spectrography

Universität Hamburg, Department of Chemistry,

Contact Person: Prof. Dr. Markus Fischer, Deputy Head of the Department

Tel: +49 40 42838-4359/7, Email: markus.fischer@uni-hamburg.de

#### (ii) XRF, Raman, FTIR spectroscopy

Universität Hamburg, Centre for the Study of Manuscript Cultures (CSMC),

Contact Person: Dr Sebastian Bosch, Manager of Instrumental Analytics

Tel: +49 40 42838-9408, Email: sebastian.bosch@uni-hamburg.de

#### (iii) SAXS, WAXS

Technische Universität Hamburg (TUHH), Institute for Materials and X-Ray Physics (M-2)

Contact Person: Prof. Dr. Patrick Huber, Institute Director

Tel: +49 (0) 40/8998-5836, Email: patrick.huber@tuhh.de

Laura Gallardo Dominguez, Email: laura.gallardo@tuhh.de

#### (iv) Computer Tomography (CT) Scanning

Deutsches Elektronen-Synchrotron (DESY), Hamburg

Contact Person: Prof. Dr. Christian Schroer, Lead Scientist PETRA III

Tel: +49 (0) 40/8998-2503, Email: christian.schroer@desy.de

### PONDICHERRY

#### (i) Analysis of biogenic silica in palm-leaves and soil

French Institute of Pondicherry, Department of Ecology,

Contact Person: Mrs. Dr. Doris Barboni, Head of Department

Tel: +91 9600785073, Email: doris.barboni@ifpindia.org

#### (ii) Analysis of carbon/nitrogen ratio in palm-leaves

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