LAMINATION OF ARCHIVAL PAPER MATERIALS

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CONTENTS

- INTRODUCTION
- PAPER
- FACTORS OF DETERIORATION OF PAPER
- CONSERVATION
  - DUPLICATE CONSERVATION
  - PREVENTIVE MEASURE
  - CURATIVE MEASURE
- MATERIALS USED FOR CONSERVATION OF PAPER
- DISCUSSION ON
  - REINFORCING MATERIAL
  - MATRIX MATERIAL
- CONCLUSION

INTRODUCTION

The concept and use of conservation, is an age old tradition. The sole idea behind conservation is to ensure stabilization and protection of records against dangers and also correction of damaged wealth. The priority of placing materials in conservation is based on their rate of deterioration. The more rapidly decaying materials are given first importance than others. One such material is paper, as far as conservation of paper objects are concerned, the lamination process is the most widely used method. This paper focuses mainly on the materials used for the lamination of paper, their characteristics and their compatibility for paper conservation.

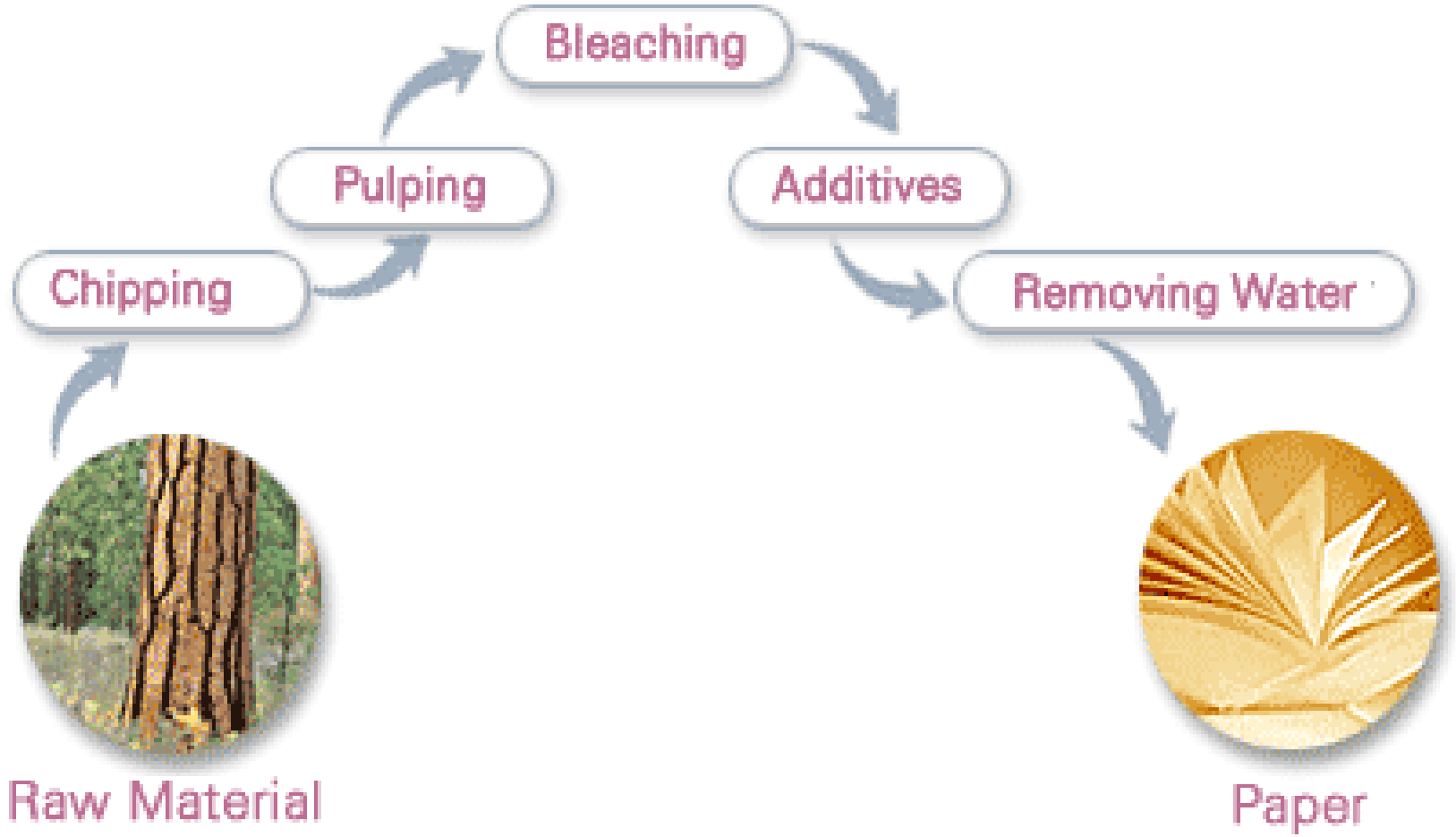
PAPER

- **Paper is a thin material used for writing, printing or packaging.**

- **It is produced by the amalgamation of fibers, typically vegetable fibres composed of cellulose, which are subsequently held together by hydrogen bonding.**

- **Paper can be classified into types based on the type of manufacturing:**
  - **Hand-made paper**
  - **Machine-made paper**

PAPER MANUFACTURE



PAPER DOCUMENT

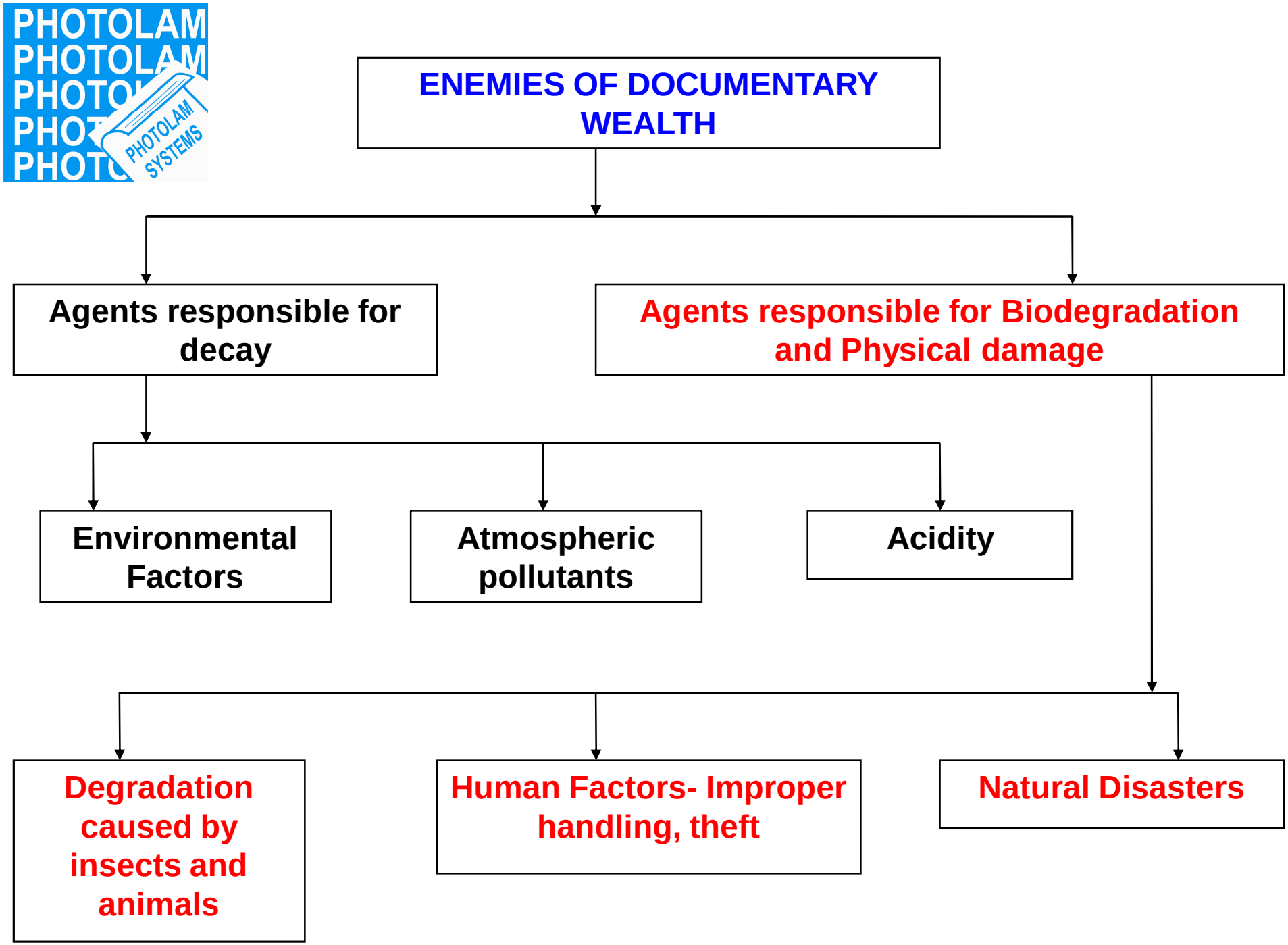
- A **document** is a bounded physical representation of body of information designed with intent to communicate. The documents are created with the aid of paper, media/ink and the sizing layer on the paper. The chief constituent of paper is cellulose.

Deterioration factors

The paper can be damaged or deteriorated with the following factors:

The sizing material alum rosin in majority of paper causes acidity and makes it acidic paper.

- **Environmental factors:** like light, temperature, humidity, dust, dirt, pollution, water, fire, etc.
- **Biological factors**: microorganisms like fungi, bacterial insects, silver fish, cockroaches, bookworms, book lice, termites, rodents, etc.
- **Chemical factors:** formation of acids in paper.
- **Human factors**: like handling and improper stacking, theft, etc.
- **Natural Disasters**: like floods, earthquakes, etc.,


ENEMIES OF DOCUMENTARY WEALTH
Agents responsible for decay
Agents responsible for Biodegradation and Physical damage
Environmental Factors
Atmospheric pollutants
Acidity
Degradation caused by insects and animals
Human Factors- Improper handling, theft
Natural Disasters

DETERIORATED DOCUMENTS











PRESENT SCENARIO IN PAPER CONSERVATION









CONSERVATION

"Conservation is defined as the process of dynamic management of change in order to reduce the rate of decay, and to prolong the life cycle of the concerned objects. The cultural, scientific and natural heritage must be conserved as authentic documents. Intervention should be limited to actions strictly necessary to insure the techniques and materials used should not impede future treatment or examinations."

Source: Sir Bernard Feilden, Director, international Centre for the Study of the Preservation and Restoration of Cultural Property, Rome (ICCROM), 1986.

CONSERVATION

- Duplicate Conservation
- Preventive conservation (Passive way)
- Curative conservation (Active way)

CONSERVATION

DUPLICATE CONSERVATION

- MICROFILMING
- COMPUTER SCANING–DIGITAL
- PHOTOCOPYING
- PHOTOGRAPHS

CONSERVATION

PREVENTIVE CONSERVATION

- STORAGE
- GOOD HOUSEKEEPING
- PEST CONTROL
- TEMPERATURE CONTROL
- HUMIDITY CONTROL
- PROPER HANDLING.

CONSERVATION

CURATIVE CONSERVATION

1. **Fumigation.**
2. **Deacidification.**
3. **Cleaning.**
4. **Encapsulation.**
5. **Lamination.**

FUMIGATION

- **Due to biological factors, papers get deteriorated**
- Chemicals preferred:

  Thymol -Fungus

  Para dichlorobenzene - Insects



DE-ACIDIFICATION

- Aqueous de-acidification.
  - Barrow's Process

    (calcium hydroxide and calcium bicarbonate)
- Vapour phase de-acidification.
  - Ammonia process.
- Mass de-acidification. (not in practice in India)

VAPOUR PHASE DE-ACIDIFICATION

AMMONIA PROCESS





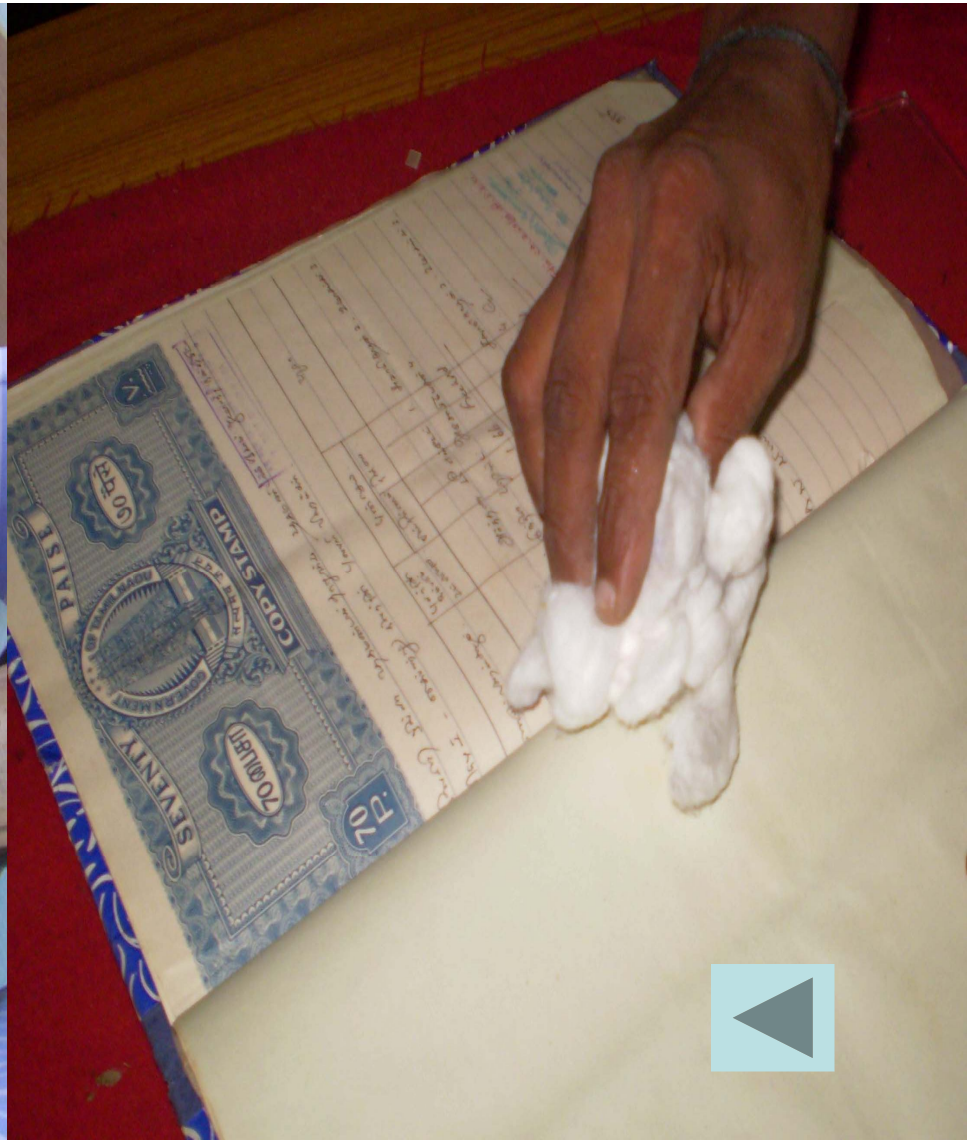


PHYSICAL CLEANING

- water soluble inks: rectified spirit.
- water insoluble inks: distilled water and steam bath.

WASHING AND CLEANING

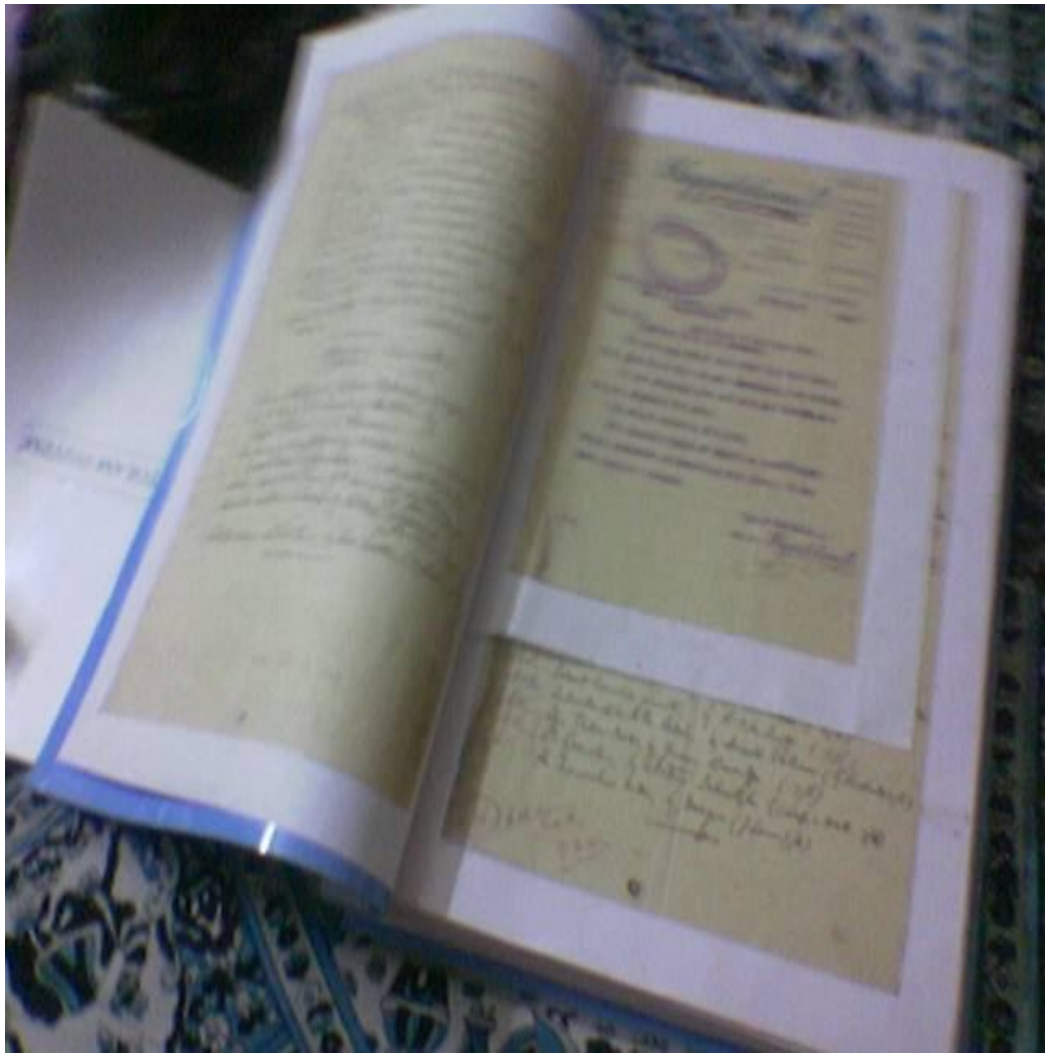




ENCAPSULATION

- De-acidified document placed in between two polyester films and vacuum is created then the four sides are sealed.

- Air in between causes degradation of paper



LAMINATION

- **Lamination is a general term for fusing together thin layers of different materials sandwiching the records.**

- **The standard method, developed by William Barrow, used heat and pressure to fuse a paper record between two thin sheets of a plastic (usually cellulose acetate). This refers to the cellulose acetate lamination invented during 1930s.**

- **The new methods evolved simply by replacing the materials and employing a different procedure for conservation of paper records.**

LAMINATION

- CHIFFON LAMINATION.
- TISSUE LAMINATION
- SOLVENT LAMINATION.
- MACHINE LAMINATION
- PHOTOLAM SYSTEM.



Conventional Laminate



Photolam System's Laminate



Cellulose Acetate method's laminate

MATERIALS USED for lamination

- The different lamination methods employed for conservation of paper is compared to the processing of composite material.

- Composite materials are engineered materials made from two or more constituent materials with significantly different properties which remain separate and distinct within the finished structure.

- Composites generally has two main components
    - a reinforcing layer
    - a matrix.

Reinforcing Material

- **Strength providing component.**
  - **Chiffon-cloth (chiffon-silk, chiffon-synthetic fibres)**
  - **Tissue paper.**
  - **Synthetic Polymers.**
    - **Polyethylene.**
    - **Polypropylene.**
    - **Poly (vinyl chloride).**
    - **Cellulose acetate foil**
    - **Polyesters.**

Selection Criteria – Reinforcing Material

- Must provide mechanical strength to paper records.
- Must protect the paper records from environmental factors such as light, temperature, humidity, dust, dirt, pollutants, water, fire, etc.
- Must be resistant to chemicals, acids and solvents.
- Must be able to resist the attack of biological microorganisms such as fungi, bacterial insects, silver fishes, cockroaches, bookworms, book lice, termites, rodents, etc.
- Should not produce any acidic, toxic products.

Selection Criteria – Reinforcing Material

- **Should provide an aesthetic look and high optical resolution while reformatting while digitalizing, microfilming and photocopying.**
- **Should not crumble after lamination.**
- **Should not produce any change in colour during service life.**
- **Should have long term mechanical properties and must be durable for a very long period.**

Matrix Material

- **Adhesive/glue applied on surface of the reinforcement.**
  - **Starch based adhesive.**
  - **Methylcellulose derivatives.**
  - **Cellulose acetate foil and acetone.**
  - **Hot melt plastics.**
  - **Acrylic copolymers.**

Selection Criteria
- matrix material

- Should never develop wrinkles or shrinkages after setting.
- should not be hydrophilic and react with the environment gases.
- should be characterized by forming stable and flexible film.
- Stability, durability and reversibility are the desired characteristics of a quality adhesive.
- should be colorless and should not change its colour after setting.
- should be free from acidity.
- must provide an aesthetic look.

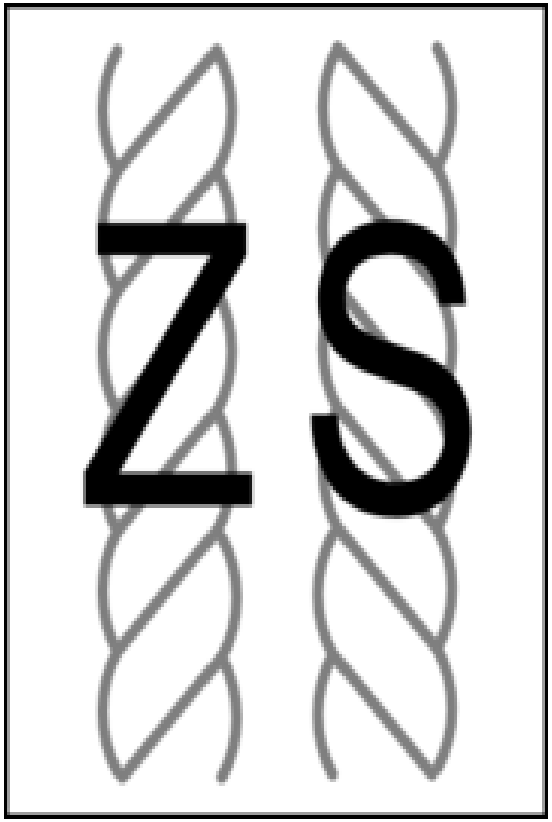
Chiffon lamination

Chiffon Based Materials

- **Chiffon, a French word for cloth, is a lightweight, balanced plan-woven sheer fabric woven of alternate S- and Z- twist crepe (high-twist) yarn.**

- **The twist in the crepe yarns puckers the fabric slightly in both directions after weaving, giving it some stretch and a slightly rough feel.**

- **This is a reinforcing material used in the chiffon lamination process.**



Chiffon Based Materials

- **Disadvantages:**
  - **The records treated with chiffon may be detected by pieces of thread sticking out of the edges.**
  - **Since the material is of natural source, there are many possibilities for biodegradation to take place.**
  - **Since the surface is rough, it facilitates dust accumulation resulting in the absorption of moisture attracting mould growth.**
  - **The size of the laminate becomes very large and the legibility is poor.**
  - **The removal of chiffon-silk while reversing is a difficult task as paper crumbles.**
  - **The aesthetic look is poor and problems arise while duplicating by photocopying, microfilming, etc. and also photographing.**

Starch Based Adhesive

- **Starch-based adhesives are made from natural polymers derived from roots, tubers and seeds of higher plants such as maize, potatoes, wheat, rice and tapioca.**

- **Dextrin is a type of dry roasted starch. A wide range of gums and pastes can be developed by controlling acidity, moisture content, and roasting temperature, varying levels of solubility and viscosity can be produced.**

Starch Based Adhesive

- **Disadvantages**
  - **As starch is a biological substance, they are easily susceptible to attack by biological factors and lead to biodegradation.**
  - **Starch based adhesives are water soluble and the reversibility is justified.**
  - **When very brittle paper already laminated is reversed with water, the information gets lost and bleeding of ink is seen.**
  - **Starch based adhesives have poor moisture resistance and enhances mould growth, fungal attack, etc.**

Tissue paper lamination

Tissue Paper

- **Japanese tissue paper is a thin, strong paper made from vegetable fibres. Japanese tissue may be made from one of three plants, the kozo plant, the mitsumata shrub or the gampi tree.**
- **Tissue made from kozo, or kozogami, comes in varying thicknesses and colours, and is an ideal paper to use in the mending of books.**
- **The Japanese tissue is used as a reinforcement material in many lamination processes.**
- **The extremely thin Japanese tissue papers are sometimes produced in grammages as small as 6 to 8.**



KOZO PLANT



Extract being mixed well



Gampi Plant



Mitsumata plant



Japanese tissue

Tissue Paper

- **Disadvantages**
  - **Tissue paper is also a kind of paper which has similar degradation properties of an ordinary paper.**
  - **This type of paper generally fails when inappropriate adhesive is used**
  - **The tissue paper reduces the shine, clarity of the original documents, altering their colors and appearance.**
  - **Legibility is less after lamination.**

Methyl Cellulose Adhesive

- **Two categories**
  - Methyl Cellulose
  - Sodium Carboxymethyl Cellulose

Disadvantages

The cellulose backbone adheres well with the paper record at the same time is subjected to the same kind of degradation mechanism as that of paper.

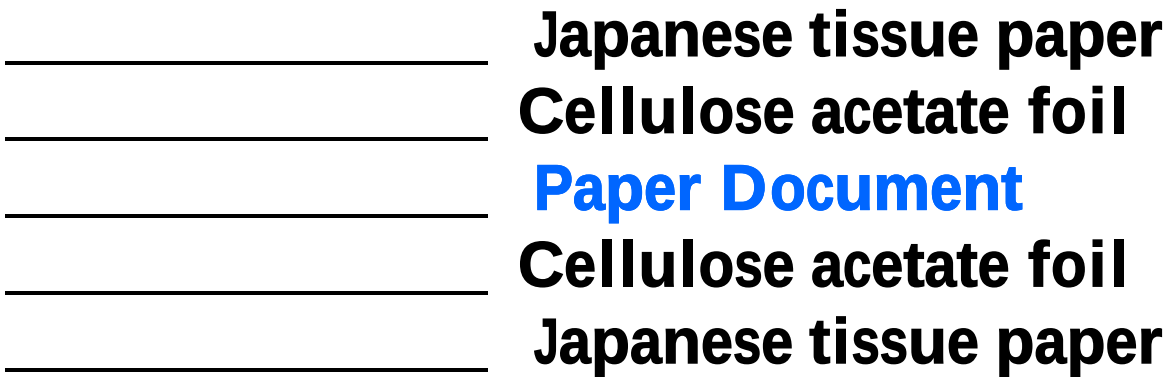
As the reversing medium is water, the information present in the paper records will get lost if the ink is not a permanent one.

Poor resistance to moisture will lead to peeling off the layers.

Cellulose Acetate and Acetone Lamination

Cellulose Acetate and Acetone Lamination

- **Cellulose acetate foils along with acetone have been used as adhesive for lamination during 1950 and 1960.**
  - **Reinforcing Material - Japanese Tissue**
  - **Matrix - Cellulose acetate and acetone**



Laminate structure

Cellulose Acetate and Acetone Lamination

Disadvantages

- **The formation of acetic acid due to the reaction of cellulose acetate and acetone causes further degradation of paper. This phenomenon is generally referred as vinegar syndrome.**
- **The objects treated with this become strongly yellowed and damaged by acetic acid or hydrochloric acid emitted by the film material or migration of its external plasticizers.**
- **The application of heat and pressure during lamination was sometimes poorly controlled, resulting in charring of papers.**
- **The cellulose acetate laminate greatly alters the appearance and texture of documents, giving the paper a shiny surface with an uncharacterized hard, plastic feel.**

Cellulose Acetate and Acetone Lamination

- Cellulose acetate is considered to be inherently unstable and prone to degradation easily which results in warping, stretching, peeling off and creating greater stress on the paper material.

- The plasticizers added to increase the flexibility, exuded as a liquid may collect on the surface of the laminate, giving it an oily appearance and often leaving the surface quite sticky.

- The unstable laminate and plasticizers do not affect single document rather it starts the degradation of the paper material at its vicinity and neighborhood.

Synthetic Polymers

Synthetic Polymers

- **Synthetic polymers used for paper conservation include both the reinforcing material and the matrix (adhesive/glue).**
  - **Polyethylene.**
  - **Polypropylene.**
  - **Poly (vinyl chloride).**
  - **Polyester.**
  - **Acrylic copolymers**

Classification based on temperature

- Low Temperature/Commodity Plastics: (upto 150°C)
  - **Polyethylene.**
  - **Polypropylene.**
  - **Polyvinylchloride.**
- Engineering thermoplastics:(200 - 300°C)
  - **Polyesters.**
  - **Acrylic polymers.**

Polyethylene (PE)

- **Polyethylene is a polymer consisting of long chains of the monomer ethylene. It is created through polymerization of ethylene.**

Polyethylene (PE) - types

- Ultra high molecular weight polyethylene (UHMWPE)
- Ultra low molecular weight polyethylene (ULMWPE - PE-WAX)
- High molecular weight polyethylene (HMWPE)
- High density polyethylene (HDPE)
- High density cross-linked polyethylene (HDXLPE)
- Cross-linked polyethylene (XLPE)
- Medium density polyethylene (MDPE)
- Low density polyethylene (LDPE)
- Linear low density polyethylene (LLDPE)
- Very low density polyethylene (VLDPE)

Polyethylene (PE)

- **High density polyethylene (HDPE)**
  - Density = 0.96 g / cm3
  - Melting temperature = 125°C-130°C
  - Glass transition temperature = -20°C
  - Continuous operating temperature = **110°C**
  - Short term temperature = **120°C**
- **Low density polyethylene (LDPE)**
  - Density = 0.92 g / cm3
  - Melting temperature = 120°C
  - Glass transition temperature = -20°C
  - Maximum temperature =**80°C**
  - Minimum temperature =**50°C**
- **Linear low density polyethylene (LLDPE)**
  - Density = 0.92 g / cm3
  - Melting temperature = **120°C to 160°C**
  - Glass transition temperature = -20°C
  - Maximum operating temperature =**50°C**

Bi-axially Oriented Polypropylene (BOPP)

- **Polypropylene is manufactured by the polymerization of propylene.**

- **The general properties of polypropylene are given as follows**:
  - » Density = 0.85-0.95 g / cm3
  - » Melting Point = **165°C**
  - » Glass transition temperature = **-10°C**
  - » Improved stiffness, high tensile strength, excellent optics and good water barrier properties

Polyvinylchloride (PVC)

- **Polyvinylchloride is a thermoplastic manufactured from the monomer vinyl chloride.**
- **This is the most widely used thermoplastic in many fields of applications.**

Polyvinylchloride (PVC)

Important characteristics:

- Melting point: **212°C**
- Glass transition temperature = **60°C**
- Available in both rigid and flexible form
- Being **thermally sensitive material**, it gradually degrades before reaching the melting point. So heat stabilizers are added.
- Undergoes thermal degradation liberating hydrochloric acid(HCl) vapours.

Disadvantages of commodity plastics

- **The materials once sealed cannot be removed i.e., they are irreversible.**
- **High temperature conditions damage the paper record and the plastic material used.**
- **The hot melt gum, generally polyethylene based glue turns yellow within a short span.**
- **The operating temperature and the pressure conditions are to be maintained accurately or it results in degradation of paper.**
- **Paper materials which are very fragile and brittle cannot be treated as they get broken because of high temperature profile and while passing through the rollers.**

Disadvantages of commodity plastics

- **While using polyvinylchloride based films, one must be very careful in temperature settings as it is a thermally sensitive material.**
- **PVC films generate toxic products such as vinyl chloride monomer, dioxins, etc.**
- **PVC films are very vulnerable as they liberate hydrochloric acid vapours which are totally unacceptable for paper conservation.**
- **These commodity plastic films generally turn yellow and the pages stick to each other on long run.**

Photolam system

Photolam system

- **Photolam System is a reversible type manually operated laminating system, developed in India during 1997.**
  - **Reinforcing Material – Specially processed polyester film**
  - **Matrix Material - Acrylic – Cellulose co-polymer**
- **Special coatings like waterproof, antiglare, anti-reflective, heat retardant, non sticky coating are done on one side of the film.**
- **Research is on the way to produce fire retardant coatings also.**

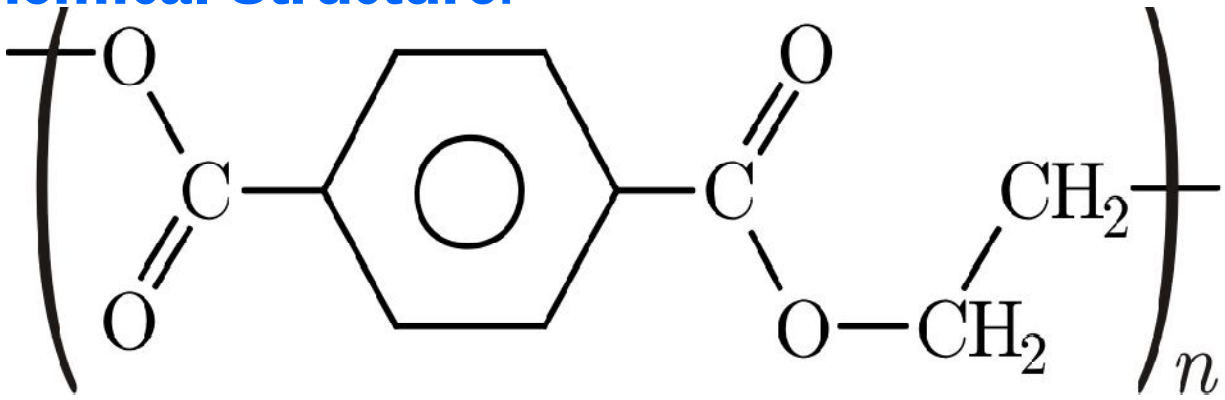
Polyester Films

- **Polyesters are engineering thermoplastics made from the condensation polymerization of diacid and a diol. It is one of the most environmentally safe polymer products made today.**

- **Polyester is available in two forms:**
  - **Polyethyleneterephathalate (PET)**
  - **Polybutyleneterephthalate (PBT)**

Polyester Films

- **Poly(ethyleneterephthalate) is polymerized from the following monomers:**
  - **ethylene glycol**
  - **dimethyl terephthalate (DMT).**
- The commercially available polyester films are **Mylar®, Melinex®, Teijin®, etc.**
- **Chemical Structure:**



Polyester Films

Polyester film and its properties:

Thickness :	18-22 micron
Density:	1.4g/cc(ASTM-D1505)
Tensile strength at break MD/TD:	1800kg/sq.cm (ASTM D882)
Percentage elongation:	120 (ASTM D882)
Haze:	65%
Luminous Transmission:	80%
Melting point:	255˚C
Shrinkage@150˚C 30min MD:	1.6%
TD:	0.5%
Resistance to dilute acids and alkalis:	Good
Resistance to i.) Conc. HCl:	Fair
ii.) conc. sulphuric acid:	Good
Resistance to grease, oils and fats:	Good
Resistance to solvents, alcohol and hydrocarbon:	Good
Resistance to Phenols and chlorinated phenols:	V.Poor

SPECIAL COATING FOR WATERPROOF, ANTIGLARE, ANTIREFLECTIVE, NON-STICKY PURPOSES ON ONE SIDE OF THE FILM

Polyester Films

- **Disadvantages**

Catalyst	Temperature	Pressure	Time	Product
$NaCOOCH_3$	220°C	-	4hr	TPA & EG
H2SO4	90 °C	1 atm.	Minutes	TPA & EG
NaOH 10%wt	200 °C	15-20 atm.	>4hr	Solid TPA & EG
NaOH	100 °C	1 atm.	<1hr	Solid TPA & EG

Source: Hydrolysis of PET, by John Scheirs (1998). Polymer Recycling – Science, Technology & Applications, New York: Wiley Interscience.

Acrylic adhesive

- **The acrylic adhesives can be of two categories:**
  - **Thermoplastics based**

    eg., polymethylmethacrylate (PMMA), polymethacrylate (PMA)
  - **Thermosetting plastics based**.

    eg., cyanoacrylates

- **A heteropolymer or copolymer is a polymer derived from two (or more) monomeric species, as opposed to a homopolymer where only one monomer is used.**

Acrylic adhesive

The specifications are

pH :	**7.80±1**
Viscocity/RVT/5/20/30°C :	**40-60**
Solid at 105°C for 3hrs :	**55±1%**
Appearance :	**Milky white emulsion**
Flammability :	**Non-flammable**
Toxic :	**Non toxic**

- Photolam Reversing Liquid, which consists of acetone, paraffin, hydrocarbon and ammonia in a calculated percentage.
- This helps in deactivating the adhesive bonding with the paper and releases the original document.

Conclusion

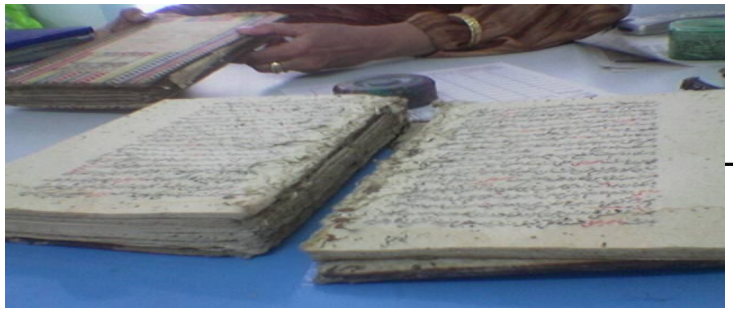
- Having dealt with the materials used for paper conservation, it is high time for the conservators to select the right materials.

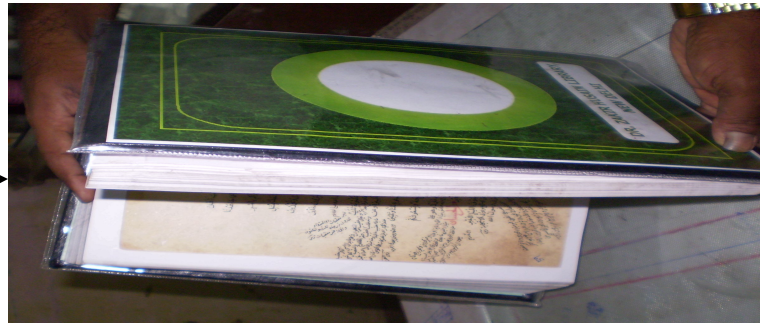
- The materials should ensure that the life period of the paper has been prolonged and there is no further prone to attack from the deteriorating factors.

- There is no standard with BIS for conservation of paper documents in India.

PHOTOLAM CONSERVED DOCUMENTS

PHOTOLAM SYSTEM













BEFORE CONSERVATION

AFTER CONSERVATION

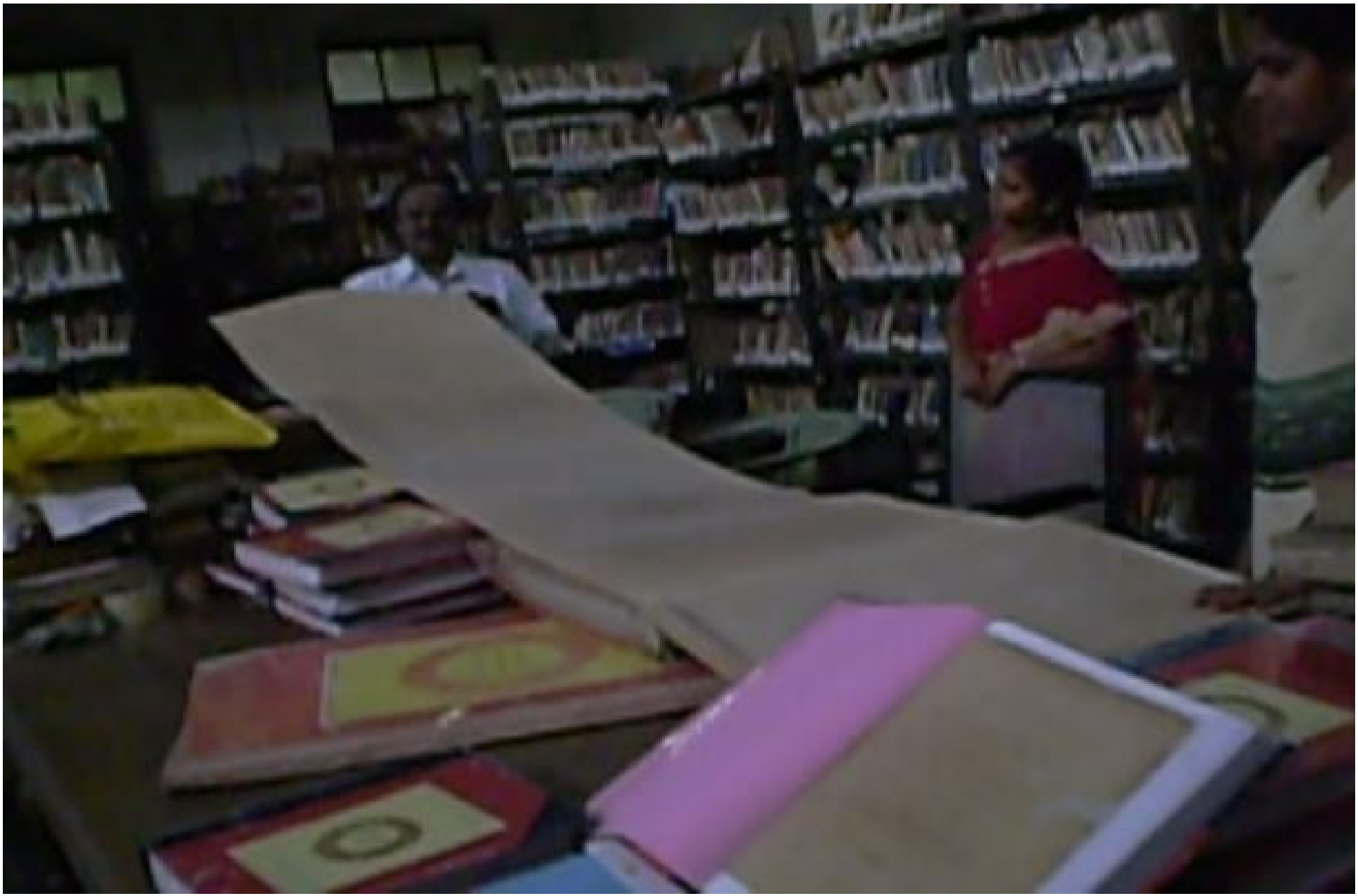
ALL THE BOOKS PUBLISHED DURING 17TH AND 18TH CENTURY

COURTESY: MADRAS LITRERARY SOCIETY, CHENNAI



DRAWING OF GANGES CANAL PUBLISHED DURING 1859 A.D

COURTESY: MADRAS LITRERARY SOCIETY, CHENNAI



DRAWING OF GANGES CANAL PUBLISHED DURING 1859 A.D

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THE WEEK & BHASABHOSINI MAGAZINES

COURTESY:M/s. MALAYALA MANORAMA Co .LTD. KOTTAYAM



MALAYAL MANORAMA DAILY NEWSPAPER

COURTESY:M/s. MALAYALA MANORAMA Co. Ltd. KOTTAYAM





LOYOLA COLLEGE ANNUAL MAGAZINES

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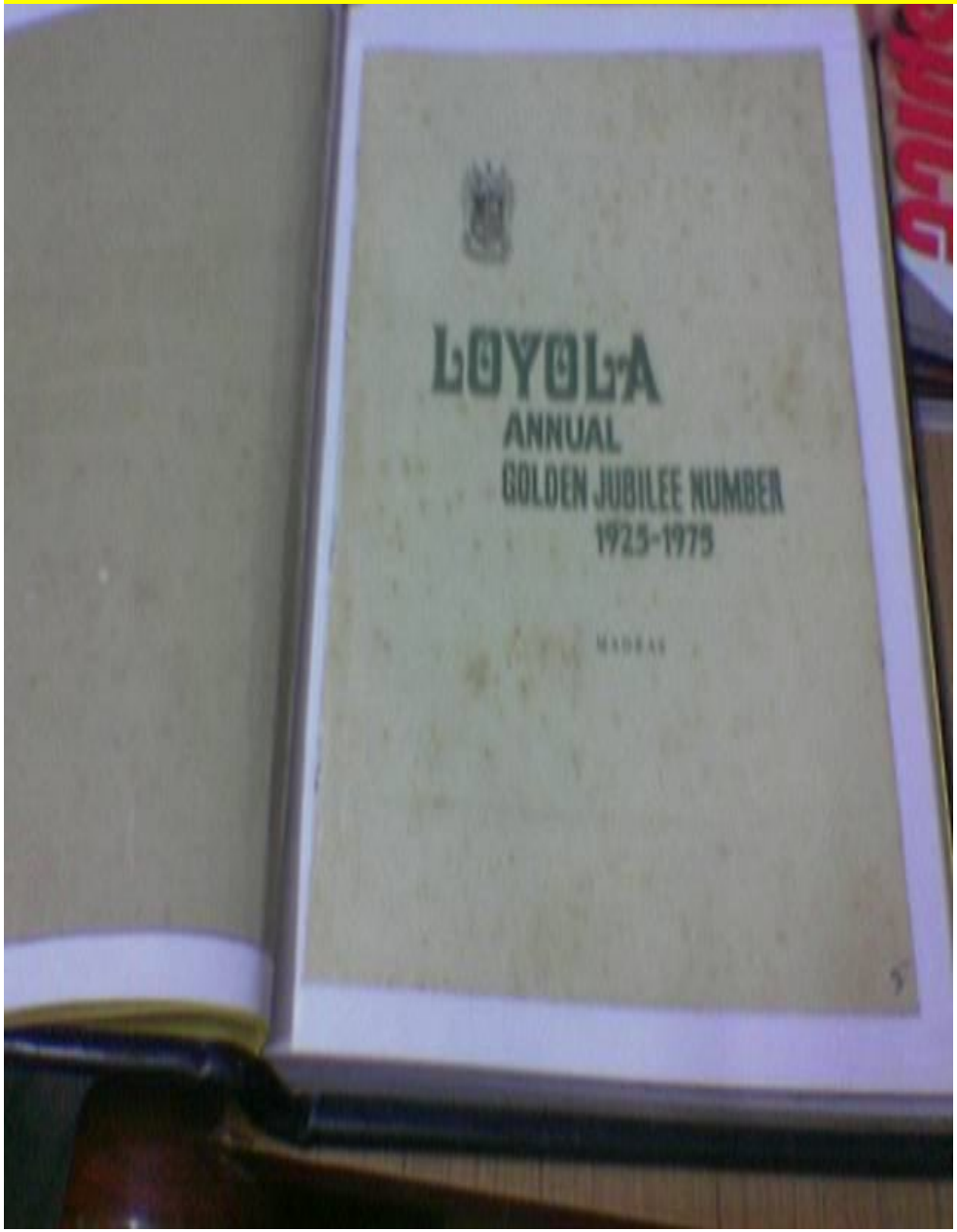



SANSKRIT MANUSCRIPT

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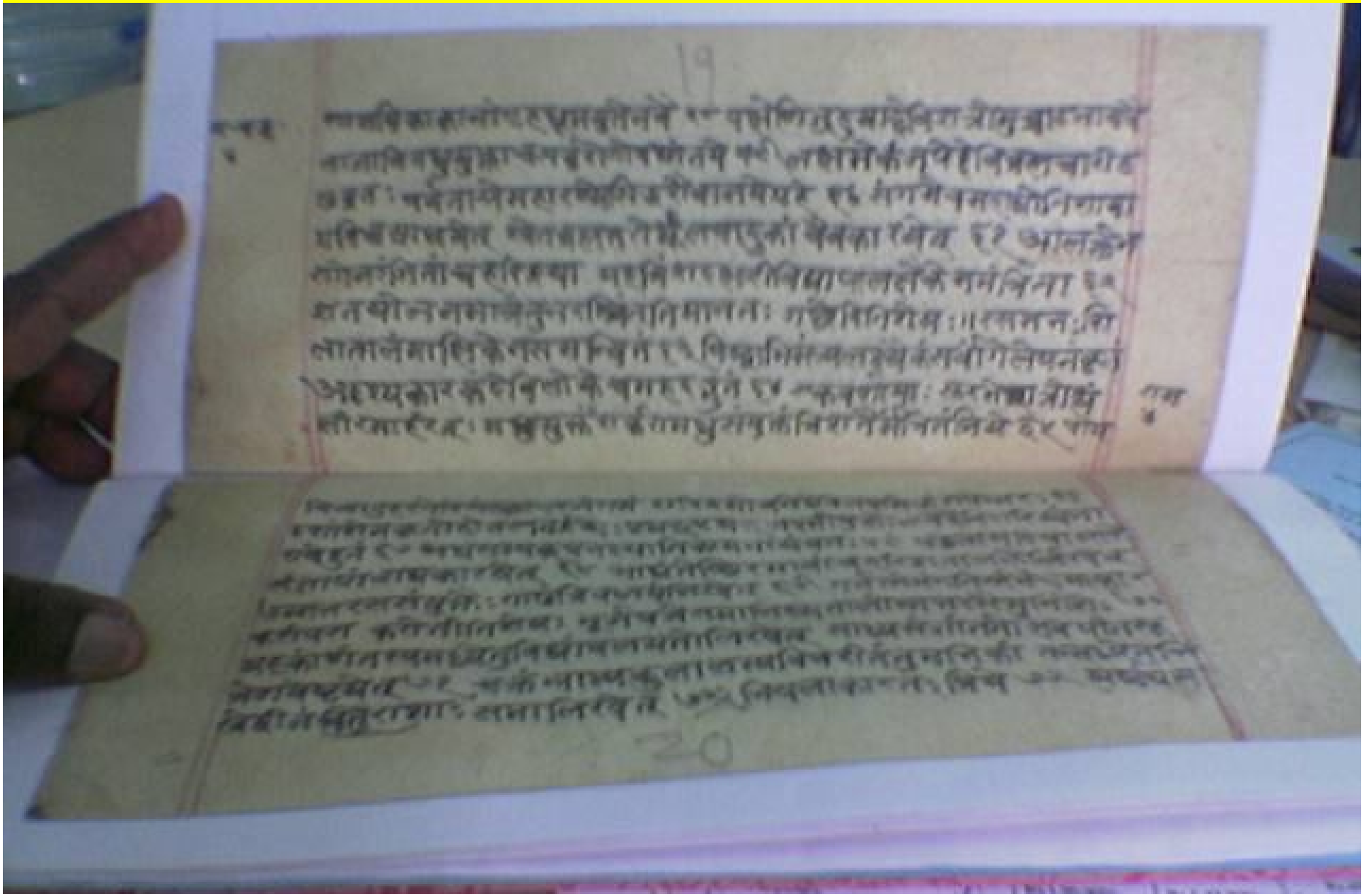

ARABIC MANUSCRIPT

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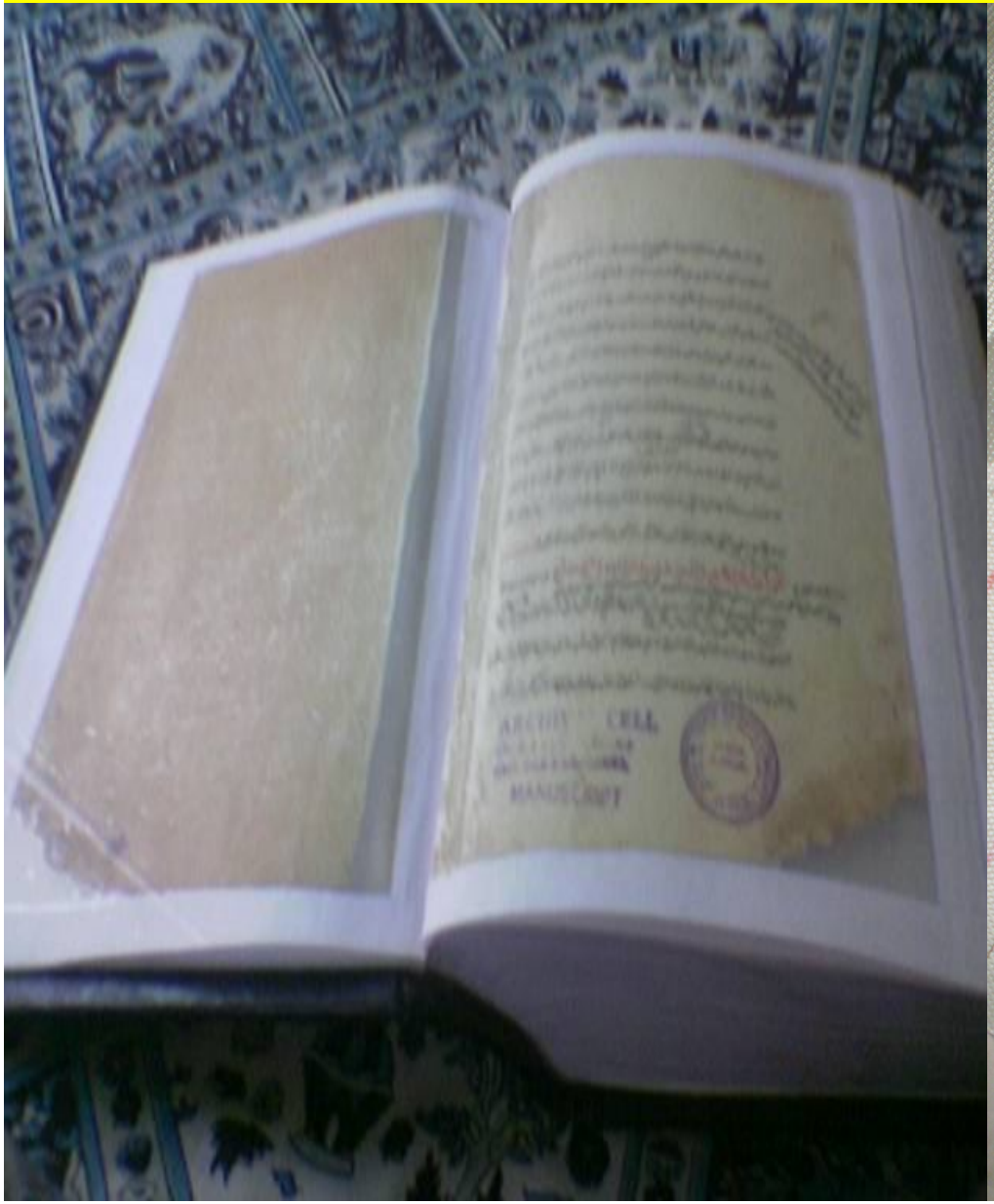
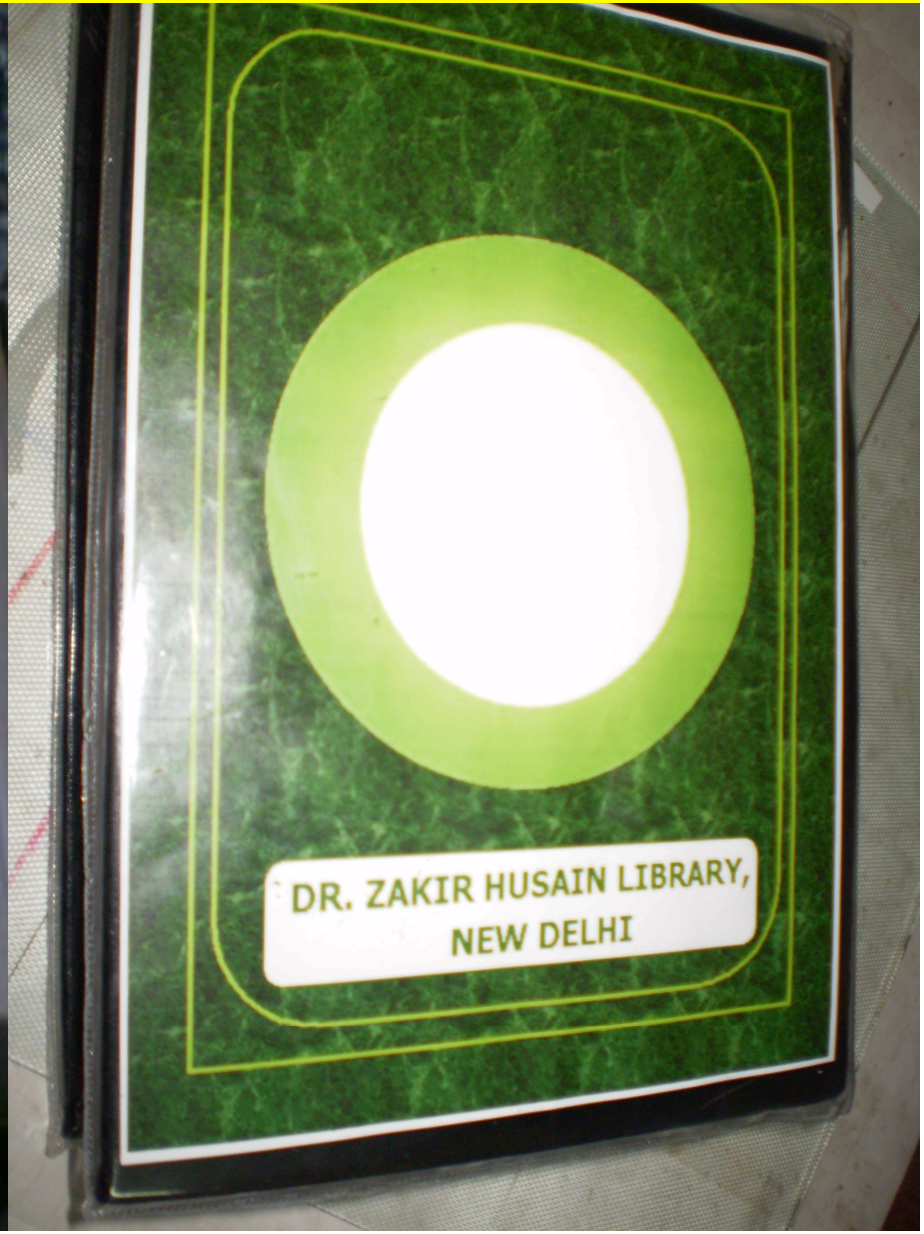
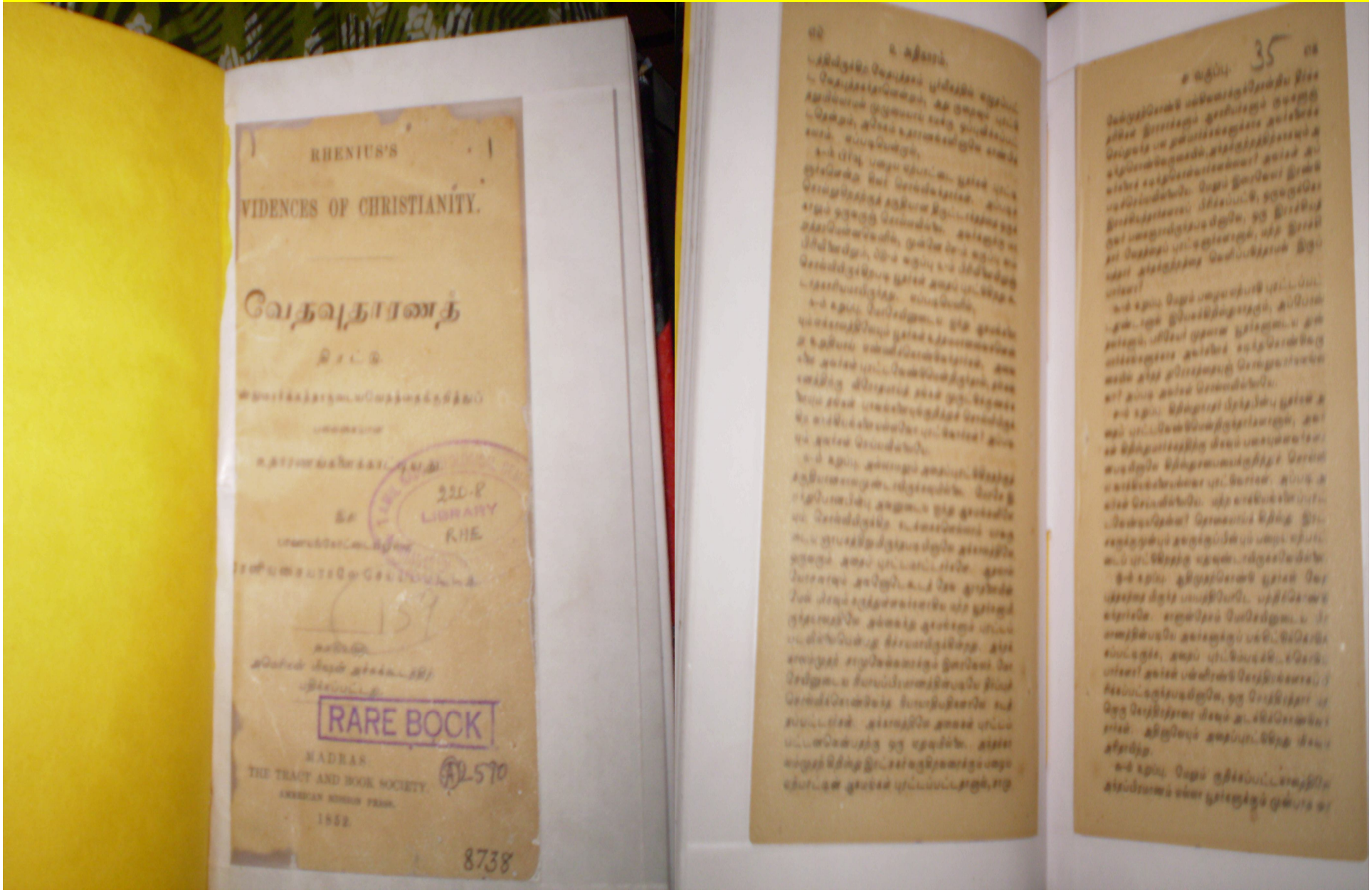




TAMIL BIBLES PUBLISHED DURING 18TH CENTURY

COURTESY: TAMILNADU THEOLOGICAL SARAKUM, MADURAI



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