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3.1 Introduction

There are various natural and man-made actions going on unabatedly on all books, manuscripts and art and cultural properties everywhere. From stone inscriptions to the paper, all are exposed to deterioration from temperature, humidity, light and other climatic and environmental factors. At the same time, biological factors like fungi, insects, animals and human interference are other major factors of damage. Manuscripts of all types are worst affected by these environmental and biological factors right from its origin. Because of its biological origins, from papyrus to paper, manuscripts are susceptible to even a slightest change in the climate, micro or macro. ‘Not only large wooden sculptures, and architectural timbers are affected resulting in cracks, but the delicate manuscripts too contract and expand with changes in relative humidity in the atmosphere’ (Agrawal, 2006). From the past to the present numerous efforts have been made to preserve these delicate entities, but with less success. ‘Care of manuscripts was a major concern in the past and effort was made to protect them from the different agents of deterioration. One of the most important of these deterioration agents is microbial growth’ (Gupta, 2006).

3.2 Factors causing damage to manuscripts and preventive measures

Factors causing damage to manuscripts may be categorised in three major types, viz., environmental or physical factors, biological factors and chemical factors. There are also some other factors directly or indirectly helps in causing damage to manuscripts, these are man-made factors and natural calamities. As all these factors of deterioration are active and very fast in their actions, traditional
methods for preservation of these wood-origin manuscripts seem to be inadequate and very slow to tackle those deteriorating agents. Scientists have developed some modern techniques to tackle such deteriorating agents which are fast, effective and reliable. Various study, research and experiment indicate that if environmental factors like temperature, humidity and light are controlled, the deterioration of sensitive and fragile manuscripts can be prevented to a large extent. As all the manuscript degrading factors are interlinked, the preventive measures would definitively be interdependent and interrelated. In the following sections, along with the factors of manuscript deterioration, some modern preventive measures and techniques also have been discussed.

3.2.1 Environmental factors of manuscript deterioration

The scientific studies so far conducted on manuscript preservation reveals that climatic conditions of a place have tremendous influence on the manuscripts, especially on the aspects of deterioration.

Climatic condition of a place is the sum total of many factors like temperature, humidity, sunshine, rain, etc., which are again governed by altitude and surroundings. Climate may also change depending on its proximity to the sea, or river, or to the mountains. So, climate is a term which describes conditions of a large area or region.

There might occur local variations of climate in a limited area, such as a city, a monument, a building or even in a display case. When climate of a city is influenced by factors like domestic and industrial fire, radiation and absorption capacity of buildings, houses, roads and pavements, traffic, plantations and open areas, likewise, climatic conditions within a monument or building also varies depending on structure, materials and orientation of the building, thickness of the walls, openings and ventilation of the building, fountains and ponds, vegetation and population of the surroundings, etc. For a sensitive entity like manuscripts, microclimate is more important than macroclimate.
The deterioration may be fast or slow depending on the level of temperature, humidity, light and the other pollutant that react with the biological agents of the manuscripts. As these factors directly influence the morphology and physical properties of manuscripts and wood-origin materials, these are also called physical factors of deterioration.

3.2.1.1 Temperature

One of the most important components of climate that affect manuscripts mostly is temperature. Temperature of a place may be defined as the degree of hotness or coldness prevailing therein. Some regions have a much narrower temperature range over the course of year and some have wider temperature changes from summer to winter. These variations make a difference in the way indoor air reacts to heating and cooling.

Temperature may trigger growth of various kinds of wood decaying fungus in manuscripts. 'The environmental conditions required for fungal growth (RH 65%, temperature ≥ 20°C) are very often found in sacred places, museum storage conditions, and other locations' (Giuliani and Nugari, 1993). 'The environmental conditions most suitable for the growth of fungi are temperature between 24-30°C and relative humidity above 65%, and slightly acidic condition' (Agrawal and Barkeshli, 1997). Not only fungal growth, increase in temperature and frequent fluctuations also influences the relative humidity (RH) of the air which otherwise causes heavy damage to the manuscripts with splitting, flaking and forming cleavage.

Moreover 'exposure to high temperature increases the rate of aging of the manuscripts even for a short period of time' (Agrawal and Barkeshli, 1997). Guidelines for archival and library spaces emphasize moderate temperature. 'Since the late 1960s, many preservation specialist have recommended a relative humidity of 50% and a temperature around 60°F (16°C) for storage areas, 24 hours a day, 365 days a year' (Balloffet and Hille, 2009).
i. Control of temperature

a) Use of Thermometer

It is necessary to get a clear picture of temperature for observation of microclimate of the building. A simple device to measure temperature is ‘thermometer’. A clinical thermometer which is used for measuring body temperature is not used. A simple thermometer will only provide temperature of a particular moment of the day. It does not provide maximum and minimum temperature during the course of a day or night. For this purpose a thermometer called ‘maximum and minimum thermometer’ is used. These days digital hygrometers are use to record both temperature and humidity together. Recording hygrothermograph is still preferred by many for regular recording. The graph of the drum is calibrated to get the temperature of a desired time.

b) Use of Air Conditioning

Use of Air Conditioning system is recommended only when it is used for 24 X 7 throughout the year uninterruptedly with regular monitoring and adjustment of the temperature fixed to a desired level, i.e. around 60°F (16°C).

But, there is a need to adjust air conditioning during summer and winter depending on the overall climatic condition outside of the building. To have relative humidity at the safer level of 35-38%, at winter, the temperature may be lowered to 60°F (16°C) or even below. Likewise in summer, the interior temperature can be little warmer, as long as the air conditioning is able to dehumidify to 50% or below, 24 hour a day, every day till the end of the summer. (Balloffet and Hille, 2009).
c) **Use of HVAC System**

The Heating, Ventilation, and Air Conditioning (HVAC) system is a modern system designed for the need of libraries, archives and museums. The system has capacity to provide constant relative humidity and moderate temperature in storage space, 24 hours a day, 365 days in a year. Within 24 hour period the relative humidity should not change by more than ±2% (This means 2% above or 2% below the specified level, not “approximately 2%”). A good HVAC system, properly maintained and operated, will help preserve all the materials in the library or archive by reducing the stresses caused by constant change in relative humidity. Moderate and cool temperature help retard many kinds of deterioration (Balloffet and Hille, 2009).

3.2.1.2 **Humidity**

Other than the temperature, humidity is another important component of climate. The humidity is defined as the ratio of the amount of moisture actually present in one unit volume of air to the amount of moisture required to saturate the same volume of air at the same temperature. A unit of air is said to be saturated when it is unable to take up any more water in the form of vapour. To express the ratio in percentage, it is multiplied by 100. The term “relative” in the “relative humidity” (RH) refers to the amount of moisture actually in the air compared to the amount of moisture that it can hold at that temperature.

There is strong relationship between humidity and temperature. Air can take a variable amount of water vapour; the warmer the air is the more water vapour it can hold. This means the relative humidity is low and the weather is dry. If the temperature drops, the air’s capacity to hold moisture will drop. This means that when RH rises, the weather becomes wet. The practical implication of relative humidity on manuscripts in an enclosed space is very significant.
i. Effect of Low RH on manuscripts

In winter, heating the air in an enclosed space of a manuscript repository causes low RH. As during winter the enclosed space already contains less moisture, the decrease in RH due to heating will increase the capabilities of the air to hold more moisture. As a result, the air will begin to take moisture from the manuscripts and other hygroscopic materials of the surroundings. The wood-origin manuscripts are likely to shrink, desiccate and will suffer mechanical stress due to loss of excessive moisture and dry condition.

ii. Effect of High RH on manuscripts

In summer, cooling the air in an enclosed space of manuscripts repository causes high RH. During summer, naturally moisture remains high in the air, the hygroscopic materials, such as manuscripts and others absorb moisture and swell. Due to even little cooling of the enclosed space, the RH will increase and the air will release moisture that will be absorbed by the manuscripts. This will cause more strain to the bindings and packets and may make it difficult to remove manuscripts from tightly packed bundles or folders.

"Another major danger is the onset of a mold infestation. When mold is found growing on books and other materials that were not affected by flooding, it means that environmental conditions are favourable for its growth. These conditions include high humidity, high temperature" (Balloffet and Hille, 2009).

When the heat rises and lowers abruptly or the air conditioning system is turned off and on, the changes in temperature cause the relative humidity of the air in the building or in the enclosed space, to change every time. As the temperature goes down, the RH goes up, and the manuscripts start swelling. When the temperature goes up, the RH goes down, and the manuscripts start shrinking. These repeated shrinking and swelling of manuscripts have adverse affect and start deteriorating. Furthermore, there is every possibility for a situation of
condensation during the period of high RH. "Condensation can cause water damage as surely as can a flood" (Balloffet and Hille, 2009).

Relative humidity also has profound influence on fungal growth on manuscripts. As stated by Agrawal and Barkeshli, (1997), the environmental conditions most suitable for the growth of fungi are temperature between 24-30°C and relative humidity above 65%.

iii. Control of Relative Humidity

a) Use of Hygrometers

Hygrometers are humidity measuring instruments. Various types of hygrometers are available now days. Digital hygrometers are battery operated, show current temperature and humidity. They have memory function; push buttons reveals the highest and lowest temperature and humidity all together.

b) Use of dehumidifiers

Air conditioning is excellent for dehumidification, but need constant monitoring for adjustment of temperature. Moreover, the system should run 24 hours a day, 365 days in a year at a desired constant level. But, there is a need to adjust air conditioning during summer and winter, and even at day time, and night. The overall climatic condition outside of the building during these periods frequently changes. The relative humidity during winter should be at least at the level of 35-38% though not below. For this, the temperature may be lowered to 60°F (16°C) or even below. Likewise at summer, the level of humidity must be at the level of 50% and not above. This condition should prevail 24 hour a day, every day till the summer exists (Balloffet and Hille, 2009).

The Heating, Ventilation, and Air Conditioning (HVAC) system is the best to dehumidify storage areas and to control relative humidity level at 50% round
the year. But, in summer and winter, monitoring and adjustment of the HVAC system is required to keep the relative humidity at a constant level.

e) Dehumidification by dehydrating chemicals

In the absence of air conditioning, the only method of minimising the deleterious influence of excessively high humidity is the use of dehydrating agents. Anhydrous calcium chloride and silica gel are quite satisfactory as dehydrating chemicals for use on manuscripts. As silica gel is mostly preferred, it can be reactivated for reuse after heating the saturated chemical in open pen.

The quantity of silica gel to be used for a specific room capacity will depend on room temperature, rate of air circulation and moisture content of the outside atmosphere. However, approximately 2 to 3 kg of silica gel may be sufficient for a room of 20-25 cu meter capacity. The requisite quantities of silica gel may be spread in dishes and kept in different places in the room. After use for 2-3 hours, the silica gel may get saturated and need replacement with fresh chemical, while the saturated silica gel may be reactivated for further use (National Archives of India, 1978)

3.2.1.3 Light

Light has intense and deep effect on manuscripts of wood origin. Depending to its source, light can be of two types: natural light and artificial light.

i. Natural Light:

Though the natural visible light rays ranges from 400nm to 700nm wave length of solar light spectrum, invisible natural light rays such as ultraviolet and infrared have profound influence on manuscript preservation.
a) **Ultraviolet (UV) Light**

The ultraviolet light ray, ranges from 400nm to 100nm are not visible to human eyes. The short wavelength having 3.1 to 12.1ev (electrovolt) energy is abundant in the sunlight and is most damaging to wood origin manuscripts. “Fading, colour changes, brittleness, cracking and delaminating are all result of the accelerated aging that is caused by UV light” (Balloffet and Hille, 2009). Direct sunlight has maximum amount of UV radiation which causes more deterioration to the manuscripts, but indirect light from north-facing windows also has huge UV radiation and affects manuscripts to a great extent.

b) **Visible Light**

The light spectrum ranging from 400nm to 700nm is visible to human eye. Though not in the UV range, high intensity and prolonged exposure to this visible light cause deterioration to sensitive manuscripts. According to Balloffet and Hille (2009), the deterioration to manuscripts by visible light occurs at a much slower rate than the UV radiation.

c) **Infrared (IR) Light**

The infrared light rays ranges from 700nm to 1400nm are not visible to human eyes. The long wavelength having 1.24 to 1.7ev (electrovolt) energy is available in the natural light is felt as radiant heat. Sunlight coming through windows and skylights generate significant amount of heat inside the building which often influences the inside temperature and relative humidity at micro level.

ii. **Artificial Light**

In comparison to natural light from sun, the man-made artificial light is less brighter, but even then it causes fading and deteriorates sensitive manuscripts in archives and libraries if exposure of this light is not controlled. There are many types of commonly used indoor artificial lighting which are described below.
a) Fluorescent Tubes or Lamps

This is most commonly used indoor lighting found in institutional buildings. Tubes and lamps are available; their light is more pleasant to the human eye and does not radiate much heat. But after natural light, the most common source of UV radiation is fluorescent tubes or lamps. Some methods or combination of methods must be used to reduce UV radiation in the storage and exhibition areas.

b) Incandescent (Tungsten) Lamps

Incandescent lamps are normal light bulbs found in homes. The filament is made of tungsten and therefore it is also called tungsten lamp. The tungsten lamps give off very little UV radiation and heat, and are said to be safer than fluorescent tubes or lamps if maintained at a distance of about four feet from the object.

c) Tungsten-Halogen Lamp

The tungsten-halogen lamps are also called Quartz-Halogen Lamps. Though small, tungsten-halogen lamps are powerful and give off significant level of UV radiation and heat. These are not used inside enclosed space and should be shielded when used to prevent any contact with flammable objects.

d) High Intensity Discharge (HID) Lamp

The HID lamps are similar to fluorescent lamps but require some time to light up completely after they are turned on. There are several types of HID lamps. The high pressure sodium lamp discharges very little UV radiation, while Mercury and metal halide HID lamp gives very high UV radiation and are not suitable for indoor lighting. The high pressure sodium lamp which gives off very little UV radiation is sometime used in large storage space.
e) Fibre-Optic Lighting

Presently, fibre-optic lighting system is gaining popularity for lighting exhibition and storage area. A fibre-optic lighting system has three main components, viz., projector, fibre cables and lenses. Light from a halogen bulb is beamed through a projector on the ends of several small-diameter cables (called fibres) that are bundled together to connect the lenses, also called luminaries at the opposite ends. The beam travels through the fibres to the ends where it is focused into beams of the desired intensity, size, and shape by various lenses called luminaries. There are three types of optical fibres in use for exhibition lighting, viz., Glass fibre, Solid core fibre and Acrylic fibre.

1. Glass fibre

Vary small in diameter glass fibres bounded together are used to transmit light to the luminaries. Glass fibres transmit both UV light and heat and are not safe for storage area having sensitive manuscripts.

2. Solid core fibre

Solid core fibres are made of large diameter flexible plastic that do not transmit UV light as well as heat. The light is slightly yellow and the fibres tend to turn more yellow and brittle as it ages. Solid core fibres are safe to use for storage areas but with a little caution.

3. Acrylic fibre

The acrylic fibres are polymethyl methacrylate (PMMA) fibres. By its nature, these fibres do not transmit UV light and heat. The white colour it transmits has the same colour balance as the natural sunlight, without the harmful qualities. Acrylic fibres can remain in good condition over ten years when used with a high quality projector. Acrylic PMMA fibres are most widely used fibre-optic for exhibition and storage areas.
In fibre-optic lighting system, each projector can power dozens of fibres, and multiple light sources can be created by splicing several fibres or by running more than one fibre to the exhibit. “Several luminaries can be placed inside enclosed display cases to illuminate individual exhibit. The amount of light and shape of the beam can be adjusted to the appropriate levels easily. Since no heat is transmitted and the fibres do not carry electricity, the system can be lighted during installation” (Balloffet and Hille, 2009). This is a safest way to place light inside the display cases and gaining popularity day by day.

iii. **Control of light exposure**

a) **Measuring light level**

Two types of light meters are available to measure intensity of light. Ultraviolet light meters are used to measure ultraviolet radiation emanated from natural light, fluorescent or halogen fixtures which are rich in ultraviolet rays. There are also visible light meters that provide normal light intensity of natural light. The intensity of light is measured in the unit of foot-candle or lux. A foot-candle is equivalent to 10.76 lux. The recommended limits of light level in exhibition areas are 5-15 foot-candle. But, one should be aware of the fact that lower the overall light level, the less is ultraviolet rays.

b) **Protection from light exposure**

Use of appropriate filter may help to protect sensitive and fragile manuscripts. There are ultraviolet filters which can be used in all fixtures of light sources, such as fluorescent fixtures, windows and skylights. This will cut down a significant amount of ultraviolet rays from reaching exposed materials. In some cases opaque shades on curtain windows and skylights may be used especially during brightest part of the day.
Use of ultraviolet absorbing paints and ceiling tiles absorb maximum amount of ultraviolet rays. These products contain titanium dioxide which absorbs a great deal of ultraviolet radiation.

c) Use of acrylic fibre optic light

The acrylic fibre optic light consists polymethyl methacrylate (PMMA) fibres. By its nature, these fibres do not transmit ultraviolet rays and heat. The white colour it transmits has the same colour balance as the natural sunlight, without the harmful qualities. In the sensitive storage area and exhibition cabinets, use of acrylic fibre optic light is beneficial.

3.2.1.4 Air pollution

Air pollution is another major hazard that severely deteriorates manuscripts. Air contains many types of gases like sulphur dioxide (SO$_2$), Nitrogen dioxide (NO$_2$), Carbon dioxide, (CO$_2$), Carbon monoxide (CO), Hydrogen sulphide (H$_2$S) produced from industries and automobiles and release to the atmosphere through smokes. Air also contains metal dust, carbon particles from industries and sand and soil particles from stones, construction sites, desert, dry river basin and barren hills. All these pollutants and air borne bacteria and fungi along with free moving pollens and insects create tremendous deterioration of manuscripts. The moisture content of the manuscripts and air moisture due to high relative humidity plays an important role in occurring chemical reactions with the gaseous and dust pollutant.

According to Agrawal and Barkeshli, (1997), sulphur dioxide is converted to sulphuric acid by action of traces of iron and cupper present in the paper. Sulphur dioxide deteriorates even high cellulose paper. Accordingly, particles of silica deposited on the surface of manuscripts produce chemical reaction and physical deformation. "Dust is not an inert material; it contains acidic as well as metallic ions which may sometimes cause degradation. Furthermore dust
particles (settled on manuscripts) attract moisture, which in turn give rise to chemical reactions. It has been shown that dust is hygroscopic in nature” (Agrawal and Barkeshli, 1997)

i. Control of Air pollution

a) Use of Air conditioning

Use of air conditioning is an effective way to control air pollution inside the library or museum. The outside air get filtered while coming in with the help of activated carbon filter or air pollution filters used in the air conditioning unit. Likewise, use of Heating, Ventilation, and Air Conditioning (HVAC) system, regulates relative humidity and temperature inside the library or museum, should be used for the purpose of air filtering. It is important to note that much more stringent exposure limits are set for collections because the collection is also expected to have a longer life and exposure period, hopefully several hundred of thousand years, which means that even a low level of gaseous pollution will have a significant cumulative effect”. (Lull, 1995)

c) Use of wrappers and covers

In Indian tradition of manuscript keeping, clean starch free cloth is used to wrap manuscripts together before storing in the display case. Use of wooden box, covered almirah, display case, microchamber, are also effective in controlling air pollution, but all these are not free from trouble if there is large scale air pollution in and around the repository.

3.2.2 Biological factors of manuscript deterioration

The biological factors are equally responsible for large scale manuscript damage along with environmental factors. There are also intricate relationships of environment or climate with that of growth of biological agents that damage manuscripts. Tropical and sub-tropical countries, where temperature and
relative humidity is favourable for rapid growth of biological agents are mostly affected. The problem of biological deterioration though seems to be less in the countries of temperate climate; more or less this problem exists everywhere in the world.

From the point of view of physiological characteristics, biological agents can be divided into three categories, viz., micro-organisms, insects and rodents.

3.2.2.1 Micro-organisms

Human eye cannot see micro-organisms, but perceived its action and presence through microscope. Micro-organisms can exist and live in any environment, even in adverse conditions and can multiply very rapidly. Due to its intrinsic quality of developing rapid resistance to any drugs and its capacity to travel any distance vary fast, through any media, has posed a great problem to stop its activity on manuscripts and other wood-based materials. There are various types of micro-organisms prevalent in the environment, of which few have been described below.

a) Fungi

Fungi are most common micro-organism which cause more damage to wood origin manuscripts than any other micro-organism. Wood origin manuscripts become susceptible to fungus because of its fragile structure and hygroscopic nature. Though fungus are considered as one of the primitive plants, “due to absence of chlorophyll they do not produce their own food, rather, fungus are dependent on other organic materials, living or dead, for their survival. They are therefore harmful to the materials on which they grow” (Agrawal and Dhawan, 1985).

Fungi generally grows on the surface where traces of carbon, hydrogen, oxygen, nitrogen, potassium, sulphur, calcium and manganese or any one of them is
found. “All carbon containing compounds are influenced by fungus, and for this reason, carbohydrates, like cellulose, starch and similar materials are greatly affected by fungus” (Agrawal and Barkeshli, 1997). When conditions become favourable, fungi starts germination on a suitable matter to develop conidium or spore. The Spore develops into a germ tube and in due time the germ tube develops into hyphae. “The body of fungus is composed of these hyphae, resembling like branching threads called mycelium” (Agrawal and Dhawan, 1985).

“Though, a specific temperature and relative humidity, which is respectively 24-30°C and above 65% is favourable for fungi growth, some species of fungi, like Aspergillus and Penicillium can even survive in a low relative humidity of 10%” (Agrawal and Barkeshli, 1997). Fungus grows faster in moist places such as cellar, vault, underground room and stores where ventilation or adequate air circulation is not possible. The speed of deterioration of fungus infected manuscripts may vary depending on various factors. Sometimes within a few days a manuscript may be damaged completely or it may take several months together. It may not be easy to recognize a fungus infected manuscripts at the beginning, but patches of various colour formations on the manuscript and mode of weakening the manuscripts into soft, limp and absorbent materials are indicators of fungus infection. “There is a characteristic difference between the damage caused to the paper by acidity and that caused by fungus. While the fungi make the paper soft and weak, it may still be possible to handle it and fold it without causing any damage. On the other hand with acidity the paper may become so fragile and brittle, that it may break into pieces on mere touching” (Agrawal and Barkeshli, 1997). Fungus behaves differently with different quality of papers.

b) Yeasts

Yeasts are other micro-organisms that cause deterioration of manuscripts. It causes colour formation on the manuscripts and accelerates decomposition.
Yeasts can grow in damp, humid and non-ventilated area of storage section. “Yeasts cell walls contain chitin and fat” which causes reddish colouration on the surface of manuscripts.

c) Foxing

The occurrence of mould and mildew is very common in manuscripts and other paper materials especially in a hot and humid climate. Mildew is a term popularly used to designate a variety of vegetable organism among fungi. Growths of these micro-organisms are usually detected by the presence of brownish to greenish patches on the manuscripts or other paper materials. These species are capable of causing stains or spots on the surface of the materials which are technically known as ‘foxing’. These micro-organisms grow very slowly at low temperature, 4.5°C (40F) and rapidly at 27-35°C (80-95F) differing with different species (National Archives of India, 1978). Mildew generally occurs in tightly packed or bundled manuscripts and other paper materials where the intervening atmosphere is reduced to a thin flat stagnant air pockets favouring the growth of mildew. The extant of foxing spots present in the paper depends on the impurities present in it. Agrawal and Barkeshli (1997) observed that papers of earlier periods, for example of the 14th or 15th centuries, which contains almost pure cellulose are less affected then the papers of 18th or 19th centuries.

3.2.2.2 Insects

Insects cause a considerable amount of damage to manuscripts of any kinds. Insects are commonly found when the surroundings is damp, dirt, warm and humid in condition and have enough hiding places like cracks, rifts, holes and gaps between planks, gaps between loose folios of manuscripts, damage book spines, book jackets, etc. Under favourable conditions, insects multiply very rapidly. The commonly found insects that act on manuscripts and other paper
materials are silverfish, cockroaches, book-worms, psocids and termites or white ants.

a) Silverfish

Silverfish is a tiny insect with glistering silver grey scales with a fish like appearance. Silverfish is a surface feeder and generally damage the outside of the volumes or records by eating them. Silverfish are abundant in materials containing starch and glue.

b) Cockroaches

Cockroaches are known to everybody for its nocturnal venture for food at dark places. They have a dark brown colour having two protruding antennae. They are closely related to grasshoppers and crickets. Cockroaches have numbers of varieties of these species, out of which common house-hold cockroach is omnivorous, exhibiting a marked liking for sweetened and starchy materials. That is why they are attracted towards, manuscripts, books and records in search of their food stuff and damage them by eating and also with their excreta that again invite fungus.

c) Book-worms

Book-worms are inside feeder and damage the inner portion of documents. *Gastrallus Indicus* is a book-worm or book-beetle, has two stages of development, viz., larvae or grubs and fully winged beetle. The larvae generally travel from the surface down the bulk of the volume and cause damage in the form of pinholes and empty parallel side tunnels, while beetle is the main cause of spreading the infestation to un-infested records (*National Archives of India, 1978*).
d) Psocids of book-lice

Psocids or book-lice are tiny insects which are mainly found in stored manuscripts or books which have remained untouched for a long period of time. This insect can eat almost all types of wood origin and animal origin materials including parchment. They produce vary tiny holes throughout the materials.

e) Termites or white ants

Among all the insects that damage wood and cellulose, termites are most dangerous which can wipe-out the entire collection of manuscripts or book or any other records. The infestation is detected only when their infestation is severe and already a considerable amount of damage has been made. These are found all over India, usually build their nest underground and extend their routes to the site of attraction in concealment. These insects build branching shelter tubes or mud covered runways on the foundation walls to the site of attraction. The reproductive rate is extremely high in this species and a female queen produces thirty thousand eggs a day on an average. So, termites or white ants are great menace for wood origin manuscripts and other materials.

3.2.2.3 Rodents

Besides micro-organisms and insects, common household rats can create menace by cutting and destroying manuscripts and other important records. These small and insignificant appearing animals are very quick in their actions. Rats often find entry into building from outside and a great deal of trouble can be saved by preventing their entry into the building.
3.2.2.4 Control of biological agents

a) Application of modern amenities for biological control

As discussed in previous sections that micro-organisms grow when there are favourable conditions for them to grow. Temperature and relative humidity have tremendous influences in their growth. Though micro-organisms can grow anywhere, everywhere, irrespective of temperature and relative humidity, scientists have proved that a specific temperature 24-30°C and relative humidity of 65% is most favourable for the growth of micro-organism. And this suggests the application of modern amenities like, air conditioning, HVAC systems, and maintaining optimum light levels to keep the temperature and relative humidity at desirable level, respectively at around 60 F (16°C) and 50% is the key to deter growth of microorganism. All these have been discussed in the previous section for temperature control and humidity control segments.

b) Fumigation

i. Thymol fumigation

An airtight fumigation chamber is prepared for thymol fumigation. The chamber contains some rack like framework of wire net some 15 cm from below, through which fumes of thymol can pass easily. The manuscripts needed for treatment are kept open with folios on the wire like racks. A 40-60 watt electric bulb is installed at the base of the chamber over which a thymol containing dish is placed. When the bulb is on, the thymol containing dish is heated out and the thymol starts vaporizing to get saturated inside the sealed airtight chamber. A concentration of 100-150 gm² per cubic metre is often sufficient, and the time for fumigation varies from six to ten days for which heating requires 2 to 4 hours every day. After 10 days the chamber is opened and folios are cleaned with cotton ball. With this process all types of fungal infections are treated (National Archives of India, 1978).
ii. Para-dichlorobenzene and Killoptera fumigation

The process of para-dichlorobenzene and liquid killoptera (a mixture of carbon tetrachloride and ethylene dichloride) fumigation is more or less same with the process of thymol fumigation. The fumigation is carried out in an airtight fumigation chamber where manuscripts are kept with folios open on the shelves. Para-dichlorobenzene is used in a concentration of 1.5 kg per cubic meter whereas killoptera is used in a concentration of 225 ml. per cubic metre. Both these chemicals vaporise at ordinary temperature. As these gases are heavier than air, unlike thymol, these are placed in the upper-most shells of the fumigation chamber. The time of fumigation by para-dichlorobenzene is for 7 to 8 days and fumigation by killoptera takes 24 to 26 hours. The heavy fumes come down from the upper shelve to the lowest shelve gradually and kills living larvae of insects and active beetles. This process does not kill eggs of beetles which are laid under the binding joints and boards. The eggs take a time of 20-21 days to be hatched and so the fumigation process may be repeated to catch them next.

iii) Vacuum fumigation

Vacuum fumigation is one of the most effective means of getting rid of the insects and beetles. Vacuum fumigation with ethylene oxide mixed with carbon dioxide (1:9 by weight) is used. This is one of the most effective method of eliminating insects and beetles.

b. Sterilization

In this process sterilization of the microclimate of the room is possible by spraying 10% solution of thymol in methylated spirit in the air. This process will check the growth of fungus in the room where there is no arrangement for bringing down the relative humidity below 75% especially during high
temperature and rain. This process is done in a closed room and just before the 
end of the library or museum so that it does not affect human beings.

c. Control of cockroach and silverfish

Use of insect repellent chemicals like naphthalene, D.D.T., pyrethrum, sodium fluoride, etc., reduces chances of cockroach attack. For silverfish, spray of naphthalene powder is most effective. While spraying these poisonous drugs or insecticidal liquids, it is to ensure that the spray is directed only towards the wall, dark corners, and crevices frequented by insects, and not to the manuscripts, books and records. These toxic chemicals are harmful for materials as well as man.

d. Control of termites

The termite grows in an alarming way as their reproductive rate is astonishingly high. A female queen produces 30,000 eggs in a day. It is better to find out the entire colony near or under the building for its eradication. White arsenic, D.D.T. powder, 1% solution of sodium arsenic in water or 5% solution of D.D.T., Dieldex emulsible concentrate with water, 1:60 (4-5 litres per metre) are quite satisfactory for the treatment of termite.

d. Control of rodents

If not controlled and preventive measures are not taken, rats can make a library or archive a shelter and a breeding ground to create havoc for the materials. To prevent rats, hygienic condition of the building and disciplined storage condition is a must. All non-essential openings to the outside should be sealed, essential openings should be of 8-9mm in diameter.

The menace of rats can be effectively controlled by poisoning and trapping. Poisons are always used with baits which are spread over places, frequented by
rats. Sausage, rusk, dry ground biscuit mixed with water, sugar meal (9 parts of wheat flour, soaked well and formed into a thick paste), are some good baits bases. Some of the good rat poisons are Zink Phosphide (3-5%), arsenous oxide (10-15%) Barium Carbonate (10-15%), ANTU (Alphanaphthyl-thiourea) and warfarin (3, Lactonyl-4 hydroxy coumarin) are commercial poisons sold under trade names can be used with baits.

There are also different types of rat traps available where baits can be used effectively. It is however desirable to change the position of the trap and change of the bait and poison at intervals for effectiveness.

3.2.3 Chemical factors

The environmental factors and chemical factors of deterioration are interrelated and have no much difference. As a result, both, environmental and chemical factors sometime overlaps with each other. Here, under the heading chemical factors of deterioration, actions which are brought about by chemicals present in the wood origin manuscripts and papers or in the atmosphere are discussed. The acidity of papers, acidic gases and elements present in the atmosphere, actions of ink present in the manuscripts and paper, action of pigments on papers, all are destructive in nature and plays great role in deterioration.

3.2.3.1 Acidity

In some wood origin manuscripts and papers, acidity remains as intrinsic quality because of presence of various organic and inorganic acidic components. These acidic components will always react with cellulose, the basic component of wood and breakdown its basic structure. These changes will take place even if these are kept in ideal climatic conditions. However high temperature and relative humidity, as they occur in tropical climate, will accelerate these reactions considerably (Agrawal and Barkeshli, 1997).
Acidic gases, smoke and metallic dust particle of the air comes into contact with paper and manuscripts and with the help of moisture reacts with cellulose to degrade it.

3.2.3.2. Browning of paper

Browning of paper is a phenomenon of oxidation where print area and the back-board of the stored box become yellow or brown. This happens even if the material is kept in an ideal condition. Research conducted by Hofenk de Graaff (1994) shows that the browning of paper in the window opening is a result of water evaporation on the paper surface. It has been shown that the browning of paper results from degradation of cellulose at the wet-dry interface due to the evaporation of water. Since there is an absorption and desorption of water by the paper in the window opening, browning in the area occurs. It was also observed by Hofenk de Graaff that the browning increases with the frequency of changes of the relative humidity, and the paper would deteriorate more where the browning i.e. oxidation of cellulose occurs (Hofenk de Graaff (1994).

3.2.3.3. Reaction with Ink

Generally, the ink used in the manuscripts are iron-gall ink which are highly acidic having pH value from 2 to 3.7. It is seen that manuscripts written with iron-gall ink gets damaged due to corrosion of ink. The writing get fudgy all around the letters, ink discolours the paper to brown, and ultimately burn the paper.

In iron-gall ink, ferrous sulphate is commonly used which reacts with gallotannic acid to form iron-gallo-tannates and sulphuric acid. In this process the excess ferrous sulphate is converted to ferric oxide and sulphuric acid which causes acid hydrolysis. A similar reaction will take place in the case of carbon ink to which ferrous sulphate is added (Agrawal and Barkeshli, 1997).

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3.2.3.4 Action of pigments

Certain metal and alloy based pigments, such as blue-green copper based pigment, green pigments of brass, bronze, etc., reacts with paper and percolate through the sheet, usually causing the paper become brown and finally destroying it. These phenomena are quite complex to understand as much research has not been done in this area.

3.2.3.5 Control of acidity and acidic materials

Acidity of papers, browning phenomena, reaction of ink and action of acidic pigments are complex problems and difficult to arrest such development. Even if papers or manuscripts with the above phenomena are kept in ideal microclimatic conditions, viz., temperature at 60 F (16°C) and relative humidity at 50%, the gradual degradation will occur due to its inherent acidic conditions or due to presence of acidic materials such as, ink, pigments, etc.

W. J. Barrow pioneered a process of neutralizing the acid content of wood-origin papers. This process is widely adopted all over the world for mass deacidification of papers and known as Barrow's deacidification process.

a. Barrow's deacidification process

Three enamelled trays containing calcium hydroxide (0.15%), fresh water and calcium bicarbonate solution (0.15%) are taken. Each paper or manuscript needs treatment are placed on a waxed paper larger than the documents and both emerged in the tray containing calcium hydroxide solution. Depending upon the depth of the tray (2.5 to 6 cm), 5-10 sheets can be immersed in one operation. After 20 minutes the sheets are removed, excess of calcium hydroxide is drained, and the sheets are immersed in fresh water for a couple of minutes and then the sheets are again immersed in the calcium bicarbonate solution for 20 minutes. The sheets are then placed in fresh water to remove excess of calcium
bicarbonate. The treated papers are finally pressed in pads of blotting papers and left on the racks for drying without any disturbance. An amount of 1000cc of each solution will generally suffice for 10 to 15 sheets of foolscap size.

b. Deacidification with ammonia gas

Use of calcium hydroxide solution and calcium bicarbonate solution is applicable for those papers where ink is insoluble in water. Papers containing water soluble ink are deacidified with diluted ammonia fumes. The documents for deacidification are placed on perforated shelves in a cabinet and the diluted ammonia (1:10%) is placed at the bottom rack of the cabinet and the documents left for 4-5 hours. After exposure to ammonia fumes, the treated papers are exposed to fresh air for 10 to 20 hours to disperse excess ammonia from the papers. Though water soluble inks are not affected by ammonia, certain dyes of paintings may get damaged. It is there advised that the paper should be tested before ammonia treatment (W. J. Barrow)

c. Stabilization of papers with calcium and magnesium

W. J. Barrow recommended another deacidification treatment for all types of printed paper. The solution is prepared by passing carbon dioxide for 2 hours in a mixture of 1.5-2gm of calcium carbonate and 15-20gm of magnesium carbonate in one litre water. After the undissolved particles are settled, the clear solution is decanted and used for treatment purpose. The papers are then soaked in the magnesium carbonate solution overnight and after that the excess solution is drained out from the paper. Later on the papers are dried. The calcium and magnesium bicarbonates are absorbed in the paper to get converted into insoluble carbonates which inhibit the acidic properties to grow on cellulose fibres.
d) Use of chemical inhibitors

Chemical inhibitors such as sodium pyrophosphate have been successfully used as inhibitor. The inhibitor solution is made in water and impregnation is carried out in the same manner of stabilization of papers with calcium and magnesium. Generally an inhibitor solution is successfully used to deacidify acidic papers. The solution is made of sodium pyrophosphate (42 gm), potassium ferrocyanide (4.7 gm) and sodium carbonate crystal (washing soda) (14 gm) all are added with 4.5 litre of water.

3.2.4 Man-made factors and natural calamities

Manuscripts are also vulnerable from the point of view of some man-made factors of destruction as well as consequence of natural calamities.

3.2.4.1 Man-made factors

Human being sometimes may act as biggest destroyer of manuscripts. History tells us how wars have destroyed so many famous libraries in the past. Mishandling, vandalism, ignorance, neglect, superstitions, myth, all contributes to manuscript destruction.

Improper way of handling manuscripts while studying, replacing, transporting, while providing preventive or curative treatment to fragile manuscripts, improper way of storing, displaying, exhibiting all accounts for destruction of manuscripts. These are man-made factors and can be cured generating awareness among public and stakeholders.
3.2.4.2 Natural calamities

Fire, flood, earthquakes, landslides, tsunamis, are other most devastating agencies which cause destruction of properties and valuable lives. Numerous incidents have occurred where thousands and thousands of manuscripts along with libraries and repositories have been destroyed by fire and flood so far in the world. Though human beings have little control over natural calamities, well planned protection measures might save many of the lives and properties of cultural entities. Disaster Planning and Response System is a modern concept to safeguard lives and properties.

3.2.4.3 Control on man-made factors and natural calamities

Control on man-made factors like, mishandling, vandalism, ignorance, neglect, superstitions, myth, can be have with stringent rules and regulation as well as bringing awareness among stakeholders, users and masses through various channels of administration and education. But, as far as natural calamities like, Fire, flood, earthquakes, landslides, tsunamis, etc., are concerned, human beings seems to be helpless in many fronts. But, preventive measures like fire-proof buildings with adequate amenities of fire extinguisher for preserving cultural entities, earthquake resistant structure, high-rise buildings with strong foundation for preserving cultural entities from possible floods and tsunamis are possible, and many countries have adopted such measures.

3.3 Indigenous Preservation practices

Manuscript preservation was a matter of great concern of the past. All most all civilization acquired or invented some or the other methods for preservation and protection of manuscripts from different agents of deterioration. But, it seems that those protection measures are understood to prevent biological agents only. These protection measures are being in use by various societies all over the world with locally available ingredients from the time immemorial. In the
passage of time, these practices have become indigenous to particular societies which are being used traditionally generation after generation.

India’s history of using indigenous preservation practices, such as herbs and other natural products against the activity of bio-organisms is very long. Some of the traditional methods have been in use in our country for centuries. India has also produced a variety of writing support, viz., palm leaf, paper, birch bark, bamboo leaf, sanchi manuscripts and so on, which were characteristically different from each other and needed different preservation practices. Basically, for preservation of manuscripts, India has two types of traditional herbal practices, insecticides and fungicides. Various parts of plants and their products in the form of powder, oil are being used as insecticides and fungicides in India. Some of them have been discussed in the following sections.

3.3.1 Widely used indigenous preservation practices of India

Various plants and plants materials have been used in India as insecticides and insect-repellents; moreover, plants and its products are also used as vaporizers, insect growth regulators, feeding deterrents and also as confusants. Besides use of plants, some indigenous practices of preservation are also prevalent in India. One of the major causes of use of this methods and materials is that the methods and materials are easy to follow and abundantly available.

3.3.1.1 Use of plants and plant materials

Various medicinal plants, their parts and product are being used in manuscript preservation in various parts of India.

In Tamil Nadu, when palm leaf manuscripts become dry, various oils are applied on manuscripts as softening agents to impart flexibility to the manuscripts folios. These are also used as insect repellents and anti-fungal agents. These oils are extracted from various plants. These are as given below,
Cedar wood oil  Eucalyptus oil
Sandal wood oil  Citronella oil
Lemon grass oil  Olive oil
Turpentine oil  Palm leaf oil
Agar oil

At the Saraswathi Mahal Library, Tanjavor, the following plant materials are used in combination as insect repellent.

<table>
<thead>
<tr>
<th>Black Cumin</th>
<th>1 part</th>
<th>Pepper</th>
<th>¼ part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinnamon bark</td>
<td>1 part</td>
<td>Sweet flag</td>
<td>1 part</td>
</tr>
<tr>
<td>Cloves</td>
<td>¼ part</td>
<td>Green camphor</td>
<td>a little.</td>
</tr>
</tbody>
</table>

The above combination of plants materials is said to be an effective insect repellent against termite (Jayaraj, 2006).

At the Saivite Mutts of the Erode Districts of Tamil Nadu the following plant materials are used in combination as disinfectant, insecticides and insect-repellent

<table>
<thead>
<tr>
<th>Black Cumin</th>
<th>1 part</th>
<th>Black pepper</th>
<th>¼ part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinnamon bark</td>
<td>1 part</td>
<td>Sweet flag</td>
<td>1 part</td>
</tr>
<tr>
<td>Cloves</td>
<td>¼ part</td>
<td>Green camphor</td>
<td>25gm.</td>
</tr>
</tbody>
</table>

All the above ingredients are dried in the shade and then pulverized separately, one at a time, and then mix together thoroughly. Then 5.0gm of the mixture is then packed into cloth sachets of 4 inches dimension. These packets are kept between the bundles of manuscripts and on the shelves (Maheswaran, 2006).

According to Gupta (2006), the neem oil prepared from neem tree (Azadirachta indica) is known to be effective against 400 insects. The leaves, tree and seeds
of neem are widely used in the Indian subcontinent. Neem is effective against insects in various ways, namely:

1. Disrupting or inhibiting development of eggs, larvae, or pupae,
2. Preventing the moulting of larvae,
3. Repelling the larvae and adult,
4. Disrupting mating and sexual communication,
5. Deterring females from laying eggs,
6. Poisoning larvae and adults,
7. Feeding deterrent
8. Blocking the ability to swallow.
9. Preventing metamorphosis and arresting growth.
10. Low toxicity for human beings.

Like neem, turmeric is also widely used in India for manuscripts preservation. In certain regions of India, particularly in Orissa, turmeric paste is applied on the surface of the palm leaf. In paper manuscripts, every third or fourth folio is sometimes is found to be coated with turmeric (Subbaraman, 2006).

There are numerous plants and their materials are being used in conservation of manuscript. A list of plants used in India has been provided in the Appendix IV.

3.3.1.2 Use of traditional practices

Besides use of indigenous plant and plant materials, certain traditional practices are still prevalent in India including Assam. These seem to be quite effective in preserving manuscripts from environmental and biological agents and providing longevity to them.
a) Use of cloth wrapper

From ancient times, India has adhered to the practice of covering manuscripts with various types of cloths tightly with laced around so that the folios remain intact without dislodgment from its position. Generally, the cloth used is starch free cotton cloth with varied colours. Generally, three colours, viz., red, yellow and white are used. Among these three colours red is predominant, may be due to the fact that red is commonly used in the books and manuscripts in India (Gupta, 2006). Another reason may be that the red colour is strong for the eyes of insects that create sensitivity. A lace protrudes from one corner of the cloth wrapper which is generally stitched together with the piece of the cloth, or sometime the lace is provided separately. There is a style of wrapping the cloth around the manuscripts so that no part of the manuscripts remains open from outside. The cloth used generally act as protection from insects, rodents, dust and also act as dehumidifier.

b) Use of flat wooden support

Normally, two pieces of wooden flat support is provided at top and at the bottom of the manuscripts to support the entire bundle of folios to remain straight. The supporting wooden plates are generally made from hard wood having the properties of insect-repellent or insecticidal. The neem wood plank is generally preferred for this purpose. The wooden supports used are some-time beautifully decorated. These wooden supports provide extra strength to the fragile manuscripts and save from stress and strain during transportation and from possible fluctuation of temperature.

c) Use of wooden box

All important manuscripts are kept in specially made wooden box, from hard wood having the property of insecticidal characteristics. The box is sometime decorated. This protects manuscripts from dust, insects, and rodents.
d) Use of kitchen loft and resining

In India, keeping manuscripts in kitchen loft was a common practice. This practice is seen generally in personal repositories. It is believed that the smoke from various materials used in cooking kept the insect away (Gupta, 2006). Resining is still a common practice in Indian household. The smoke from resinous product has the ability to repel insects for a certain period of time.

e) Use of lime stone lump and camphor

Lump of lime stone are used for dehumidification. The solid pieces of limestone in small packets using cotton cloth are made and kept in corners of the box or cabinets where manuscripts are stored. In certain period of time the lime stone inside the packet become powdered due to absorption of moisture of the surroundings. The packets are changed with fresh lump of lime stone. The lime stone lumps are effective dehumidifiers especially in hot, humid and rainy days.

There are some disadvantages of using these practices. The methods and practices are not clinically proven and most of the products are not truly effective insecticides. Moreover, their effect is slow and a not less poisonous as it is believed. But even then, there are many institutes and repositories where, as claimed, many herbal and traditional practices are being used from generations, successfully. There are lots of scope for study and research and further development of these herbal products (Agrawal, 2006)

On the other hand, there are concerns for environmental pollutions due to use of chemicals with the modern technology. The toxic environment due to pollution from the chemicals used for preservation of cultural property is a hot debate around the world today, and lots of emphasis has been given to solve this problem of chemical pollution by reintroduction of proven natural products in the field of manuscripts preservation.
3.4 Preservation of sanchi manuscripts in Assam

In this section, a systematic and scientific approach has been made from preservation aspects to analyze the Indigenous Technical Knowledge (ITK) or the craftsmanship that has been employed in processing the bark of Agaru tree (*Aquilaria agallocha* Roxb) to prepare as a writing support in ancient and medieval Assam. The basic idea of preparation of sanchi manuscripts has been taken from the records of Sir Edward Gait who authored the book ‘A history of Assam’ in 1905. This is the first and most trusted recorded evidence of indigenous sanchi manuscript preparation techniques of Assam. Moreover, idea has also been taken from the people who still have the knowledge of craftsmanship of sanchi manuscript making.

There is a belief in Assamese society that the preservation techniques or preservation entities of sanchi manuscript lays within the process of sanchi manuscript making techniques. The selection of a plant like Agaru tree for making writing support which itself has anti-fungal quality, the harsh and tedious process of seasoning the bark to enhance its durability, adding selective alkaline natural ingredients during its preparation process sequentially to increase alkalinity of the paper at source, varnishing the bark to enhance elasticity, stress and strain bearing quality, all these suggest that the sanchi manuscript were prepared keeping in view of its long term preservation aspects. And that is why, till today no specialized preservation technique has been employed to preserve these manuscripts anywhere in Assam. Still these manuscripts exist in Assam bearing onslaughts of very harsh environmental conditions such as high humidity and high temperature. In Assamese language, “sanchi” means “preserve” or “protect”, probably the name “sanchi manuscript” justify its existence.

In this section, an attempt has been made to analyse its preparation techniques keeping the preservation aspects in its backdrop.
3.4.1 Recorded evidence of sanchi manuscript making process

A sachi tree of 15-20 years of growth and of 30-50 inches in perimeter is selected as best for bark for preparing sanchi manuscripts as shown in Photo. 3.1. The bark of the selected tree is considered from four feet above the ground to 6 to 18 feet high of the tree. The bark is split in these two ends of the tree with the help of a knife to stripe it off from the trunk from below, rolled up upwardly, at a size of 3 to 27 inches in width. The rolled strips are kept under the sun for some days until they dry up completely. The roll of dry bark is then kept immersed into water for at least 3 to 4 days constantly. The bark is then cut into a definite size, normally, 9 to 27 inches long and 3 to 18 inches broad. The pieces of bark then again dried in the sun for few days. The dried bark is now boiled in alkaline water in a big iron pan for a long time. Once the boiled pieces of bark are cools, the outer layer is removed by scraping carefully with the help of a knife. These inner layers of bark are then dried again for at least half an hour under the sun till it dries up completely and then placed with the inner layers flat, one by one, on a wooden plank, the surface is rubbed with a piece of highly burnt (but smooth and even surfaced) brick specially made out of sand and clay used by potter for the purpose. The bark is then thinly smeared with a paste of black-gram, locally known as Matimah (Phascolus radiatus), and dried for some time. The dried layers of bark with thinly smeared Phascolus radiatus are then dyed with Arsenic Sulphide, locally called Haital. Arsenic Sulphide is applied along with gum of wood-apple on the both side of the layers of the bark. To make the boundary and the edges more colourful and bright, another dye made of Mercuric Sulphide (HgS) (vermilion), locally called Hengul is applied along with gum of wood-apple. The layers of bark are then dried completely. Now, placing the bark strips flat, one by one, on a wooden plank, both the surface of the strips are rubbed with a highly smooth but big seed of *Entada purseaetha* DC, locally called as Ghila-guti until the stripes gives varnishing effect. Now, one can use the processed bark as a writing support (Gait, 1905).
3.4.2 Analysis of the sanchi manuscript making process

To know the science behind preparation of sanchi manuscripts, the following analysis has been made. The manuscript preparation technique will reveal how concept of preservation is associated with the method of preparation itself to protect it from weather, animals and insects.

Photo. 3.1 A matured Sanchi tree (*Aquilaria agallocha* Roxb.)

Step 1: A Sachi tree of 15-20 years of growth and of 30-50 inches in perimeter is selected for bark for preparing sanchi manuscripts.

Analysis:

A sachi tree of 15-20 years of growth can yield better quality of bark as the quantity of crystalline cellulose are more in matured tree bark and fibres are strong and tough, and can withstand stress and strain during processing to give longevity to the processed Sanchi bark. In this research work, a fresh processed bark has shown the tensile strengths 66.92 MPa, which is too good for a writing support. The microfibrils of matured cellulose consist of 60-70% crystalline cellulose and 30-40% amorphous cellulose surrounded by a hemicellulose and lignin matrix (Ek et al., 2009). Moreover, crystallinity is an important property of woody materials. Approximately 30% of wood weight is cellulose in its crystalline form (Andersson et al., 2003). (Detail about cellulose has been discussed in the chapter 5.). Besides, barks of immature trees are soft and thin and are prone to infestation of insects and environmental degradation.
Step 2: The bark of the selected tree is considered from four feet above the ground to 6 to 18 feet height of the tree. Fig. 3.1 shows the cut section of a sanchi bark. The bark is split in these two ends of the tree with the help of a knife to stripe it off from the trunk from below, rolled up upwards, at a size of 3 to 27 inches in width. Photo. 3.2 illustrates the various traditional cutting, scraping and peeling tools used in the processing of sanchi bark. Though apparently looks one, the bark has two layers finely attached to each other - uneven and rough outer layer and smoother slippery inner layer.

Analysis:

The bark of the ground portion of the tree is never considered good for making writing support as this portion is rough, uneven. Internally, the ground portion has high concentration of organic acid like lignin, pectin, sugars and carbohydrates which cannot be removed by normal treatment like drying and boiling, so elasticity, stress, strain and durability of writing support would be questionable if sanchi manuscript is made out of it.
Step 3: The rolled strips are kept under the sun for some days until they dry up completely.

Analysis:

Drying up bark under sun helps light energy, in the form of waves to penetrate to the core of the molecules of the barks and starts photochemical reactions. This causes heating, thermal expansion and evaporation of cellular substances like organic acid, oil, sugars, and carbohydrates with water to a great extent.

Step 4: The roll of dry bark is then kept immersed into water for at least 3 to 4 days constantly.
Analysis:

It has two effects; one, this process softens up the outer rough portion of the bark to make it little bit of easier to separate from the inner smoother layer, manually. On the other hand, due to excessive absorption of water by cells of the bark, the hydrophobic acid like lignin partly gets dissolved into water to reduce its concentration.

**Step 5:** After keeping inside the water for 3 to 4 days, the bark is taken out of the water and cut into a definite size of pieces, normally, 9 to 27 inches long and 3 to 18 inches broad, or as per requirement of the author or copier. It is important to note that the bark is made into pieces while it is wet in condition.

Analysis:

If bark is made into piece of its required size in its dry condition, the edge of the new folio may split or break unevenly while cutting due to non-cohesive tendency of dry bark fibres. To avoid early breakage of the edge of the folio, the bark is cut into pieces as soon as it is taken out of the water.

**Step 6:** The pieces of bark is then again dried up under sun for few days.

Analysis:

This is necessary to remove water from the bark and make the inner layer of the bark weathered and tough.

**Step 7:** The dried up bark is boiled in alkaline water in a big iron pan for a long time.
Analysis:

Boiling makes the pieces of bark soft which helps to scrape and remove the outer rough layer of the bark. Boiling also helps to dissolve the hydrophobic acid like lignin and other cellular substances like oil, sugars, and carbohydrates to reduce and remove from the bark. This makes the bark partly acid free. Boiling kills insects and other microorganism and removes their harmful secretions if infested into the bark. Photo 3.3 shows the scraping activity during processing of a fresh sanchi bark.

![Scraping of sanchi bark with a knife](image)

**Photo.3.3** Scraping of sanchi bark with a knife

**Step 8:** Once the boiled pieces of bark is cooled down, the outer layer is removed by scraping carefully with the help of a knife.

**Analysis:**

Now both the surface of the inner layer is exposed. This inner layer is the main writing support and future sanchi manuscript.

**Step 9:** These inner layers of bark is then dried again for at least half an hour under the sun till it dries up completely and then placing the inner layers flat, one by one, on a wooden plank, the surface is rubbed with a piece of highly...
burnt (but smooth and even surfaced) brick specially made out of sand and clay by potter for the purpose.

Analysis:

This process makes the inner layers smooth, seasoned, flexible and elastic.

Step 10: These smooth and flexible layers of bark is then thinly smeared with a paste prepared from a pulse called Black-gram. The botanical name is Phascolus radiates (locally known as Matimah (Urad Dal in Hindi). After the process of smearing, the bark is dried for some time.

Photo. 3.4 Phascolus radiates (now Vigna mungo)
Analysis:

Phascolus radiatus or Matimah paste develops high concentration of alkalinity ranges from pH 7.65 to 8.5. The crude extracts of Phascolus radiates (Photo.3.4) possesses alkaline β-Glycerophosphatase which shows high phosphatase activity against a variety of compounds and act as a strong inhibitors (Rao, et al.,1960). It is also used as an adhesive. This makes the layers of bark almost alkaline and act as anti-acid agent to increase the lifespan of the writing support.

Step 11: The dried layers of bark with thinly smeared Phascolus radiatus is then dyed with Arsenic Sulphide, locally called Haital. Arsenic Sulphide is applied along with gum of wood-apple or Beal-fruit on the both side of the layers of the bark. It gives yellow colour to the writing support which is more or less permanent in nature.

Analysis:

The Arsenic Sulphide (As₂S₃) (yellow orpiment) is a yellow coloured (Lemon-yellow to golden or brownish yellow) naturally available stone (salt) shown in Photo. 3.5. The pH concentration ranges from 6 to 13 i.e. neutral to highly alkaline. It is very poisonous and has long lasting effect. When mashed with water gives yellow colour dye. It acts as a long lasting outer layer of laminated wax to the writing support to prevent insects from eating.

As it is highly toxic, it was also used as a fly poison and to poison arrows in ancient time. Orpiment was ground, processed and used for centuries as a pigment in painting and for sealing wax, being one of the few clear, bright yellow pigments available to artists up until the 19th century.

Orpiment presented problems, however, such as its extreme toxicity and its incompatibility with other common pigments like lead and copper-based substances such as verdigris and azurite. The use of orpiment as a pigment
material ended almost entirely with the advent of the cadmium yellows and the various dye-based colours of the 19th century.

Photo. 3.5 The Arsenic Sulphide (As₂S₃) (yellow orpiment)

The Beal fruit, scientifically known as *Aegle marmelos* has mucilage inside. Mucilage mixed with water is used as a glue, especially for bonding paper items such as labels, postage stamps, and envelope flaps. The glue acts as a natural adhesive (Ferdinand, 2009).

Photo. 3.6 *Aegle marmelos* (Beal fruit)
Step 12: To make the boundary and the edges more colourful and bright, another dye made of Mercuric Sulphide (HgS) (vermilion), locally called Hengul is applied along with gum of Wood-apple or Beal-fruit (Photo. 3.6) on the edges and boundary of the writing support.

Analysis:

The Mercuric Sulphide (vermilion) is a naturally available stone (salt), bright red in colour and highly poisonous having pH concentration ranges from 6 to 10. It is used as many dye as well as insect repellent. From the ancient time, civilization has used vermillion as dye in paintings and manuscripts. Generally, borders and edges of manuscripts become more prone to get attacked by insect and other factors. The Mercuric Sulphide (Photo. 3.7) acts as a first line of defence before an insect come into contact with Arsenic Sulphide which acts as a second line of defence thus protecting the writing support. Indigo blue and Kaolinite are some of the other commonly used dyes or colours used in sanchi manuscripts (Photo. 3.9).
Step 13: The layers of bark is then dried completely. Now, placing the bark strips flat, one by one on a wooden plank, the both surface of the strips are rubbed with a highly smooth but big seed of *Entada pursaetha*, locally called as Ghila-guti until the stripes gives varnishing effect. The processed bark is now ready for use as writing support.

**Analysis:**

The seed of *Entada pursaetha* (Photo. 3.8), a plant locally available, which is big in size but highly smooth and too hard to get corroded while rubbing. While rubbing the stripes, the silky-smooth surface of the Ghila-guti smoothly runs to and fro on the surface of the stripes and generates heat. The heat and the constant friction over the surface of the stripes make the writing support varnished and create a glaze of a permanent in nature. The stripes are now ready to be used as writing support.

The above analysis in the backdrop of indigenous sanchi manuscript making technique reveals application of tremendous amount of ITK throughout the
process. Right from the process of repeated boiling and sun-drying till the application of Arsenic Sulphide (As$_2$S$_3$) and Mercuric Sulphide (HgS), the entire process is focused towards developing an alkaline writing support and incorporating the ingredients of preservatives at the source itself so that the manuscripts attain more and more longevity in the typical climatic condition of Assam. The entire process of sanchi manuscript making is a rare indigenous effort towards achieving perfection on developing a breed of writing support only with locally available means and materials.

Photo. 3.9 Some other dyes used in sanchi manuscript colouring

3.4.3. Relevance of scientific preservation of sanchi manuscript in the context of climatology of Assam

Assam belongs to the humid subtropical region and hence the climate is characterised by hot, humid summers and cool, dry winters with monsoonal influences. There exists a variation in the local climatic conditions particularly temperature, rainfall and humidity across the state of Assam.

The rainfall varies from 100 cm to 400 cm and most of the annual rainfall occurs in the monsoon months from June to September, with the eastern parts experiencing pre-monsoon thundershowers from March to May. The central
portion is situated in a rain shadow area of the southern hills. In the rest of the plains area, annual rainfall gradually increases to 300 cm. The annual mean basin rainfall around 230 cm and rainfall increases gradually from west to east. Fig. 3.2 shows the map of Assam showing the districts for climatological analysis.

In most of the plain districts of Assam the air is highly humid throughout the year. During the months of January to April relative humidity is comparatively less ranges from 50 to 65%. Throughout the rest of the year, the relative humidity being usually over 70%. During the period of south west monsoon season, the relative humidity is above 80%. Table 3.1 and Fig. 3.3 gives an overview of the local differences in relative humidity for four districts of Assam viz., Kamrup, Dibrugarh, Cachar and Bongaigaon.

Winter lasts from late October to late February. The minimum temperature is 6 to 8 °C. Nights and early mornings are foggy, and rain is scanty. Summer starts
in mid May, accompanied by high humidity and rainfall. The maximum temperature is 35 to 38°C.

Table 3.2 indicates the local differences in Annual mean rainfall, minimum temperature, maximum temperature and average temperature for four districts of Assam viz., Kamrup, Dibrugarh, Cachar and Bongaigaon. Fig. 3.4 and Fig. 3.5 clearly represent the Annual mean rainfall and temperatures (maximum, average and minimum) respectively for the above districts.

With such a high average relative humidity of over 70% (minimum 50% and maximum above 80%) and temperature ranging from maximum 35 to 38°C with high annual mean basin rainfall around 230 cm to fluctuate both relative humidity and temperature frequently, is certainly not good for sanchi manuscripts of Assam. As stated above in this chapter that ‘the environmental conditions most suitable for the growth of fungi are temperature between 24-30°C and relative humidity above 65%, and slightly acidic condition’ (Agrawal and Barkeshli, 1997). Not only fungal growth, increase in temperature and frequent fluctuations also influences the relative humidity of the air which otherwise causes heavy mechanical damage to the manuscripts with splitting, flaking and forming cleavage. Moreover ‘exposure to high temperature increases the rate of aging of the manuscripts even for a short period of time’ (Agrawal and Barkeshli, 1997).

Due to humid subtropical characteristics, Assam falls under the Indo-Malayan biodiversity hotspot region where abundant of insects and microbial organism grows due to this favourable climatic condition. Wood and wood origin materials decaying micro-organism such as Aspergillus, Alternaria, Fusarium, Memnoniella, Penicillium, Scopulariopsis, Stachybotrys, Stemphylium, Trichoderma and Chaetomium are tested to be the fungi with most cellulolytic activities in this temperature and wider relative humidity range.
<table>
<thead>
<tr>
<th>Month</th>
<th>Kamrup</th>
<th>Dibrugarh</th>
<th>Cachar</th>
<th>Bongaigaon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>79</td>
<td>81</td>
<td>80</td>
<td>78</td>
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<tr>
<td>Feb</td>
<td>64</td>
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<td>56.5</td>
<td>67</td>
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<td>Apr</td>
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</tr>
<tr>
<td>May</td>
<td>75</td>
<td>82</td>
<td>80</td>
<td>74</td>
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<td>Jun</td>
<td>81.5</td>
<td>84</td>
<td>83</td>
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<td>Jul</td>
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<tr>
<td>Dec</td>
<td>76.5</td>
<td>84</td>
<td>85</td>
<td>72</td>
</tr>
</tbody>
</table>

**Table**: Average relative humidity of four districts of Assam

*Source: IMD Borjhar*

**Fig. 3.3** Average relative humidity (%) of four districts of Assam (1901-2002)
### Table 3.2

Average annual rainfall and temperature of four districts of Assam

<table>
<thead>
<tr>
<th></th>
<th>Kamrup</th>
<th>Dibrugarh</th>
<th>Cachar</th>
<th>Bongaigaon</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Month</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average annual rainfall (mm)</strong></td>
<td>64.8</td>
<td>71.9</td>
<td>82.3</td>
<td>101.2</td>
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<tr>
<td><strong>Minimum temperature (°C)</strong></td>
<td>1.9</td>
<td>2.7</td>
<td>2.1</td>
<td>3.0</td>
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<tr>
<td><strong>Maximum temperature (°C)</strong></td>
<td>25.1</td>
<td>25.8</td>
<td>25.6</td>
<td>26.5</td>
</tr>
</tbody>
</table>

Source: www.india Water Portal

Average annual rainfall and temperature of four districts of Assam (1901-2002)

Abbreviations: Kam = Kamrup, Dib = Dibrugarh, Cac = Cachar, Bon = Bongaigaon

<table>
<thead>
<tr>
<th>Month</th>
<th>Kam</th>
<th>Dib</th>
<th>Cac</th>
<th>Bon</th>
</tr>
</thead>
<tbody>
<tr>
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<td>22.4</td>
<td>23.7</td>
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<td>15.9</td>
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<td>9.1</td>
<td>9.3</td>
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<td>Sep</td>
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<td>11.3</td>
<td>11.5</td>
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<td>16.5</td>
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<td>Nov</td>
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<tr>
<td>Dec</td>
<td>27.2</td>
<td>27.4</td>
<td>27.6</td>
<td>27.8</td>
</tr>
</tbody>
</table>

Source: www.india Water Portal
Fig. 3.4 Annual rainfall of four districts of Assam (1901-2002)

Annual rainfall of four districts of Assam (1901-2002)
Fig. 3.5 Annual Maximum, Average and Minimum Temperature of Four Districts of Assam (1901-2002)
3.5 Conclusion

The fluctuating climatic condition of Assam suggests controlled microclimate environment for manuscript repositories or archives for their sustenance so that this unique cultural property can be preserved for a longer period, may be another few hundred years, or thousand years, or more.

From the analysis of the rigorous sanchi manuscript preparation technique in ancient time, it is understood that our forefathers showed the path of preservation of these valuable entities by integrating the preservation aspects, such as Arsenic Sulphide (As$_2$S$_3$), Mercuric Sulphide (HgS), and other alkaline substances at the source, so that these could be preserved for the longest ever time and everlasting. But the changing climatic condition of Assam demands more protection to these invaluable assets in the form of controlled microclimate with application of state-of-the-art technology.