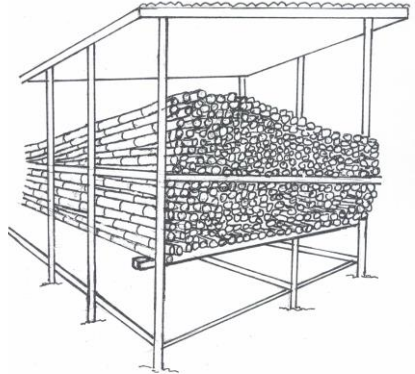
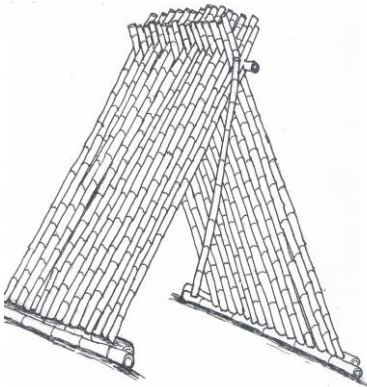




Guidelines for Bamboo Preservation

A guide for bamboo furniture artisans and other
bamboo users



Kenya Forestry Research Institute (KEFRI)

June 2024

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**A guide for bamboo furniture artisans and other bamboo
users**

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- An A-frame for drying bamboo culms – cover caption
- A bamboo storage shed – cover caption

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1.0 INTRODUCTION

Bamboo is the fastest growing plant that generates substantial amounts of biomass within a short period of time. It is a versatile species with multiple economic and ecological benefits that make it one of the most important non-timber forest resources which can play an important role in the reduction of timber consumption, environmental and forest protection, poverty alleviation and sustainable development of rural economies. However, Bamboo is susceptible to biological degradation as raw material and processed products as insects and fungi quickly attack it due to starch and sugar in the culms.

The termites, longhorn beetle (*Cerambycidae*) and the shot hole insect (*Bostrychidae*) are responsible for 90% of bamboo insect attack (NMBA, 2007). The perishability of bamboo curtails its value and wider application. Therefore, there is need for treatment to enhance its utilization in furniture making and as a structural material that can substitute wood. The purpose of preservation treatment of bamboo is to remove the nourishment that attracts insects and other pests that feed on bamboo

Various preservatives are found in the market, including boric acid-borax, coal tar creosote, copper-chrome-arsenic composition, acid-copper-chromate composition, and Copper-chrome-boron composition, copper-zinc-Naphthenate, copper azoles among others. The use of borax and boric acid is considered as eco-friendly wood preservation agent which has been used in treating indoor furniture and structures. Borax and boric acid solution is cleaner and cheaper and can be applied using simple methods which are available to SMEs. Borax and boric acid solution has many industrial applications and works as a fire retardant, antifungal agent, and insecticide (KS 2855, 2019).

This guideline provides the required information in the simplest method practicable for SMEs to treat round bamboo and splits in small quantities. However, for a large-scale operation, further guidance on industrial strategy for treating commercial volumes of bamboo using the vacuum-pressure impregnation can be obtained from National Forest Products Research Programme, KEFRI. It is hoped that this guideline will enhance

the use of treated bamboo and increasing the shelf life and value of bamboo and bamboo products.

2.0 BAMBOO PRESERVATION TREATMENT

Bamboo, in its natural state, is not a durable material. It is easily attacked by insects and fungi due to the presence of starch and sugar in the culms. Preservation treatment is essential to enhance durability of culms during storage and of finished products. When treated with chemicals, borers, termites and fungi will not eat bamboo. Use of hazardous chemicals in preservatives may cause illnesses and therefore the treatment must not be toxic to people.

Artisans in many parts of the world have traditionally used some natural methods of preserving bamboo. Although such traditional methods provide some resistance to insect and fungal attack on freshly cut culms, they do not ensure long-term durability and are not recommended for bamboo that will be used for commercial products.

2.1 Non-Chemical Methods

Some traditional/non-chemical methods of treating bamboo include:

2.1.1 Culm curing:

The culms are cut and left in place in a vertical position with branches intact for up to 4 months. The evaporation in the leaves reduces the moisture content and leads to the fermentation of starches in the culm. The threat of beetle attack is reduced, but attack by termites is not diminished, and fungal attack and rotting are still possible.

2.1.2 Leaching in Water:

Freshly cut bamboo is stored in rivers or streams for 3-4 months to leach out starch. The method takes a long time and provides no guarantee of long-term durability.

2.1.3 Smoking:

Freshly cut bamboo are placed in closed chambers under a fireplace and smoked. The smoke produces toxic agents and heat that destroy starch in bamboo, thus making them less palatable to insects and pests. The process also blackens the culms, but the heat usually causes the culms to crack.

2.1.4 White-washing:

Bamboo culms are painted with slaked lime to reduce moisture absorption. This prolongs durability, but the threat of termites remains.

2.1.5 Post-harvesting transpiration of bamboo culm;

The method adopted for lowering the sugar content in felled bamboos *is* keeping harvested culms with some leaves upright for a few days. Parenchyma cells in plants continue to live for some time, even after felling utilizing the sugar and starch increasing resistant to attack from borers and staining fungi.

All the above methods are too slow for commercial use, and their effectiveness is unpredictable.

2.2 Chemical Methods

Many chemicals are used as a preservative for wood, and some have also been used for treating bamboo. The three major chemicals used for preserving timber are Creosote, Pentachlorophenol (PCP) and Chromated Copper Arsenate (CCA). These

chemicals are usually applied to wood using pressure systems. Creosote and PCP are not soluble in water, so for treatment they are usually dissolved or diluted in a petroleum-based solvent such as light oil. The oil acts as a carrier to help the preservative penetrate a spaced stack of timber or bamboo when it is heated and pressurized in a large steel cylinder. CCA, on the other hand, is a combination of inorganic salts dissolved in water and forced into the wood or bamboo

These chemicals combine well with wood, resulting in little or no loss on subsequent contact with humidity, rain and groundwater. However, they are toxic and hazardous to people!

Phosphate based insecticides that are used in the agricultural industry are known for their allergenic potential, while creosote is carcinogenic. So far, the only petrochemical agents that are acceptable are the pyrethrin based insecticides like Permethrin and Deltamethrin (INBAR). These products are among the most popular and widely used insecticides in the world. They are used for protecting wood products and by many bamboo furniture industries in Asia. All these agents are applied with turpentine or

kerosene, and generally have a foul odor. They are not recommended for products that will be used indoors. Borax and boric solution is much cleaner and cheaper and has been regarded as an eco-friendly wood preservation agent (Practical Action). Borax is an important boron compound which is a white powder consisting of soft colorless crystals that dissolve easily in water. It has many industrial applications, and works as a fire retardant, as an antifungal agent, and as an insecticide. Borax is available in granulated or powder form as Boric Acid and Borax Oxide.

2.3 Borax Solution for preserving Bamboo

- Preservation of bamboo is achieved using a 5% Borax solution, which is pH neutral.
- The pH neutral solution is made using equal amounts of Boric Acid (2.5%) and Borax Oxide (2.5%), both in powder form, and dissolving them in warm water.
- The concentration of both chemical agents dissolved in water is 50kg per M³ (i.e. 5kg per 100 L of water)

Effective Duration

The borax solution remains active for 1 to 2 months

Output

1000 liters of borax solution will require one 25 kg sack of Boric Acid and one 25 kg sack of Borax Oxide. This can be used to preserve over a hundred or more bamboo culms, depending on their size.

Safety Precautions

The 5% borax solution is pH neutral and is not hazardous or harmful to the skin. Nonetheless, long-term contact should be avoided.

- Workers preparing the solution are advised to wear rubber gloves, nose masks and goggles.
- Care should be taken to avoid getting their clothes soaked with the solution; it is recommended to wear protective clothing when working with chemicals.
- Never drink the solution!
- If the mixture comes into contact with the eyes, wash immediately with water.

Regulating the Concentration of the Solution

Higher concentrations of borax will leave a white powder on the surface of bamboo. This indicates sometimes that the boron concentration is becoming too high and that there is insufficient water in the mixture. This effect is natural since the poles suck up the water quicker than the borax, thereby increasing the concentration of the solution. This should be avoided to avoid wasting the chemicals and controlling costs. It can be countered by adding water to the mixture. However, the best way to control the concentration is with electric resistances. There are commercial measuring devices available that will indicate the targeted 4 to 6 % solution at an allowable range between 12.000 and 16.000 Micro Siemens. If you want to use self-made testers, just calibrate by measuring the electric resistance of 50 grams of borax oxide/boric acid in one liter of water.

2.4 Borax/Boric Acid Solution Preparation

- Preservation of Bamboo is achieved using a 5% Borax: Boric acid solution, which is pH neutral.

- The pH neutral solution is made using equal amounts of Boric Acid (2.5%) and Borax Oxide (2.5%) ratio of 1:1 in a 5% concentration solution formulation, both in powder form and in warm water.
- The concentration of both chemical agents dissolved in water is 50kg per M³ (i.e., 5kg per 100 L of water), i.e., the ratio of 1:1.
- One thousand liters of borax solution will require one 25 kg sack of Boric Acid and one 25 kg sack of Borax Oxide. It can be used to preserve over a hundred or more bamboo culms, depending on their size
- When used several times in a trough, the borax solution will become murky and may produce foul smells. This can be remedied by adding algae control products that are used for maintaining swimming pools
- The borax solution remains active for 1 to 2 months

Regulating the Concentration of the Solution

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2.5 How Borax Works

Borax treatment works by immersing the solution into the bamboo, or alternatively by submerging the bamboo into the solution. For the solution to act on the whole culm, the diaphragms of the nodes need to be perforated so that the solution fills the inner part of the culm.

Through a process of osmosis, the borax solution gradually penetrates the inner and outer tissues of the culm. But this osmotic diffusion process only works when the cell walls of the culm are still alive and active. Dry bamboo will not take up boron molecules; dry bamboo will absorb the water, but the boron will remain on the surface and not permeate through the cell tissues that have dried out. It is therefore useless to attempt treatment of dry culms. Borax treatment only works when the bamboo is still green. Freshly felled bamboo takes up boron faster than one- or two-month-old poles.

The practical formula for diffusion under normal tropical temperature of 20 to 30°C involves using a 5 % borax solution (which is pH neutral) for at least 1 week.

3.0 BAMBOO MATERIAL PREPARATION

3.1 Bamboo Sizing

Three methods of treating the bamboo with these preservatives are as follows.

Put the solution into the trough, using a plastic bucket. Before putting the bamboo into the trough, cut it to the required length, splitting it if required, in order not to treat bamboo which will not be used. All bamboo should be covered with preservative. Put big stones on the bamboo, enough to keep the bamboo down (Figure 1).

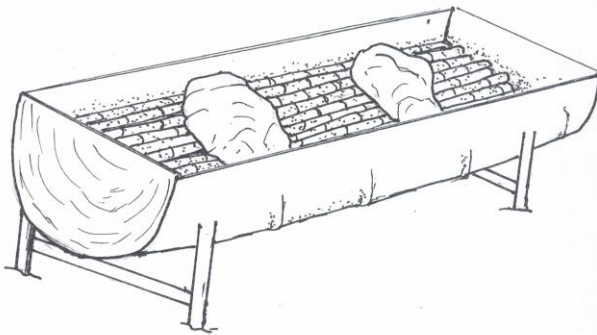


Figure 1: An illustration of bamboo treatment in a trough

- The standard commercial size of bamboo culms is six (6) metres in length. Such long culms are useful for construction purposes.
- The culms can also be shorter (2, 3 or 4 metres) depending on the application
- Sizing bamboo is done using a hacksaw or cross-cutting machine
- Perforation of the diaphragm is done by either punching with a long metal rod or drilling.
- The metal rod should have a blunt tip; do not sharpen it since it may get stuck in the nodes, making the penetration of nodes very difficult. Culm with all nodes except bottom perforated for vertical treatment
- The way that you punch the nodes will depend on the type of preservation treatment that is used.
 - For vertical soak diffusion treatment, all nodes are punched except the bottom node.
 - For horizontal dip diffusion treatment, all culm nodes are perforated.

Before treatment, the culms should be adequately cleaned. All dirt should be removed using water and a rag or plastic brush.

3.2 Perforation of Diaphragms

Perforation of the diaphragm is done either by punching with a long metal rod (Figure 2 and 3) or drilling. The metal rod should have a blunt tip; do not sharpen it since it may get stuck in the nodes, making the penetration of nodes very difficult. The way the nodes are punched will depend on the type of preservation treatment used. All nodes are punched except the bottom node for vertical soak diffusion treatment. For horizontal dip diffusion treatment, all culm nodes are perforated (Figure 4).



Figure 2: Punching the diaphragm using a long metal rod

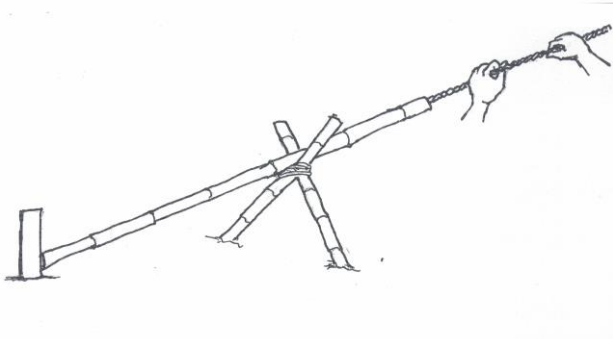


Figure 3: An illustration on perforation of diaphragm

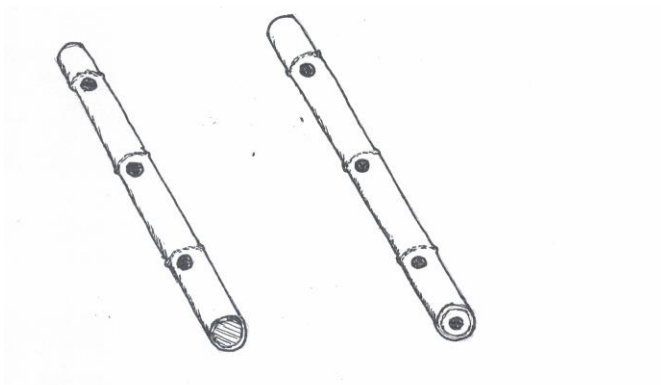


Figure 4: An illustration showing culm perforation for vertical treatment (L) and horizontal treatment (R) where the bottom node is not perforated, and all nodes are perforated respectively

3.3 Alternate node drilling for treatment solution entry

To enable penetration of preservative within the culms, holes on opposite sides of the lower and upper part of each internode must be made by drilling throughout the entire culm. This avoids puncturing the diaphragm. (Figure 5 and 6).



Figure 5: An illustration of drilling holes at alternate nodes



Figure 6: An illustration of drilled holes at alternate positions within the internodes

4.0 PRESERVATION METHODS

Although there are various ways of preserving bamboo, they are not used widely by artisans due to lack of know-how and the absence of treatment facilities. Some methods are, however, simple, efficient, and cost effective. Two effective and closely related methods are:

- (1) Vertical soak diffusion
- (2) Horizontal dip diffusion.

Both methods make use of 5% Borax solution as a preservative agent.

To successfully preserve bamboo, it is essential to stress the following points:

- Culms that are to be preserved should be newly felled and should not be more than two weeks old.
- Borax treatment only works when bamboo is still green.
- Dry bamboo will not absorb the chemical preservation agents!

- Chemical preservation requires that the diaphragms at each node be perforated to allow the chemical agent to penetrate the inner tissues of the culm.

The procedures for preserving bamboo are described and illustrated in the following pages

4.1 Vertical Soak Diffusion Treatment

Linda Garland and the Environmental Bamboo Foundation pioneered vertical soak and diffusion in the 1990s. It beats other approaches for treating bamboo rapidly and cheaply, especially in the backyard or village. Filling the bamboo-like cup of water inserts the solution. This allows the solution to enter the bamboo without entirely submerging it (Figure 7). The skin is more challenging, contains more silica, and is rarely attacked by wood borers.

For this type of treatment, the culms are checked if they have borer holes. To seal the holes candle wax is used to seal the hole to prevent leakage during treatment.

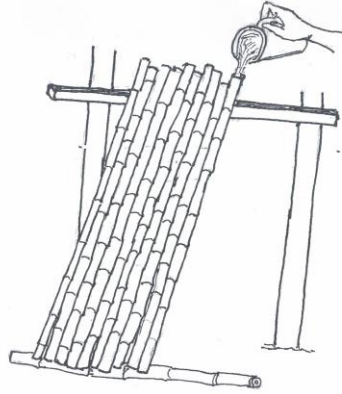


Figure 7: Illustration on vertical diffusion method where the chemical being poured into the culms

In vertical soak diffusion all the nodes except the last one are drilled with a long iron rod.

Bamboo culms are vertically positioned in a drum or container (Figure 8), and borax: boric acid solution preservative is poured into them.

The culms to be treated are placed vertically in empty oil barrels. The culms should rest against rail support. The culms are filled with the borax solution (max. 300 degrees Celsius otherwise, any wax seals will dissolve). The culms are left in a vertical position for 8 - 10 days.

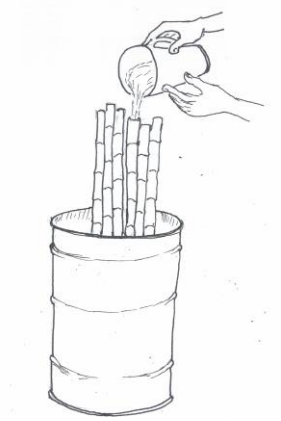


Figure 8: Bamboo culms vertically positioned in a drum in readiness for treatment

4.2 Horizontal Dip Diffusion

Horizontal Dip Diffusion is when all the nodes are penetrated with a long iron rod. The bamboo culms are then dipped in a trough filled with borax solution.

It is advisable to use troughs made from steel barrels or a concrete pool for a slower cold method.

Troughs can be custom-made according to the required length. An open tank is a trough of about

4m long. This can be made by cutting two 200-litre drums in half vertically and welding them together like a canoe (Figure 9). Cut the drums with a cold chisel and a hammer; flatten the shape edges with a hammer. After welding, paint the inside with bitumen, tar, or anything like that to protect the drums from corrosion.

Put the solution into the trough, using a plastic bucket. Before putting the bamboo into the trough, cut it to the required length, splitting it if required, in order not to treat bamboo which will not be used. All bamboo should be covered with preservative. Put heavy weights such as big stones on the bamboo, enough to keep the bamboo down

Elevate the barrel about 20cm from the ground using concrete stones or blocks and ensure the barrel is level and stable to avoid tipping

Prepare a fire under the elevated barrel filled with preservative to heat the barrel.

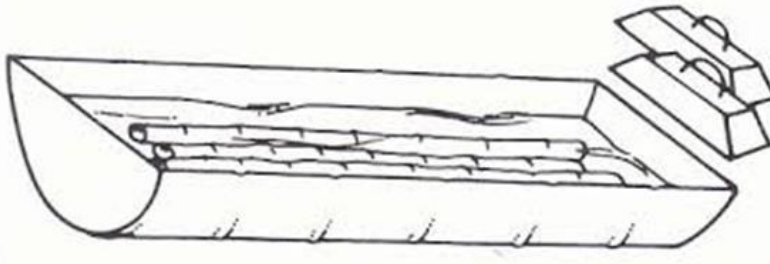


Figure 9: An illustration of bamboo in preparation for treating in a trough and heavy weights prearranged

4.2.1 Hot treatment method

Hot treatment methods necessitate using an open tank system that is elevated from the ground to create an accessible fireplace beneath the tank (Figure 10). The heat encourages the borates to enter the bamboo's woody mass more quickly. Bamboo must soak for approximately 24 hours at a constant temperature of approximately 60 degrees Celsius (UNIDO 2012). With a constant heating temperature of 100 degrees Celsius, bamboo can be treated in as little as 8 hours. Timing may also vary according to the type of bamboo being treated.

Using this method, up to four loads per day are possible. The steps are as below

- Fill the trough with treatment solution.
- Fill the trough with 5% borax solution.
- Start a fire underneath the trough to heat the solution.
- Feed the fire so that the temperature of the solution is maintained at 70 – 800 C
- Place the culms in the trough when the solution is heated
- Place concrete blocks on top of bamboo poles to submerge in the solution.
- Boiling time for thin-walled culms is at least 1.5 hours
- For thick-walled culms, the time required is 2-3 hours.
- Refill with the pre-prepared borax solution as needed.
- Start a fire underneath the trough to heat the solution.
- Place the culms in the trough when the solution is heated
- Place concrete blocks on top of bamboo poles to submerge in the solution.

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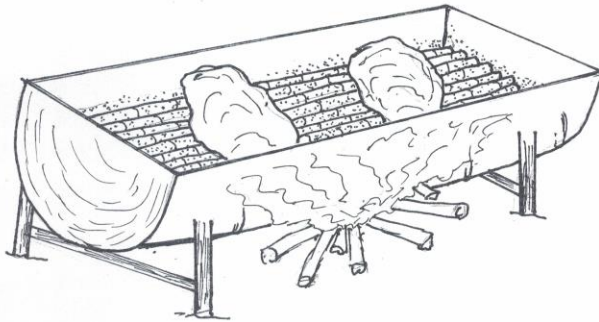


Figure 10: An illustration showing hot treatment

4.2.3 Cold treatment method

Cold treatment necessitates an open tank system under a roof to protect the poles from the elements and keep your solution from being diluted by rain. Bamboo must soak for 7-14 days in the cold soak method. This assumes a tropical setting. It could be even longer in cold weather. The steps involved are as below;

For this method, a metal trough or concrete pool may be used.

- Fill the trough or pool with 5% borax solution.
- Place the perforated culms in the pool for at least seven days.
- Make sure the culms are submerged. Use blocks or heavy stones if necessary.
- The solution can be used several times.
- If necessary, refill the pool with the borax solution before reloading.
- Using this method, one load of Bamboo can be preserved every week (7 days)
- A good variant for split bamboo is the dip-diffusion method: dip the bamboo for 10 minutes, as before, but in a higher concentration, and next wrap it in plastic for one week. Then season it in a vertical position for at least three days.

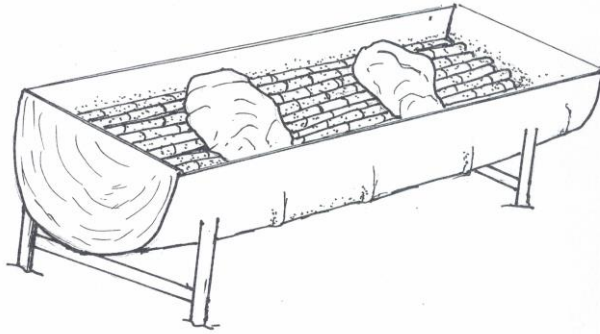


Figure 11: An illustration of cold treatment

5.0 TREATED BAMBOO DRYING AND STORAGE

Bamboo's fiber saturation point (FSP) is around 20-22 %. During the drying of Bamboo, it shrinks in diameter (10-16%) and in-wall thickness (15-17%). Such behavior in shrinkage and density leads to drying defects, such as collapse and cracking, and affects the quality of Bamboo. Therefore, it needs to be adequately dried to overcome such challenges by using the following process:

5.1 Drying bamboo

Air drying takes 6-12 weeks, depending on the initial moisture content and wall thickness.

- Immature culms may collapse due to non-uniform shrinkage of the culms; only mature bamboo should be used.
- Kiln drying can be used on bamboo splits and not round culms. Even under mild drying conditions, higher temperatures enhance the incidence of cracking and collapse
- Split bamboos do not pose any problems in air drying and can be dried even in the open sun.
- Split bamboos standing upright dry faster than horizontal stacking.

5.1.1 Using A-frame drying method

- Set up an A-Frame to support treated culms for releasing chemicals from the treated Bamboo.
- Choose a shady location with good air circulation.

- Use diagonal braces to support the A-frame to not fall over under a heavy load (Figure 12).
- Use broken or unusable culms to elevate the drying culms from the ground.
- Never dry the culms under direct sunlight.
- If there is direct sunlight, the culms should be rotated several times a day.
- The drying process should be slow; otherwise, the culms will crack.
- Withdraw from the A-frame after 3 - 4 days.
- Store the poles in a dry area.
- Air drying takes 6-12 weeks, depending on the initial moisture content and wall thickness.
- Immature culms may collapse due to non-uniform shrinkage of the culms.
- Split bamboos do not pose any problems in air-drying and can be dried even in the open sun.
- Split bamboos standing upright dry faster than horizontal stacking.

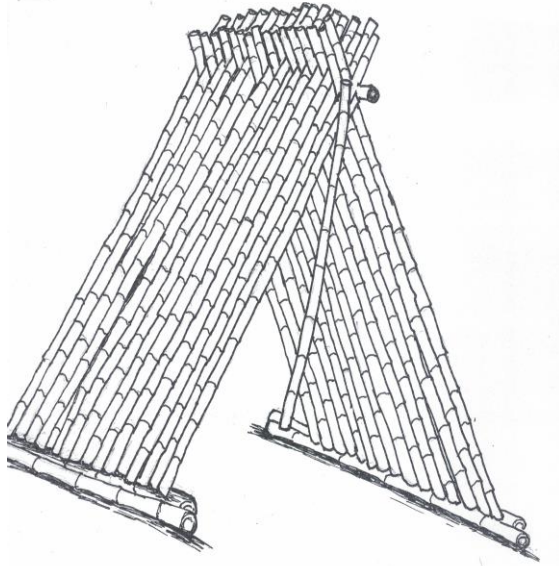


Figure 12: An A- frame for drying bamboo

5.2 STORAGE

- Store the poles in a well-ventilated shelter, never in a closed area.
- Pile the poles in stacks of different diameters.
- Categorize between base and middle stem.
- Stack them with distance splits to allow air flow.
- After three (3) months you can assume 20% humidity in the bamboo.

- Sort and classify the preserved culms according to size, diameter and quality.
- You can pile them now without spacers but 20cm off the ground (Figure 13).
- The best way of storing treated bamboo culms is in horizontal racks.

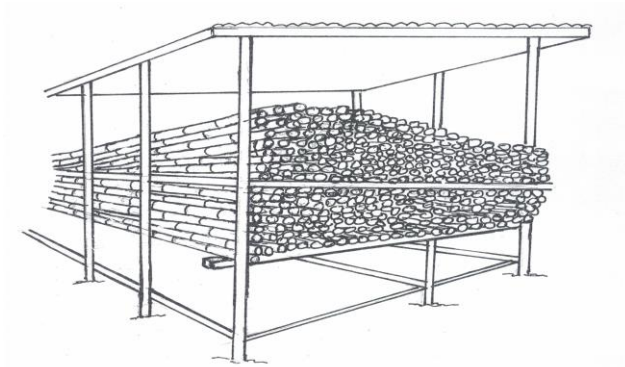


Figure 13: An illustration bamboo storage on horizontal racks

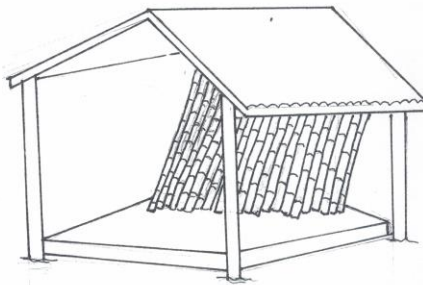


Figure 14: An illustration of bamboo stored in a well-ventilated shelter

6.0 HEALTH AND SAFETY PRECAUTIONS

- The 5% borax solution is pH neutral and is not hazardous or harmful to the skin. Nonetheless, long-term contact should be avoided.
- The preservative should be handled with great care, and precautions should be taken during the preparation of the solution, treating operations, and handling.
- The treatment area should be well ventilated with no unauthorized entry
- Workers preparing the solution are advised to wear aprons, rubber gloves, nose masks, protective goggles, and safety boots
- No drinks or food should be consumed in the treatment area.
- Care should avoid getting their clothes soaked with the solution.
- If the mixture comes into contact with the eyes, wash immediately with soap and water.
- Empty containers should be placed out of reach of non-technical personnel and

children and should be appropriately disposed of.

- Avoid making higher concentrations of borax solution than recommended in 2.0 as the borax concentrations above 5% are hazardous.
- Preservatives should be stored according to the manufacturer's instructions.
- Never release preservatives into the environment, and never use bamboo that has been treated with preservatives to fuel a fire.
- Dispose of treatment solutions properly. Water should be allowed to evaporate, and precipitates should either be buried underground or dumped in chemical dumping grounds.
- In case of eye contact, flush with water for at least 30minutes or until the chemical is removed. For skin contact, there is no irritation but wash off immediately to prevent long-term effects.
- The treatment area should be isolated and secured with restricted access. In case of

prolonged treatment in an area, the floor should be cemented for solution collection in case of spillage.

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