





BAMBOO TREATMENT FACILITY STANDAR OPERATIONS PROCEDURE

IOM BANGLADESH

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Definitions

Borak Bamboo - A common local name for a bamboo species used for load-bearing support in sector shelter design.

Muli Bamboo - A common local name for a bamboo species used for weaving wall panels and building structural rafters in sector shelter designs.

Borax - Sodium tetraborate decahydrate- a naturally occurring mineral with anti-fungal properties.

Boric Acid – Trihydrooxidoboron - a naturally occurring mineral insecticide and fungicide.

Culm – A bamboo culm.

Node - A swollen circular portion which divide a culm into segments by a diaphragm

Diaphragm – The plant section which grows through center of each node.

Cellulose - The main body of a plant cell wall it creates the stiff and strong portion of the bamboo.

Vascular tissues – are the fluid conducting cell which transports the phloem and xylem saps which feed the bamboo.

Hydrometer – An instrument used to measure the specific gravity or relative density of liquids.

EnRoute - A labor service provider who facilitates the hiring and payroll of support staff for IOM programming.

Volunteer – Support staff provided through EnRoute.

Team Leader – Manages specific areas of the facility. Volunteers will report directly to a Team Lead.

Day Labor - Host community members hired through a labor contractor. This represents most of the workforce and perform the day to day processes of the facility.

Acronyms

IOM - International Organization for Migration

BTF - Bamboo Treatment Facility

QCT - Quality Control Team

GOB - Government of Bangladesh

BFRI - Bangladesh Forest Research Institute

DOE - Department of the Environment

TNB - The Natural Builders (Technical Consulting Team)

TSA - Transitional Shelter Assistance

MTS - Midterm Shelter

CSU - Community Shelter Upgrade

SMSD - Site Management Site Development

PPE - Personal Protective Equipment

Preface

This document is the standard operational procedure document for IOM's Bamboo Treatment Facility located in Cox's Bazar, Bangladesh. It is based on the processes established through two years of planning,

Background

Over 24 million culms of bamboo were used during the emergency phase of the Rohingya refugee crisis response in Cox's Bazar. The urgent necessity of bamboo as main structural material in the camps led to a rapid deterioration which quickly became visible as the monsoon season approached. This deterioration was due the attack on the bamboo by termites, boring beetles, and fungal rot caused by construction methods which placed the bamboo into direct contact with the ground.

In 2018 field assessments were performed independently by ARUP, Humanitarian Bamboo, and The Natural Builders in support of the sector and implementing agencies. During inspections extensive pest damage and fungal rot were observed throughout the camps.

As the crisis continued the need for a durable building material for construction became crucial. As most of the camp lies in Government of Bangladesh Forest Preserve, the land is protected, and construction of permanent structures is strictly limited. This limitation led the shelter cluster to look for alternative construction solutions in order to facilitate both transitional and long-term construction programming.

After a focused study of construction materials, the cluster came to a consensus that treated bamboo would be the best path forward for future construction in the camps. The treatment of bamboo adds longevity through resistance to insect damage and some resistance to fungal rot.

By treating bamboo, 2.5 million US dollars can be saved per each set of fifty thousand shelters constructed. This is due to the increased life span of the bamboo reducing the need for ongoing camp wide distributions of new material each year. Additionally, it reduces the environmental impact by reducing over farming of both the private and GoB bamboo forestry groves.

Construction of IOM's pilot BTF began in October 2018 and became operational one month later. The pilot allowed for the testing of theories and quickly became a functioning facility. With the knowledge gained the design of the main facility was started. In February 2019 construction began on the main facility with operations commencing in June.

Staffing

The core of BTF operations is three IOM staff, five maintenance assistants, three team leads, and ten volunteers. The workforce is host community day laborers. The team leaders and volunteers are hired through the Enroute staffing agency and the day labor through Reliance Construction.

IOM staff have humanitarian sector experience both planning and managing day to day activities and working toward future programming needs. This core team coordinates with IOM's shelter, procurement, supply chain, logistics, and site development teams. Additionally, the staff maintain governmental relationships with BFRI and the DOE.

Team Leaders works as operational on ground management and in skilled oversight positions. Their focus is in three areas chemical testing and treatment oversight, inventory control, and facility operations. Volunteers are focused on specific activities in the complete process and will directly oversee the Day Labor.

The QCT operates as a separate team. It is composed of one IOM staff, one team lead, and five volunteers. Though a part of the shelter team this unit operates directly with IOM's logistics team who provides the Day Labor to match the daily needs of incoming bamboo delivery trucks. This team assure all incoming bamboo meets the quality standards set for receiving.

‡ See Section 10 reference for quality control standards.

Workforce break down by task.

Role	Quantity	Basic Description
Project Manager	1	Oversight and support of all programing and facility.
IOM QC Project Assistant	1	Leads quality control team
QC Team Lead	1	Supervises daily labor to assure quality
QC Volunteer	6	Monitor and control the materials arriving to the BTF
IOM Senior Project Assistant	1	Daily operations oversight
IOM Project Asst. Assistant	1	Daily operations oversight
BTF Maintenance Assistants	5	Maintain electrical, plumbing, and machinery
BTF Team Leads	3	Direct supervision of working areas
BTF Volunteers	10	Conduct daily supervision of labor
QC Day Labor	15	Monitor and control the materials arriving to the BTF
Day Labor – movement to prep	37	Moving bamboo from storage to cutting
area		
Day Labor - cutting	17	Cutting the culms to length
Day Labor - cleaning	63	Cleaning node material to expose the inner tissue
Day Labor – node drilling	30	Using drills to remove the nodes
Day Labor – loading tanks	133	These workers organize the material in the pools
Day Labor- ballast movement	12	Placement and removal of frames and pools
Day Labor – solution transfer	8	Movement of solution for filling and emptying pools
Labor – pumping and mixing	8	Provide the technical support
Labor – unloading tanks	118	Unloading tanks and movement to vertical drying
Total labor in a day	441	This number varies based on production.

Facility Process Workflow

The BTF maximizes efficiency of culms passage through the plant. The major steps in the process are:

- 1. Quality Control
- 2. Cutting
- 3. Cleaning
- 4. Drilling
- 5. Washing
- 6. Pool Loading
- 7. Ballast Placement
- 8. Soaking
- 9. Pool Unloading
- 10. Vertical Drying
- 11. Horizontal Drying and Storage
- 12. Charcoal Production and Filtration



Quality Control and Pre-Treatment Storage

Covering 8,400 SQM the bamboo storage area allows space for both receiving and quality checking of all incoming bamboo. The open layout allows trucks to park inside the facility for offloading and bamboo which has gone through the QC process to be loaded for movement to the processing plant.

Bamboo Delivery

Labor	PPE	Tools	Average Duration per team
N/A	Gloves	Tape Measure, Calipers	Average time 10-15 minutes.

Objectives:

This step determines the vendor and allows for a visual scan of materials. When a truck arrives with a large amount of bamboo which is either an unaccepted species or inferior quality bamboo, a visual preliminary inspection can lead to a complete rejection of a load. This rejection increases time-efficiency of the QC team, preventing the labor of a culm by culm inspection. Once a few trucks are rejected vendors begin to assure proper materials to avoid the loss incurred in a rejection.

- 1: Guards verify appropriate paperwork.
- 2: QC team performs visual inspection on the truck prior to entry into the facility. At this point the truck will be accepted or rejected.
- 3: The truck is guided into the correct unloading slot

Quality Control Inspection

QC	Labo r	PPE	Tools	Average Duration per team
1	10	Gloves, closed toe shoes	Calipers, Measuring tape, current version of material specifications	3-4 hours per truck (average 400-450 bamboo culms)

Objectives:

To assure only materials that can be effectively treated and used in the projects are accepted. Optimizes the efficiency of the process, reducing waste, and improving the final product.

- 1: The QC lead organizes the unloading team for opening the truck.
- 2: Day Labor unloads the truck onto the ground behind the truck for individual inspection of each bamboo culm.
- 3: A visual inspection is first performed as labor unloads culms; the QC staff should examine each culm visually. Perform closer examination as needed including measuring of dimensions.
- 4: Approved culms should be stacked neatly in the scheduled short-term storage area.

Note 1: 15 hours on the job training inspecting culms will allow a QCT to visually grade from 3 meters. Measuring tools should always be kept available for verification if asked by vendor.

Note 2: Assure bamboo is kept off the ground and stacked in an orderly manner with air flow after QC inspection.

Culm Movement

Labor	PPE	Tools	Average Duration per team
5-12	Gloves, Hard	Carts and hand carrying	Carts require 6 Daily Labor per cart with
5-12	Hats	in confined areas	capacity of 40 culms.

Objectives:

In the plant bamboo is always moving to different workstations.

Workers carry the bamboo balanced on one shoulder. Establishing one- way travel paths for materials and people creates a safer work environment. Carrying a 20-foot culm requires situational awareness in order to assure injuries are avoided, PPE such hard hats, and gloves are provided for this protection.

Carts create greater efficiency and increase worker safety. A heavy-duty carts capacity is 35 culms for ease of movement through the facility.

- 1: Workers balance the cart on a kick stand cut from a bamboo culm.
- 2: One worker balances the cart while other workers load culms from the station or storage or storage area.
- 3: The team works together to move the cart, typically stabilizing it by resting it again on the bamboo kickstand for unloading.

Note: Creating one-way pathways during daily operation ensures worker safety and ease of operations.

The Bamboo Treatment Facility

Covering 9,000 SQM the bamboo treatment facility was purposely designed to allow for movement and flow of bamboo culms through the treatment process.

Pre-Treatment Processes

Cutting Area

Approved culms are transported to cutting stations. Teams measure and cut each culm to fit the treatment tanks. Cutting exposes fresh vascular tissue and increases the absorption of orthoboric solution during soaking.

Labor	PPE	Tools	Production per Daily Labor
17	Gloves, closed toe shoes	Measuring tape, story stick, hand Saw	59 per person daily

- 1: The responsible volunteer will specify area bamboo is to be taken from.
- 2: Material are transported to the cutting area.
- 3: Each culm is measured using a premeasured "story stick" and cut to 6 meters.
- 4: Saws sharpness should be maintained to keep the teams working effectively. This process can also be done with electric circular saws.

Note: This is a final opportunity for culm inspection, the BTF volunteers and workers should focus on the material to assure conformity to current treatment standards.

Cleaning Area

Culms are transferred to cleaning stations. Cleaners remove the branches and outer portions of the nodes with machetes. This exposes the vascular tissue close to the outside. By cleaning the nodes, the culm absorbs solution more effectively during soaking.

Labor	PPE	Tools	Production per Daily Labor
63	Gloves, closed-toe shoes	Machete	production is 16 culms daily

- 1: The responsible QC staff should aid the workers in assuring efficient workstation setups, this means assuring that the workers have the appropriate PPE and tools to perform their tasks. In addition, QC should track productivity as well as workflow, regularly recording outputs using a ledger. Those outputs are collected by the BTF officers and submitted in daily reporting to the Shelter Information Manager.
- 2: Workers transport the culms from storage to the cleaning area
- 3: Cleaners remove the outer portion of the nodes and branches using a sharp machete. With the blade flat against the bamboo sliding the machete away from the body while gently turning the culm until a complete node is cleaned.
- 4: As culms are cleaned workers move the material to either a staging area (temporary Storage) or directly to the hole drilling station.

Note: Maintaining sharp tools keeps the workflow efficient, causing less fatigue on the workers bodies and maintaining quality cuts on the bamboo.

Drilling Area

Bamboo is transferred to drilling stations on carts. Drills fitted with custom 3.5-meter drill bits drill a hole through all nodes of the culm. Two teams are at each end of the culm, drilling from opposite sides.

Labor	PPE	Tools	Production per Daily Labor
30	Gloves, closed-toe shoes	Drill, Custom drill bit	44 per day

- 1: Workers Transport the culms from cleaning area stacked on a cart
- 2: Full carts are placed in the drilling area and the existing placement supports are put underneath the load.
- 3: Drills are fitted with custom 3.5 M drill bits made of High-Speed Steel. The drill bit tip width is 2.2 CM.
- 4: One Day Labor holds the drill.
- 5: A second Day Labor places the tip of the drill bit against the desired node.
- 6: The Day Labor holding the drill applies enough pressure to hold the tip of the drill bit on the node.
- 7: The second worker releases the rod and the drill operator begins drilling.
- 8: Maintaining even pressure on the drill each node is bored through the full depth of the 3.5 M drill bit.
- 9: Removing the drill take care and run the drill at a low speed while pulling the drill bit out of the culm.
- 10: After the holes have been drilled the culms are moved either to a staging area or directly into the next empty tank.
- Note 1: Workers should not attempt to grab a moving rod during any activity, hands can easily be cut, and gloves caught up in the drill bit.
- Note 2: Maintaining sharp tools keeps the workflow efficient, causing less fatigue on the workers bodies and maintaining holing of the bamboo.
- Note 3: Oil drills daily by placing 3-5 drops of motor or tool oil into the chuck from a vertical position.
- Note 4: As drills fail under such heavy use, keep several on standby. If a team drill fails, it should be swapped out for a working drill and given to the maintenance assistant for repair.

Washing Station

Before entering the soaking pools, all culms are pressure washed to remove dirt and debris picked up during transport and production. This process helps to prevent accumulated particulate in the pools. It reduces filtering of the orthoborate solution and cleaning the treatment pools.

Labor	PPE	Tools	Production per Daily Labor
2 per station	Rubber gloves, safety glasses, and gum boots	Pressure washer.	40 culm carts - 10 Min

- 1: As carts are brought from the drilling area the carts proceed through the washing area.
- 2: Once staged the carts contents are pressure washed starting at the top of one end of the cart and moving through towards the back.
- 3: The cart team shifts culms to expose for the cleaning.

Treatment Process

Pool Loading

The treatment process begins by loading culms into the soaking pools. Each pool is $6\times17\times1.5$ meters and allows for 2,000 culms to be treated. The facility has 13 pools: 11 for soaking and 2 for operations such as mixing, filtration, and solution storage. Each culm is lowered into the emptied tank. Culms are placed flat and orderly to maximize the pools treatment capacity.

Labor	PPE	Tools	Production per Daily Labor
133	Gloves, Rubber boots	Possibly handsaw.	2000 culms per day per team.

- 1: The responsible Team Lead and Volunteer should aid the workers in assuring the workstation is setup. and track workflow, regularly checking outputs and assuring teams have the tools they need.
- 3: Culms should be gently lowered into the hands of the receiving labor in an orderly and safe manner.
- 4: Workers in the pools should work together to neatly organize culms as flat as possible in the pools.
- 5: The pool should be filled to 30 CM from the top of the pool.

Ballast Placement

Ballast is placed on loaded culms to counterweight the buoyancy of the bamboo. The ballast keeps the culms submerged in the orthoboric solution to achieve complete treatment of all culms. The ballast consists of steel frames, plate steel sheets, and 1000-liter tanks which are topped up with solution for weight.

Labor	PPE	Tools	Production per Daily Labor
8	Gloves, gum boots	1000-liter tanks, steel frames and sheets. electric "trash" pumps.	Water tanks 8 tanks take 1.5 hours to place and fill

- 1: After filling the empty tank with bamboo the top layer is leveled as much as possible. Assuring the culms are lined up level in the tank.
- 2: The steel frames are placed on each side of the tank on top of the culms approx. 3 feet in from the edge of the tank with the length perpendicular to the culms.
- 3: steel sheets, which distribute the load, are placed evenly over the top of the frames.
- 4: Eight water tanks are placed evenly on top of the sheets.
- 5: Solution is pumped into the water tanks until they are filled to the capacity.

*Note: Electric "Trash" Pumps - Electric powered pump are used to transfer liquids. "Trash" in the name refers to the pumps ability to pass large particulate matter through the pump without damage to the pump.

Filling and Emptying the Pools

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Testing the Treatment Solution

The treatment of bamboo requires the solution to be at the correct percentage of concentration to effectively treat the culms in a standard time As the culms sit in the fluid, they absorb a portion of the orthoboric solution into the vascular tissue from the diffused solution. When the culms are removed, they take that portion of the borax and boric acid from the solution and it is important to replace the chemicals to maintain a standard of treatment.

Labor	PPE	Tools	Production per Daily Labor
1	Glasses, Rubber gloves	Hydrometer, thermometer, glass cylinder. Computer with file to BTF- Overview Document, internet	Each test takes about 15 minutes to perform and enter.

Part 1: Taking samples, PH and temperature:

- Step 1: Open the test kit and remove the, glass cylinder, PH meter and hydrometer.
- Step 2: Gently submerge the glass cylinder in the solution unit the glass is full.
- Step 3: Place the full cylinder on a flat surface.
- Step 4: Remove the PH meter from the case carefully removing the cap and storing it inside the case.

- Step 5: Turn the PH meter on and submerge the head completely win the water.
- Step 6: The meter will automatically begin to adjust to the fluid, after about 30 seconds the meter will show a stabilized reading.
- Step 7: Record the PH reading as well as the temperature displayed on the face of the meter.
- Step 8: Gently rinse the tip of the meter off with clean water, turn off the power, replace the cap and place the meter back in its case.

Part 2: Taking hydrometer readings

- Step 1: Remove the hydrometer from the case.
- Step 2: Gently place the meter with the weighted side down into the cylinder. Assure that the cylinder does not touch the bottom
- Step 3: Tap or twirl the hydrometer gently to make sure there are no bubbles attached
- Step 4: After the meter settles take the reading. Be sure to place your eye below the level of the water when reading the meter to see the bottom portion of the meters gauge correctly.
- Step 5: After reading, remove the gauge and rinse it with clean water before placing it back in its case.

*Note: The hydrometers are balanced at 1.000 accuracy, the number read as 20 on the gauge should be recorded as 1.020. Failure to provide accurate readings will have a poor effect on the solution.

Part 3: Entering data on the spreadsheets

- Step 1: Login to the SharePoint spreadsheet "BTF Overview."
- Step 2: Be sure to enter "Edit mode" by following the prompt on the top of the browser screen.
- Step 3: Click to the BB-Tank-Testing Tab in the bottom of the document screen.
- Step 4: The information is managed with each row having dedicated information for one sample.

The following is an explanation of the information log:

Date - This column is for the date the sample was taken and tested.

Tank # This is the pool identification number pulled from the drop-down menu. The syntax must be correct for the formulas to work properly, i.e. "Main 2" will tell the formula what size the tank capacity is as opposed to "Pilot 1". Be careful about mistakes like "pilot 1" or 'PILOT 1" in spreadsheets every capital letter and space count.

Hydrometer Reading: Represents the reading of the meter, enter your recorded data in this cell.

Temp: Is the reading from the PH meters temperature area, enter your recorded data in this cell.

Temperature corrected Hydrometer Reading: This is a formulaic value that corrects the hydrometers balance. **No entry needed.**

Preliminary Estimate% solution: A formulaic value that pulls from the data you enter to help provide a baseline of current % of solution. **No entry needed.**

BY: The initials of the person taking the sample.

Existing tank solution depth (cm): Record of actual recorded depth of solution in pool.

Existing tank contents (Liters): **No entry needed.**

Target Liters: **No entry needed.**

Additional Water Required (liters): No entry needed.

Additional orthoborate Required (Kg): **No entry needed.**

Borax to add (kg): No entry needed.

Boric Acid to add (kg): No entry needed.

Number runs @ 1000L: No entry needed.

ightarrowOn the spreadsheet the formula section will automatically give you the approximate %concentration of sodium orthoborate solution.

Follow Specific Gravity Measurement Protocol —- (see below)

Next measure the depth of the tank in CM and enter the value in the column on the spreadsheet.

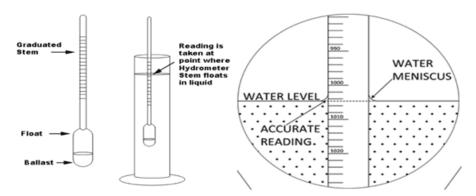
*Specific Gravity Measurement Protocol

Specific gravity measurement is a simple method for estimation of sodium orthoborate concentration in solution. Specific gravity is measured using a hydrometer, glass cylinder and thermometer.

Place the hydrometer in the cylinder, and slowly add the solution to be tested to the cylinder until the hydrometer floats (with its base no longer touching the bottom of the cylinder). Tap or twirl the hydrometer gently to make sure there are no bubbles attached. Now let the hydrometer stop moving and read the scale within from the bottom of the meniscus. Also measure the temperature of the water. The specific gravity number must be corrected by the temperature for accuracy, and this correction factor will depend on the calibration temperature of the hydrometer.

For a hydrometer calibrated at 15°C, a 7% sodium orthoborate solution measured at 15°C should have a specific gravity of around 1.027.

The correction factor for temperature can be calculated using the equation below, where HR is the hydrometer reading, RT is the reading temperature, and CT is the calibration temperature: For example, a 7% sodium orthoborate solution measured at 40°C using a hydrometer calibrated at 15°C reads 1.020, and corrected using the equation above is 1.027. The photographs below show readings of several sodium octaborate solution concentrations measured at 18°C:



Treatment Quality Assurance: Outside Testing

Working with Bangladesh Forest Research Institute, IOM verifies treatment of culms quarterly.

Samples of the treatment solution and samplings of treated culms are sent for testing.

Three sections are cut from the bottom, middle, and top of four different culms from varying pools.

Labor	PPE	Tools	Production per Daily Labor
1	Glasses, Rubber gloves	Saw and empty water bottles	10-25 minutes per sample

Bamboo Culm Samples

- 1: Remove a full culm from the tank
- 2: Cut three sections of approximately 30 cm from various sections in the length of the culm.
- 3: Label the samples with permanent marker and log the information in a log sheet. ‡
- 4: It is suggested to send 12 samples to BFRI for testing.
- 5: All Samples and supporting documents should be sent to the BFRI office in Chittagong.

‡‡ See Annex B

Solution Samples

- 1: Take an empty 1L water bottle and using a permanent marker label the tank number, date and relevant notes directly on the bottle and in the log sheet.
- 2: Submerged the bottle in the solution until the bottle is full, remove the bottle and screw on the cap.
- 3: Compile the collected samples and data logs.
- 4: All samples and supporting documents should be sent to the BFRI office in Chittagong.

All samples should be sent to:

Bangladesh Forest Research Institute, near Chittagong Educational Board, Forest Institute Road, Sholoshohar, Chittagong 4000

Mixing of Solution: Topping-Up

During the soaking of the bamboo the culms absorb a certain amount of the Orthoborate solution. We add in new Borates through agitated mixing this case we use pumps to move fluid through a closed tank slowly adding Borax and Boric acid powders. The core objective is a uniform mix of solution maintained within the desired parameters. There is a maximum amount of Borax and Boric acid solids that can be held in suspension therefore following the prescribed mixture guidelines is important with each mixing.

Labor	PPE	Tools	Time per Process
8	Boots, rubber gloves, safety helmets, & glasses	Pumps, 1000L mixing tanks, knife, water hose	Mixing 1000 L of solution at 7% takes 45 minutes to mix.

- 1: Pump solution from the pool to be balanced in the 1000-liter mixing tank. Keep the inlet line around 20 cm below the surface of the water which will prevent intake of particulate. The 1000-liter tank should be filled with 750 liters of solution.
- 2: Once the tank is at mixing level the fill valve is shut and the solution recirculation system is engaged.
- 3: The Borax and Boric acid are added to the tank slowly from the top while the pump is recirculating the solution in line.
- 4: Ratios for chemicals to be added are determined in the testing section as part of the testing protocol.
- 5: After the chemical and solution are thoroughly mixed the solution is released into the pool and dispersed through the pool through continued agitation pumping.

*NOTE: At high pressure, the mix can froth excessively, using the inlet adjustment valve can lower the pressure reducing the buildup of foam. Any caking of chemicals inside the tank should be cleaned each day to ensure mix consistency and maintenance of equipment.

Post-Treatment

Emptying the Pools of Bamboo

When treatment is complete, pools are emptied of solution, ballast is removed, culms are drained, and transported to the vertical drying racks.

Labor	PPE	Tools	Production per Daily Labor
40	Gum boots, rubber gloves, safety helmets	None	133 per hour

- 1: Volunteers should ensure that all staff have adequate safety equipment.
- 2: One set of Day Labor typically works inside the pools lifting culms from the stack placing them at an angle resting on top of the edge of the pool allowing for solution drainage.
- 4: Day Labor outside the pool take culms, lift the culm vertically in order to drain the remaining solution.
- 5: Workers carry the culm to the drying racks directly.

Vertical Drying Racks

Vertical drying racks allow gravity to assist in draining excess solution from the culms reducing the relative humidity. The rack has capacity to dry 4000 culms at one time. The culms remain in the vertical drying rack one to three days until the relative humidity reaches 35 percent.

Labor	PPE	Tools	Production per Daily Labor
20	Gloves, safety helmets	none	133 per hour

^{*} These are the same Day Labor who are working to empty the pools.

- 1: In each bay there is space for two rows of culms on each side of an aisle. The first rows are placed carefully crossing the tops of the culms in an alternating pattern.
- 2: The second row of culms are placed on a second brace at the top tightly.
- 3: Material is given between 1-3 days in this vertical position before being moved to horizontal racks.

^{*}NOTE: Draining culms is critical for both the retention of solution and environmental protection.

^{*}Note: Care should be taken to stack the material in an efficient manner. Assuring an orderly staking of bays in succession allows for the easy rotation through storage areas.

Horizontal Drying Racks and Storage

Before shipment to sites the culms are stacked in horizontal racks. They continue to dry lowering the relative humidity. The horizontal racks are covered and divided into bays and serve as the treated culm storage area. Each bay can have a distribution truck loaded for shipment to multiple sites. The coverings help protect the treated culms from UV light and rain, which can deteriorate the treatment properties in the bamboo

Labor	PPE	Tools Production per Daily	
20	Gloves, safety helmets	none	140 per hour

- 1: Culms are moved from the vertical drying rack either by hand or with the aid of a cart.
- 2: They should be stacked in an orderly manner to assure the most efficient use of space.
- 3: It is best to fill each bay evenly so that loading space for truck staging is optimized.

Loading Trucks for Transportation to Site

Safe and efficient loading of material for delivery to project sites.

Labor	PPE	Tools	Production per Daily Labor
Varies	Gloves and Hard Hats	Gloves, safety helmets	Varies

- 1: The truck is cleared by Logs Base staff for entry into loading area.
- 2: The truck is staged in the appropriate position in the bays.
- 3: Logs Base staff place a counting labor team to monitor culm quantities.
- 4: Labor teams load culms into the truck one at a time, assisting the truck drivers in creating a secure load.
- 5: Logs Base staff record the final quantity of culms loaded before signing the release paperwork and releasing the truck.

^{*}Note: Care should be taken to line up the material at the front edge of the bays for optimized workflow around the racks.

^{*}Note: Max delivery by trucks to camp is limited to 200 per truck. This is to promote safety and ease offloading in the camp.

Other Processes

Filtration

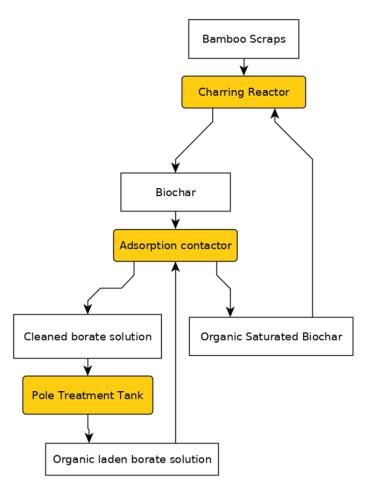
Solution filtration is for the removal of dissolved organic carbons (DOC) from the solution. DOC's naturally build up in the tanks as the orthoboric solution replaces the sap in the bamboo culms. Filtering the solution removes the DOCs and assures absorption of the chemicals into the bamboo culms. This filtration is done after a solution batch has treated 20.000 culms.

Labor	PPE	Tools	Production Rate
4	Rubber Gloves, safety helmets & glasses, N95 masks	Plumbing tools, and pumps	10,000 liters per hour

- 1: Filtration systems were constructed using 5,000-liter plastic tanks according to filter construction guidance in Annex C.
- 2: The solution should be run to fill the tank at a low flow rate to hydrate the filter completely. The optimal flow rate will be determined by the outlet speed of the fluid flow through the medium.
- 3: Pulling from a solution pool the outlet line should be placed in a clean holding pool to preserve the integrity of the filtered solution.
- 4: During initial filtration, samples should be taken after the first flush of liquid (Approximately 5,000 Liters of liquid) than at approximately 60,000 Liters of filtered fluid 90,000 liters and after 120,000 Liters, respectively. These samples should be refrigerated for preservation. Sample sizes should be minimum 500 ml, a clean water bottle may be used in lieu of sample tubes. These samples are to be sent to Chittagong University of Engineering & Technology or any capable lab for testing.

Filtration charcoal will load over time as the DOCs build up in the carbon pours which will slow down and reduce the effects of the filtration process. The charcoal can be air dried and re-charged through firing in the same manner as the charcoal production.

5: As preliminary guidance the filter setup described should be used for $1\times120,000$ Liter pool run.



Producing Charcoal for Filtration

Charcoal is the carbon residue produced by removing water and other volatile constituents primarily from plant-based materials. Bamboo charcoal is produced by slow pyrolysis or the heating of cellulose material in the absence of oxygen. For this purpose, a special kiln has been constructed to convert waste from the treatment process in to charcoal for use in the filtration.

Labor	PPE	Tools	QTY per duration per team
2	Gloves and Hard Hats	Charcoal kilns, shovels, buckets, water tank	18 Kg per 2-hour cycle

- 1: Bamboo off cuts are split into smaller pieces, the length should be no longer than 60 cm..
- 2: These materials are packed in the charcoal kiln A metal drum manufactured with metal pipe passing through its center acting as a flu. The flue allows for gases released during the combustion to escape.
- 3: Carefully pack the material into the drum around the kiln flu, filling as much void space as possible.
- 4: Secure the door of the kiln before firing.
- 5: A small fire is built underneath and around the kiln inside the wall frame.
- 6: Continually feed stock to the fire. The kiln designed takes between 2 hours per batch.
- 7: At the completion of the cycle let the fire burn down and then careful extinguish the fire.
- 8: Once the fire is extinguished the kiln can be cooled using water until the drum itself is cool to the touch.
- 9: When safe to do so open the door of the kiln and add water to cool the base material
- 10: Empty the contents onto the ground and assure saturation with water and flames are extinguished.
- 11: Allow the material to air dry for 1-2 hours and then bag the material for preparation for filtration process.
- 12. Charcoal should be broken into multiple sizes from 26 -76 mm in size.

Tank Cleaning

Cleaning the tanks allows for the removal of bulk sediment which builds up over time.

Labor	PPE	Tools	QTY per duration per team
10	Gloves and Hard Hats	Shovels, hoes, rakes	5 days per tank

- 1: Remove the as much solution from the tank as possible.
- 2: Move all slurry to one side of the tank.
- 3: Build a sandbag wall three bags high, lightly stacked in the midpoint of the tank, allow space between bags for liquid to drain out of the slurry.
- 4: Let the liquid drain from the slurry by letting the material stand for a few days. This timeline can vary based on the amount of silt buildup.

- 5: Remove liquid as needed.
- 6: Once the material is quite dry, remove the sandbags and spread the material across the base of the entire pool.
- 7: Allow another day or two for the liquid to evaporate from the solid.
- 8: When the remaining soil is dry, remove the soil and bag for remediation. If storing place in a cool dry place under cover from rain.
- 9: If repairs are required scrape and pressure wash the walls and floor of the tanks to remove dirt and loose material before making repairs.

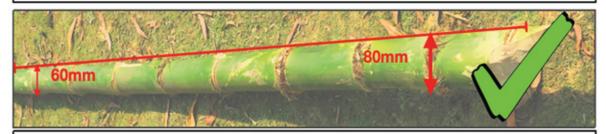
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Annexes

Annex A: Quality Control Parameters for Borax Bamboo for Treatment

The following grading standards are intended for the sorting of material to be treated in the IOM Bamboo Treatment Facility. All material not confirming to thee standards should be passed to other projects for non-treated use.

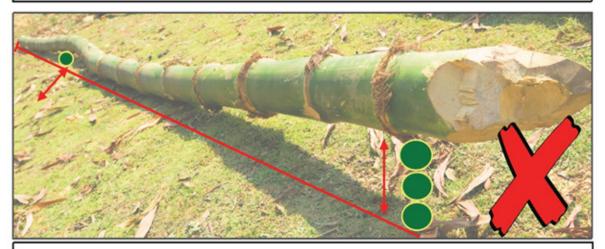


Optimal poles are an even taper from need to end with a base of approximately 80 mm and approximately 60mm at the top. The Poles should be free of insect damage and adhere to the other conditions of age.



C- Curve poles: Typically recognizable by a slight and continuous arc, this poles often naturally lay flat. Sorting should remove C curve poles with greater than 4x diameters of deflection.

S curve poles: material with complimentary opposing arcs in a single pole. These arcs occur in the same plane such that the pole may appear to lay flat on the ground. Sorting should remove S curve poles with greater than 4 cumulative diameters of deflection.



Z curve poles: Material with multiple planes of deflection. The distinctive zig zag of this material is harder to move around, will take up more room in the treatment tanks as well as in storage and during transportation. Any poles with more than 4 diameters of deflection should be removed.

Annex B: Treated bamboo sampling sheet

<u>Treated Bamboo Sampling Procedure</u>







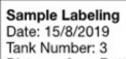




Sample Labeling Date: 15/8/2019 Tank Number: 3 Distance from Bottom: 5m Sample number: 2 of 3

Sample Labeling Date: 15/8/2019 Tank Number: 3

Distance from Bottom: 3.5m Sample number: 3 of 3

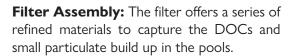


Distance from Bottom: 1.5m Sample number: 1 of 3

Sample Date	Tank#	Distance from Bottom (m)	Sample #	Notes
15/8/2019	3	1.5	1/3	Pole from bottom 2/3 of tank
15/8/2019	3	3.5	3.5 2/3 Pole from bottom 2/3 of	
15/8/2019	3	5	3/3	Pole from bottom 2/3 of tank

Annex C: Filtration Unit

Manifold Assembly: The manifold brings the solution in to the tank bottom. Use a 2" pvc pipe to the bottom of the tank switching to a semi-rigid pipe for the feeder line as shown in the diagram. 12mm holes drilled every 10 cm lengthwise on the top of the feeder line distribute solution evenly through the tank. Placing bricks flat side down on both sides of the line on the tank floor help to isolate the filter line and prevent movement while loading the filtration materials. An additional 2" pipe to the bottom of the tank is for extracting solution in order to drain the tank to replace spent charcoal. At the top of the tank there is a 7.6 CM outlet with a cam lock fitting which is the primary outlet for the filtered solution.



- 1: A layer of (25 76 mm) washed rock spread to 305 mm around and over the filter manifold.
- 1.5: A layer of 76 mm washed rock is spread over top of the first layer.
- 2: A layer of geo-textile fabric is spread to completely cover the rock forming a floor for the next layer. Leave enough fabric to wrap 300 mm up the wall of the tank. Fine sand is then packed to the edges and leveled.
- 3: Geo- textile bags filled 3/4 full of charcoal and carefully folded closed are layered and packed. Starting the courses with course material and with the finer material on top. Fill with charcoal bags to 1.2 m. Be sure to pack the bags closely together lying flat reversing the course between layers.
- 4: A layer of geo-textile fabric is spread to completely over the charcoal forming a floor for the next layer. Leave enough fabric to wrap 300 mm up the tank wall. Fine sand is then packed to the edges and leveled.
- 5: A layer of 10 mm stone is spread evenly to 150 mm.
- 6: Last, a layer of 20 mm stone is spread evenly to 150 mm.

