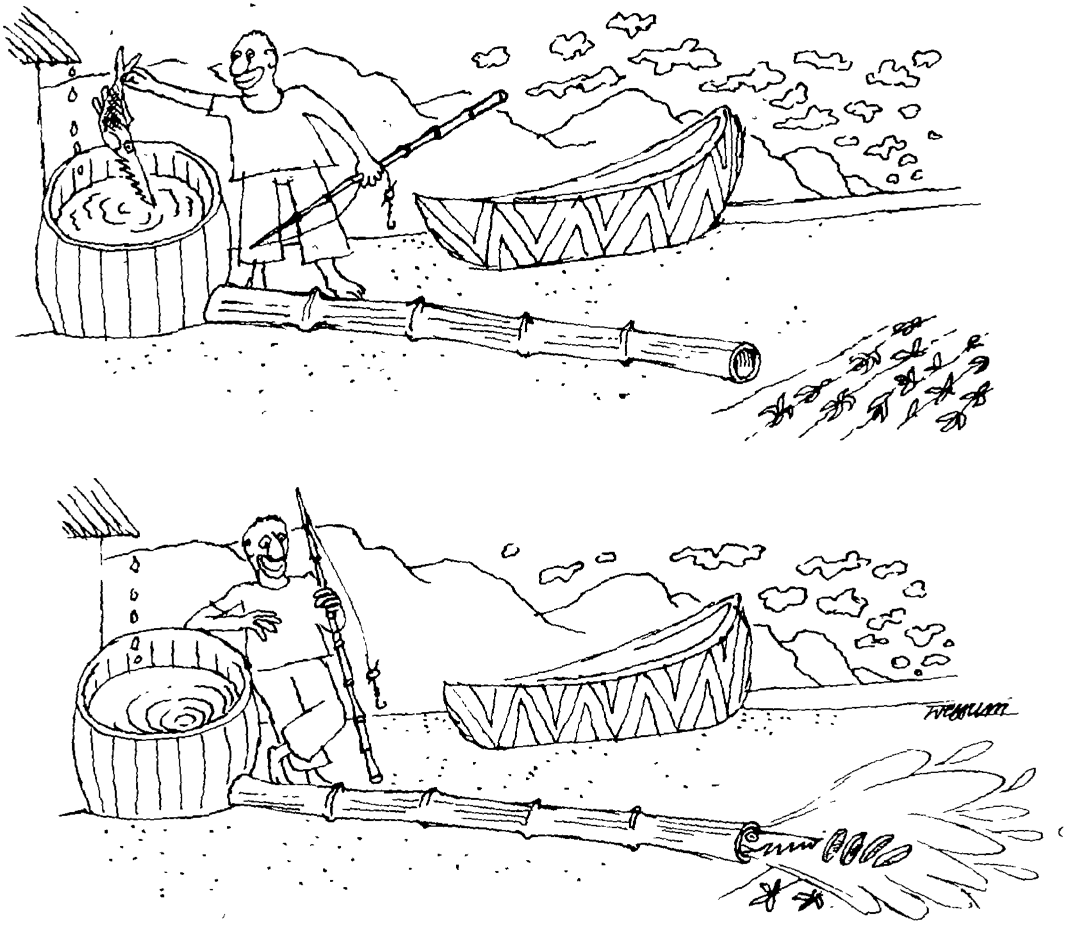
.mboo for Rural Water Supply

ıtive for Self-Reliance

Kick van den Heuvel



Wood and Bamboo for Rural Water Supply

Wood and Bamboo for Rural Water Supply

a Tanzanian Initiative for Self-Reliance

Kick van den Heuvel

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CONTENTS

Kwa Ndugu Zangu,

Kitabu hiki ni matokeo ya utendaji wa shughuli zote za kazi za Mgama, Igoma na Sehemu zinginezo.
Katika kitabu hiki ni mfupisho wa ujasiri na ujuzi wa mabomba ya mianzi na kutoa ushauri jua ya Utafiti zaidi.
Kitabu kimeandikwa kwa kiingereza sababu kiswahili changu siyo kizuri sana, labda kitabu kingine nitaandika kwa kiswahili. Ninatoa shukurani kwa msaada kunihifadhi na kushirikiana kwa pamoja kwa wakati wote niliokaa Tanzania.
Picha zilizochukuliwa mwaka jana za wafanyakazi wa Miradi, mbele ya Hotel ya Iringa, jalada la kitabu haikutokea vizuri sasa nimeweka picha ingine juu yake.
Nilikuwa na furaha zaidi kwa kufanya kazi nanyi.

On various subjects I was informed and guided by people with more expertise than I had Mr. White and Mr. Nangawe instructed me in preservation of bamboo. Mr. Strik of the Department of Toxicology, of the University of Wageningen, the Netherlands, guided me in the toxicological part of the report and we discussed the cost estimates at the department of Economy of the same University.
I am grateful for all this support.
Also the work of Eero Meskus who has done all the chemical analysis for the project with very limited facilities, supported me and the project very much.
The Centre for Appropriate Technology, Delft, has been very cooperative and the Centre supports the project with enthusiasm enabling the project to extend the research and to publish this study.

En dan natuurlijk harstikke bedankt voor het snappen van mijn "engels" Caroline, en michiel voor het typen (he typed half of my report!) en Piet natuurlijk.

Kick v.d. Heuvel
July 1980, Amersfoort

Forword CAT

This report on bamboo preservation is the first of a series of technical reports to be edited by the Center for Appropriate Technology (C.A.T.) in the near future.

It contains results of a bamboo preservation field experiment done in the Iringa Wood/Bamboo project in Tanzania. The project investigates the possibiblity to use bamboo pipes for village water supply. A main problem is to obtain a sufficienty effective and safe method for protection of the bamboo pipes against termites and rot. In the Iringa project pipes made of local bamboo were treated with preservatives.

In the beginning of 1979 Delft University of Technology, through its Center for Appropriate Technology was asked to give assistance to the Iringa research project. The research on the Dutch side refers specifically to preservative concentration and distribution in the material and preservative concentration in the drinking water coming through the pipe.

The Iringa project and the Delft research program are still not finished. We think however, that the results which have been obtained untill now, are very promising and justify the publication of this book. We hope that it will be informative and will stimulate our readers to exchange ideas on the subject. Furthermore the project as a whole is a good example of how activities of a research group in a developing country and in an industrialized country can be a combined effort for the benefit of a community.

Joop de Schutter

PREFACE

In the period of September 1978-May 1979 I participated in the research work of the Tanzanian Wood and Bamboo Pipe Project.
The objectives of my research work were:

. to determine the technical feasibility of bamboo drinkwater pipes with special attention on the preservation of the pipes.
. to determine the economical feasibility of bamboo drinkwater pipes.

The Tanzanian National Research Council (UTAFITI) enebled me to carry out the research into this "appropriate technology" for rural water supply.
I was already familair with the project from a visit to Tanzania in 1975 and was impressed by this Tanzanian initiative for economic and technological self reliance, so I contacted the project and offered my support.

Although I reject the general concept of "intermediate technology" (Dickson 1974) I think that in a command economy appropriate technology can be of importance.
Through the introduction of labour intensive technology (appropriate technology) in rural areas and capital intensive technology in urban areas under free (world) market conditions, the inequality in third world countries will grow.
A command economy will be a prerequisity to protect the traditional sectors with a low productivity.
A local price system has to distribute the surplus from the capital intensive industries to less productive sectors.
In this way the existence of technologies with a different productivity within one country will be possible without serious social conflicts (Amin 1971).

In Tanzania with a partly command economy the government supports the introduction of bamboo water pipes to save foreign currency, drained through the German owned Plastic Industries.
Whether the bamboo pipe is 'appropriate' to the interest of the rural population is not only a question of the existence of a 'plan' economy but also dependent on the cost and the performance of the technology. These two aspects are evaluated in this report.
The appropriate technology should also contribute to what Rweyemamu (1972) calls "a strong and healthy (national) technology producing sector". This contribution is unfortunately rather limited in most of the appropriate technology projects because they are dominated by western initiatives and support.
In this report we will concentrate on the technical issues of the bamboo pipe technology and we hope to receive reactions on the technical solutions chosen by the project.
Special attention must be paid to the question of the toxic chemical solutions used for the protection of the bamboo drinkwater pipes.
The address of the project is P.O.Box 570, Wood and Bamboo Project, Iringa, Tanzania.
Finally I continue this report in the "we" form because I was quided and assisted by the staff and workers of the project and the people in the villages during all my activities.

1. THE WOOD AND BAMBOO PROJECT

1.1. *Introduction*

The bamboo pipe technology is the central subject in this study. The Wood and Bamboo Project of mr. T.N. Lipangile, developed this technology with very limited facilities and was not able to finalize the investigations before the project was granted to construct bamboo pipe water supplies.
The image of the project is very positive all over the country, now that some village water supplies with bamboo pipes are operating satisfactorily.
However the imperfections of the bamboo pipe technology, discussed in this report, have to be solved before the project will have the National significance which it deserves.

Except for the the bamboo pipe technology the project also introduced the use of wood for water conveyance and storage in Tanzania.
The introduction of this already developed technology, i.e. the woodstave technology, is a matter of adjustment, testing and demonstration.
Official support for the woodstave technology was sought at university level and among officials of the Forest Division of the Ministry of Natural Resources and Tourism.
In this chapter some aspects of the introduction of wood stave constructions will be discussed next to some general information about the history of the project and its position in the Tanzanian industrialization strategy.

Before we elucidate all the technical questions around the bamboo water pipe in chapter 3.4. an enumeration of the activities for bamboo piping will give the necessary insight into the technology.
Talking about bamboo water pipes means for the project bamboo drinkwater pipes, in chapter 6, application of the bamboo water pipe for irrigation and drainage purposes is discussed.

1.2. *History of the Project*

In december 1974 a regional water engineer mr. T.N. Lipangile started experiments with bamboo and palm trunks as water throughs.
He was assisted by a Dutch volunteer worker, Cees Landman, who contacted foreign organisations for the technical backing.
The basic idea of the project was according to Lipangile "to use local materials which are cheaper and available within the reach of villagers for rural areas water supply and irrigation" (Lipangile '78).
After a year of investigations the experiments were extended to the village of Kayenze (Mwanza District, Nov. '75).
A 1500 m. bamboo pipeline was constructed for the 1500 inhabitants and the water for the irrigated rice fields was transported through a 300 m. wooden pipe of palm trunks (Borassus flabillifer, Muhama).
The experiment with the bamboo pipeline was a failure,
The buried pipe started to crack and the joints leaked after the system was dried.
The cause of all the trouble was a fuel shortage which brought the pumped water supple to a halt. Organic decay of the pipes was a result of fungal growth on the moist pipes. Also termites destroyed pipe sections. (fig. 1)

figure 1.

Bamboo waterpipes with bitumen coating attacked by termites

The palm trunk pipes are naturally durable and are still in good condition. The strong support of the National Tanzanian Party for the project enabled the continuation of the experiments in an other part of the country, in April 1977.
The whole investigation team was stationed together at Likuyufusi. The crew was also receiving lectures (Lipangile '78). Instead of a pumped water supply a gravitywater supply was selected to avoid the drying of the pipeline.
A new problem arose, however when 200 m. of the pipeline was attacked by termites. The application of chlorinated hydro carbons (aldrin and chlordane) solved this problem for the time being. Meanwhile foreign funding organisations has expressed their interest and supported the project with grants.
The opposition to the project, especially from water technicians, was not yet neutralized and requests to abandon the project were send to the government by several senior officials.
The criticism of the technical aspects of the bamboo pipe project is and was of great importance for the project, it had a positive effect on the quality of the work.
Irrational criticism is however useless since it does not deepen any questions or solve any problem, and the people with the irritional criticism do not support the search for technological innovations based on local materials.
The questions which is important is not "Should the Wood and Bamboo project be abandoned or not? "but" Is the use of bamboo and wood for rural water supply both technically and economically feasible?".
This negative attitude towards technological innovations or as Koloko. M. (1979) calls it; "the institutional biases in technology in favour of modern western technologies is supported by westernized elites".

Koloko continues; "these elites have every reason not to seriously consider rural development or intermediate technology. Often they have psychologically rejected their own cultural/rural backgrounds.
Their training and socialization have encouraged acceptance of western concepts of development and modernization.
Positive reinforcements are available from international business, international and technical assistance programmes and from bilateral assistance programmes from major powers".

We do not suggest that all the criticism of intermediate technology or what ever you wish to call,is should be pushed aside as technologically biased criticism.
The current rage of intermediate technology in Third World countries involves quite some ideological obscurity (Dickson, '74) and technical immaturity, justification of the chosen technology in National Industrialization perspective is a rare activity. We will review this issue at a later point.
An example of an negative attitude towards the attemps to develop a cheap and practical technology is the publication of a comment on the wood and bamboo pipes of somebody who made never any endeavor to investigate the feasibility of the issue.
We cite" . . . . (bamboo) being vegetable matter(it) is very susceptible to decay and once this sets in and is accelerated by moisture, the compression strength is rapidly reduced with intermittent flow, bacterial growth develops and this pollutes the water and gives it an unpleasant taste".
"With material of varying diameter and uneven cross section it is virtually impossible to make a lasting and watertight joint especially where pressures are high".
"It will be found that except in a few cases bamboos will have little advantage if any over well proven conventional material". (WHO, 1977).
In this article we meet the same tendency in comment on wood stave pipes tanks and flumes.
This technology of woodstave constructions was introduced to the project by mr. Scorrer, an expatriate, working for TWICO (Tanzanian Wood Industry Corpor.)

His experiences with woodstave culverts in Kenia along the Kitale road motivated him to introduce the woodstave technology to the project.
The culverts in Kenia were removed after eight years in pursuance of governmental directives and replaced by concrete culverts, though no failure or decay of the culverts was noted!
The introduction of the woodstaves in Tanzania seems less problematic at least the stages of testing and demonstration of the constructions. (fig. 2).

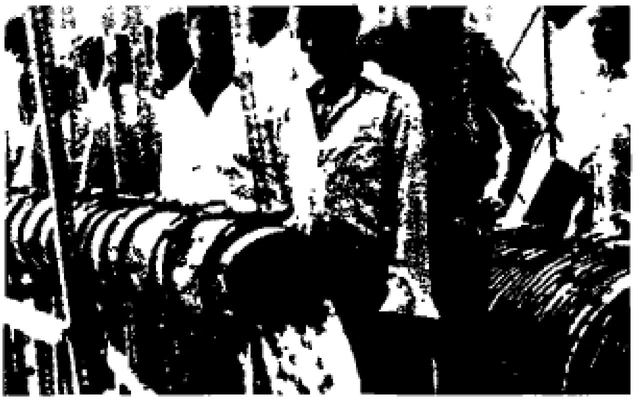


figure 2, Tests

(photo Daily News 28.8.79)

The project consulted both local contracters and the national wood industry (TWICO) for prices and feasibility of woodstave production.
A pipe section and flume section was constructed for tests followed by a recent research program at the University of Dar es Salaam with a 5000 gallon tank a 61 cm. (24") pipe and flume of both pine and cypress and 15 cm. (6") pipe. The results of these tests are expected in the early part of 1980. The demonstration and testing of the woodstave structures in an irrigation pilot scheme and the erection of woodstave tanks in villages in the next stage of the introduction.
In the meantime the bamboo pipe system spread in 1978 four projects were constructed at villages in Iringa, Rukwa and Ruvuma Region.
Four projects were completed in 1979, some of the villages are Ujamaa Vijiji. (fig. 3).

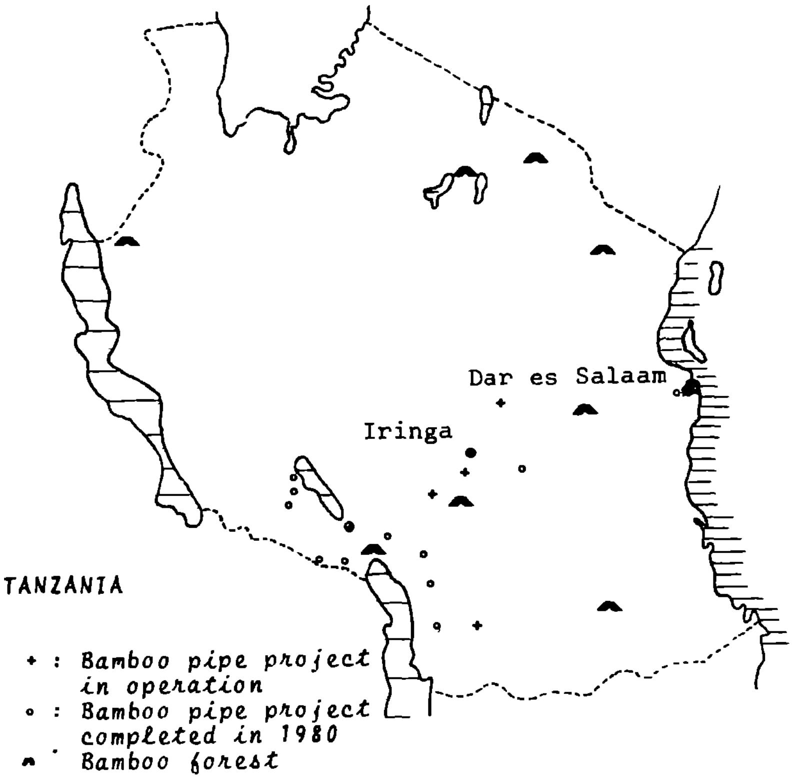


figure 3. Bamboo areas and bamboo water pipe villages.

About 14000 people in Tanzania tap their water from a bamboo pipe distribution system, the total lenght of which is now 30 km.
According to Lipangile (Daily news, December 1979) the costs of these nine water supplies were 3.030.000/-TSH; the costs of conventional material like PVC or Polythene would have been three times more.

1.3. *The use of bamboo as water pipe elsewhere*

The use of bamboo water pipes on a scale comparable with the Tanzanian village schemes was reported by Robert Lamb (Daily News, February '79). A well known project in "alternative technology circles" is the Mezan Teferi project in Ethiopia (Morgan, 1974) where a 4 cm. (1.5") bamboo pipe with simple cow hide and iron wire joints provides 500 people with clean water. The article continues "Bamboo pipes have been traditionally used in hill villages in Taiwan, Indonesia and the Phillipines to transport water under gravity. During World War II, when faced with acute shortage of raw materials the Japanese used them in their cities".
A six kilometer bamboo pipeline on the slopes of the Merapi Volcano (Indonesia) an experiment of mr. A. Sudjarwo, has recently been replaced by iron pipelines (Oey, 1979). The lack of bamboo preservation was the main reason.
Unfortunately we did not succeed in contacting a Taiwanese project where some bamboo pipes'. ". . . burried and treated with preservaties . . . have been supplying a safe and constant supply of water for more than 15 years (Yung, 70)".
Also Tanzanian villagers are using bamboo for water transport. Employees of a foreign contracter reported the use of bamboo in a village in the ULUGURU MOUNTAINS (Morogoro Region).
The bamboo culms were cut open at the nodes to remove the partition walls inside of the bamboo. These half open pipes were inserted into each other.

After checking and rechecking all the rumors and information about research into bamboo pipe it seems however that the Wood and Bamboo Project is the only one developing a durable bamboo pipe, at the moment.

1.4. *The wood stave pipe, flume and tank*

1.4.1. *The woodstave technology*

The wood stave construction, the second "leg" of the project, consist of a replacement of the wooden or palm trunks introduced as pipes in 1975.
Wood seems ill adapted for water transport and storage although in medieval Europe hollow wood pipes were used for this purpose. We mention evidence of this being a three hundred year old pipe still intact (Wood pipe handbook 1945) and the leak free domestic water supply in London operating from 1802-1898 (Gayer, 1935). The hollow pipes were improved in the United States around 1860 by the introduction of wood stave pipes. Two types were developed, the continuous stave wood pipe with wood staves of different lenghts, which is assembled in the field and the machine banded pipe, manufactured in the factory with a fixed lenght (fig. 4).
The diameter of the pipes is between 15 cm. and 6.0. m (6-240").
This technology was introduced in Australia at the end of the nineteenth century and somewhat later in Europe.
In 1918 a Dutch engineer investigated the suitability of woodstave pipes for Indonesia, a former Dutch colony.
His conclusion was that woodstave could be introduced if a suitable specie was found in Indonesia (Leeuwen, 1918).
At that time not only pipes were cheap as alternative water throughs also woodstave flumes were quit common in America.
In 1930, sixty percent, 300 km., of the flumes in the States were constructed of wood stave (Scobey, 1930).
Other applications of woodstave are water storage tanks, pulp storage tanks, chemical storage tanks, waste treatment tanks and pipes for hot saturated gasses (Barret, 1972).
Some firms in North America and Scandinavian countries are still producing woodstaves.

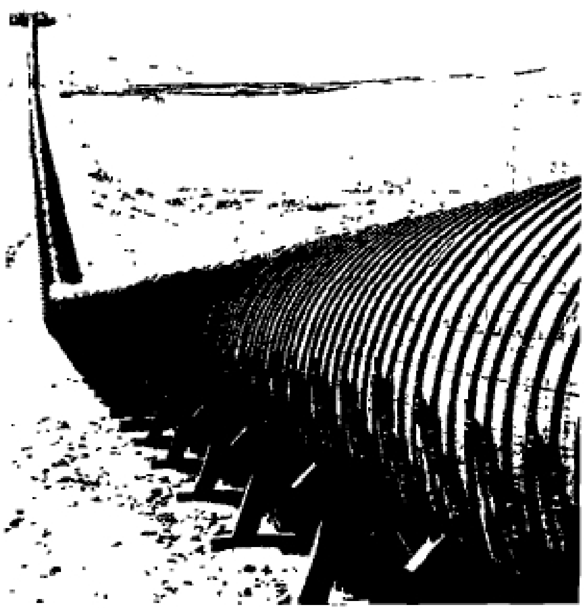


figure 4, Continuous woodstave pipe

figure 5, Woodstave pipe in Jamaica

Examples of the application of wood for water transport and storage in third world countries are not overwhelming.
We mentioned already the woodstave culverts in Kenia, an other woodstave construction in this country is a 800 m. creosoted pine pipeline with a diameter of 90 cm, constructed at Mewani Sugar Mills (Kisumu, 1957).
Figure five shows the 2 m Ø pipe in Jamaica for hydro-electric development with a maximum search head of 78 m.

1.4.2. Introduction of wood stave technology

Once more we should stress the rational approach to the introduction of (the wood stave) technology in Tanzania.
A decisive factor should be the costs (economic valuation, chapter 5) of the wood stave products compared with imported material. In case of wood shortage in Tanzania the gain of foreign currency through wood export should be compared with the saving of foreign currency through the production of wood stave constructions (Jacobs, 1978). The advantages of the development of a national woodstave industry should be expressed in the calculations and compared with the disadvantages of an import orientated economy.

What we call an irrational approach is the argument used by a senior officer who argued that wood stave products would not be cheaper or better because if, they were, the European contracters would use them in Tanzania (sic.).
The opposite could be nearar to the truth, the European contacters and international aid organisations will not introduce a technology of minor importance for western industries.
To illustrate the relation of western organisations with the introduction of the wood stave technology in Tanzania we consider the introduction of woodstave pipes for irrigation or hydro-electric development. The diameter of the competitive woodstave pipes is at least 25 cm. (Table 1) The larger pipes and flumes are more competitive but interesting only for large scale projects.

Most of these projects are designed, financed and constructed by foreign contracters and international aid organisations, both closely related with western industries. Therefore, the support for the development of a National Tanzanian Woodstave Industry from these organisations will not be impressive.

The only foreign contracters interested in the introduction of wood stave technology are the wood stave producing companies (Canbar, 1977). Who can not compete with plastic or metal pipe producing firms. These wood stave industries are not less capitalistic than any conventional pipe producing industry, they even exported the staves to Jamaica from Canada, but they do have the key for a propably cheap technology in the interest of the Tanzanian economy.
Therefore, with a strong policy from the government woodstave technology could be advantageous for Tanzania.

The introduction of the smaller woodstave constructions like tanks and small pipes for small scale projects and Ujamaa village schemes should not be any great problem, when all technical problems have been solved.

Table 1

Class B (6ATM) price comparison pipe material (Tanzanian Shillings per meter)

Pipe material:		Wood stave	wood stave	polythene	polyvinychl.	steel pipe,	galven. steel
Contracter		: Saggu, Iringa	Twico Sao Hill	Simba DSM	Simba DSM	Kurasini, DSM	
Date sales prices		:12/8/77	1978	-/6/79	-/6/79	1978	1978
Inch.	2.5cm	2/50		5/20			18/00
1.5	5.8	5/50		11/20			22/85
2	5.1	9/10		18/20			31/70
3	7.6	12/00		36/00	23/00		54/00
4	10.2	19/00			28/90		63/20
6	15.2	40/00	72/00		60/40	165/00	
8	20.3	82/00			120/00	220/00	
10	25.4	100/00				275/00	
12	30.5	120/00	128/-			430/00	
18	45.7	300/00	320/-				
20	50.8	430/00				610/00	
24	61.0		450/-			1166/00	
36	91.4		600/-				
54	137.2		983/-				

The introduction of smaller wood stave constructions in village schemes starting with a pilot irrigation scheme should benefit both the project and the farmers.
The selected pilot scheme should be small to avoid failure due to scale problems. The farmers should be acquainted with irrigation finally, erosion problems or permeable soils should justify the use piped irrigation water.
Support for initiatives of the farmers by the project would be the best solution for both, for example the farmers of Kihurio (Pare District) who use trees as water pipes (Daily News, Jan. 25, '79). Replacement of the trunks by wood stave construction should be considered in projects like this (fig. 6)

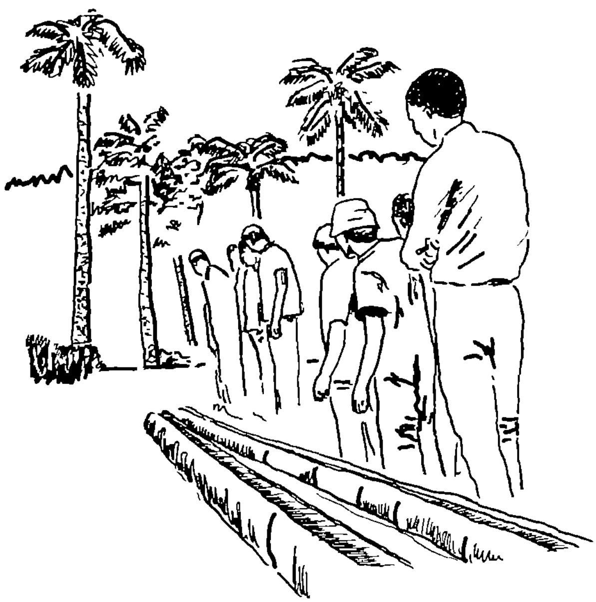


figure 6. Trunks for water pipes, a farmers initiative in Kihuria, Para District (photo Daily News).

Introduction of wood stave constructions in villages without an irrigation tradition and without the need for piped irrigation water would force the farmers to accept ill adopted technology.
The most positive cooperation from the peasants is to be expected in schemes where they have indicated themselves the need for piped water (like in Kihurio) and where the risk of the introduction of wood stave constructions is minimized through the availibility of alternative materials.

1.5. Position of the wood and bamboo project in Tanzania

The support from senior government officals for the Wood and Bamboo Project indicates the Tanzania policy towards technology and industrialization. Professor Rweyemamu (1972) proposes; "towards a socialist industrialization strategy .. to concentrate on the production of iron and steel and chemicals, in her (Tanzania) first efforts towards a self sustaining economy."

He also describes a plan for technical change in development. " . . .the plan should establish indigenous industries for machine tools machine building and repair, material and component manufacture.
These industries are not large establishments, they are contrary to what is often beleived, labour intensive industries.
They accelerate the process of technical change through their intimate contacts with the technology users . . . Building up such industries in the Tanzanian context means starting on the ground floor and a relatively low technical level in some cases.

By a combination of imaginative improvisation and adaptation, the absorption of scientific knowlegde from abroad an emphasis on technical training, tolerance of initial imperfections by the customers and accumulated experience and confidence emanating from self achievement, Tanzania is capable of establishing al through and healthy technology producing sector over the next ten to fifteen years". To stimulate initiatives for technical change "the government must institute incentive rewards schemes for inventions, as well a patent protection for local adaptions of foreign designs".

The plan of Mr. Rweyemamu is like a scenaria for the introduction of the bamboo pipes.
Whether the Wood and Bamboo Project will become part of a "healthy technology-producing sector" is however questionable.

First of all the Wood and Bamboo Pipes should be considered as a temporary solution.
The National Planning for rural water supplies; for the early 1980's is:

- each village has a source of potable water for 1991 or in other words that, every villager should have easy to clean and potable water (Strauss, 1979) An easy access refers to an average distance of 400 m. to a water point.

After the famine in 1974 the government emphasized the irrigation development (Daily News, 25 Jan. 1979).
The shortage of foreign currency and production and transport limitations of conventional pipes in Tanzania hamper the realization of these water development goals for rural areas. Extension of the water supply units with bamboo and wood pipe units could be a solution.
The wood and bamboo pipes are an alternative for imported material as long as the Tanzanian industry is in transition towards a self sutaining industry based on local materials.
The development of the bamboo and wood pipe technology seems a temporary development the future price development conventional pipe material will determine the future of the wood and bamboo pipes.
The contribution of the project to a "healthy technology producing sector" (Rweyemamu, 1972) will be consequently temporary too, but it can have a significant influence on other projects.
If all technical problems are solved the Wood and Bamboo Project contributes to the accumulation of experience and confidence in self reliance in National Technological Development.

The commitment of workers and villagers to the technical development of the project and a collective responsibility for the project should incorporate the project in the Tanzanian rural society according to Rweyemamu.
As a village technology the project should also stimulate development of other rural technologies as soon as the population is acquainted and conscious of their own capability to develop local technology as was demonstrated by mr. Lipangile and the workers of the project.

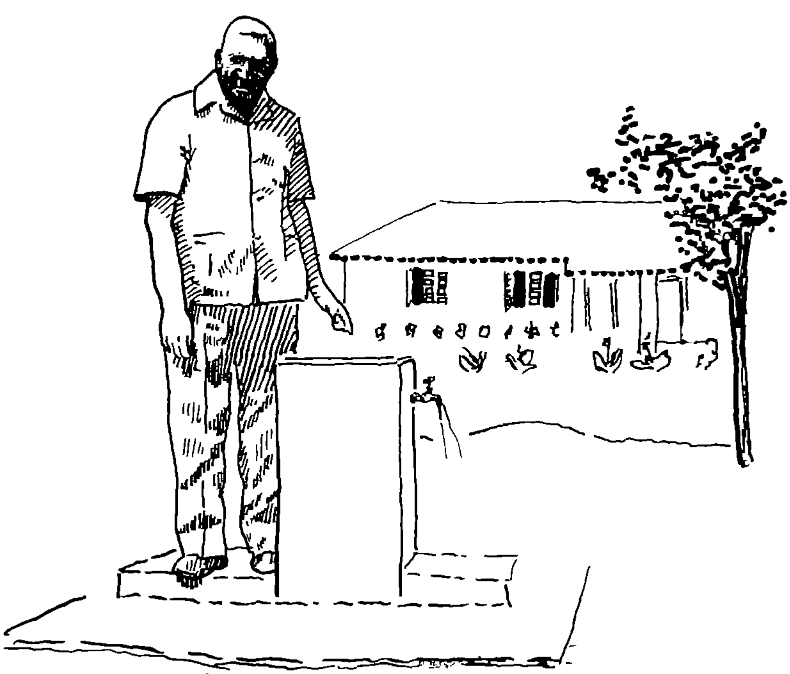
The incorporation of the project in the Tanzanian rural community will be limited, already development of this village technology has somehow become isolated from the village.
There are some reasons for this development;

- the scale of the project exceeded the village level, centralization was necessary for the cutting of bamboos, the design of the water supplies and the research for and development of the bamboo (and wood) pipe technology.
- the technical problems became very specific (especially the protection of the pipes) exceeding the ability of the people in the village to solve them.
- the dependence of expatriates (who were/are sincerely commited to the project) and foreign institutes.

The people in the village do sympathize with the use of local materials although they will initially have some doubt about the technical feasibility of the application of bamboo and wood for piping.
The collective responsibility for the bamboo pipe system and technology will be less when the technology is developed outside of the village, however.
The development of the bamboo pipe technology in the village is not feasible at the moment but in a later stage when the protection of the pipes is guaranteed, the research and development or improvement of the pipe system should be returned to the village.

More serious is the dependence on expatriates, for Tanzanian technicians it is to great a risk to start a career with an experimental project like the Wood and Bamboo Project.
Only incentive rewards could motivate technicians but this procedure will result in a doubtful selection of employees.

Technical training for village people who return to their village will be beneficial both for the maintenance of the the bamboo pipe system and the development of the bamboo pipe technology. Replacement of the expatriates by Tanzanian technicians and scientists will also be necessary.
Career guarantees of the government in case of abandonment of the project could be considered.
Finally, the basic equipment for research on bamboo and wood pipes should be at the disposal of the project.
This would not only further the progress of the research program but also pave the way for an independent position with regard to foreign institutes.



Mr. Lipangile, head of the project at a waterpoint of the Mgama bamboo water supply.

2. BAMBOO SPECIES FOR WATERPIPES IN TANZANIA.

2.1. Introduction

Two species of bamboo were used in the first water supply of the WB project in Mwanza district. A small type of bamboo (5 cm. internal diameter of the stem) were seriously affected by insects, and not very suitable for water-pipes.
According to Clayton (Clayton, W.D., 1970) this Kigoma type of bamboo was *Oxytenantera Abyssinica (A. Rich) Munro.*
The second specie was from West Lake region (Bukoba) and probably a Bambusa Vulgaris (Lipangile 1978).
For the new project implemented in 1976 near Songea a new specie of bamboo was taken from the forests around Rungwe Mountain (Tukuyu Disctrict).
This bamboo specie is still used in the bamboo water pipe schemes of the project.
We determined this specie as *Arundinaria Alpina (K. Schum)* which concides with the description of the A. Alpina of Clayton (Clayton W.D. 1980 pag.9).
The bamboos for Nyakipambo (Iringa Region) completed in 1978 were collected in the highlands around Dabaga (Iringa).
Although we did not determine the specific forest exploited for the project, it is probably also A. Alpina.
We expect A. Alpina in this area because a group of bamboos determined nearby Dabaga village (Kinigu, Idewa Forest) (Iringa Region) was A. Alpina.
According to the information we have at the moment it seems that A. Alpina is the most common bamboo in Tanzania and because of its size and availibility it is the most suitable bamboo for the water pipe.
For this reason we will discuss the relevant features of the A. Alpina.

2.2. Arundinaria Alpina, the african alpine or mountain bamboo.

The A. Alpina growing at an attitude of 2500-3400m.
(Eggeling W.J.'57) gregariously but not in clumps, is also found as irregular patches or as isolated plants in mixed forest down to 1860m. The length of the culms is 2-19.5m and the external diameter of the culms is to 12.5.cm (Clayton, 1970 fig. 7).
Wimbush (Wimbush S.H. 1945) gives for Kenya a density of the mountain bamboos per acre of 4000-7000 stems (10.000-17.500/ha).

The growth of the Arundinaria Alp. begins some weeks after the onset of rainy weather and it continues apace for 1-2 months. At the end of this time the full heigth and girth of the bamboo has been reached. The thin branches and leaves do not develop until after the stem his finished its height growth.
The stem grows no more in height or thickness after the first season. Every bamboo plant spreads by the underground extension of its rhizomes from which the aerial culms or bamboos spring. The early tight formation of the clump becomes lost as the older culms at its centre die and disappear. They are replaced by new culms which spring from the extensions of the old rhizomes, but these new culms are more widely spaced and the continuation of this process over a long period tends to obscure the clump effect and give a homogenous appearance to a forest of this species. (fig. 8).

2.2.1. The life of a bamboo culm

For the bamboo pipes it is said that only the mature bamboos are suitable.
In the forest the labourers select the bamboos with moss and lichen on the nodes and internodes.
According to Wimbush this moss occurs after three years at the nodes, after 5-7 years the moss extends to the internodes and little or no lichen is present.

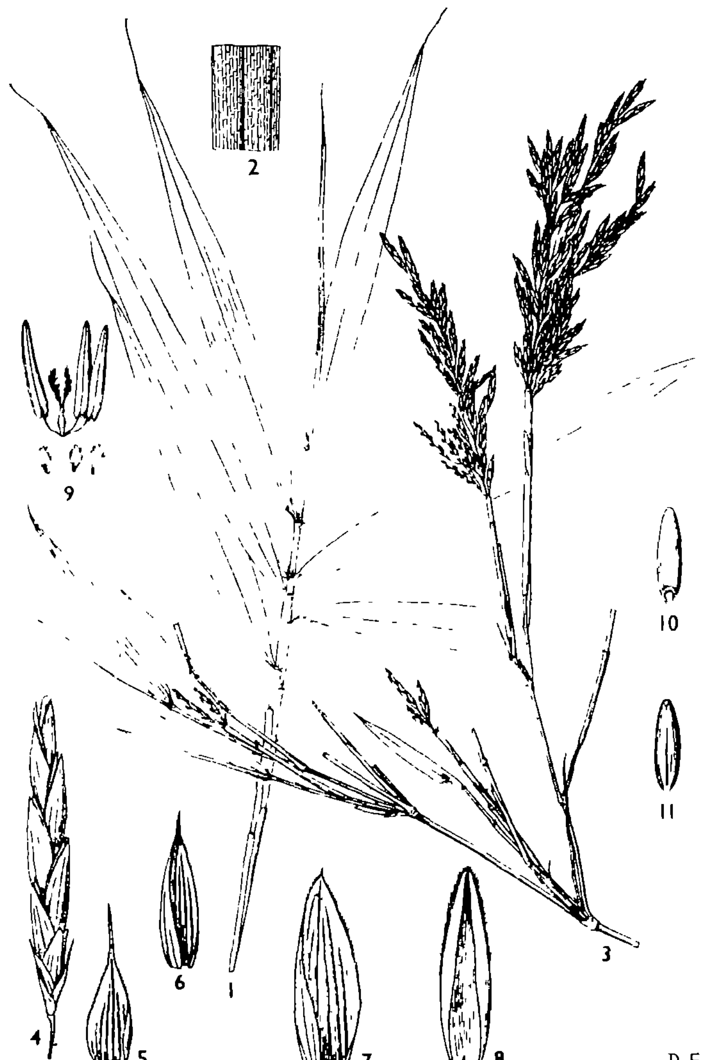


figure 7. *Arundinaria Alpina-1*, leafy shoot, 2. part of the underside of leaf-blade showing tessellate venation, 3. flowering shoot, 4. spikelet, 5. lower glume, 6. upper glume, 7. lemma, 8. palea, 9. flower, with lodicules dissected free, 10. caryopsis, dorsal view, 11. same, ventral view. (from Clayton 1970).

The one year old bamboo is dark, even green with a rich brown "velvet" at the nodes, and a smooth and "downy" stem.
The lifetime of a culm is around 14 years (on the Aberdane Range, Kenya).
The bamboos selected for the project are 5 years or older.

2.2.2. *The flowering bamboo forest*

A bamboo plant ends its life after flowering (although not all).
In Kenya flowering and dying of the A. Alpina is known to occur in patches of one or more acres extending over several hundred acres of bamboo forest at a time.
On the Aberdare Range (Kenya) the mountain bamboo has a life cycle of more than 40 years and on the Mt. Elgon (Kenya) the cycle is 15 years. (Clayton, '70).

2.2.3. *Recovery of bamboos after cutting*

From observations in the Kikuyu Escarpment forest, in plots that were cut eleven years ago it has been found that normal fullsized culms may appear in the eight or ninth year after clear cutting bamboos on a fairly level site, on steep slopes where the soils dry out more rapidly several years more may elapse before full sized culms are produced.
If however, some of the old culms are left standing at the time of cutting, it appears that this period of recovery may be shorter by one more years, depending upon the number of culms left standing.
If 50 percent of the number of culms are left standing evenly distributed, the recovery period may be as hort as three or four years.

2.2.4. *Cutting cycle for the bamboos*

The cutting cycle is the period that must elapse between two succesive cuttings of an area of bamboo. It will be governed by the lenght of the recovery period, to which must be added the number of years that is needed to produce a full complement of normal sized bamboos. If we take an area with a density of 5000 culms per acre (12500 bamboos per ha.) and an average of 1800-2000 (4500-5000/ha) new produced bamboos per acre every three year, in addition with the recovery period (8-9 years) gives a cutting cycle between 14-21 years for clear cutting.
Cutting of bamboos during the growing season lengthen the cutting cycle with several years.For the Rungwe Forests this growing season in around January, February, March and April.

2.2.5. *The quality of the bamboo*

The quality of a bamboo culm is determined by soil and weather conditions. The Arundinaria Alp. flourishes best on deep volcanic soils rich in humus and is usually poorly developed or absent where rocks are near the surface.
The altitude could be of influence since the competition between the mountain bamboo and other species intensifies on lower altitudes.
During the bamboo inventory which was carried out in April 1979 around Igoma Village (Mbeya district) we found out that the larger bamboos predominate nearby streams in the fertile soil. On the hilltops, steep slopes and near the edge of the forest the bamboos are smaller due to eroded soils and regular clearing by the villagers.

2.2.6. *Conclusion*

According to the available knowledge about bamboo in Tanzania it seems that the African Alpina or mountain Bamboo (A. Alpina) is the most important bamboo resource for the WB project at the moment. The average internal diameter

of the selected mountain bamboo is 2". The bamboo is very straight and according to Wimbush, it is also strong. However the distance between the nodes is rather long, (65-80 cm). The nodes give strength to the bamboo through the connection of the vertical fibres, bamboos with more nodes per unitlength are stronger when other characteristics like wall thickness, and wall structure are simular. The Bambusa Vulgaris is an example of a stronger thick-walled bamboo, growing in Tanzania, but for pipe material the mountain bamboo is of much more importance than any other big-sized bamboo in Tanzania because of its availability.
The locations of the mountain bamboo forest in Tanzania which should be investigated are: (see fig.8)

- Mbulu District, on the Oldeani volcano between Lake Manyari and Lake Eyasi and Nou Hills (Mlowe, 1979)
- Arusha District, on Mt. Meru South slope,
- Mbeya District, Igali Pass,
- Morogoro, Uluguru Mountains, Lukwangule plateau (This bamboo in the Uluguru is probably an Arundinaria Alpina)

figure 8. Arundinaria Alpina, Rungwe Mountain.

- Iringa Region; Nzungwa Scarpment, Ulangambi New Dabanga Forest reserve, Mufindi Scarp, Kigogo forest reserve. Kipengere Forest reserve, Matamba forest reserve, Madeheni an Ndumbi Valley (probably the A. Alpina).

2.3. *Other bamboo species for waterpipes*

Information on the other Tanzanian bamboo species does not come from reliable sources. Local forest officials estimated the total acreage of bamboo forest in Kigoma and Kibondo District and in Linde Regiom to be 165.000 acres (70.000 ha).
In "Flora of tropical East Africa" (Clayton W.D. 1970) this bamboo is described as *Oxytenanthera Abyssinica*, a bamboo growing in dense clumps, culms 3-10 m. high in diameter erect, at first densely silky with appressed hair, solid or thick-walled; culm sheaths with dark brown bristly hairs, tipped with an involute pungent blade 1-2 cm. long.
Leaf blades lineair lance, 5-25 cm. long and 1-3 cm. wide, somewhat glaucous, with inconspicuous transverse weins gradually narrowed to a fine pungent tip: leaf sheats with inconspicuous with a deciduous setea 2-5 mm. long on the shoulders, without auricles. (fig. 9).

The negative experiences with this bamboo in Kigoma where the culms were affected by insects, should not stop the project from compiling a more extensive bamboo inventory of the O. Abyss. In case of location of an area of high quality, large O. Abyss. bamboo,new villages in remote areas could be supplied with bamboo waterpipes.

Location of the Oxytenanthera Abyssinica in Tanzania:

. Buha District (Kigoma) Kasulu Highlands between Manyovu and Heru Juu.
. Lindi District: Nachingwea and Kilura Forest Reserves (Mlowe, 1970).

The Oxytenanthera macrothyrsus which is found in
. Uzaramo District, Kiserawe and Kasi is probably the same type of bamboo.

The Oxytenanthera braunii, well known in Tanzania because of the Ulanzi (bamboo wine) which is extracted from the culm of the bamboo, is according to Clayton W.D. similar to O. Abyss. But as far as I known the O. Abyss. is not used for the production of local beer. The O. Braunii was used on an experimental basis for waterpipes.
It proved to be easy to preserve with a water soluble wood preservative, and sizes to 7.5 cm. (3") internal diameter were available.
The major disadvantage of Oxytenathera is the irregular internal diameter with very thick walls at the bottom side, the bends in the culm and the availibility. (fig. 10). The people in the village do not cultivate the larger culms because of the bamboo wine for which purpose only small culms are needed.
The scatterd clumps of O. Braunii would raise the otherwise unnecessary problem of the transport cost of the pipes.
The relation of the Oxytenanthera Braunii with the O. Abbys. is still obscure.

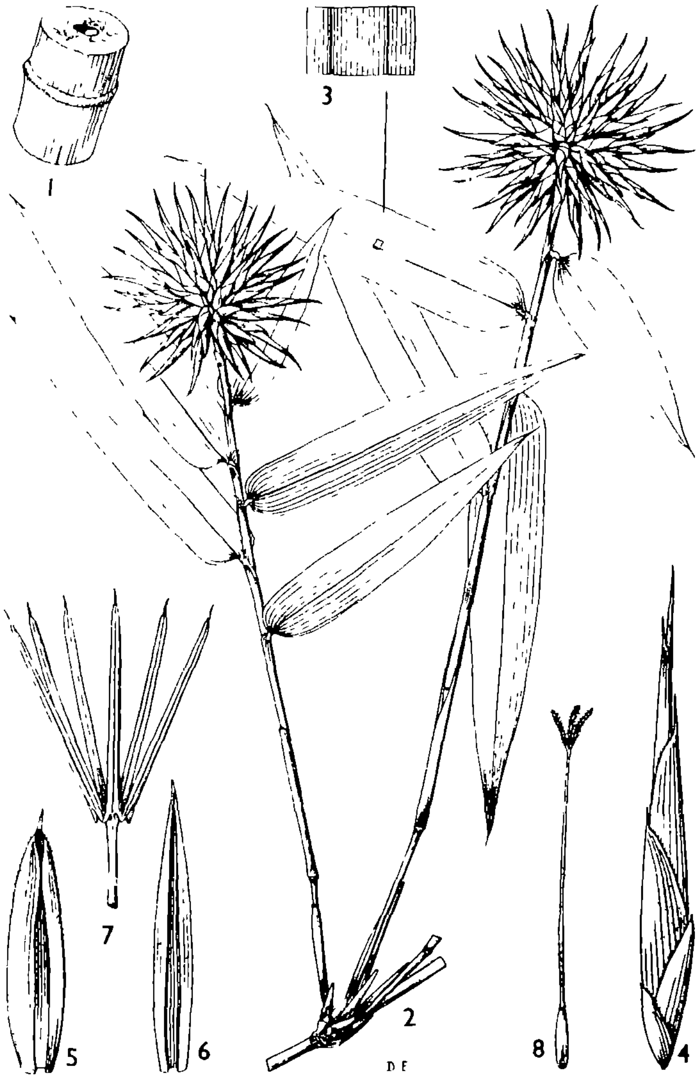


figure 9. *Oxytemamthera Abyssinica-;* 1. piece of culm taken 6 m. above ground level, leafy branchlets with inflorescences, 3 part of underside of leaf blades howing tessellate venation, 4 spikelet 5, lemma; 6 pales; 7 androcium; 8 gynoecium (Clayton 1970).

figure 10. Test pipe of Oxytenanthera Braunii impregnated with a preservative (CCA sap displacement).

Location of Oxytenanthera braunii (Ulanzi bamboo)

The last natural bamboo specie we located in Tanzania was in Tukuyu District/ Rungwe District.
Clayton describes this bamboo as *Oreobambos buchwaldii bamboo*, in small dense patches or solitary clumps, culms 4.5.-18 m. high 5-10 cm. in diameter spreading or drooping rarely erect, green, hollow, culm sheaths at first clothed with appressed stiff brown hair tipped with a short subulate blade and fimbriate shoulders (fig. 11).
Leaf blades lanceolate or oblong lanceolate, 10-35 cm. long and 2.5-6 cm. wide, pale green or slightly glacous acutely acuminate the transverse veins very obscure, leaf-sheaths not ciliate on the shoulders.Perfect pipes with nodes every 30-40 cm. The culms we determinated were all erect, the internal diameter was up to 9 cm. (external diameter 11 cm.). The bamboos were collected along the road from Itagala to Mwakaleli. (Tukuyu)
Like O. braunii this bamboo is cultivated by the village people for construction purposes and can only be found in scattered patches nearby the village. It grows in forest clearings often by rivers on an altitude between 300-1950m.

Location of the oreobambos:

- E. Usambara Mts., Derema & Sigi
- Rungwe District: Ryimbilo, Ruwarisi stream.

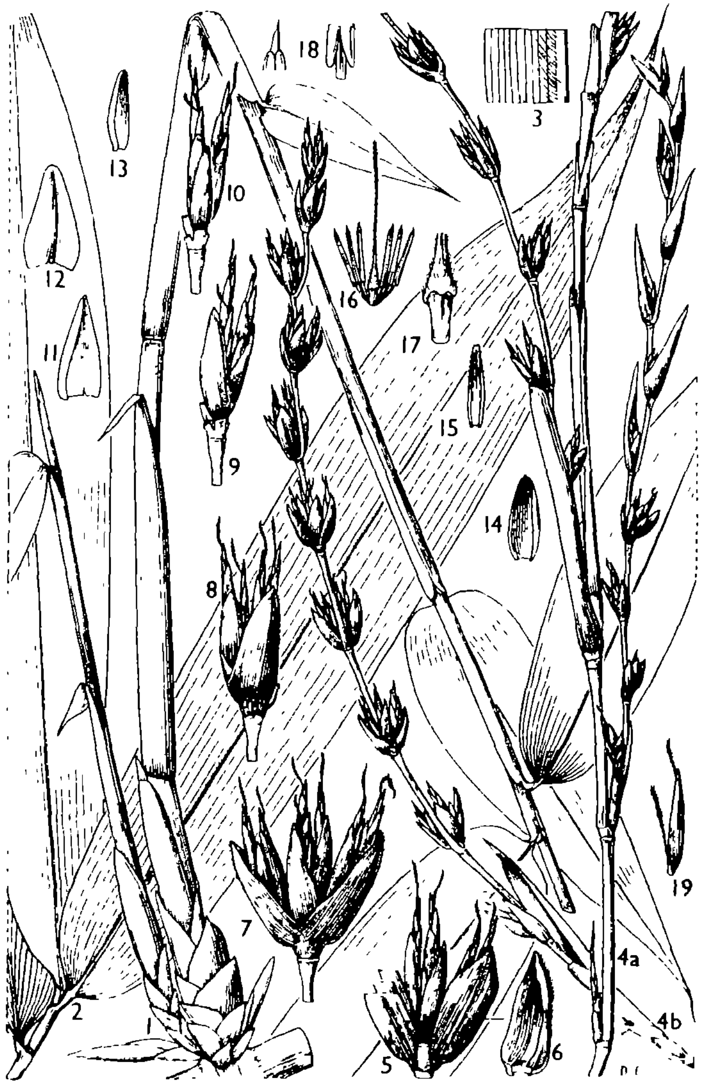


figure 11. *Oreobambos Buchwaldii* 1. leaf branchlet; 2. leaves; 3. part of dorsal surface of blade showing tesselate venation; 4a, 4b, flowering branchlets; 5. spikelet cluster; 6. bract; 7. spikelet cluster (Clayton, 1972).

Apart from these local species there are some other species introduced by the Germans.

The bambusa vulgaris is most common of these introduced species. In Tanzania two varieties can be distinguished, the yellow bamboos with green stripes and the green type. It is said that the green form predominates in the United States (frost free areas) and in the Caribbean area while the yellow type predominates in Central America. The Bambusa Vulgaris was planted in Tanzania for decorative purposes only, in gardens and on colonial estates.
The green type was found along the Dar es Salaam-Bagamoyo road. In Tanga on an estate (Segoma) dense patches of green and yellow B. Vulgaris were located, sizes up to 12.5 cm. (5").
In the forest of the forest division(Moshi), some individual yellow and green forms of the B. Vulgaris were determinated.

The B. Vulgaris was suggested by the project as the future waterpipe bamboo. Cultivation of the B. Vulgaris would give a more uniform and higher quality waterpipe.
Although the positive features of the B. Vulgaris are many as, strength, ecological tolerance ease of vegetative propagation, the short cutting cycle (5-6 year) and the size, (McClure FA'66) we should consider the disadvantage of the B. Vulgaris as well. The partition walls are not easy to remove by handpower for the production of waterpipes.
Of interest is one specie detected along the dust road to Arusha National Park with an internal diameter of 5 inch (12.5.cm.!!!) growing in between B. Vulgaris which were all planted along a small stream. This specie could not be determined.

2.4. Conclusion

With the objective of minimizing the transport costs for the bamboo pipes inventory in Kigoma and Lindi Region and in Usambara Mountains should investigate the possibilities of the use of Oxytenanthera Abyss. and Macrothyrsus and Oreobambos buchwaldii. Next to the advantage of having bamboo waterpipe resources spread over the country there could also be advantage of treatibility with wood preservative.
Impregnation through sap replacement could be more succesfull with non-Arundinaria species.

The decision to cultivate bamboos for waterpipes should only be considered in case of major failures with the natural available species in Tanzania.

2.5. Bamboo inventory

Discussion with the officials of the Ministry of Natural resources and Tourism indicated that no reliable information about the availibility and location of bamboos was available. Most of the regional and district officials know where bamboo forests are but no records of species, acreage or quality are kept.

We agreed that a bamboo forest inventory would be necessary not only for the Wood and Bamboo Project but also for the Forestry department since bamboo is a multipurpose crop.
It is hardly necessary to mention the Pulp and Paper Industries, Building & Construction Industry and handicrafts.
A preliminary forest inventory was carried out near the village of Igoma (Mbeya District) with the object of standardizing the procedure for the Project and the Forest department.

2.5.1. *Bamboo inventory of Arundinaria Alpina*

The objective of the inventory was to investigate the quantity, quality and accesibility of the mountain bamboo, suitable as pressurized waterpipes.

The first stage of the problem is to define the various parameters involved.

Suitable for pressurized pipes are culms;

. mature with moss and lingin on nodes and internodes (lifetime of 5 years or more)
. external diameter 5 cm. (2"inch) or more,
. undamaged

Quantity of useful bamboos
For the Project it is most practical if quantity is expressed in length of bamboo pipe material per unit area.
For instance 50 km. pipe material per ha.

Quality of the bamboos
. shape, erect or bent,
. number of insect holes, or diseases,
. useful length, is length of the culm section with a external diameter of 5 cm. (2") or more.

Accesibility of the bamboo forest:
The condition of the road to the forest.

2.5.2. *The aerial photograph*

With the help of the aerial photograph it is possible to distinguish the bamboo patches or forest on the 1:25000 maps used by the Department. In case of understorey bamboo crop this will be more complicated but for mature mountain bamboos (A. Alpina) it is not a problem.
The young bamboo forests with small sized bamboos are not exploitable for the Project.
We investigated one plot in a young bamboo forest of at least 10 years old (according to the aerial photographs) and did not find any bamboo exceeding 5 cm. (2") external diameter or 8 meter height.
On the aerial photographs the height of the bamboo can be compared with individual trees growing in the bamboo forest. For the A. Alpina the height of a mature big sized culm is 15 meter of more, which corresponds with or exceeds the top level of the tropical forest in Rungwe District.
In this way an initial selection is made possible between mature and inmature bamboo forests because the shadows of surrounding of individual trees will indicate the lenght of the bamboo culm (see photograph)(fig. 12)

Figure 12. Bamboo forest with individual trees rising above the bamboo forest level.

More conclusions can be drawn consulting the aerial photograph.

- Forest near villages are not exploitable for the Project due to excessive clearing by the village people.
- Bamboo forests on fertile soils should be selected for the exploitation of big size bamboos.
- Accesibility.

2.5.3. The Fieldwork

The inventory is now being carried out by the Forest Division of the Ministry of Natural resources and Tourism, mr. Kissima (1979) gives a detailed description of their work.
The usefull lenght of bamboo pipe we found on the three investigated sample plots was between 300 and 950m. per 100 m2 bamboo forest. These figures give indication of the yield of bamboo pipes in the Arundinaria Alpina forest.
The inventory of bamboo species growing in patches like the Oreobambos and the Oxytenanthera will be more complicated than the inventory of the Arundinaria Alpina.

3. THE PERFORMANCE AND PRODUCTION OF BAMBOO WATERPIPES

3.1. Synopsis of the production and installation of pipes

- Village workers from Igoma Village (Rungwe) cut mature bamboos and carry them out of the forest. The bamboos are stored and covered with branches.
- The lorry transports the bamboo to the project villages.
- The villagers construct a dam for a reservoir in which the fresh bamboos are submerged after removal of the partition walls inside of the bamboo, immediately after arrival. (desapping).
- After two or three months the bamboos are prepared for installation, the partition walls are now completely removed.
  Cracked sections of the culm are removed, and each bamboo is exposed to a pressure test of 2 ATM. Insect holes or other spot holes are blocked with pieces of bamboo.
- The trench of 60-80 cm. deep and 30-40 cm. wide for the pipeline is treated with *chlorinated hydro carbon insecticide (aldrin or chlordane)*.
- The bamboo ends are sharpened with a knife for the insertion into the rubber or Polythene joint.
  The bamboo end and the joint are glued (Tangit) together.
  In case of rubber joints iron wire is used to fasten the joint.
- All T-branches, connections with pressure relief chambers kiosk's overflows etc., are of conventional material connected with the bamboo by polythene pipe sections.
- Pipeline sections with a Head exceeding 2 ATM. are reinforced. The bamboo pipes are reinforced by iron wires coated with bitumen and fastened with the aid of a plier or a piece of wood.
- A stock of bamboos is kept for repairs.

3.2. The partition walls in the bamboo

3.2.1. Removal of the partition walls with a handtool.

The partition walls are drilled twice, the first time for submerging the culms in water, the desapping, and a second time to remove all remaining parts in the pipe.
In this report these two activities are discussed in one section.

The sponge like material of the partition walls is much softer than the bamboo wall material.
The A. Alpina is not hard to drill with a handtool, species like Bambusa Vulgaris and Oxytenanthera have tougher partition walls.
The projectworkers designed their own bit for the drilling (fig. 13) and connected the bit with a two meter bar made of galvanized steel pipe with a diameter of 2 cm. (3/4").

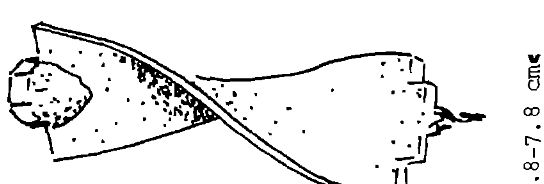


figure 13. Bit for removal of the partition walls.

The width of the bits varies between 3.8-7.5 cm. to fit the different internal culm diameters.
The procedure is as follows, the bamboo is held by a vice (fig. 14) The size of the bit is selected and connected with the bar.

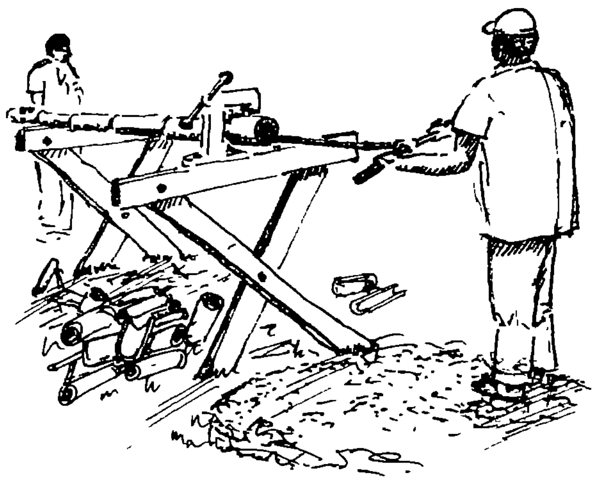


figure 14. Manual removal of the partition walls.

One person pushes the bar and bit through a partition wall, turning the bar slightly to exted the hole.
The long culms which exceed the length of the bar are turned by the second person who handles the vice and the remainings of the partition wall are removed from the other end. In this way some hundred culms are drilled daily.
This simple village technique is well adapted to the facilities in the schemes. The disadvantage of the technique is the insufficient removal of the partition wall material resulting in extra energy losses in the water pipe. (fig 15)

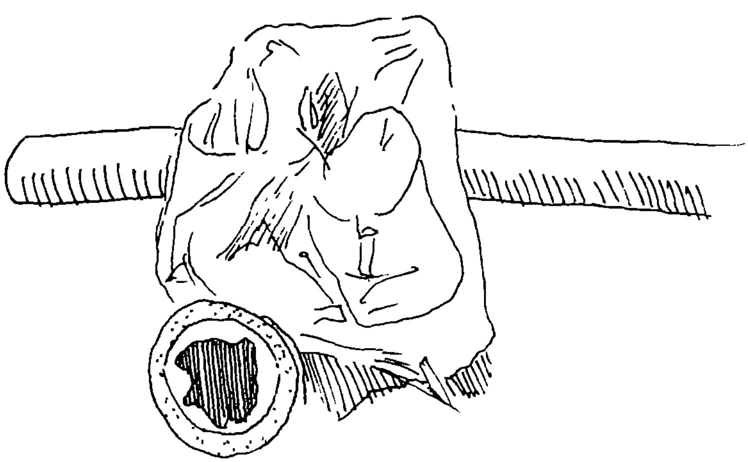


figure 15. Cross section of water pipe with remains of a partition wall.

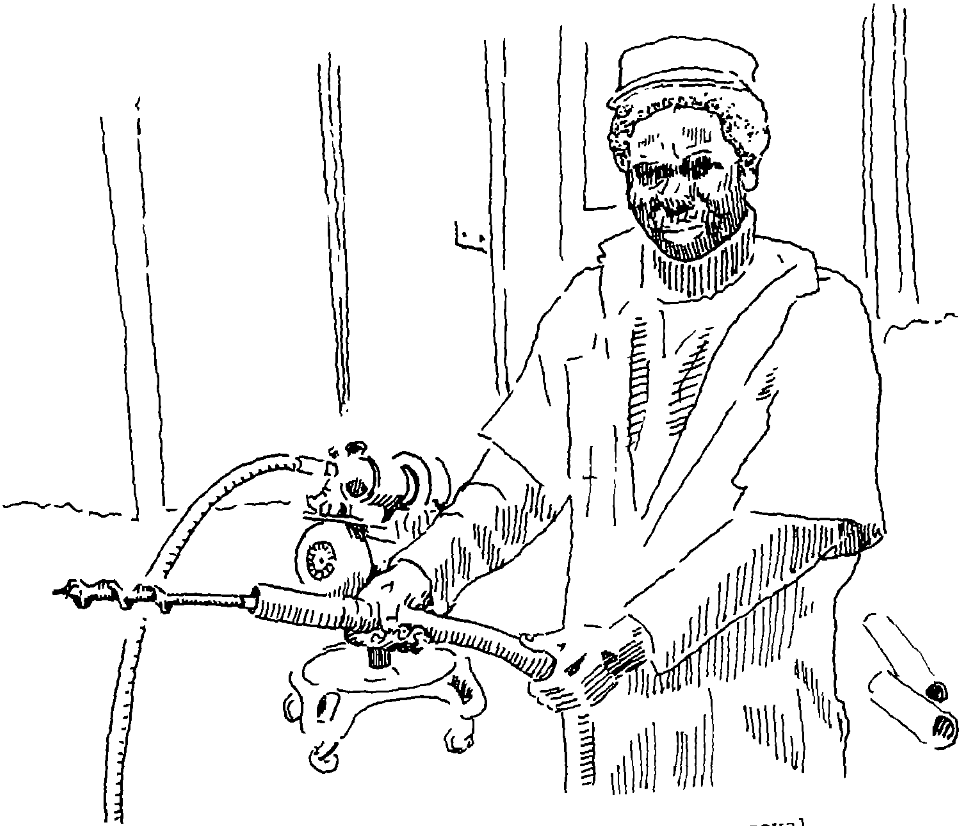


figure 16. Flexible drive with adapted bit for the node removal.

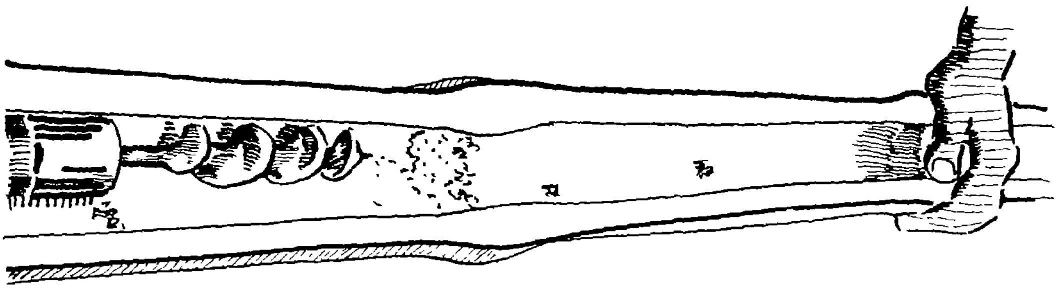


figure 17. Interior of a "smooth bamboo pipe".

3.2.2. With a flexible drive

The project ordered a flexible drive some years ago, to improve the removal of the partition walls.
This electrical powered equipment is designed for the cleaning of pipelines in factories.
We adjusted a normal wood drill of 2 cm. (3/4") for this purpose. With a hacksaw the sides of the bit were roughened in this way the bit can both drill and rasp. (fig. 16). The play on the flexible drive enables the removal of partition walls with diameters exceeding the diameter of the bit (fig. 17)

The removal of the partition walls with the flexible drive is carried out as follows; the bamboo is rested on a trestle, one person handles the drive while a second person instructs the other one where the bit should be situated, to be sure that only the partition walls are rasped and not the internodes. A lower speed of the bit also dimished the damage to the internodes.
The bit is easy to locate with a hand on the outside of the culm. As soon as the bit reaches a node the bamboo is turned once around its axis by the second person.
The flexible drive is easy to handle even for long pipes.

The drive was tested on 230 Arundinaria Alpina bamboos before it broke near the weld of the bit. For species like Bambusa Vulgaris this weld is too weak and should be adjusted by using an other drive.
Correspondence with the manufacturer of the drive could improve the equipment.

The average time taken to remove a partition wall was 27 seconds or two to four minutes per bamboo pipe.

3.2.3. Bamboo wall roughness coefficient

The effect on the roughness coefficient of the bamboo water pipe, of the mechanized removal of the partition walls was tested at the University of Dar es Salaam and compared with the handtool method. (Faculty of Engineering, 1979). The investigations included series of 36 tests performed on 5 different pipes, two were prepared with the flexible drive.

The "rough" pipes had a roughness coefficient of the Manning equation . . . .

$$v = 1/n.S^{1/2}\,R^{2/3} \quad (m/sec) \qquad ,n = 0.016\ (sec/m^{1/3})$$

The C value of the rough pipe from the Hazen Williams equation . . . .

$$v = .345.C.D^{0.63}\,S^{0.54} \quad (SI\ units) \quad ,was\ C = 75.$$

For the smooth pipes prepared with the flexible drive the *n value* was 0.013. The *C value* was 90.

3.3. Desapping of the bamboos

The extraction of saps, starch and other substances from the bamboo culm wall is called, desapping.
The use of fresh-cut bamboos without a desapping treatment result in odorous water. The organisms and substances in the bamboo which are responsible for this contamination of the drinking water, accelerate the decomposition of the bamboo pipe aswell. The amount of sap in the bamboo seems to be related with the decomposition, bamboos harvested in the rainy season have more sap and are more effected by termites (Bauingenieur, 1969).

The project was forced to use the desapping treatment because of the strong smelling and contaminated drinking water in fresh bamboo pipes.

The selected method of desapping in Tanzania is the submerging of the pipes for two three months in non-stagnant water. This method is most simple and practical for the moment compared with the alternatives.
Lipangile (1978) states that submerging is not effictive for all species, Bambusa Vulgaris for instance, has to be submerged in chlorinated water.

A temporary water defiency in the pipe in a dry bamboo pipe system reactivate the growth of bamboo destroying organisms and contaminate the water, probably resulting in smelling water.

3.4. *Pressure test*

Pressure testing of the bamboos in the village is done with a small waterpump of three horse power.
The pressure on the pipe during the test does not reach 2 atmospheres which is the working pressure of the pipes in the system.
A proper test on the bamboos should be carried out with pressure up to 2.5 atm. This, however will be complicated in the absence of equipment to pressurize the pipes.
The current method in the project is to pump in the water through a connection of a galvanized steel pipe with a rubber joint which fits the bamboo.
A person (tries to) close(s) the end of the pipe with clothes while the engine is given full speed.
A mobile construction able to hold bamboos of various sizes will improve the pressure tests of bamboos.

3.5. *Strength and reinforcement of bamboo*

No profound study on the strength of the Arundinaria Alpina has been carried out yet.
But indications of the strength are available from some minor tests and experiences gained from the pipeline system.

The bond between the parallel fibres in the bamboo culm is weak, at the nodes the tangential bond is stronger.
Each specie of bamboo has its own strength characteristics (United Nations, 1972).
For the Arundinaria Alpina the average pressure resistance in pressurized bamboo water pipes was determined by two students of the University of Dar es Salaam (Iringili et al, 1978)
The average burst strength was 4.3 bar. (N=8; standard dev=1.4 var. =1.8).

It seems that apart from the number of nodes per unit length the diameter and the wall thickness also affect the strength of the bamboo water pipe.
Atrops (Bauingenieur, 1964) found that the shear stress increases with increasing thickness of the bamboo culm wall. He continues that the bending stress of bamboos with smaller diameter is higher because the portion of strong sklerenchym fibres for the smaller bamboos exceeds the portion of this strong fibres in bigger bamboos, per unit area.

To reinforce the bamboo pipe, iron wire protected by bitumen is wound in regulair intervals around the pipe.
According to the condition of most of the wire material it does not support the pipe for a long time.
Alternative reinforcement material as suggested by Jacobs and Lundborg (1978) should be considered seriously as soon as long-life preservated pipes are available.

Sisal rope reinforcement was tested. The rope impregnated with copper naphtenate or pentachlorophenol is not a suitable reinforcement material for bamboo pipes. The sisal will not have a service life of 10 years under conditions of

soil burial, 10 years is the expected lifetime of the preservated bamboo pipes (Himmelfarb, 1957).
Pentachlorophenol treated sisal ropes buried on the test plot detoriated significantly after three months.

An American student suggested the application of formaldehyde and H_2SO_4 to re-inforce the bamboo culm.
These chemicals react with the cellulose of the parallel fibres which are cross linked in this way.

2 Cellulose-0-OH + HCHO . . . . .Cellulose-0-CH_2-0-Cellulose).

An effect of the formaldehyde treatment mentioned by Nicholas is the resulting severe embrittlement of wood (MacConal, 1979). The drawback of this method is the introduction of poisonous formaldehyde. The reaction should also take place with a low pH and high temperature.
For the time being it is advisable to concentrate on more urgent problems and to discontinue the research on formaldehyde.

3.6. Seasoning of bamboo

During the storage of bamboo harvest and during the transport to the villages, the bamboos dry. This drying (seasoning) of bamboos is a sensitive aspect of the bamboo pipe production and should be avoided as much as possible.
Wood and Bamboo shrinkage is said to occur as soon as it is dried below the waterlogged moisture content.
The shrinkage of the bamboo pipe results in small hair cracks and weaken the pipe seriously.
A group of 31 bamboos was seasoned for three months, 30% was affected by visual cracks.
The pipes were covered by a plastic sheet during the seasoning process, enabling the air circulation around the pipes.

A second attempt to season 20 bamboos failed. Saturated bamboos were taken from the pond to season the pipes and the compare the performance of the seasoned pipes with un-seasoned pipes under pressure.
After two weeks all the pipes were seriously cracked, only small sections were not affected by cracks.
The conclusion is that seasoning of Arundinaria Alpina is not feasible for bamboo water pipes, it results in excessive losses of bamboo pipes.

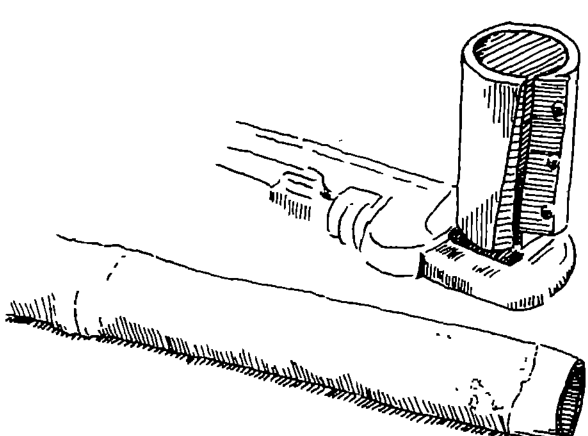


figure 18.
Bamboo-
sharpener

3.7. Joints

Many joints have been suggested and tested during the last five years (Lipangile, 1976) Most practical is the use of 20 cm. Polythene or Poly Vinyl Chloride pipe sections and a PVC paste, called Tangit.
The bamboo is shaped with a knife or with a kind of pencilsharpener (fig 18) to make the bamboo suitable for insertion into the plastic joint. The Tangit glue is applied to make the joint water tight.

An alternative rubber + bamboo joint as suggested by *demotech* (1978) was tested (fig. 19).

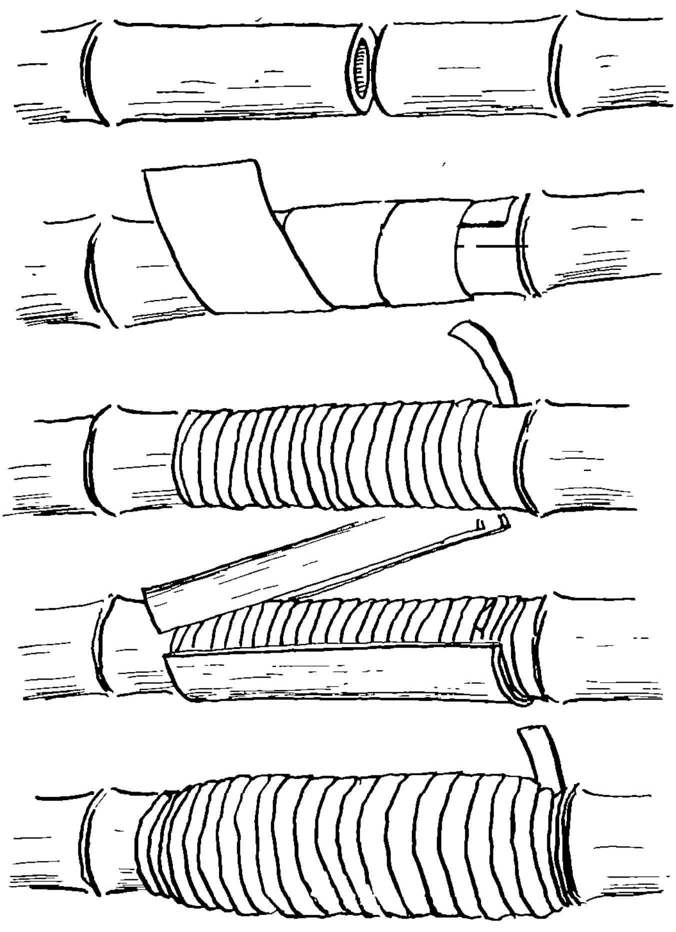


figure 19.

rubber winding
(6 x 60 cm)

rubber string
(2 x 200 cm)

bamboo collar

bamboo string
(2 x 200 cm)

Eight different windings were tested under low pressure (0.5 atm) We found that a good rubber joint is more expensive than a plastic joint. Due to the market value of second hand rubber material in many African countries.
The connection of the rubber + bamboo collar joint is rather time consuming (15-30 minutes).
For repairs it is possible to use the rubber + bamboo joint to replace the current method involving the disturbance of three pipes (fig.21). The rubber + bamboo repair joint can, in some cases be connected without disturbance of the pipeline.

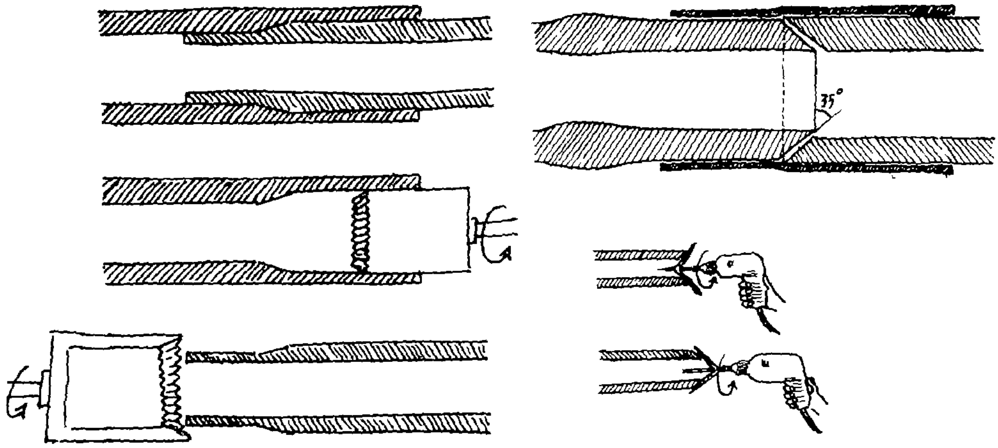


figure 20. Alternative joints.

A number of joints has been designed to improve the connection between the two bamboo pipes.
These improvements include preshaping of the bamboo culm end for a more water tight connection and less energy losses at the joint. The improvements are nevertheless negligible. (fig. 20).

figure 21. Repair of bamboo pipeline.

3.8. Pump water supplies and gravity water supplies

The pump water supply of Kayenze village Mwanza District) was a failure for the bamboo pipe project (section 1.2.) The project concentrated after this negative experience on gravity water supplies. The percentage of gravity water supplies in Tanzania is 17% (Jacobs, 1978).

The bamboo pipes crack in warm soils when the water supply is blocked for several months, shallow burial accelarates the drying and consequently the bursting of pipes.

A solution for this problem could be the use of a water tank to avoid an empty system.

In case of failure of the pumps or fuel shortage, water from the tank is used to keep the system saturated.

During this period the taps are removed. Cleaning of the pipeline after a longer period with stagnant water in the system will be necessary before the system is used for comsumption.

4. THE PROTECTION OF THE BAMBOO WATER PIPE

4.1. Introduction

The unprotected bamboo pipes in Lukuyufusi (Songea), the second water supply scheme of the project were damaged by termites within a week. (Lipangile 1978). The expected lifetime of preserved bamboos, in contact with the soil and not protected against weather influences, is according to Purushotham and others (Purus 1953) 10-15 years. The main research objective of the Wood and Bamboo project at the moment is; to determine whether a safe and durable protection of 10 to 15 years for bamboo pipes is possible.Twenteen years is the assumed lifetime of a village water supply according to the ministry for Waterdevelopment and Power in 1975.
Except from termites there is also a group of insects, the wet wood-borers attracked by wood/bamboo with a high moisture content. However we did not register any damage of bamboo pipes by these insects.
The chance for bacterial wood destruction of the pipes is rather small in the saturated bamboo culm wall. A last threat for the bamboo pipe could be fungous detoriation. There is a probability of soft rot affection of the pipes because this fungus occurs under very wet conditions with sufficient oxygen. (Bleijendaal 1978, cooling towers).

4.1.1. Protection of the pipes

Many wood experts were consulted for the solution of the specific preservation question of bamboo water pipes. In this chapter we will review and discuss these suggestions.
The criteria for judgement of all these suggestions are;
- the contamination of drinking water in the protected pipes
- the cost of treatment
- the performance of the treatment on large scale.

We devided the suggestions for protection of the pipes in two groups; the first group is protection with non-toxic treatments and the second group has toxic treatments.

4.2. Protection of bamboo pipes without toxix chemicals

The most simple application of bamboo for water conveyance is the use of half open bamboos (flumes), erected on bamboo stalks. The flume can be protected against climate and contamination by a bigger sized bamboo on top of it (Rijsdijk 1979). This method may be appropriate to Asain conditions, it is not feasible in Tanzania. Here the bamboos are concentrated in some areas (chapter 2) and have to be transported to the villages on government initiative. The villagers would of course object to this alternative water supply offered by the government. Compared with the conventional plastic pipe supply some villages would get a less practical, less safe and less reliable water supply and in case of self help projects the villages have to rebuilt the system every three years. A technical argument against this solution is the cracking of Arundinaria Alpina exposed to Tanzanian weather conditions. (see section 6.2) A concrete coating for the pipes, applied after installation has been suggested several times. From the field of building construction we know about the good performance of bamboo with concrete.
Unfortunately the price of cement in Tanzania is too high at the moment to make a concrete bamboo pipe competative. With future price changes in the plastic and cement prices new investigations into the feasibility of protected bamboo pipes should be considered.
For a sub-soil system we considered various methods of protection.

The desapping of the bamboo culm was discussed in section 3.3.. The desapping of starch contents of the pipe decreases the attack of dry wood borer (Roonwal 1966), but desapping does not give any protection against termites like was demonstrated in Likuyufusi (see page 33) An alternative treatment applied in Vietnam is the desapping of the bamboo culm in sea water (Rijsdijk 1979). The period of treatment is rather long. It takes about two years to accumlate the salt content in the culm wall. This method gives the pipes a long protection. It can be 30 years in areas with termite infestation. For Tanzania this method is not appropriate while the salt would be leached out, giving the drinking water a salt taste. Also the transport costs for the pipes would raise significantly.
A test carried out with bitumen coating on bamboo pipes in Likuyufusi in 1977 showed that termites are not stopped by the non toxic bitumen layer, which is also rather expensive (figure 1).

Another non toxic treatment is the impregnation of bamboo pipes with a 5% solution of borax; boric acid in 1:1 ratio by weight as suggested in the Village Technology Handbook (watersupply VITA, 1966). This would give the pipe a protection for 5 to 6 years. The leaçhing of the water soluble solution will be severe in a water pipe, diminishing the lifetime of the pipe. In a termite infested area the use of boric acid, borax impregnated bamboo, is not feasible.

The conclusion for non-toxic treatments of the bamboo waterpipe is that, with a more favourable price ratio between plastic and cement price, and a reliable supply of cement, concrete protected pipes would be feasible.

4.3. The protection of bamboo pipes with toxic chemicals

The use of toxic chemicals for drinkwater supply systems in possible in three different ways;
- application of the toxic chemical in the soil layer surrounding the pipe.
- impregnation of the bamboo culm with the toxic chemicals.
- impregnation of the bamboo pipes with the toxic chemicals which are seperated from the drinkwater flow by a waterproof layer.

4.3.1. Soil treatment

The treatment of the soil around the pipe is intended to keep the termites and other insects away from the pipe. The concentration of the chemical in the soil seems to be less important than the thickness of the treated soil layer (Kofoid 1934). Soil treatment is a common practice for the protection of wood foundations. It was suggested by the Utilisation Section of the Forest Division of the Ministry of Natural Resources as an appropriate solution for the termite problem of the project in Likuyufusi. The chemicals selected for treatment were Aldrin and Chlordane, both chlorinated hydrocarbon insecticides. At the moment five villages have a bamboo pipeline protected by aldrin and the rest of the villages have, or soon will have, a chlordane treatment. An alternative soil treatment which is under investigation is the application of preservated saw dust around the bamboo pipe.
The preservative is a chromated copper arsenate (CCA); a common wood preservative. Both treatments have the advantage that the bamboo pipe is free from any toxic chemical. The soil treatment however does not give any protection against fungi or bacterial decay.

4.3.1.1. Protection of the pipes with chlorinated hydro carbons

The chlorinated hydro carbon pesticide is sprayed in the trench twice. First the sides and bottom of the trench are treated with a 0.5% solution of aldrin or chlordane. The trench is filled up with a 10-15 cm. soil layer to separate

the bamboo pipes from the chemical and after installation of the pipeline another layer of 10-15 cm. is applied to cover the bamboo pipes.
The second application of aldrin is sprayed in the trench before the final back-filling. About one liter of the solution is sprayed per meter trench. The distribution of the solution in the trench is irregular with puddles of the solution in depressions and dryer patches elsewhere. The protection however is still effective in Likuyufusi with serious termite infestation for almost three years now. The expected persistence (i.e. the period in which 75% of the chemical has been effective) is;

- Chlordane, 60 months (Matsumura 1972, Meyer 1972)
- Aldrin, 24-36 months (Meyer 1972)

The half life time of duration of activity for Aldrin is 10 years and for Dieldrin this is 6 years (Weber 1977).

The decomposition of the chlorinated hydro carbons depends on various factors like moisture content, absorption capacity of the soil, organic materials content, PH and temperature. The performance of the pesticides in the soil is rather complex. A high retention and absorption of the pesticide in the soil for instance does not always result in good protection against insects. In soils with a high absorption capacity more insecticide should be applied to have the same protective effect compared with a smaller dose in a soil with a lower absorption capacity. The decomposotion of the Aldrin and Chlordane in warm organic soils with a high oxygen content and a low PH with regular watertransport is a matter of some years. The protection of the pipes will be less than ten years. A reapplication in necessary for 15 years of protection of the pipe-system.

4.3.1.1.1. The toxicity of chlorinated hydro carbons

The chlorinated hydro carbons are the most persistent and hazardous pesticides (Weber 1977, safe drinkwater committee 1977). It takes many years before the residues are decompsed. The residue of Aldrin is Dieldrin which has the same toxicity as Aldrin. The toxicity of the pesticides for human beings is not well understood (Meyer 1972). What we know is that the pesticides accumulate in the fat layers of the body. The excretion of the organic material accumulated in the body is a very slow process. The individual tollerance differs very much and depends amongst other factors on the diet. In times of malnutricion the fat layers diminish and the chance for poisoning increases. This process is very well know in Northern countries when birds die due to the winter diet which is not sufficient to keep the concentration of the insecticide in the fat tissue on a safe level.
The application of these chemicals around water pipes hence is a tricky business. The dangers are very well illustrated by the Safe Drinking Water Comittee in 1977; "These are the most hazardous of all pesticides because of their persistence, fat storage and central nervous system target site . . .
Human illness and death have been observed after poisoning during manufacturing, spraying or accidental ingestion of the cyclodiens (i.e. Aldrin, Chlordane). Typical symptoms of poisoning result from stimulation of the central nervous system and include headache, blurred vision, diziness, slight involuntary muscular movements, sweating, bad dreams, and general malaise. More severe illness is characterized by jerking of the muscles or groups of muscles and epileptoform convulsions with loss of conciousness, involuntary incontinence of urine and feaces, disorientation, personality changes, psychic disturbances and loss of memory. Such seizures may reoccur for 2 to 4 months after cessation of exposure and are marked by abnormal encephalographic patterns. These symptoms of severe poisoning have developed in 10-20% of the spraymen working in WHO-House Spraying Programs, and such poisoning has not been eliminated in any program. The results of chronic feeding of the cyclodiens to laboratory animals are extraordinarily severe. The daily intake of

Dieldrin and Chlordane also increases the probability of cancer."In the light of the above and taking into account the carcinogenic risk it is suggested that very strict criteria should be applied when limits for Dieldrin and Chlordane in drinking water are established."Before a limit for Aldrin can be established more toxicological data must be gathered and evaluated" True no-adverse effect dosages, for chronic feeding of Dieldrin and Chlordane, have never been determined, according to the Drinking Water Committee.
In the past some drinking water standards were recommended for the concentration of Dieldrin, Aldrin and Chlordane in drinking water.
Ettinger and Mount (1967) suggest,

Aldrin	0.25 ppb
Dieldrin	0.25 ppb
Chlordane	0.15 ppb

In 1968 the U.S. Public Health Service Committee recommended.

Aldrin	17 ppb
Dieldrin	17 ppb

The World Health Organisation suggests a maximum daily intake of Aldrin and Dieldrin of 0.0001 mg/kg. body weight.
For a person of 60 kg. who uses three liter water daily, a concentration of Aldrin and Dieldrin in the drinking water of

Aldrin	2 ppb
Dieldrin	2 ppb

would be the maximum allowable concentrations.

4.3.1.1.2. Water quality in the bamboo pipe water supplies

Water samples of the Bamboo Pipe Water Supplies were analysed in May 1980 both at the Tropical Pesticides Research Institute, Arusha (Tanzania) and in the Netherlands at the Delft University of Technology, the Department of Chemistry.
Water was sampled at the intakes of the water supplies, where fresh surface water was collected and along the bamboo pipeline at domestic points of the Aldrin treated pipeline.
The five liter samples were transported in plastic containers.
The results of the analysis are shown in Table 2.

Table 2

Aldrin and Dieldrin contamination of drinking water in Bamboo Pipe Water Supplies and of surface water.

Village	date of sampling	time of sampling	length[1] pipeline	date of[2] treatment	Dieldrin ppb	Aldrin ppb
A[3] Mgama	7.12.79	10.00	0(intake)	July/	.193	0.01
D (Iringa)	5. 4.80	12.00	0(")	Nov. '78	NIL	NIL (4)
A	7.12.79	6.00	2100		.270	0.01
A	7.12.79	10.00	2100		.174	NIL
A	7.12.79	6.00	3300		.330	NIL
A	5. 4.79	6.00	3300		.370	.014
A	7.12.79	6.00	4000		.094	NIL
D	7. 4.80	6.00	4000		NIL	NIL
D	5. 4.80	12.00	4000		NIL	NIL

Table 2 (continued)

Village	date of sampling	time of sampling	length pipeline	date of treatment	ppb Dieldrin	ppb Aldrin
Likuyufusi						
A(Songea)	22.11.79	17.00	0(intake)	Sept. 1977	.310	.080
A	23.11.79	6.00	550		.017	.010
A	22.11.79	17.00	550		.197	.006
A	22.11.79	6.00	1060		.160	.004
A	22.11.79	17.00	1060		.004	NIL
Nyakipambo						
A(Iringa)	27.11.79	15.00	0(intake)	April/ July 1978	.240	.009
Nyanzwa (Iringa)	7. 4.80	16.00	0(intake)	June/	.500	.070
	7. 4.80	16.00	7600	Sept. 1979	NIL	NIL

1) Length of pipeline in meters between intake and sample point
2) Period of application of insecticide to the trench
3) Laboratory, A=Arusha, TPRI; D=Delft, University of Technology.
4) This water sample contained another unindentified chlorinated insecticide.
5) The bamboo pipes in Likuyufusi are coated with bitumen.

Examination of Table 2. unveils that the Aldrin and Dieldrin contamination in the bamboo pipe water supplies is below the recommended levels of U.S. Public Health Committee standards and below the World Health Organisation standard (when we neglect the intake of these insecticides through foodstuff). In three drinking water samples the concentration of Dieldrin is higher than the proposed value of Ettinger and Mount (1967) of .25 ppb.
More alarming is the high concentration of the watersamples of surface water in the four villages. If these fugures are representative for the surface water of rural Tanzania, than we expect a serious contamination of surface water in Tanzania with insecticides. The contamination of surface water in dense populated agriculture areas and urban areas is probably worse, because the four villages we investigated are in remote areas.

Mr. Madati, the Chief Chemist of the Tanzanian Governemental Laboratory already warned this year in an interview for the unlimited import of pesticides which are restricted or prohibited in Western Countries and therefore dumped on Third World markets is not only a threat for the Tanzanian Environment but also for the Consumers in Western Countries through the agriculture products from the Third World.
A repetition of our tests is most desirable, with proper sampling methods and large scale sampling the seriousness of the contamination of surface water has to be determined.
According to the available data it seems that the contamination of drinking water with Aldrin and Dieldrin is less in bamboo pipe water supplies compared with the surface water.
The Aldrin treatment of the bamboo pipe line is acceptable as a temorary solution for the protection of the bamboo.

The contamination of drinking water in bamboo water supplies treated with a Chlordane soil treatment is not yet investigated.
These analysis will be included in the research program.

4.3.1.1.3. Conclusion of chlorinated hydro carbon soil treatment

Although no technical danger of drinkwater contamination was proved, the use of pesticides should be abolished. The introduction of pesticides in rural tropical areas should not be supported by the project because of the environmental dangers of the chlorinated hydro carbons. The complex toxic aspects and the environmental effects are not well understood and with the limited research facilities in Tanzania it will be difficult to control the use of these pesticides. The awarenes of the dangers of the pesticides among the project workers is nihil; careless handling of the pesticide Aldrin was observed in Mgama village. The 'sprayman was covered by Aldrin-dust, not realizing that the contact with the skin with Aldrin dust is as dangerous as oral intake of the harmless looking powder. The amount of Aldrin and Chlordane used by the project will be negligible in comparison with other applications of the pesticides as for instance for agricultural purposes. Nevertheless I do not support the introduction of Aldrin protected bamboo water pipes which minimize the public health advantages of piped water for domestic use. The water quality control in the existing bamboo water supplies treated with Aldrin or Chlordane has to be continued of course.

4.3.1.2. Saw dust soil treatment

In some tropical countries the roof-beams and ceilings houses are protected against termites by a layer of saw-dust impregnated with Dieldrin solved in pentachlorophenol on top of the walls (Scorrer DDC, 1978). The idea of using saw-dust was transformed to the case of the bamboo pipe protection and resulted in the application of saw-dust impregnated with chromated copper arsenate (CCA) around the bamboo pipe. The selection of CCA salt as a preservative is discussed in section 4.3.2. The idea is similar to the Aldrin soil treatment. The toxic and distasteful saw dust discourges the insects (termites) to approach the pipe. The saw dust treatment will only be effective against insects. Whether the treatment will give a durable protection is uncertain. It depends on the fixation of the preservative and the reaction of the insects. The major advantage of this soil treatment is the use of inorganic, naturally ubiquitous chemicals without environmental hazards. Some minor tests were carried out to investigate the possibilities of the saw dust CCA treatment. A 46m. bamboo test pipe was treated with a saw dust layer. The amount of saw dust per m. pipe lenght was 6-7 lt., and the layer was about 5 cm. of thickness as is shown in figure 22.

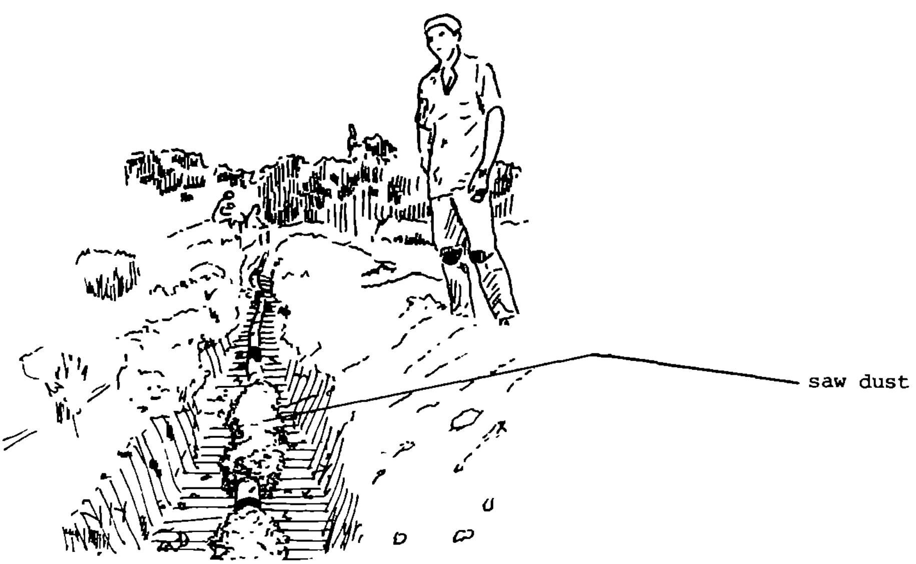


figure 22. Bamboo testline with CCA treated saw dust envelope

The saw dust was taken from the Sao Hill Saw Mill (Iringa Region), where much pine is processed and impregnated with a 16% solution of CELCURE (a CCA salt), which is done by submerging it in a tank for 12 days. The fixation period for the CCA in the saw dust was 12 days before the saw dust was applied around the pipe. Both the concentration of the solution and the time for impregnation can be diminished. A concentration of 4-5% CCA and a submerging period of 2-4 days should be sufficient for optimal impregnation.
The fixation period of two weeks or more will give an optimal fixation of the salt (Dahlgren 1975). The fixation and impregnation of the CCA salts will be discussed in section 4.3.2. The preservation of saw dust is said to be different from log timber preservation (Evans 1978) with other leach and fixation characteristics. Due to the proportion of end grain per unit surface area and the size of the saw dust specimen the leaching from saw dust will be more intensive than that from logs and culms. The change of contamination of the drinking water by copper, chrome or arsene was tested on the research plot of the project. The 46m. test pipe protected with the treated saw dust was closed for several periods to create an extreme situation for contamination. The water standing in the pipe was collected for analyses.
There was a neglectable pressure (less than 0,1 atmosphere) in the bamboo.
The results of the test are summarized in table 3. Table 4 shows the standards for the tolerance of the three components in drinking water. For the discussion on this tolerance see section 4.3.2.8.

period of water standing in the pipe	leaching of, Cu mg/l	Cr mg/l	As mg/l
15 days (08.03.79)	0,05	0,20	0,15
2 days (10.03.79)	0,01	0,08	0,17(0,13 *)
17 days (17.04.79)	0,009	0,062	- (0,25 *)
flowing (14.04.80)	0,016	Nil	Nil

* results of 23.11.79

Leaching of CCA in saw dust treated pipe Table 3

	Cu mg/l	Cr mg/l	As mg/l	Remarks
U.S. public health service	1,0		0,01	Recommended
		0,05	0,05	Mandatory limit
WHO	1,0	0,05	0,05	Maximum allowable
International '58	1,5			Exessive limit
WHO European '61	0,05	0,05	0,05	
Tanzania	3,0	0,05	0,05	
Standards for Aquatic life	0,02	0,05	1,00	also for livestock

Standards for Cu, Cr, As in water after Todd, 1970 and Eriksson 1977

Table 4

4.3.1.2.1. Conclusions for CCA treated saw dust

The results suggest that under normal circumstances with running water there will be no danger of water contamination. Further tests on the contamination in long pipelines treated with CCA impregnated saw dust and stagnant water are implemented. No decisive conclusion on the contamination of water in the bamboo pipe surrounded by CCA treated saw dust can be drawn at the moment.

The protective value of saw dust is unknown and the behaviour of termites is hard to predict. The behaviour of various termite species vary from one place to another. It seems for instance that the two species observed in Mgama are less destructive than the species known from Likuyufusi (Songea).
If however the soil treatment with impregnated saw dust is as effective as the Aldrin Chlordane treatment and the fixation of the preservative comparable with the fixation of CCA in wooden poles (see section 4.3.2.), a protection of 10 years or more can be expected in a stable soil with a compact saw dust layer.

The costs of the saw dust treatment are discussed in chapter 5. The facilities for treatment of saw dust such as atreatment tank, should be established nearby a saw mill. A lorry load of saw dust is enough for 3 km. of pipeline protection. Transport in the village is problematic. The saw dust should be kept on the compound of the project in the village to prevent consumption of the treated saw dust by the village stock. Consumption of saw dust is however not dramatic for the health of the animals (Arsenault 1975). Yet it should be avoided.

4.3.2. Impregnation of bamboo pipes with toxic chemicals

The most practical and elegant solution for the protection of the bamboo water pipes is the preservation of the pipes by impregnation of chemicals toxic for wood destroying organism. Preservatives toxic for these organisms are to some extend also toxic ofr human beings. The contamination of the water in the treated bamboo pipe is of course the most sensitive aspect of the use of toxic preservatives. Before we treat this aspect we will make a selection of preservatives suitable for the impregnation of bamboo water pipes. These preservatives should have the following characteristics:

- For water quality control it is necessary to have a preservative with known toxicity and tolerance standards for the contaminated drinking water and the toxic elements should be detectable in Tanzanian laboratories.
- The impregnation of the bamboo culm with the preservative should be feasible
- The preservative has to lengthen the lifetime of the bamboo to make the construction of bamboo water supplies feasible.
  The preservatives suggested for bamboo fence pole protection by Purushotam and others in 1953 are;
- coal tar creosote and fuel oil, 50:50 by weight, In highly termite - infested areas it is preferable to add 1% Dieldrin and in highly decayinh areas also 1% of pentachlorophenol.
- Copper, cupric, chromate composition (ACC)
- chromated zincarsenite (CZA type)
  The utilization section of the forest division (Nangawe 1978) proposed the use of;
- copper naphtenate
- pentachlorophenol.

Creosote, copper naphtenate and penthachlorophenol are not suitable for the treatment of fresh bamboos. The toxicity of these organic preservatives is not completely understood. Creosote for instance has more than fifty toxic components and pentachlorophenol contains dioxine TCDD and benzofuranes, which chemicals increase the propability of leukemia.

The cost of the organic preservatives are high due the use of oil solvents. The last argument against the use of organic preservatives in oil sovents and creosote is the nasty taste and the flavour of the water form pipes treated with oil products.

Three types of inorganic salts are suggested for bamboo protection in tropical regions (Purushotam 1953). We selected Chromated Copper Arsenate (CCA) for the treatment of bamboo water pipes because of its availability in Tanzania and because of the experiences with the salt in wooden cooling towers, wooden storage tanks, wooden water pipes for potàble water and other applications. We mention mushroom trays, playground equipment, tomato and grape stakes, feeding and watering throughs (Arsenault 1975).

4.3.2.1. The preservation of bamboo water pipes with CCA

Three types of CCA salt are available in Tanzania, Tanalith C/106, Celcure A and Boliden K 33. The components of these preservative are $CuSo_4 . 5H_2\ 0$, $K_2Cr_20_7$/or $NaCr_20_7 . 2H_2\ 0$ and $As_20_5 . 2H_20$.

The ratios between the three components are slightly different for the three brands of the preservative.
The CCA is solved in water before it is impregnated in the wood or bamboo. Purushotham suggests a minimum retention of 5-6 kg/m^3 for a 10 to 15 year protection of bamboo fence poles or other applications of bamboo in the open air. (retention of CCA is expressed as dry weight of the chemical in kg. per m^3 bamboo culm material).
The proposed solution strenght of the preservative is between 2.5% (Wimbush 1945) and 10% (Bleyendaal 1978). According to Purushotham, a solution of 8% is the optimal concentration for bamboo impregnation. Plumptre (1964) suggests that a stronger solution result in higher retention of CCA.
We believe however that stronger solutions are only succesful in case of pressurized impregnation, slow diffusion or sapdisplacement processed with high concentrated solutions results in to early cristalization of the salt and consequently blockage of the transport channels before complete penetration of the CCA.

In future the relation of the solution strength with the retention of CCA in the bamboo should be investigated more profoundly.

4.3.2.2. The fixation of CCA in the bamboo culm

The fixation of CCA in the bamboo or wood is a complex reaction dependent on time, pH and temperature.
The presence of water and the amount of water in the bamboo or wood during the period of chemical reactions is important for fixation.
Too rapid removal of water during the fixation period can decrease the rate of crystal growth of CCA components thus increasing solubility of finely dispersed particles and consequently increasing the leaching of CCA.

Loss of moisture itself is not a requirement for adequate fixation, an adequate amount of time at low to moderate temperature (15 - 20°C) is an important requirement for optimal fixation. (Arsenault 1975).
A test carried out by the Project with twelve bamboo samples divided in four groups of equal moisture content, also showed that air drying of bamboos does not improve the fixation on the contrary it decreases the retention of Arsenic and Chromium.
(Wood and Bamboo Research note 9, 1979).

The fixation reaction involves the reduction of hexavalent Chromium to trivalent Chromium with formation of a complex mixture of insoluble Chromates. Some Copper is bound to Chromium and some to wood components. The Chromium fixes the Arsenic preferentially to the Copper but also fixes some Copper.
A higher retention of total CCA salt results in less loss of Copper and Arsenic than lower retention.

The fixation time for Boliden K 33 is dependent on temperature and solution strenght. A four percent solution with a temperature between 15-20^{o}C has a primary fixation period of 6-9 days in treated pine saw dust.
The fixation period in the treated bamboo pipes will be around a month. Control of the fixation is possible with pH measurements the pH increases until all the Chromium is precipitated. By that time all Copper and Arsenic have been precipitated. The maximum pH (4-5.5.) coincides with the fixation of the Chromium.

4.3.2.3. Optimal conditions for CCA fixation in bamboo

During the fixation period only a small amount of culm sap is allowed to evaporate, to avoid extreme shrinkage and consequently cracking of the culm.
The temperature should be moderate, between 15-10^{o}C, for this reason the treated pipes are stored in a shady place in the forest and covered with branches.
The fixation period between the treatment and the desapping and leaching treatment in the river is one mounth.
Excessive drying of bamboo is not necessary and should be avoided. The retention of CCA in the fresh treated bamboos should not be less than 6 kg CCA/m^3 of culm material.

4.3.2.4. The impregnation of bamboo culms

The impregnation of bamboo pipes is tested since September 1978. All suggested treatments were considered or tested and the bamboo samples were analysed with an Atomic Absorption Spectrometer at Governmental Laboratories in Dar es Salaam. For description of the methodology of the analyses we refer to The Analyst (Williams 1972).

The impregnation methods for bamboo are:

- Steeping or dipping: of fresh or saturated bamboos for a month or more, in a preservative. Impregnation takes place through diffusion of the salt from the preservative into the culm sap.
- Soaking : of air dry bamboos (moisture content 10-20%) in a preservative for one month or longer.
- Sapdisplacement : in freshly cut bamboos which are placed in a tin with preservative immediately.
  The evapotranspiration of the bamboo plant results in the impregnation of the preservative in the vascular bundles.
- Hollow bamboo treatment : "The hollow bamboos are hung from the branches of a tree vertically and the topmost nodes are filled with the solution after scratching the inner culm wall with the steel incisor". After an initial period the sap starts flowing form the lower end of the bamboo and later the solution comes out. This solution should be collected for re-use after bringing the solution to the requiered strength.

The upper nodes filled with the preservative should be filled again and again. (indian building 1960).

figure 23

the sapdisplacement method

. Boucherie method : is a more sophisticated application of the sapdisplacement method. The preservative is forced through the vascular bundles of the culm. This process is established through the connestion of the bamboo culm with partition walls intact, with the pressurized preservative. The pressure in the preservative is established either by a handpump or by elevation of the tank.

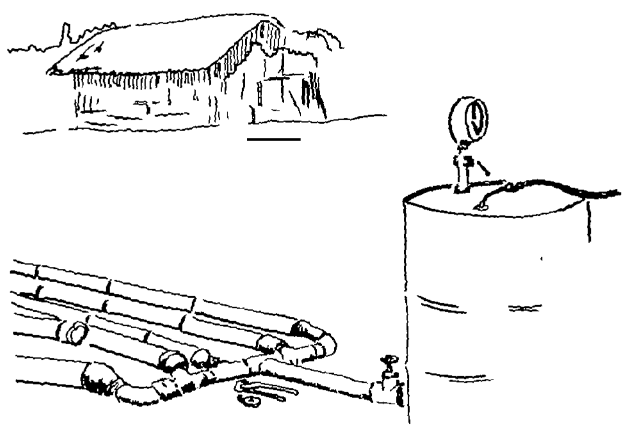


figure 24

Boucherie method

. Pressure treatment : is the most sophisticated and effective treatment of wood and bamboo culms. In a pressure tank the preservative is pressurized and forced into the dry poles or culms through alternate under and over pressures.

. Hot and cold bath treatment : involves the expansion of air in the culm wall during the hot water bath treatment of the bamboos followed by an under pressure as soon as the bamboo is submerged in the cold preservative. During the contraction of the air in the cold bath the preservative is forced into the culm.

4.3.2.5. The selection of suitable CCA treatment of a bamboo water pipe

The impregnation methods succesful with air dry bamboos only, had to be abandoned because we failed to season the Arundinaria Alpina bamboo (section 3.6). These methods include: Soaking of air-dry bamboos
Hot and Cold Bath treatment
Pressure treatment

The Hollow bamboo treatment was not tested because it is too laborious for the scale production of the project.
Steeping of fresh and saturated bamboos in a CCA solution for one month resulted in Copper, Chromium and Arsenic retention almost equal to the retention of these elements through sap displacement (see appendix 2) But the main disadvantage of the steeping method is the crystalization of the salt on the inner and outer culm wall, the workers will touch the salt during transport and installation of the pipes and also the drinking water in the bamboo pipe is in direct contact with the preservative. Steeping impregnation tested on bamboos with all partition walls intact, to avoid contact of the inner culm wall with the CCA was notsuccesful (appendix 2). The pipes were submerged in a three percent solution ofr three months but the penetration through the culm ends was not sufficient.

More succesfull was the sapdisplacement with non-Arundinaria Alpina species. The preservative is transported in the vascular bundles inside of the culm wall and therefore not in contact with the inner and outer surface of the pipe.
The major disadvantages of the sapdisplacement impregnation for the project are the unfavourable weather condition for sapdisplacement impregnation in the mounytainous Arundinaria Alpina forests and the bad longitudinal distribution of the preservative in the culm (appendix 2). Consequently this method is only suitable for bamboos growing in areas with high atmospheric demand and only small sections (about 4 m.) of the culm do have sufficient CCA for long term protection.
In may 1980, the Boucherie method was tested by Johan Lammerink, a Dutch Volunteer working for the Project. Some hundred mountain bamboos were treated with succes (appendix 2). The results of these teste are expected within one year.

4.3.2.6. Conclusions for the CCA impregnation of bamboo

The fixation of the copper, chromium and arsenic in a bamboo culm is related with the method of treatment. (see table 3, appendix 2).
The Boucherie method is suitable for the impregnation of CCA in the Mountain Bamboo used as water pipe.

Sap displacement is suitable for other species but the distribution of the CCA is less favourable in comparison with the Boucherie method.

4.3.2.1. *The leaching of the CCA components in the water pipe*

The research of the Project is for the time being concentrated on the issue of leaching in CCA treated bamboo water pipes.
The lifetime expectation of 10 - 15 years for bamboo fence poles suggests a low level of leaching. Unfortunately we did not find any publications of leaching of CCA elements from treated bamboo.
The performance of CCA treated bamboo pipes under various conditions like intermittent flow, with standing water of after a period with an empty system, should be well understood before the CCA treated pipe is introduced in a village water supply.
For this reason we started tests in the Mgama Test Plot where five test lines were constructed with CCA treated bamboo pipes.
Before we discuss these tests we will review the publications of leaching from CCA treated wood under severe leaching conditions and the toxicity of the CCA components.

"The wood species may effect the rate of leaching. Hard-woods generally do not fix CCA components as well as softwoods". (Arsenault 1975) Other conclusions in the article of Arsenault are summarized below.
" . . the rate of leaching decreases markedly with increase in the size of the specimen and it also decreases when the proportion of end grain exposed per unit surface area leached is reduced". The distribution and concentration of preservative components in the wood may affect the rate of loss.
Higher retentions of total salts of CCA result in less loss of Copper and Arsenic than lower retentions.
Leaching tests with CCA treated piling after 18 years in service at Wrightsville Beach, North Carolina showed that there has been no significant loss of any of the components.
More experiments discussed in the article of Arsenault showed no loss from original retentions. Over time periods of 9 to 12 years experiments with slats from a cooling tower showed a retention of CCA after 10 years varying between 67-82% dependent on the wood specie (Gjovik et al 1972). Dunbar (1962) determined that there was no progressive leaching of CCA in cooling towers and no change of component ratios.

The firms producing the CCA preservatives invest a lot of money and energy to "prove" the perfect performance of their product.
On this perspective we should read the article of Arsenault, technical director of Koppers Company Inc.

But other sources also support the conclusions of Arsenault, Liese (1979) states that properly impregnated wood is no threat for the environment also under severe leaching conditions in contact with flowing water and that properly impregnated and installed wood incooling towers has a estimated lifetime of 20 years.
A ten-years leaching test of the Norwegian Institute of Wood Working and Wood Technology in Oslo, Norway, included the determination of the leaching in nine CCA treated Pinus Sylvestris poles in a continous water flow of fresh water. The impregnated preservatives were Boliden K33 (5 poles) and Tanalith C (4 poles) The results of this ten-years leaching test (Dvans 1978) indicate that:

- There is no leaching of the Chrome component in either of the two preservatives tested.
- There is no leaching of the Copper component in any of the preservatives tested.
- Both preservatives seem to have lost some of the Arsenic component during the first few months of the test (see fig. 25 next page).

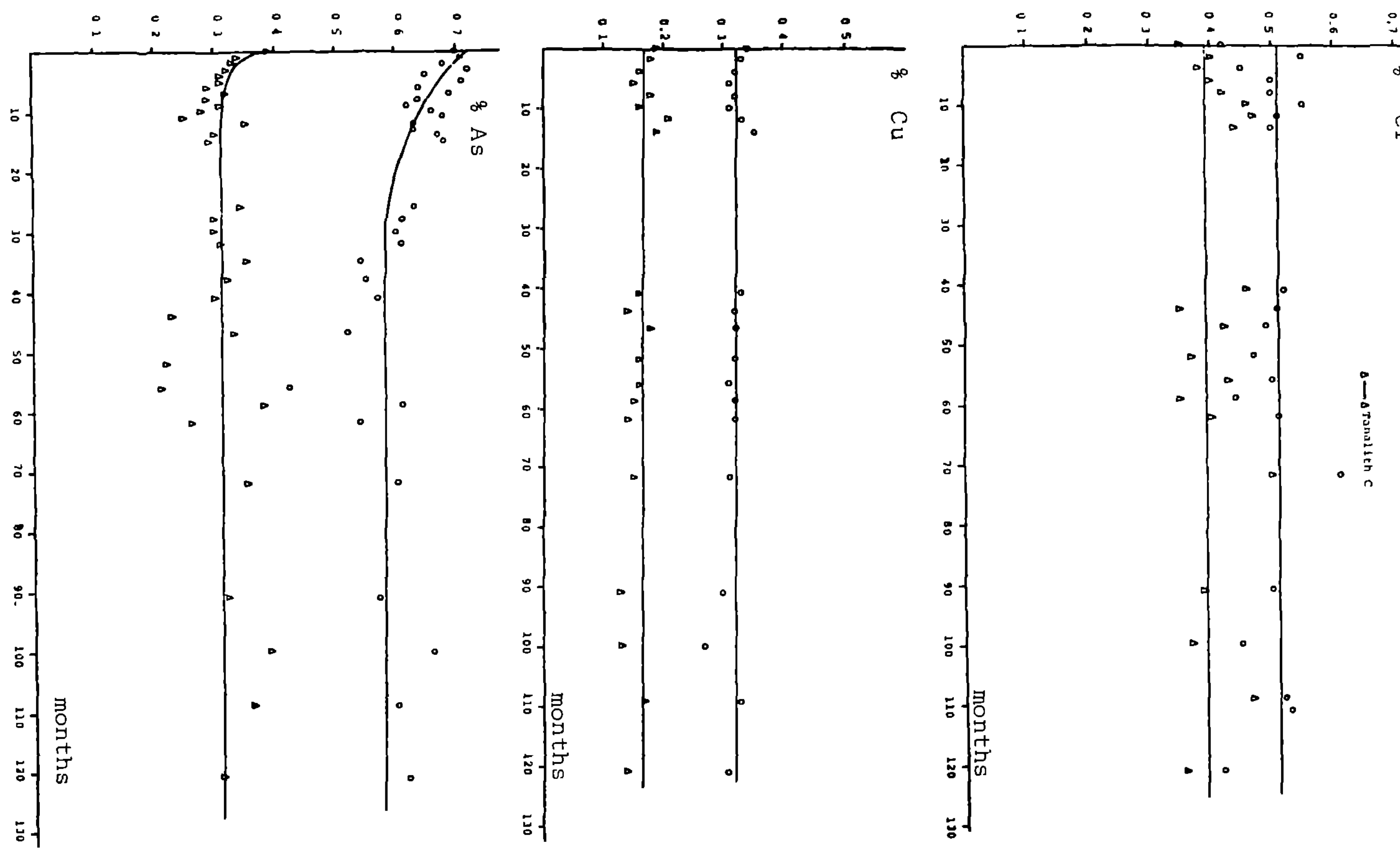


figure 25. The amount of Chrome, Copper and Arsenic in the outmost 5 mm. sapwood in % of dry wood.(Evans 1978)

The rate of leachibility seems to be decreasing with time and the content of Arsenic becomes constant. There is no trend of leaching of Arsenic in the preservatives tested after about 15 months (Tanalith C) and 30 months. (Boliden K33) The leaching of the Arsenic from both preservatives is about 20% of the initial concentration. This means that with Boliden K33 a greater amount of arsenic is leached out than with Tanalith C, because Boliden K 33 has a higher concentration of arsenic.

Unfortunalely the work of CCA impregnated wood has limited value for the research with CCA treated bamboo.
The different cell structure and the different chemical composition of bamboo in comparison with wood, influences the leaching process. The lower retention of CCA in bamboos increase the leaching of the components.

We will have to wait for the results of the current research program with the CCA treated Mountain Bamboo.
The research program was extended and CCA leaching and retention analysis are now carried out in Tanzania and in the Netherlands.

4.3.2.8. Toxicity of the CCA components

For a proper interpretation of the results of the leaching test some insight in the toxic characteristics of the Chrome and Arsenic for human beings, is necessary.
Again we have to consult the paper of the Kopper's Company employee, Arsenault. He argues that in wood preservation trivalent Chromium is the ultimate end product in the wood, the same Chromium form that is a necessary trace element for the existence of life.
This is supported by the Safe Drinking Water Committee (1977) ". . .trivalent Chromium is considered by most investigators to be relatively innocious and even . . . . essential to human health".

Similarly there are differences in toxicity of arsenic compounds and few of them are extremely dangerous. The most widely known toxic form is white arsenic trioxide, As_2O_3.

This form is the trivalent state with an appreciable vapor pressure and extremely irritating characteristics.
In treated wood arsenic is in the pentavalent state the form in which it is ubiquitous in nature. It is in this valence state that Arsenic is naturally found in food, water, soil and living things. The daily intake of Arsenic as a normal constituent in food varies between 0.4 to 1.0 mg and this equals the daily output.
Even the estimated maximum allowable diet intake of 4.84 mg. is matched by the daily output of 4.84 mg.

The allowable concentration of the three major elements in drinking water is according to Tanzanian Standards:

Copper . . . . 3.00 mg/l
Chromium . . . . 0.05 mg/l
Arsenic . . . . 0.05 mg/l

A person consuming three liter water daily has a daily intake of 0.15 mg Arsenic which is 32 times less than the maximum allowable intake when we neglect the intake of Arsenic through foodstuff. (Safe Drinking Water Committee 1977). In case of accidents the maximum allowable concentration of the Arsenic in the drinking water could be as high as 1.6 mg/l, according to the maximum allowable daily intake and a consumption of three liters daily per person.

"Arsenic is non toxic in these low doses, is excreted rapidly and does not accumulate in human tissues. Arsenate (the pentavalent form) is excreted and is not reduced by the body to the trivalent state". (Arsenault).
Tests conducted on the toxicity of treated wood to large animals showed no Arsenic in the livers of sheep fed with 220 mg per day, Arsenault argues that there has been no demonstrable link between Arsenic and any form of tumor or cancer in over 40 animal studies over the years.

The correct application of the Standards for Drinking Water and regular tests will assure the distribution of clean and safe potable water for many villages through bamboo pipes as soon as the leaching from the CCA treated pipes is constant.
The Project workers responsible for the impregnation of the bamboos run more risks than the villagers consuming the water daily. Instruction of the workers and facilities for safe bamboo impregnation should be handled with great care.

4.3.2.9. The measured leaching in CCA treated bamboo pipes

Factors which can influence the leaching of the CCA components in the impregnated bamboo pipe are:

- Method of impregnation of CCA
- Chemical load of CCA in the bamboo culm (kg/m^3)
- Fixation period
- Chemical composition of the transported water
- Length of the treated pipeline
- Diameter of the pipes
- Stream velocity
- Bamboo specie
- The type of CCA

After we had succeeded in the impregnation of some bamboos we used these pipes for the construction of five CCA test lines.
Although we did not keep the above mentioned variables, constant we will draw some conclusions from the results of the leaching tests summarized in Table 5.

Leaching of copper,
According to the Tanzanian Water Quality Standards and the WHO International Standards (excessive limit see Table 4) there is no danger of copper contamination in CCA treated pipe up to 35.0 m. long, even under severe leaching conditions.
Samples were collected directly after installation of the pipes, and from standing water after two weeks.
In seventy nine percent of the samples the concentration of Arsenic, leaching from the pipe was higher than the concentration of the Chromium and Copper elements.
These results coincide with the results of Evans (fig. 27). The Copper concentration of Arsenic increases more in standing water than the concentration of the other elements. (Table 1, appendix 2)

Except for standing water samples there seems to be a tendency of decreased leaching level of CCA components in all the pipes.
The amount of Arsenic and Chromium in the standing water can reach dangerous levels (sample 10.5).

The low figures of testline 1 and 5 are surprising because in both test pipes a fine layer of precipitated salt was observed.
Also the high concentrations in the sapdisplacement test pipe are surprising because there is no direct contact between the transported water and the

preservative, (section 4.3.2.4.)
The higher chemical load of the sapdisplacement test line does not results in a higher level of leaching in comparison with a testline with low CCA concentration like testline two. (table 5).

4.3.2.10. Discussion and Conclusion

The leaching tests with CCA treated bamboo pipes have raised more questions than solved. It seems that the leaching in bamboo is more intensive than the leaching of softwoods.
Allowable leaching levels were registered in most of the test lines.

For the moment we will be brief in our conclusions awaiting the results of the research program of the Project.
Ir. Piet Schreur analyses the leaching in bamboo pipes, CCA impregnated pipes with the Boucherie method and in Tanzania a 200 m. CCA treated bamboo pipeline has been constructed for leaching tests, recently.

4.3.3. The application of a waterproof layer to seperate the drinking water from the toxic preservative

The use of water repellent material in combination with toxic preservatives was suggested in the United Nations Report. (1972).
American Voluteers suggested the insertion of a permeable film liner and the application of protection coatings for the bamboo. (VITA correspondence 1979).

The application of a water repellent material like parafine and waxes on the inside of the bamboo was considered. We rejected the idea because the application of the parafin inside of the culm will be very complicated and in case it is possible to produce a water proof layer it will probably not be effective for a long period due to mechanical wear.

The solution proposed by American sources are very sophisticated, a polyvinyl chloride film liner is inserted in the bamboo culm.
The 0.003 mm film liner is sealed by heat.
An alternative to the polyviny-chloride is a coating with epoxy resins cured with long chain fatty acid derivates, (UNOX series resins), this is proposed as a low cost highly flexible resin system. The costs of the suggested material will make the bamboo pipe more expensive than the plastic pipe, in Tanzania.

4.4. Soft rot

A specific threat for wood under very moisty conditions, for instance in cooling towers, is the attack by soft rot. For bamboo water pipes we can expect a similar decay.
We will briefly discuss the soft rot in wood for a better understanding of this decay.
Levy, Dickinson and Sorkoh (Swedish Wood Preservation Inst. 1976) state "where failure occured in properly treated poles it has invariably been shown to be due to soft rot of the treated sapwood at ground line". They continue that these attacks lies with the specie rather than the type of preservative used. The soft rot caused decay of the hardwood leaving the ray - parenchyma unattacked and had no effect on the softwood.
According to the authors the distribution of the preservative in the wood tissue is determining the attack by soft rot, in softwood there is a more or less equal distribution of preservative which guarantees protection against soft rot, in hardwoods there is a accumulation of the salt in the rays and vessels which are consequently not attacked.

Table 5
Leaching of Cu, Cr and As in CCA treated bamboo pipes

Testline 1: treatment . . . . steeping (67 days)
in 5% solution of Tanalith C/106
fixation of the testline 2.65 m.
Specie: Arundinaria Alpina

no. of sample	date	[1]discharge (m^3)	[2]Cu mg/l	Cr mg/l	As mg/l
1.1.	17. 1.79	0	0.198	0.562	0.50
1.2.	18. 1.79	standing(23 hrs)	1.338	9.281	10.60
1.3.	19. 1.79	standing(8 hrs)	0.647	0.700	2.90
1.4.	24. 1.79	53.0	0.018	0.021	0.09
1.5.	26. 2.79	110.0	0.015	0.021	0.03
1.6.	9. 3.79	standing(240 hrs)	0.123	0.156	12.35
1.7.	4. 4.80	112.0	Nil [3]	Nil	Nil

Testline 2: treatment . . . pressure treatment (2.30 hr)
in 1.5% solution of Tanalith C/106
fixation period for the CCA = 36 days
length of the testline 9.8 m.
specie: Arundinaria Alpina

no. of sample	date	discharge(m^3)	Cu mg/l	Cr mg/l	As mg/l
2.1.	17. 1.79	0	0.015	0.028	0.04
2.2.	18. 1.79	standing(34 hrs)	0.006	0.015	8.00
2.3.	20. 1.79	standing(8 hrs)	0.355	0.403	2.50
2.4.	24. 1.79	44.0	0.093	0.159	0.55
2.5.	26. 2.79	104.0	0.044	0.053	0.33
2.6.	9. 3.79	180.0	0.450	0.868	0.01
2.7.	5. 4.79	215.0	0.010	0.009	

Testline 5: treatment . . . . .steeping of saturated bamboos (67 days)
in 8% solution of Celcure AP
fixation period, no
length of the testline 21.9 m.
specie: Arundinaria Alpina

no.	date	discharge(m^3)	Cu mg/l	Cr mg/l	As mg/l
5.1.	17. 4.79	7.5	0.021	1.003	0.05
5.3.	13. 8.79	flowing(96 days)	0.053	0.010	Nil
5.4.	20. 8.79	standing(3 day)	0.010	Nil	0.23

Testline 9: treatment . . . . hot and cold bath (1 hour)
in 8% solution of Celcure AP
fixation period for the CCA = days
length of pipe 22.5 m.
specie: Arundinaria Alpina

no.	date	discharge (m^3)	Cu mg/l	Cr mg/l	As mg/l
9.1.	28. 2.79	0	0.033	0.288	0.24
9.2.	10. 3.79	3.0	0.033	0.043	0.14
9.3.	17. 4.79	standing (17 day)	0.189	0.050	0.19
9.5.	13. 8.79	flowing (96 days)	Nil	Nil	Nil
9.6.	22. 8.79	standing(2 days)	0.014	0.400	0.170
9.7.	4.4.80	flowing	0.012	Nil	Nil

Testline 10: treatment . . .sapdisplacement (2-7 days)
in 8% Celcure AP solution
fixation period for the CCA = 5 - 11 days
length of the testline 35.0 m.
specie: Oxythenantera Braunii

no.	date	discharge (m^3)	Cu mg/1	Cr mg/1	As mg/1
10.1	2. 3.79	0	0.043	0.153	0.37
10.2	8. 3.79	1.9	0.013	0.043	0.09
10.3	10. 3.79	2.9	0.032	0.065	0.13
10.4	28. 3.79	standing (18 day)	0.233	0.696	1.43
10.5	17. 4.79	standing (16 day)	0.436	13.437	14.80

1) The stream velocity of the water is between 0.01 - 0.40 m/s
2) The concentrations of Cu, Cr, and As in the water used for the experiments are, 0.006, Nil. Nil.
3) Nil is a concentration below the detectable level of the chemical analysis, i.e. for Cu = 0.005 mg/l;
for Ce = 0.005 mg/l; for As = 0.020 mg/l.

Insight in the micro distribution of the wood preservative in the bamboo tissue impregnated by means of Boucherie or Sapdisplacement will be necessary to predict the change of soft rot in CCA treated bamboo pipes.

4.5. Conclusions of Chapter Four

The use of toxic chemicals is necessary for the protection of bamboo water pipes in areas with termite infestation, at the moment.
The lifetime of the pipes can be extended to 10 years or more according to the experiences with treated bamboo fence poles.

The Boucherie method is the most appropriate impregnation method for CCA impregnation of bamboo water pipes, because it can be adapted to scale production of bamboo water pipes and because the treatment gives a uniform radial and longitudinal distribution of CCA in the bamboo culm.

A saw dust envelope treated with CCA, around the bamboo pipeline is a promising alternative for the CCA impregnation of the culm.

We advise to abolish the application of persistent insecticides for the protection of bamboo pipes, these chemicals disturb natural chemical processes to an unknown extent.
Once more we want to emphasize on the control of the surface water in rural Tanzania, now we determined chlorinated hydro carbons in some streams.

5. COST ESTIMATES

5.1. Introduction

A Swedish consultant estimated the costs of an untreated bamboo pipeline in the village of Kayenze (Mwanza District). These costs were compared with the prices of a one and a half polythene plastic pipe. The conclusion was ". . . that if we take only one joint per metre for replacement we need a lifetime of more than four years to make the bamboo pipe cheaper" (Wooden and Bamboo Pipes for Water Schemes 1977).

A review of these cost estmates will be necessary because most of the variables changed:

. The transport costs for the new schemes have to be included in the calculations.
. Prices changed, the price of plastic has been raised almost 300% since 1977.
. The costs of the various protection methods of bamboo pipes were not included yet.

The alternative pipes for rural water supply compared in the cost estimates are:

. Bamboo pipes protected by a 0.5% Aldrin soil treatment.
. Bamboo pipes impregnated with CCA wood preservative.
. Bamboo pipes protected by CCA treated saw dust.
. Plastic pipes of one and half incn polythene (P.E.), Class B.
. Plastic pipes of two inch polythene, Class B.

5.2. Costs

5.2.1. The financial costs per meter pipe

The results of the calculations, worked out in appendix 3, are shown in Table 6. The financial costs of five selected schemes are compared.

Conversion to annual costs results in the costs of Table 7. For the annual costs we add the depreciation costs plus the interest costs. Two extreme situations are considered, one village scheme is situated nearby the bamboo forest and the expected lifetime of the pipeline in the village is 15 years.
The second situation is a scheme 50 kilometers drom Dar es Salaam, where the bamboo pipe line has an expected lifetime of 2 years. The plastic pipes are bought and collected in Dar es Salaam (DSM).

Table 6

The financial costs per meter pipe for various pipe material in Tanzanian Shillings (TSH) in five selected schemes.

distance to DSM	distance to forest	Aldrin	CCA imp	Sawdust	P.E.1.5."	P.E.2.0."
300 km	550 km	11/26	10/81	12/06	18/96	25/07
950	100	9/05	8/60	9/85	19/68	26/96
1050	500	11/02	10/57	11/82	19/93	27/30
1150	400	10/55	10/10	11/35	20/18	27/59
50	900	12/99	12/54	13/79	17/48	24/34

(the forest is in Mbeya district)

Table 7

Annual costs of bamboo and plastic per meter (July 1979)

Location/lifetime	Aldrin	CCA imp	Sawdust	P.E.1.5."	P.E.2.0."
100 km to forest lifetime 15 yrs.	1/42	1/34	1/55	3/08	4/23
50 km to DSM bamboo 2 years plastic 15 yrs.	7/67	7/39	8/14	2/74	3/41

5.2.2. Economic valuation

The financial costs do have a limited value because they do not discriminate between local and foreign labour nor products.
Capital investment in bamboo pipelines is mainly re-distributed in the local economy while the capital for the polythene pipes is partly absorbed by the German owned Plastic Industry. To estimate the extend to which local resources are utilized, we adjust the financial costs to "resource or economic cost" Adjustment of the financial costs of one meter pipe according to the economic criteria mentioned in appendix 3, change the figures of Table 6 into the economic costs of Table 8.

Table 8

Economic costs per meter pipe in five selected schemes

distance to DSM	distance to forest	Aldrin	CCA imp	Sawdust	P.E.1.5."	P.E.2.0."
300 km	550 km	18/47	17/23	19/41	29/12	45/79
950	100	13/77	12/53	14/71	32/51	53/86
1050	500	17/94	16/90	18/88	33/08	55/22
1150	400	16/95	15/71	17/89	33/57	56/41
50	900	22/13	20/89	23/07	27/84	4265

According to Table 8 the bamboo pipes are always cheaper than polythene pipes at any location in the country. However in Table 8 we assume an equal lifetime for plastic and bamboo, what has not been proved yet.
It will be interesting to know how long a bamboo pipe should operate to become competative with plastic, this period we will refer to as "The economical lifetime" of the bamboo pipe.
This economical lifetime is depentend upon the location of the village scheme, the method of protection of the pipes and the size of the pipe. In order to determine the economical lifetime we first calculate the Annual Economic Costs (A.E.C.) per meter pipe of all the different pipes based on lifetimes between 2 and 15 years for the bamboo pipe and 15 years for the plastic pipes. The relation between the A.E.C. and the distance from the collection point of the pipes to the site is illustrated in figure 26
To determine the economical lifetime of a bamboo pipe supply somewhere in Tanzania we composed figure 27. The distance from the water supply to the forest and to Dar es Salaam are related to the economical lifetime.
For example, in Nyakipambo (=N in the figure) located 250 km. from the forest and 700 km. from Dar es Salaam,a bamboo pipe protected by aldrin will be economical after 5 years in comparison with a one and half inch polythene pipe. If the villagers install a two and half inch bamboo pipe comparative with a two inch polythene pipe, it will take only three years for the bamboo to be economical because of the significiant price rise with increasing diameter.

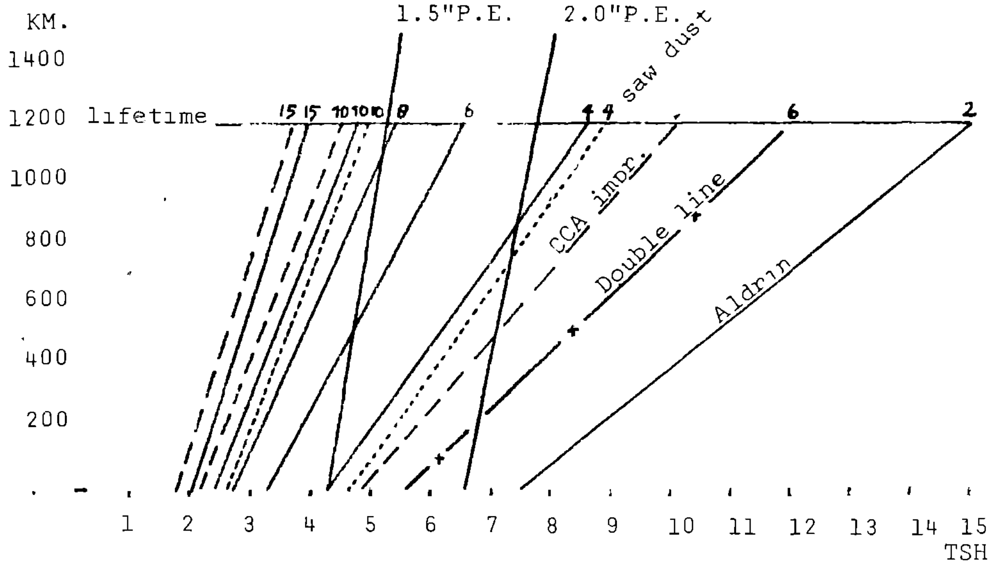


figure 26. Costs (economic valuation) per meter bamboo and per meter polythene pipe in relation to the distance from the collection point to the site and to the lifetime and method of preservation.

CCA impregnated bamboo pipes have to operate four years to compete with a plastic one and half inch pipe, in Nyakipambo.

A village nearby Dar es Salaam (=D in figure) is less favourable for the bamboo here it takes nine years to become competative, for an aldrin protected bamboo pipe.

The effect of the transport costs on the meter price of the bamboo pipe is well illustrated in figure 27.A village some 30 km. from Arusha, in the North of Tanzania can obtain the bamboos from the Mountain Bamboo forest on the slopes of Mount Meru also nearby Arusha instead of transporting the bamboos from Mbeya in the South of the country. The Aldrin treated pipes from Mount Meru have an economical lifetime of 3 years while the bamboo pipes from Mbeya have to operate for 8 years before the bamboo pipe system is economical in comparison with a one and half inch polythene pipe system in this village.

The "economical lifetime" of bamboo water pipes in various villages are summarized in Table 9.

Table 9.

Economical lifetime of bamboo pipes compared with one and a half inch and two inch polythene pipes (years).

Village	Forest km	DSM	Aldrin/p.e. 1.5"	Aldrin/p.e. 2.0"	CCA/p.e. 1.5"	CCA/p.e. 2.0"	Sawdust/p.e. 1.5"	Sawdust/p.e. 2.0"
Mgama	400	550	5-6	3-4	5	2-3	6	3-4
Nyakipambo	300	700	4-5	3	4	2	5	3
Lupalilo	375	850	5	3	4-5	2-3	5-6	3-4
Likuyyfusi	550	1050	5-6	3-4	5	2-3	6	3-4
Nyanzwa +)	575	400	6-7	3-4	6	3	7	4
Kayenza +)	650	1250	5-6	3-4	5-6	3	6	3-4
Rangi Tatu	900	50	9-10	5	9	4-5	10	5-6
Arusha village ++)	930	689	8	4-5	7-8	4	6-7	5
Arusha village ++)	50	680	7-4	2-3	3-4	2	4	3

+) Bamboos from Kigoma Forest ++) Bamboos from Mount Meru

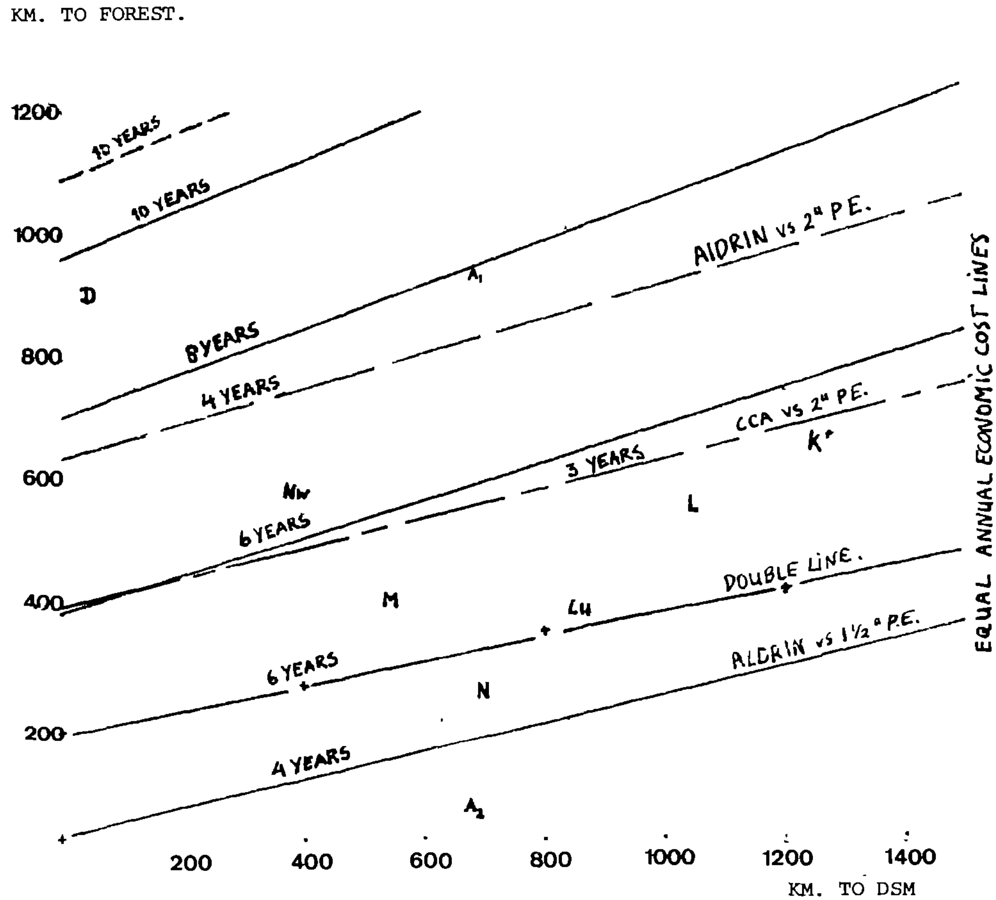


figure 27. Location of the village water supply related to the economical lifetime of bamboo pipes.

An alternative we did not yet discuss is the use of a double bamboo pipeline instead of a two inch polythene pipe, this double pipeline has been established in some villages.
In figure 27, the equal A.E.C. line of two, one and half inch (internal diameter) bamboo pipelines is drawn. The double line is compared with a two inch polythene pipe. The economical lifetime of this alternative is between 6-9 years in most of the villages. More interesting is the use of a double two inch bamboo pipe line instead of a three inch polythene pipe.

5.3. *Conlcusions*

There are four variables of importance for the economic evaluation of the use of bamboo water pipes:

. Lifetime of the bamboo pipe
. Price of the plastic pipe
. The discharge through the bamboo pipe (diameter, wallroughness)
. Transport cost (length of transported bamboo pipes) .

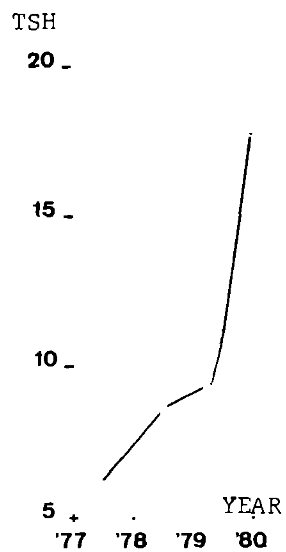
5.3.1. *Lifetime*

Dependent on the lifetime of the village water supply a minimum lifetime is required for the bamboo pipeline to become cheaper than plastic.
For a two inch bamboo pipe this period varies between 3-9 years if the bamboo is impregnated with CCA. Protection of the bamboo for a period of 10 years makes the bamboo 10 to 60 percent cheaper than plastic (prices of July 1979). Although we saw that a bamboo lifetime of 2-3 years is economical feasible in some villages, it is not advisable to construct these short-life bamboo water supplies. The enormous amount of labour required for the construction, maintenance and renewal of the short-life bamboo water supplies would limt the scale of the Project significantly. The villages would have an unreliable and irregular water supply. The villagers will oppose such a project. A lifetime of 10-years is a minimum for succesful implementation of a bamboo water supply scheme.

5.3.2. *Plastic price*

The plastic price has risen almost 300% since 1977 (fig. 28) With the present oil crisis, the price is not likely to stabilize in the near future. Consequently the "economical lifetime" of bamboo pipes will decrease in future. In fact the increase of the plastic price from 11/20 TSH for one and half inch, Class B polythene pipe (July 1977) to 17/80 in January 1980, decreased the calculated "economical lifetime" of this Chapter already. The price of the one and half inch polythene pipe in January 1980 is comparable with the price of the two inch polythene pipe in July 1979. (see Table 9).
This price rise results in a reduction of the "economical lifetime" of 40% within one year!

figure 28



The price trend of one and half inch polythene, "Class B".

5.3.3. *The discharge through bamboo pipes*

Because of the exponential rise of the plastic price with increasing diameter of the pipes, it is quite easy for bamboo to compete with two and two and a half inch polythene pipes. The economical lifetime of bamboo competative with two inch polythene is 40% lower than bamboo replacing one and half inch polythene pipes. Instead of increasing the diameter of the pipe, the discharge can be increased. Reduction of the wall roughness of the bamboo pipe (section 3.2.2.) through proper boring techniques makes, the bamboo pipe more competative with polythene. The Project should pay attention both to the selection of big-size bamboos in the forest and the improvement of the boring techniques for the removal of the partition walls.

5.3.4. *The transport cost*

The transport cost weighs heavily on the bamboo pipe costs. These costs can be minimized by selection of village water supplies nearby the forest or by exten-

tion of the number of exploited bamboo forests and by reduction of the loss of bamboos during and after transport.
As long as the bamboo lifetime is not known in a bamboo water supply, it is advisable to implement water supplies near by the forests. Investigations in new bamboo forests could extend the area of "economical bamboo water supplies" as was illustrated with the village near by Arusha (section 5.2.2.).
For the time being we suggest to select schemes not more than 600 km. from the forest corresponding with an economical life-time of the bamboo of 5-6 years (price level 1979) or 3-4 years (price level 1980). Later on more remote projects could be justified depending on the experiences with the durability of the bamboo pipes in the existing village supplies and on the research findings.

Reduction of the transport and storage losses of bamboo has also a positive effect on the transport costs. In this way the length of transported pipe material is increased, reducing the cost per meter transported pipe. To reduce these losses we suggest:

- Careful selection of bamboo before loading, removal of cracked and badly shaped culms.
- Pressure testing (section 3.4.) before transport, to avoid useless transport of unsuitable bamboos.
- Careful and efficient loading of the lorries.

6. OTHER APPLICATIONS OF BAMBOO WATER PIPES

6.1. Bamboo drains

More than ten percent of the bamboos crack before installation. These pipes are useless as pressurized water pipes, but could serve as drains. More applications of this waste material are imaginable for instance in building construction, basket making and other handicrafts.
In case of CCA impregnation of bamboo pipes the destruction of its waste material, the cracked specimen, will be more complicated than alternative application of the bamboo.

Within the scope of this report we would like to concentrate on the application of bamboo pipe waste material for drainage.

The use of bamboo pipes for subsoil drainage has been suggested by Boulle (1961) and in the United Nations Report (1972). The conclusions in the article of Boulle about the application of bamboo in subsoil drainage are quite positive, The estimated lifetime of the system was estimated between 4 to 25 years, it is not clear if these pipes were preserved.
The "Boulle type"of drain is installed by placing the smaller top end of the bamboo into the larger basal end of the succeeding bamboo. A detailed description is given by Boulle (1961).
On the test plot of the Project we tested two alternative types of drain:

- . the "Hole type", suggested in the United Nations Report (1971).
- . the "Split type".

The "Hole type" operate properly for one and a half year now (fig. 29). The "split type" drain is not suitable as drain, the drain was constructed of cracked bamboo culms hold together by three iron wires. The drain pipes were jointed like is shown in figure 29, but even after months no water passed through the drain.

- . Slotted bamboo drains were not tested but could be investigated in future research (fig. 30).

The advange of slotted bamboo drains is an minimal chance of blockage by sediments. Slotted plastic drains are common in subsoil drainage. The size of the slot is around 0.6 mm wide and 25 mm long. Per meter there are about 40 slots.

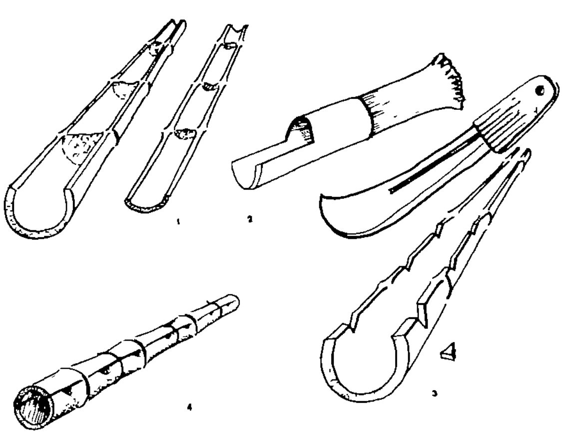


figure 29.
Installation of the "hole type" drain

1) The bamboo is split in two unequal parts.
2) The diaphragms are removed either by a hammer or a chisel with a bended end.
3) Notches, 2 cm wide each, are out in the edge of the bigger bamboo part, every 10 to 15 cm.
4) Connection of the two parts in their original relation, secured by three iron wires.
5) The bottem of the drain trench is covered with gravel or trash material forming the filter envelope for the drainage pipe.

In our test we applied debris of plants, the risk with organic envelopes is the clogging of the drains by fungi.

6) The smaller bamboos are selected fro the upstream end of the drain and the bigger once for the downstream end.
7) The drains are placed in the trench with the holes below the horizontal. the advantage of this system is the uptake of relative clean water because the sediments are most of the time not transported upwards. Blocking of the perforation by soil dropping from above is also avoided. (Key 1960)
8) The first bamboo drain pipe is closed at the upstream end with a piece of bamboo.
9) The joint with the second pipe is established by a two-piece bamboo collar.
10) The installed bamboos are secured against movement during installation at the joints.
    Immidiately after jointing the pipes the joints are covered with the filter material and some soil is dumped on the joint.
11) After a last check on the installed drain, the filter material is applied on the uncovered pipe section.
12) Back-filling of the trench.

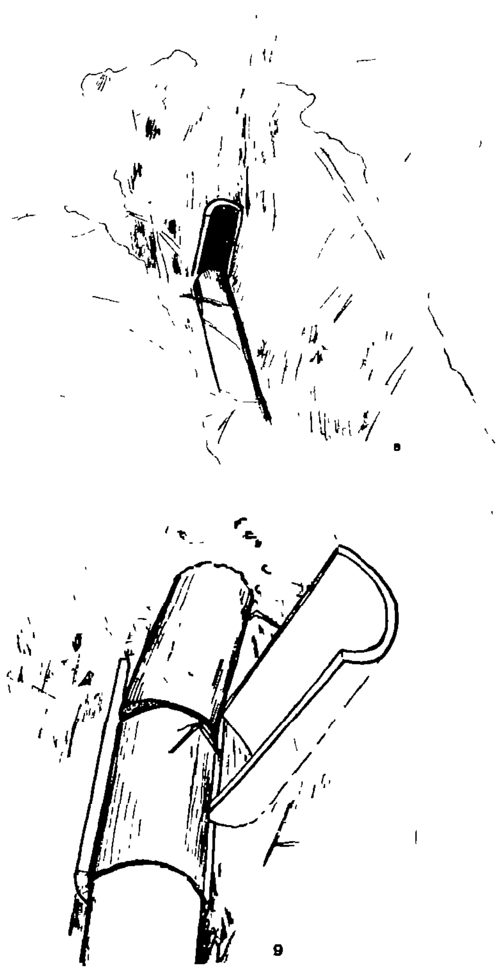


figure 29 (continued)

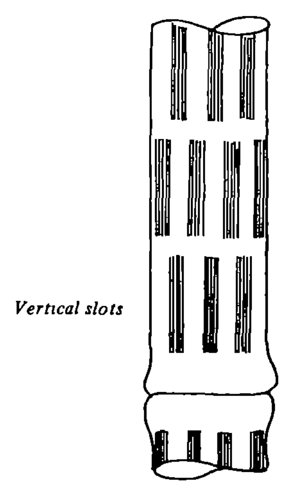


figure 30
The slotted bamboo pipe
(from Appropriate Techn.
vol 5. no. 1)

In an article about well casing and screens of bamboo stalks (Allison 1978) a slot of 0.3 mm is proposed for bamboo. The 0.3 mm slot is made with a 0.5 mm thick blade, the vertical slots decrease after immersion with water by 30% in width according to this article. The production of the slotted bamboo screens and drains with a manually operated slotter is described by Allison.

6.1.1. Conlusion

The performance of the bamboo drains both on large scale (Boulle) and at village level in Mgama (research plot of the Project) proved to be promising. The replacement of plastic drains by bamboo drains results in an considerable saving of Foreign Exchange. The bamboo drain can be produced with waste material locally. Only the preservative has to be imported for the manufacture of the drain.
A comperative test of the "Boulle type", "Slotted type" and "Hole type" of drain would be of interest for the Drainage Development in Tanzania and other Third World Countries.

6.2. Bamboo pipes for irrigation

In Asian and Caribian Countries the use of bamboo for irrigation is quite common. Applications of bamboo are open throughs erected on stalks in gardening, irrigation and drainage of rice basins and the conveyance through bamboo to and on irrigated fields.
The promising results of the experiments with bamboo drinking water pipes induced some preliminary tests with bamboo pipes for irrigation.
The test showed that Arundinaria Alpina did not resist the tempo rate weather conditions in Iringa Region (Mgama). The three test pipes filled with water had all cracked, above groundlevel within three days. The internal diameter of the pipes was around 7 cm.
Six mountain bamboos with an internal diameter around the 10 mm resisted the weather conditions.
The mountain bamboo is consequently only suitable for sub-soil pressure lines in sprinkler irrigation or other pressurized irrigation systems.
In Tanzania experiments with Bambusa Vulgaris irrigation pipes are carried out at the moment.

In Nicaragua an irrigation system was constructed with 2000 bamboos with an internal diameter of 0.5 cm and 535 bamboos with an internal diameter of 4 cm. The system with a pressure of 0.3 atm. irrigates one hectare of grape plants. The bamboos are not burried nor preserved according to the leaflet.(G.R.E.T. 1976).

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APPENDIX 1

Safety Precautions (from Plumptre, 1964).

The following is a list of Safety Precautions drawn up by Messrs. Celcure Ltd. for those handling their salts.

The precautions recommended for Celcure "A" can be applied to all the Copper-chrome-arsenate salts avaible in Uganda for use in the Sap displacements method of pole and post treatment.

If properly handled there is no danger from these salts (certainly less danger than in handling Pentachlorophenol or dieldrin compounds) but the salts contain up to 20% arsenic and a careful control on their use should be exercised.

General. All varieties of "Celcure" other than "Celcure A" contain no arsenic or other poisons normally regarded as dangerous, The chromates which they contain can cause skin irritation and staining if not handled with reasonable care.
The undernoted precautions have been drawn up in conjunction with H.M. deputy Senior Medical Inspector of Factories and should be carefully observed by all operatives handling "Celcure" salts, solutions and treated timber.

Handling "Celcure" salts, solutions and wet freshly treated timber (and bamboo)

1. Before starting work, cover all wounds and abrasions on hands and arms with a clean waterproof dressing.

   Apply a water proof barrier cream to the hands and arms.

   Rubber (not leather or fabric) gloves may by worn as an alternative provided the insides are kept scrupulously clean.

2. Avoid inhaling the dust from salts and wear a light industrial face mask if desired.

3. Obtain prompt first aid treatment for all injuries occurring during work, including washing of the wound and covering with a waterproof dressing.

4. After handling, rinse the hands and any clothing on which salts or solutions have been spilled, in clear running water and then wash with hot water and soap.

Handling and cutting dry treated timber

1. Provide efficient dust-extraction on all woodworking machinery.

2. Collect and burn all sawdust regularly

3. Obtain prompt first aid treatment for all injuries ocurring during work, including washing of the wound and covering it with a waterproof dressing.

4. When applying "Celcure" B to cut surfaces of treated timber fit a rubber flange to the brush handle to prevent the solution reaching the hands.

5. After handling, rinse the hands and arms in clear running water and then wash with hot water and soap.

Additional Precautions necessary when handling "Celcure A"

As "Celcure A" contains arsenic the following additional precautions must be taken -

1. Good washing facilities including hot water, soap and towels must be provided.

2. The plant management must ensure that personal cleanliness is observed by all handling the salts solution and treated timber.

3. Cuts and abresions must be protected.

4. Protective rubber gloves must be worn for handling salts, solutions and solution-wet timber in addition to the use of barrier cream.

5. A dust mask should be worn when emptying salts into the mixing tank. The mouth of the drum should be held near the mixing tank tray and shielded from the wind.

6. Good agitation during mixing is essential.

Table 1 Concentration of Copper, Chromium and Arsenic and the calculated CCA load in the bamboo culm wall. preservatives, Celcure and Tanalith C/106

Treatment	Specie	Sol.[1]	m.c.[2]	treatm.[3] duration	bamboo[4]	loc.[5] sample	Cu mg/gr [6]	Cr mg/gr	As mg/gr	CCA[7] kg/m^3
soaking	Arundin	8%	air	11 days	1	23(cm)	0.20	2.34	1.24	6.30
	alpina	8%	dry	11	2	30	0.59	6.60	5.51	20.16
	Bambusa	8%	a.d.	11	3	30	0.98	17.76	17.55	55.83
	Oxythen.	5%	22%	30	4	0-5	0.68	3.73	1.72	10.67
	Braunii	5%	22%	30	4	10-15	0.34	4.76	2.39	12.49
		5%	22%	30	4	15-20	0.12	1.00	0.41	2.64
		5%	22%	30	4	15-20	0.49	7.47	6.98	23.22
		5%	22%	30	4	25-30	0.42	4.87	4.32	15.13
		5%	22%	30	4	30-35	0.46	6.78	3.39	17.72
		5%	22%	30	4	30-35	0.48	5.52	5.30	17.62
		5%	22%	30	4	35-35	0.77	6.55	6.70	21.90
	Arundin.	8%	a.d.	30	5	12	0.44	1.80	0.83	5.43
	alpina	8%	a.d.	30	6	15	0.54	6.07	3.45	16.67
		8%	a.d.	30	5	80	1.64	15.52	16.22	51.81
		8%	a.d.	30	5	135	1.49	14.95	15.91	50.01
steeping	Arundin	8%	satur-	67	7	15	0.85	5.61	0.65	13.37
	alpina	8%	ated	67	8	20	0.15	1.93	0.09	4.08
		8%	sat.	67	9	30	0.95	5.52	0.57	13.37
		8%	sat.	67	10	70	0.23	4.68	0.43	9.80
pressure treatment	Arundin.	2.5%	40%	1	11	0	1.24	3.52	1.56	11.52
	alpina	2.5%	49%	1	12	5	0.76	1.97	1.09	6.87
	Oreob.	2.5%	-	1	13	0	4.38	24.20	24.60	84.65
	Buchw.	2.5%	-	1	13	5	0.23	0.46	0.24	1.72
	Arund.	2.5%	126%	1	14	7	1.04	2.97	0.85	9.17
	alpina	2.5%	126%	1	15	80	0.98	2.30	0.90	7.83
hot and cold bath	Arund.	8%	a.d.	20 min.	16	5	0.97	2.33	1.76	8.85
	alpina	8%	a.d.	hot	17	5	1.83	3.74	2.75	14.81
		8%	a.d.		18	15	1.21	3.27	1.84	11.31
		8%	a.d.	30 min.	19	45	0.82	2.07	1.15	7.28
		8%	a.d.	cold	20	60	0.40	0.75	0.65	3.17
		8%	a.d.		21	60	0.69	1.34	0.75	5.12
		8%	a.d.		22	120	0.66	1.39	0.70	5.08

Table 1 continued

Treatment	Specie	Sol[1]	m.c.[2]	treatm.[3] duration	bamboo[4]	loc.[5] sample	Cu mg/gr	Cr mg/gr	As mg/gr	CCA kg/m^3
sap	Oxythen.	8%	sat.	7	23	5	1.17	15.63	10.47	43.48
displacem.	Braunii	8%		7	24	35	2.50	7.32	3.17	23.68
		8%		7	25	90	1.19	2.80	1.34	9.80
		8%		7	23	220	2.17	3.89	2.37	15.52
		8%		2	26	265	1.60	2.49	1.42	10.46
		8%		7	23	350	2.01	2.99	1.64	12.60
		8%		7	24	365	0.40	1.82	0.83	5.37
		8%		2	27	370	1.25	1.75	1.28	
		8%		7	25	410	0.15	0.35	0.24	1.31
		8%		7	28	420	0.59	1.28	0.52	4.49
		8%		2	29	650	0.03	0.06	0.02	0.21
		8%		2	29	665	0.25	0.74	0.32	2.39
	Arundin	8%		2	30	10	0.19	1.08	0.24	2.77
	Alpina	8%		2	30	220	0.42	0.45	0.27	2.22
		8%		2	30	370	0.16	0.28	0.13	1.08
		8%		2	30	510	0.11	0.16	0.10	0.69
		8%		2	31	15	0.32	1.29	0.30	3.57
		8%		2	31	130	0.34	0.61	0.24	2.28
		8%		2	31	280	0.16	0.17	0.09	0.83
	Arundin[8]	3%		11	N=8	20	st.dev= 7.56			
							var =49.8			
							mean CCA kg/m3 = 19.80			
		3%		11	N=8	150	st.dev= 0.55			
							var. = 1.83			
							mean CCA kg/m3 = 1.93			
		3%		11	N=8	300	st.dev= 0.15			
							var = 0.41			
							mean CCA kg/m3 = 0.02			
boucherie [9]	Arundin	10%		2 hours	40	20	1.33	2.44		14.0
	Alpina	10%		2 hours	40	130	1.02	2.18		14.0
		10%		19 hours	41	20	1.06	2.57		15.6
		10%		19 hours	41	130	1.06	3.30		15.6

Explanation table 1:

1) solution strength of the preservative in percentage of dry-chemical weight.

2) moisture content of the bamboo during the impregnation.

3) duration of the treatment.

4) number of the bamboo culm used for the sampling.

5) location of the sample expressed in centimers between the impregnated culm end and the sample.

6) concentration of copper, chromium and arsenic in mg. dry-chemical per gr. dry bamboo material.

7) the minimal chemical load of CCA is calculated with the assumption that the preservative contains Na (instead of K) according to:

$$CCA\ kg/m^3 = \frac{(Cu/mg/1 \times Mol.\ Weight\ CuSo_4.5H_2O/Mol.\ Weight\ Cu + (Cr/mg/1 \times Mol.\ Weight\ Na_2Cr_2O_7.2H_2O/Mol.\ Weight\ Cr. + (As/mg/1 \times Mol.\ Weight\ As_2O_5.2H_2O/Mol.\ Weight\ As)}{1.538\ (specific\ gravity\ of\ bamboo\ estimated\ as\ 0.65)}$$

8) summary of some of the samples examined in 1980, it showes that the longitudinal distribution of the CCA in the mountain bamboo impregnated through sap displacement is disappointing.
The CCA content was calculated with the available Cu and Cr concentrations.

9) indication of the uniform distribution of CCA in bouchery treated mountain bamboos, the CCA content is calculated with the determined Cu and Cr concentrations.

10) expressed in kg/m3.
The fixation period for the CCA exceeded two months in all the samples.

Table 2.
Radial distribution of elements in bamboo culm

Treatment	bamboo	Cu (mg/gr)			Cr (mg/gr)			As (mg/gr)		
		A(1)	B(1)	C(1)	A	B	C	A	B	C
soaking	6	3.88	0.10	2.70	21.58	0.45	29.55	11.87	0.27	16.62
	2	0.59	0.20	2.52	13.40	0.83	29.88	5.41	0.25	36.78
	1	0.82	0.15	3.49	8.43	1.56	54.19	2.86	0.49	58.56
hot bath cold bath	21	0.60	0.60	0.74	1.06	0.92	1.94	0.72	0.49	0.82
	22	1.15	0.82	0.85	3.08	1.35	2.53	1.77	0.76	1.11
sap displacem.	25	0.25	0.13	0.15	0.33	0.41	0.52	0.46	0.26	0.19
	28	0.70	0.63	0.38	1.38	1.31	1.08	0.66	0.54	0.39
	29	0.28	0.17	0.65	0.27	0.34	1.97	0.39	0.21	0.58

1) A = saw dust of outer culm layer (less than 1 mm)
B = saw dust of inter section of the culm wall
C = saw dust of inner culm layer (less than 1 mm).

Table 3.
Components ratios of Cu, Cr and As for the various treatments

Treatment	N=	mean Cu/Cr	mean As/Cr	mean Cu/As	var.	st.dev.
hot and	7	0.46			0.003	0.06
cold bath			0.65		0.016	0.14
				0.72	0.019	0.15
soaking	15	0.11			0.002	0.05
			0.75		0.060	0.26
				0.17	0.017	0.13
sap	19	0.49			0.050	0.23
displacem.			0.46		0.20	0.15
				1.13	0.340	0.60
steeping	6	0.37			0.010	0.11
			0.54		0.050	0.26
				0.82	0.110	0.37
pressure	4	0.14			0.001	0.04
treatment			0.09		0.001	0.03
				1.59	0.030	0.19
boucherie	4	0.44			0.007	0.10

abbreviations of bamboo species used in appendix 2.

Arundin. aplina	= Arundinaria Alpina
Oxythen. Braunii	= Oxytenanthera Braunii
Oreob. Buchw.	= Oreobambus Buchwaldii
Bambusa	= Bambusa Vulgaris

Appendix 3

Cost Estimates

The calculation of the financial cost per meter pipe;

1. Estimate the costs of the production and installation of the alternative pipes. These costs include:
   - . labour costs
   - . local material costs
   - . imported material costs

2. Convert these capital costs into annual costs. These annual costs can be divided into three parts.

2.1. operation and maintenance
For plastic pipelines a maintenance factor of 1% is sometimes used (Brokonsult 1977) The maintenance of bamboo pipes will be more time consuming but less skilled labour is required, the villagers themseselves can handle the repairs. For the cost comparison of the alternative pipes we assume equal maintenance costs which will be neglected.

2.2. depreciation costs
Expressed in 1/N of the capital cost if N is the expected lifetime.

2.3. interest costs
The opportunity of the capital are assumed to be 18% which is a rate of 9% during the estimated lifetime of the pipe.

3. Adjustment of financial cost to obtain economic valuation of costs. This adjustment is expressed in the following factors:

3.1. imported materials
Items from abroad become 2.5 times more expensive to benefit local material. This factor is based on the local black market price of foreign currency. In case of local assemblage this factor is reduced according to the local production participation.

3.2. opportunity cost of capital
The above mentioned 18% is rather high to express the scarcity of capital in Tanzania.

3.3. labour costs
The costs of unskilled labour for production of the pipe-systems is expressed in opportunity costs, which is 60% of the money value. In our comparison we do not include the costs of skilled and expatriate labour required for the construction of the alternative pipes, because of the complexity of such a calculation. Although we expect that construction and maintenance of bamboo pipe water supplies requires less skilled and expatriate labour as a village technology project

3.4. transport (=G)
G is expressed in Tanzanian Shillings per km. For a 7 tons Isuzu lorry we assume a price of 3/70 TSH per km. The financial costs for transport Kf = G TSH/km.
For the economic valuation of these financial costs we assume that 75% of the transport is imported material while the rest is local skilled labour and local material. The economic valuation of the transport price is:

$Ke = (0.75\ f_1 + 0.25)\ G$ TSH/km.

f_1 = correction factor for foreign exchange of 2.5

G = 3/70 TSH/km.

One load of bamboo pipes is 2500 m. of bamboo (500 bamboos).
We introduce a loss percentage of 40% to obtain the transported length of bamboo water pipes actually used in the system.
These losses include cracks due to transport, pressure testing and construction.

The average length of bamboo water pipe per load is now 1500, in a 7 tons Isuzu lorry. For the one and half inch polythene pipe we take a length of 3000 meter per load.
The length of two inch polythene per load is 2500 meter.

Two basic variables

Lifetime of the pipes

For the lifetime of the plastic pipe we use 15 years.
This period does not correspond with the lifetime of the plastic material but with the operation period of the plastic pipe system. Twenty year is the assumed lifetime of a plastic pipe water supply in Tanzania but we substract some years for the inproductive years of the system due to shortage of plastic pipe material and spareparts.
The lifetime of the bamboo pipe is uncertain expectations vary between two and 15 years or more. In our calculations we consider lifetimes of 2, 4, 6, 8, 10 and 15 years, for aldrin/chlordane treated pipes, 10-15 years for CCA impregnated pipes and for bamboo pipes with a treated saw dust envelope 4 and 10 years.

Location of the rural water supplies

The price per meter pipe is dependent to a great extent on the distance from the bamboo forest or the plastic factory in Dar es Salaam to the village site

Cost Estimates

The prices of July 1979 are used for the various items.
(the pipes are transported 300 km. from the forest and from DSM)
1. financial costs of bamboo pipes (TSH/m).

. price of bamboo	-/15		
. cutting of bamboo	-/20		
labour unskilled 16/- daily			
30 bamboos (30 x 8 m). /day			
loss 25% before transport			
40% transport etc.			
70% total loss of one culm			
. transport to the site	1/48		
km. price 7 tons Isuzu 3/70			
2500 bamboo per load loss			
40% transported over 600 km.			
is 300 km. from forest			
. manufecture of pipes (material)			
pressure tests, transport in			
the village, desapping (labour	1/-		
removal of partition walls	-/20	-/50 (mechanical)	
reinforcement, 60% of system	1/-		
joints..polythene plus glue	2/80		
rubber			(2/50)
assuming one joint per 3 m.			
. protection of bamboo			
soil treatment 0.5% aldrin	1/20		
CCA impregnation ,8 kg/m3		-/75 (+ transport)	
saw dust treatment (labour + transport)		2/-	

joints polyth. pipes				
material 75% for. exch.+				
glue, 100% for exch.	5/25			
labour 60% money value	-/24			
rubber				
material 75% for exch.				(4/78)
labour 60% of money value				(-/24)
5.5. protection of pipes				
aldrin 100% for.exch.	2/50			
labour 60%	-/12			
CCA 100% for.exch.material		1/25		
labour 60%		-/13		
saw dust 75% for.exch. for transport			1/70	
material 100% for exch. (CCA)			1/50	
labour 60%			-36	
5.6. trenches, labour 60%	1/20			

Total Cost bamboo pipe per meter (economic valuation)

1) Aldrin treatment	15/95			
2) CCA impregnation		14/71		
3) saw dust			16/89	
4) with improved node removal and rubber joints				(14/86)

6. Annual cost of bamboo (economic valuation)

6.1. depreciation, 2 years lifetime	7/98	7/36	8/45
15 years lifetime	1/06	-/98	1/13
6.2. interest 9% of initial value	1/44	1/32	1/52

Total Annual Costs (economic valuation) of bamboo 300 km. from forest:

1) Aldrin treatment, 2 years	9/42		
15 years	2/50		
2) CCA impregnation, 2 years		8/68	
15 years		2/30	
3) saw dust 2 years			9/97
15 years			2/65

7. Economic valuation of plastic price	one and half	two inch
7.1. plastic price 75% for. exch.	23/84	38/25
7.2. labour cost 60% money value	3/60	3/60
7.3. transport cost 75% foreign exchange 300 km. from Dar es Salaam(600 km)	-/74	-/89
7.4. overhead	-/11	-/18
Total Costs (economic valuation) P.E. pipe	28/29	42/92

8. Annual Cost of Polythene pipes (economic valuation) 300 km. from Dar es Salaam:

	one and half	two inch
8.1. depreciation, 15 years lifetime	1/89	2/86
8.2. interest 9% of initial value	2/55	3/86
Total Annual Cost one and hald inch P.E.	4/44	
two inch polythene.		6/72

9. Double bamboo pipe line

9.1. For a double bamboo pipe line the costs of a single line are multiplied by two minus the labour costs of a trench (2/-).
This is. 60 x 2/- for the economic valuation=1/20 TSH.

Appendix 4

Abbreviations used in the text

As = Arsenic
CCA = Chromated Copper Arsenate
Cr = Chromium
Cu = Copper
DSM = Dar es Salaam
P.E. = Polythene
TPRI = Tropical pesticides research institute
TSH = Tanzanian Shillings
TWICO = Tanzanian Wood Indsutry Cooperation
WHO = World Health Organisation.

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