PRACTICAL ACTION
Technology challenging poverty

SMALL-SCALE PAPERMAKING

Introduction

Paper making is a good example of how small industry can be developed to make use of local resources and cater for local markets while keeping capital investment down. This is especially so in countries like India where machinery and equipment is produced in-country.

Figure 1: Range of handmade paper, Bangladesh. Zul / Practical Action.

When considering papermaking, there are many factors to take into account in deciding on the scale, the type of product, the raw materials, the investment and the required skill levels. In addition, there are equally as many non-technical considerations such as environmental issues, marketing and competition, consumer expectations and economics. Together, all these issues will help you decide on the viability of the operation.

Before starting a papermaking enterprise, it is necessary to examine what is currently available on the market and to consider whether it is possible to offer a product which will compete for quality and price. The papers available may be an imported product from the high technology industry. Unfortunately, such imports have conditioned the reactions of the consumers who now believe that writing paper must be ultra white and of a certain texture etc. In practice, it is very difficult for the average person to distinguish quite large differences in the whiteness of papers except by direct comparison. Nevertheless, the larger buyers of paper often specify a certain 'brightness' number, without really understanding what it means. This alone can preclude a local product from the market place as it is frequently not possible to achieve quite such high standards in a small operation. It is therefore essential to consider consumer preferences at a very early stage. The price of the local product may need to be considerably lower to compensate for a (perceived) lower quality.

The market size should also be considered and the proposed output of the operation along with the availability of adequate raw material on a regular basis. Together, these effectively dictate the technology to be employed and this in turn determines the cost of the venture.

Having decided on a size for the operation, the next problem faced is that of finding suitable equipment. There is no difficulty for lager operations making 1000 tonnes of paper per day or more but for the 5 tonne per day plant it is more difficult to find equipment. There are producers of smaller paper production machinery and associated equipment in India. Hand papermaking less equipment. It has enjoyed a major revival over the years, using new and innovative approaches it can produce unique textures and qualities. In addition, the versatility of paper in its wet form has led artists to experiment with paper-making as an art medium, creating two- and three-dimensional images of textural richness and diversity.

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technical brief

It will be obvious from the above that the whole subject of papermaking is far more complex than it would first appear. For the best chances of success, a lot of careful study is needed for starting. Since the subject is so complex and the options are many, no sizable commercial venture should be embarked upon without expert guidance from a specialist consultant experienced in small-scale operations.

Services

When considering purchasing or renting premises for setting up a paper-making facility, care should be taken to ensure that there are adequate services provided at the premises, or that these services can be easily accessed.

One of the main points to consider is the availability of an adequate water supply. The commercial processing of raw material through to finished paper can consume as much as 50 tonnes of water for each tonne of paper produced. If this quantity of water is not available, there is little point in pursuing the project further. Although efficiencies in water consumption are improving, there will always be a need for relatively large quantities of water during the paper making process.

The next consideration is adequate power at the site. Papermaking is also an energy intensive industry, especially when the process is mechanised. This energy can come from a variety of sources such as electricity, wood, oil, gas or coal. This energy is used to provide much of the heat energy required. Crop residues, such as bagasse or rice husks can also be used as fuel. An electrical supply is required in most circumstances to power motors, pumps, lighting, etc. This can be supplied from the mains where the mains is accessible, from a diesel generator set, or from a renewable energy source (such as hydro-power or wind power). Steam raising for the drying process can be carried out using a variety of technologies; oil-fired boiler, steam engine, combined heat and power plants. Careful costing of the available options can bring considerable savings. The energy demand for processing of reclaimed paper is much less that for virgin wood.

In order to understand what might or might not be possible in papermaking it is first necessary to have knowledge of the technicalities of the process. The basic process of making paper involves two stages: the breaking up of raw material (which contains cellulose* fibre) in water to form a pulp (i.e. a suspension of fibres*), and the formation of sheet paper by spreading this suspension on a porous surface, and drying, often under pressure.

This Technical Brief only covers *small-scale* papermaking technologies for application in developing countries. For this purpose we will define scale in papermaking as shown in Table 1 below.

Category	Output (tonnes of paper per day – t.p.d.)
Large scale	More than 100 t.p.d.
Medium scale	Between 30 and 100 t.p.d.
Small scale	Less than 30 t.p.d., including hand-made paper

Table 1: Definition of scale in papermaking
Source: Small-scale papermaking, ITDG Publishing.

Typically, a hand-made paper producer will manufacture only a few tonnes of paper per year often for a highly specialised market. Mechanised plants, on the other hand, only become economically viable when dealing with an output above several tonnes per day.

In India, where paper making machinery is manufactured indigenously, and hence costs are kept lower, mechanised paper making on a small scale is very common. These mills provide higher levels of employment, not only in the mill, but amongst associated industries, such as waste paper collection and machinery manufacture. Smaller mills are more flexible in their acceptance of raw materials.

The product range is also more flexible in small paper making plants, with the ability to cater for a variety of demands, but, sometimes, with a slightly lower quality than that of the larger plants.

Types, characteristics and physical properties of paper

Paper comes in an enormous variety of shapes, sizes, qualities, grades, colours and finishes. Some of the typical characteristics used to determine paper quality are given here. The types of tests that will be carried out on a batch of new paper depend upon the use for the paper.

- Weight in grams per square metre (referred to as gsm or grammage)
- Thickness or calliper (measured in microns)
- Density or bulk (a function of the previous two qualities)
- Tensile strength
- Burst
- Folding
- Brightness / shade
- Porosity
- Smoothness / gloss
- Oil-resistance
- Moisture absorption
- Moisture content
- Optical properties

(adjustable using mineral fillers)

The quality of paper is often controlled by the National Standards organisation in the country concerned. It is always worth consulting these Standards well in advance if contemplating setting up a paper manufacturing facility.

Delivery of raw materials

For economic production of paper there must be a secure supply of suitable raw material at a reasonable price. Fortunately, there are many fibres which are well suited to paper making. In tropical developing countries, where wood is often in short supply there are a number of other sources of fibre, often by-products of the agriculture or textile industries.

It is important to ensure that there is sufficient storage capacity for the raw material. This is particularly important where seasonally available raw materials, such as straw or bagasse*, are used and a large supply will have to be stored for later use.

Raw material

The raw material for all papers is cellulose fibre which comes from a wide range of natural materials. The large scale producers rely almost entirely on fibre from timber although, especially in India, other materials such as bamboo, straws and grasses are also used. The cellulose fibre can also be extracted from such things as waste cotton rags, banana pseudostem, bagasse, - in fact almost anything which has grown naturally. However, the quality of fibres varies a great deal depending on the natural material from which it is collected. The quality, usually assessed according to the length of the individual fibres, is extremely important to the quality of the paper which can be made. A high proportion of long fibres is essential for reasonable paper quality, regardless of scale or method of production.

Figure 2: Mulberry branches used for paper making, Bangladesh. Photo: Zul / Practical Action.

Below are some examples.

Raw Material	Source	Suitability
Straw (e.g. from wheat, barley or rice)	Between 5 and 10% of all straw which is produced is burned.	Short fibred (1.5mm), it is often mixed with other pulp to provide a suitable pulp stock for a variety of uses.
Bagasse*	From sugar cane after the sugar has been extracted.	Slightly longer fibre than straw. Suitable for high quality writing and printing paper.
Maize stalks	Remaining after maize harvest.	The high moisture content and need for collection make maize stalks suitable only for

		very small-scale production. Properties similar to straw.
Bamboo	Grown for use.	Fibre length of 2.7mm, suitable for all types of paper making without addition of other fibre. Supply is often limited.
Cotton	Cuttings, lint and fluff from cotton mills.	Cotton is a high value fabric and is therefore only used for specialist papers. Has a fibre length of 25 32mm.
Rags (from cotton material)	Collected	Often require sorting and bleaching. Common writing paper.
Flax	A residue from the manufacture of linen.	Long fibres make this material suitable for high quality paper.
Hemp and sisal	From old ropes and tow from ropemaking factories.	6mm fibre length, processing similar to that of cotton.
Jute	From old sacks and hessian.	Jute does not bleach well and is therefore used for its strength rather than for high quality grades
Water Hyacinth	Weed	Paper not having adequate strength
Jute and Water Hyacinth		Unique textured paper
Mulberry Bark		Excellent, silky, transparent papers of different kinds
Jute and Hemp		A reasonable good quality paper.

Table 2: Raw materials commonly used for paper production

Recycling waste paper

Using waste paper is the easiest way into papermaking as all the difficult first stages have been done. There is no need for chemical digestion, bleaching and complex screening operations. The waste may only require repulping before being reformed as 'new' paper. Compared with producing a tonne of paper from virgin wood pulp, the production of one tonne of paper from discarded paper may use half as much energy and water.

Figure 3: Water Hyacinth used for paper making, Bangladesh. Photo: Zul / Practical Action.

The clay originally added to the paper to make it glossy will help to separate the ink from the paper during recycling.

There are limitations to recycling that need to be considered. Paper can be recycled only 5 to 8 times before the fibres become too short and weak to be reused. It is therefore essential to use as high a grade of waste as possible as the starting point. From both pulp quality and ink points of view, computer waste is a very useful raw material for the recycler. Old newspapers are commonly used to make tissue and cardboard, while magazines are often recycled into newsprint.

Figure 4: Jute used for paper making, Bangladesh. Photo: Zul / Practical Action.

Waste paper will carry some form of printing which, if not removed, will cause the product to be discoloured. The process of removing the print, called de-inking, is often, not worthwhile for the small-scale operator, involving as it does, even more, expensive equipment. It is a better policy to concentrate on unprinted materials if these can be obtained. Alternatively, paper with as little print as possible should be selected. When the final product is used for packaging it is sometimes acceptable to mask the discolouration due to ink by tinting the pulp to produce a coloured paper. One of the major parts of recycling is the collection, sorting, baling, and transportation of waste paper.

The next step is re-pulping. Industrial production involves disintegrating the bails in a hydro pulper, where they are reduced to individual fibres. Chemicals are added so that ink particles, coatings and additives, and extremely small contaminants such as fillers start to separate from the paper. Depending on the required level of improvement, the pulp is sent through several stages, where heat, chemicals, and mechanical action may be used to further improve the pulp. Finally, the pulp mixture enters a flotation device, where calcium soap and other chemicals are added. Air bubbles in the mixture float the remaining ink and contaminants to the surface as a scum, where it is skimmed away.

The pulp is sent to the stock preparation area, where it is treated and loaded into the flowbox* of a paper machine. From this point, the pulp is treated just the same as if it had been freshly made from any other raw material rather than recycled.

Papermaking

The process of making paper is based on wet cellulose fibres binding together in a random fashion when dried under restraint. The process of paper usually involves the initial separation of the cellulose fibres to form a wet pulp, some form of treatment, such as beating and refining, while in the pulped state, to enhance the quality of the final product, then forming of the sheet paper by hand moulding or by paper making machine, and drying. Some further processing is often carried out before or during drying to acquire the desired finish. The process is similar, whatever the raw material (or mixture of raw materials), and at whatever scale of paper production, but the complexity of the technology involved will vary considerably.

Figure 5: Women stripping mulberry and cutting jute for pulp, Bangladesh. Photo: Zul /Practical Action.

Small scale preparation of materials

In a small scale operation the raw materials, such as rags, are sorted manually to remove buttons, plastic, synthetic fibres and other foreign materials. Then given shaken vigorous to remove the dust and dirt. The rags are sorted and chopped into small uniform sized pieces.

Straw preparation requires the straw to be cleaned to remove dust and then cut into short lengths.

Bagasse will have been reduced to a suitable size at the sugar mill, but the pith will need to be removed. Wood will be chipped to an appropriate size. Specialised equipment is required for this kind of preparation. The material will then usually be transported to the pulping area on a conveyor belt or by hand.

Mulberry bark is prepared by cutting the branches into lengths measuring 6 to 8 inches. The bark is removed from the stem with a knife and the outer green / grey skin is removed from the bark. The bark is then beaten with a wooden hammer by placing it on a wooden block to obtain fibres.

Figure 6: Zohrabanu & Amina boiling mulberry branches for pulp. Bangladesh. Photo: Zul / Practical Action.

Figure 7: Mulberry pulp. Bangladesh. Photo: Zul / Practical Action.

If the bark is already dried then it needs to be soaked in water for 24 hours before pulping.

Use only the long stems of water hyacinth and discard the roots and leaves. The stems should measure 6 to 12 inches. The stems should be cut into small pieces measuring 2 to 4 inches and then left in the sun in the open fir 2 to 3 days to reduce the water content before pulping.

The next step is to weigh the raw material to be pulped to establish the quantity of water and chemicals to be used.

Pulping process

Digestion is the process of removing lignin and other components of the wood from the cellulose fibres which will be used to make paper. Lignin is the "glue" which holds the wood together; it rapidly decomposes and discolours paper if it is left in the pulp (as with mechanical pulping).

With mechanical pulping the raw material is broken down into its individual fibres by grinding (such as newsprint, which is usually made from groundwood* pulp with little or no chemical treatment). This process is not wholly satisfactory, as the fibre are broken into smaller pieces and relatively little lignin is released, resulting in a poor quality, 'woody' paper. The mechanical process is also energy intensive.

Industrial extraction of the fibres is usually done by chemical processes using caustic soda to dissolve away the unwanted material leaving only the useful papermaking fibres. The process uses equipment to boil the material, under high pressure, so that rapid processing can take place. This equipment, the 'digester', must be built by experts, as improvised versions could be extremely dangerous

This stage gives rise to potential problems areas for the paper producer:

- The equipment is expensive.
- The chemicals are expensive and often difficult to obtain.
- The effluent from the process is hazardous and difficult to dispose of.

Hand made paper uses labour intensive preparation of the materials that require less equipment.

Chemical pulping produces a high quality product, although the type of chemical used will determine the properties of the final product:

- Sodium hydroxide (Caustic soda), sodium carbonate (soda ash) or sodium sulphate and calcium oxide (lime) will produce a pulp with coarse, strong fibres (known as Kraft) suitable for strong boxes.
- Ammonia or calcium sulphate will produce a finer fibre suitable for high quality printing and writing paper.

Boiling caustic soda is a very unpleasant chemical.

Raw Material	Caustic Soda (gm)	Water (litre)
Jute (dry)	20-30	10
Jute (raw)	10-15	10
Mulberry Bark (dry)	10-15	10
Mulberry Bark (raw)	5-7.5	10
Water Hyacinth (sun dried)	10-15	2

The resulting solution is poured into a hemispherical pan of cast iron which functions as the pulper or digester. The weighed amount of raw material is then added.

The prepared stock is fed into the top of a digester and mixed with the cooking chemicals, which are called "white liquor" at this point. Digestion may be carried out on a batch or a

continuous basis. For small-scale mills of up to, say, 30 t.p.d., batch cooking is preferred. Batch digesters are able to cope with a variety of stock feeds, for example straw, baggase, cotton and wood, in the same mill. As the stock and liquor move down through the digester, the lignin and other components are dissolved, and the cellulose fibres are released as pulp.

In manual operations a pan containing raw material can be placed on a fire. The cooking times for the manual operation are outlined below. The contents is occasionally stirred with a wooden stick.

Raw Material	Cooking time in hours
Jute (dry)	2-3
Jute (raw)	1-2
Mulberry Bark (dry)	1-2
Mulberry Bark (raw)	1 or less
Water Hyacinth (sun dried)	1 or more

The end point is determined by observation of the fibre based on the experience of the operator. The contents will now be grey or dark brown. The content is allowed to cool.

The pulp is then rinsed, and the spent chemicals (now known as "black liquor") are separated and recycled. The cooked mass is placed on a screen of nylon and bamboo frame and cold water is passed over the material. The rinsing is complete when the pH is close to 7. At this point, the "brownstock" pulp is free of lignin, but is off white and too dark to use for some types of paper.

Bleaching and refining

The next step is to bleach the pulp by treating it with chlorine, chlorine dioxide, ozone, peroxide, or any of several other treatments. A typical mill uses multiple stages of bleaching, often with different treatments in each step, to produce a bright white pulp. Chlorine bleaching generally provides the best performance with the least damage to the fibres, but concerns about dioxins and other by-products have led the industry to move towards more environmentally friendly alternatives.

The bleached pulp is thoroughly washed until the bleaching agent is removed. The waste waster will be acidic with a pH of around 3-4.

Figure 8: Honnathara. D Karunawathi using a beater. Photo: Zul / Practical Action.

Beating

At this point, the individual cellulose fibres are still fairly hollow and stiff, so they must be broken down somewhat to help them stick to one another in the paper web. This is accomplished by "beating" the pulp in the refiners, vessels with a series of rotating serrated metal disks. The pulp will be beaten for various lengths of time depending on its origin and the type of paper product that will be made from it. At the end of the process, the fibres will be flattened and frayed, ready to bond together in a sheet of paper.

Stock preparation

The bleached pulp is now ready for paper-making and is made into a suspension in water in a trapezoidal shaped vat. Usually 1 to 2% pulp. A number of chemicals can be added at this stage to change the properties of the paper, including sizing chemicals and additives.

Sizing reduces this absorbency to lessen or prevent bleeding and feathering of watery media. Sizing also protects the fibre from oily media as well as dirt & pollution. In addition, sizing affects finish, printability, smoothness, and surface bond strength.

Below are some of the chemical additives used in the small-scale paper making industry but many other chemicals are used for dying, tinting, cleaning and quality improvement.

Chemical	Application
Caustic soda (N_aOH)	Used in the cooking or digestion* process in small mills.
Lime (C_aOH)	Used for the cooking of low quality materials such as jute or old rags.
Ammonia and calcium sulphate	Other chemicals used for the digestion of raw materials to form a pulp.
Chlorine	Used for bleaching paper. Chlorine is losing favour due to environmental pressures and is being replaced by other agents, such as hydrogen peroxide (H_2O_2), ozone or enzymes.
Hypochlorite	Also used for bleaching paper.
Alum	For pH correction, which is necessary for many of the finishing processes.
Rosin	Used for sizing* paper. Normally used in conjunction with alum as a 'sizing system'.
Alkile ketene dimer	Now used as a sizing agent in place of the alum and rosin system.
Starch	To improve stiffness of paper and board.
China clay /chalk	A filler used to improve opacity, brightness, quality and finish of paper. Up to 20% clay is used for some grades of paper. Fillers are often cheaper than fibre and used liberally.
Talc	Can be used instead of clay where the where the pH is close to neutral. Also used to reduce 'stickiness' of pulp.

Table 3: Additives used during production of paper

Forming

There are two methods of sheet formation:

- *Dipping method* (for fine/thin paper). The pulp is diluted with water and put into a masonry trough or vat. The lifting mould (mesh on a wooden frame) is then dipped into the trough, shaken evenly and lifted out with the pulp on it. The consistency of the pulp in the tank should be kept constant.

- *Lifting method* (all paper and card). A fixed measure of the pulp is poured evenly onto a mould, which is clamped between two wooden deckles (frames) in a water tank and dipped. The mould is then raised, using a lever mechanism, to drain the excess water.

Figure 9: Mrs Jayawathie Yahampath pouring the pulp, Honnathara, Sri Lanka. Photo: Zul / Practical Action.

The frames are immersed and lifted out vertically, trapping the fibres on the mesh. The thickness is controlled, mainly, by the concentration of the pulp. Although apparently simple, the process is dependent on a great deal of operator skill. Hand forming is, of course, not very fast and for commercial manufacture it is usual to employ one of the two main types of machine developed for the purpose. Both machines use a metal gauze to collect the fibres, one in the form of an endless, horizontal belt onto which is poured the pulp, the other in the form of a large drum rotating in a vat of pulp. In both cases, a continuous

Figure 10: Forming using the dipping method with a bamboo frame. Photo: Zul / Practical Action.

sheet of paper is formed then removed for drying. Neither of these systems lends themselves to the very small-scale production of paper but versions of both can be found for the production of 5 tonnes per day upwards. A drum-type machine for the production of boards at the rate of 0.5 tonnes per day is produced in India. The selection of the machine type depends upon the type of paper to be produced and the required output.

Couching is carried out after the sheet formation is completed, the wet paper is transferred onto a cloth/felt sheet and a stack of interleaved sheets is built up.

Paper making equipment - technical considerations

For the person looking to produce very small amounts of paper by hand, for use in a limited market, the problems are not quite so severe. It is possible to improvise all the equipment needed to recycle small amounts of paper. Time spent experimenting with the various parts of the basic process will quickly lead to an understanding of the principles and will enable more adventurous steps to be taken. For a very small operation, air drying should be an adequate option.

In order to move up the production scale, it is necessary to employ a little more equipment. Semi-manual (or semi-automatic) lifting devices have been developed which allow the paper to be formed with greater consistency and less individual skill. These devices lift the frame from the pulp vat by a system of levers which ensures a smooth lift and maintains the frame in a horizontal plane throughout the operation.

Many developing countries now manufacture papermaking plant indigenously, making cost savings in manufacture and also in import duties. There are also suppliers in industrialised countries that sell second hand equipment.

The table below shows the variety of equipment that is needed for a small hand made paper making process. Much of the machinery required for a mechanised production facility is sophisticated and expensive. Table 2 shows some examples of the equipment that is used for small-scale paper manufacture.

Machine name	Function
Pulper	An open-topped vessel with impeller which reduces the digested or mechanically reduced stock to a pulp.
Breaker	Similar in function to the pulper but with blades mounted on a roller inside a bath. Only suitable for batch operation.
Beater / refiner	Similar to the breaker in appearance but with a beating action for speciality papers. See fig. 2 below.
Washer	For washing the pulp prior to paper formation.
Refining equipment	For the final treatment of pulp before being sent to the Fourdrinier machine.
De-flaking equipment	Used in the preparation of reclaimed paper, these machines are inexpensive and suitable for use in small mills.
Screen	Situated just prior to the headbox of the paper machine, the screen removes undesirable particles and ensures a uniform suspension of fibres.
Cleaners	Remove sand or grit from the paper stock by centrifugal action.
Fourdrinier machine	Used for the formation of the sheet paper. This is the most common type of paper machine
Headbox or flow-box	The container (similar to a hopper) that feeds the pulp into the paper machine. On smaller machines they usually operate under the pressure of gravity.
Press	Used to expel water mechanically from the freshly formed paper. Often use hydraulic rams to provide the pressure.
Dryer	Commonly, a series of steam heated rotating cylinders which help remove the final 50 – 60% of water which still remains after pressing. Solar drying is another option when producing handmade paper.

Reeling, winding and sheeting equipment,	Handling equipment used for final treatment of paper.
Size press	Machine press for adding starch to the formed sheet paper.
Cutting machine	Used for the cutting of paper into sheets.

Table 4: Machinery used for small-scale papermaking

Pressing

The stack of hand made paper is usually squeezed in a screw press operated by hand while the mechanized systems use heavy rollers.

A hydraulic press is used to remove the excess water from the sheets. Pressing reduces the bulkiness of the paper i.e. the sheets become more compact. This improves the physical properties of the paper and facilitates drying.

Figure 11:. E D Karunawathi and Shanthi Dassanayake pressing to remove water. Photo: Zul / Practical Action.

Figure 12: Honnathara. E D Karunawathi using a screw-press to remove excess water. Photo: Zul / Practical Action.

Drying

Once the paper has been formed, it has to be dried. In order to do this it must first be removed, undamaged, from the gauze. In the case of hand formed paper, this is done by placing the frame, face down onto a sheet of felt to which the paper sticks. Another felt is placed on top of the paper, followed by another paper sheet and so on until a stack has been built up.

After pressing, between 50 and 65% of moisture remains in the sheets.

The sheets are dried either by hanging them in open areas of sunlight to remove the rest of the moisture but this requires a lot of space because each sheet must be kept away from the others, otherwise they will stick together. After a period of natural drying, during which the paper develops some strength, it is possible to hang up the sheets in an enclosed space and supply some form of additional heat and air flow to complete the drying as quickly as possible.

Figure 13: Honnathara. Indra Padmini Gunawardane hanging paper to dry in Sri Lanka. Photo: Zul / Practical Action.

Alternatively drying equipment can be used. Solar dryers can speed up this process and reduce the amount of space needed. Coloured paper is sometimes dried in the shade to avoid the bleaching effect of the sun. The mechanised production, because it produces paper continuously, demands artificial drying. This is usually achieved by passing the paper through a series of heated rollers from which it emerges dry and ready for reeling. Wherever artificial drying is required it involves cost. A great deal of energy is required to remove all the water from paper and energy is expensive.

Figure 14: Indra Padmini loading paper into the dryer, (modified cashew dryer). Photo: Zul / Practical Action.

Cleaning and sizing
Small dirt particles and other foreign matter are removed manually with a sharp instrument. The cleaned sheets are given a coating with starch to improve the physical properties of the paper and prevent feathering. This is called sizing and can be done manually with a brush or by the dipping method, where the sheets are immersed in a tub of sizing chemicals.

Calendering
The sheets are placed between metallic plates and passed through spring loaded rollers in a calendering machine. This smoothes the paper and enhances the gloss.

Cutting
The sheets are neatly cut to the required size using a cutting machine.

Figure 15: Jayawathi Yahampath and Shanthi Dassanayake calendering the dry paper, Sri Lanka. Photo: Zul / Practical Action.

Effluent treatment and disposal is an important topic which needs careful attention. The effluent from a paper mill can contain thousands of different chemical species, which, if discharged directly into the environment, would cause untold damage. In medium and large-scale plants specialised recovery equipment is used to reclaim chemicals for reuse or for incineration to provide energy. This is not cost effective in smaller plants and so some form of treatment and/or disposal is required. Biological treatment plants, such as the anaerobic digester, are sometimes used to treat the effluent. This method has the added benefit of producing methane through digestion of the organic matter in the effluent, which can be used to provide as much as 30 % of the mills energy requirement. The remaining sludge can then be disposed of on the land.

Although there are difficulties in setting up a small paper making operation, they should be no more serious than with any other industrial venture. There are strong arguments in favour of the small-scale as opposed to the recent Western tendency towards ever-larger plants in the search for 'economies of scale'. Small-scale operations can offer a degree of flexibility impossible to achieve with a large mill. An additional benefit derives from the fact that, for small-scale production, the machinery can be run at relatively low speeds and does not, therefore, need to be complicated, either in its construction or its control, operation and maintenance. This offers an opportunity for developing local skills to run and maintain an industry which, at a large scale, would be heavily dependent on imported technology and personnel.

Glossary of terms
Cellulose – the material from which all plants, such as trees, wheat stalks, rice-stalks and sugarcane are made.
Fibre – the long, thread-like wisps from which paper is made.
Groundwood – pulp obtained by subjecting wood to grindstones in the presence of water, also known as mechanical pulp.
Flowbox – prepared stock is placed in the flowbox which controls the flow of the pulp through the ‘slice’ onto the ‘wire’
Digestion – cooking of ram fibrous materials to produce pulp.
Size – liquid added to paper to control ink penetration.
Bagasse – the fibre remaining when sugar juices has been extracted from sugar cane.
Furnish – pulp that has been bleached and

Figure 16:. Shainoor and Zoshna making cards from handmade paper, Bangladesh. Photo: Zul / Practical Action.

refined, rinsed and diluted with water, and fillers such as clay or talc may be added.
Slice – the opening through which pulp flow onto the 'wire'. Flow can be under gravity or pressurised.
Wire - a moving continuous belt of wire or, more commonly nowadays, plastic mesh.

Further reading and information

- *Small-scale Papermaking* IT Publications, (First published as ILO Technical Memorandum No 1) A technical handbook to assist small-scale producers with alternative production techniques - to help them choose and apply those techniques which are most appropriate to local socio-economic conditions
- *Small-Scale Handmade Paper-Making Technology* ITDG Bangladesh, 2000 This booklet presents the process of handmade paper making and the associated technology based on the experiences of Udyog project.
- *Paper Technology and the Third World* Becker J, GTZ, Germany.
- *How to Make Your Own Recycled Paper* by Malcolm Valentine ISBN 0 85532 670
- *Creative Handmade Paper: How to Make Paper from Recycled and Natural Materials* David Watson ISBN 0 85532 730 8
- *Towards Sustainable Development: Handmade paper by TARA*, Verma S, Development Alternatives, August 1996, An article on handmade paper being produced by eco-friendly means.
- *Use Water Hyacinth!: A Practical Handbook Of Uses For The Water Hyacinth From Across The World* Lindsey K, Hirt H, Action for Natural Medicines (Anamed). This booklet shows the many uses of water hyacinth, and gives a summary of equipment and techniques used for processing. Chapters include information on the uses of this weed in agriculture, as a fertiliser and as animal feed, for handicratfs, including rope furniture and paper, and as a fuel, in the form of briquettes, biogas and other forms.
- *Plant Fibers for Papermaking* Bell, Lillian.
  A guide to making paper from natural plant fibres. Includes botanical names, cooking, beating, and sheet forming. SB, 132 pp.
- *Pulp Technology and Treatment for Paper*, 2nd Edition, d'A. Clark, James,
  The book for anyone who really wants to understand the process of papermaking. It is a clear, comprehensible explanation of paper chemistry for non-chemists. There are accurate discussions of cotton and flax properties. HB, 85 pp.
- *Hand Made Books: An Introduction to Bookbinding* Rob Shepherd,
  Aimed at the amateur with a limited budget, he clearly explains how to make both soft and hard bound bindings for journals, scrap books, portfolios, and Japanese bindings.

Useful addresses

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Fax: + 91 (0)11 686 6031
E-mail: tara@sdalt.ernet.in
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Edwin Amies and Son Ltd.
33 Amsbury Road
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Kent ME17 4DP
United Kingdom
Tel/Fax: +44 1622 745758
Suppliers of hand moulds and deckles for handmade paper making.

Small Industry Research Institute (SIRI)
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Consultancy specialising in small business and Intermediate Technology's.

This Technical Brief was updated by Neil Noble based on the handmade paper project in Bangladesh. The project ended in 1998. A local NGO called SEDS was supported in setting up the Paper Mill and in marketing, quality control, and management. Practical Action-Bangladesh withdrew from the project after the partner NGO developed sufficient capacity to run and manage the operation independently. Practical Action-Bangladesh produced a book on the project which provide useful technical information and some costs *Small Scale Handmade Paper Making Technology*

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technical brief