

A Sustainable Journey of Handmade Paper from Past to Present: A Review

Zrównoważona podróż papieru czerpanego od przeszłości do dziś

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Abstract

Paper is an excellent medium of expression and knowledge preservation and communication because of its writing, printing, and packaging abilities. It is a thin sheet or web-like structure made by a dilute suspension of cellulosic fibres. Handmade papermaking technology was mass accepted and considered a precious commodity before development of an industrialised wood- pulp based paper industry. This modern papermaking practice harms the environment as it uses enhanced natural resources (ample amount of water, trees as a primary source for wood pulp) and generates pollution due to release of harsh chemicals.

This paper reviews the history and process of handmade paper manufacturing from past to present. Along with that, all the pillars of sustainability (environmental, economic, and social) in relation to the handmade paper industry are deep rooted since ancient times and very much relevant for the present era of sustainable development. Various kinds of cellulosic raw materials from plants (Paper mulberry, Kazo, Gampy, hemp, bamboo, banana, etc.) and other used materials (old rags, ropes, nets, newspapers etc.) with the chemical-free production process and products make this industry eco-friendly. Craft based, small scale and labour-intensive guild art gives it social strength; whereas an infinite product range having functional and decorative uses, as well as strong export potential of the industry gives it an economic strength.

Due to the present need of sustainable production, waste minimisation, and circular economy, the handmade paper seems to very potential industry to recycle various kind of waste like weedy battles, textiles, tetra packs, currency, plastic etc. This paper is an attempt to review the journey of handmade papers, its recycling potential, various production processes, products, advantages and disadvantages of the industry from past to present.

Key words: handmade paper, sustainable production, cellulosic materials, recycling

Streszczenie

Papier jest doskonałym środkiem zachowania wiedzy oraz komunikacji ze względu na jego zdolności do pisania, drukowania i pakowania. Jest to cienka struktura przypominająca arkusz lub wstęgę wykonana z rozcieńczonej zawiesiny włókien celulozowych. Technologia ręcznego wytwarzania papieru była powszechnie przed rozwojem przemysłu papierniczego na bazie masy drzewnej. Ta nowoczesna praktyka papiernicza szkodzi jednak środowisku, ponieważ wykorzystuje ulepszone zasoby naturalne (duże ilości wody, drewno jako główne źródło miazgi drzewnej) i generuje zanieczyszczenie z powodu uwalniania agresywnych chemikaliów.

W artykule dokonano przeglądu historii i procesu produkcji papieru czerpanego od przeszłości do współczesności. Wszystkie filary zrównoważonego rozwoju (środowiskowy, ekonomiczny i społeczny) w odniesieniu do przemysłu papieru czerpanego występowały już od czasów starożytnych i mają bardzo duże znaczenie dla obecnej epoki. Różne rodzaje surowców celulozowych z roślin (morwa papierowa, kazo, babka, konopie, bambus, banany itp.) i innych używanych materiałów (stare szmaty, liny, siatki, gazety itp.) z bezchemicznym procesem produkcyjnym czynią tę branżę przyjazną dla środowiska. Oparta na rzemiośle, drobna i pracochłonna sztuka cechowa daje jej

siłę społeczną; mając na uwadze, że nieskończona jest gama produktów o funkcjonalnych i dekoracyjnych zastosowaniach, a także silny potencjał eksportowy przemysłu, zapewnia jej także mu siłę ekonomiczną. Ze względu na obecną potrzebę zrównoważonej produkcji, minimalizacji odpadów i gospodarki o obiegu zamkniętym, papier czerpany wydaje się bardzo idealny do recyklingu różnego rodzaju odpadów, takich tekstylia, opakowania tetra, plastik itp. Ten artykuł jest próbą opisanie historii papieru czerpanego, jego potencjału w zakresie recyklingu, a także omówienia różnych procesy produkcyjnych, produktów oraz zalet i wad tej branży.

Słowa kluczowe: papier czerpany, zrównoważona produkcja, materiały z celulozy, recykling

1. Introduction

Parallel to the development of human culture and civilisation, there was the development of various mediums through which feelings can be expressed, messages can be passed, and knowledge can be preserved. Various hard and soft mediums were used from time to time to full fill the need for written records. Paper was the material that was found most suitable and appropriate for writing, printing, and packaging purposes. *The word paper is derived from the Latin word – reedy plant 'Papyrus' and French 'Papier'.* Different styles and forms of paper were used worldwide.

Present paper technologies, both handmade and industrialised, are the rectified version of paper technology developed by China many centuries ago (A detailed, n.d.). Moreover, this invention gave birth to a *new era of civilisation*. Between 600 AD to 1500AD, the technology of handmade paper making diffused from China to east and central Asia through Buddhist monks; and from there it reached Mediterranean region and to other parts of Europe. According to the available raw materials, religions, and cultures, technology diffusion also took place after use and trade (Bloom, 2017).

Handmade paper is a thin sheet or web-like structure made by the dilute suspension of cellulosic fibres. This dilute suspension is either poured or drained through a mesh-like structure so that a layer of interwoven cellulosic fibres is achieved after drying and removal of excess of water. Various cellulosic fibrous plants (paper mulberry, gampy, mitsumata, banana, sisal, hemp, kenaf etc.) and cellulosic waste materials (textile waste, jute waste, nets, ropes, used paper etc.) are used as the primary source of raw materials for paper making.

Handmade paper making technology was mass accepted and considered as one of the very precious commodity before the development of industrialised wood pulp-based paper industry during the 18th century in Europe. This modern technique aimed to develop a wide variety of papers to meet the need of the masses and to earn profits at any cost. Industrialised production of paper wrecked handmade paper production.

This modern practice of papermaking harms the environment because it uses an ample amount of natural resources (ample amount of water, trees as the primary source for wood pulp) and generates pollution (harsh chemicals). Approx. six million km² of

earth's forest has been lost in the last 200 years (Kumar et al., n.d.). The modernised paper industry uses approx. 460 bamboo plants and 270 eucalyptus trees to produce one ton of paper (Tejjeler et al., 2001). Around 40 % of timber is used for paper production only.

This unconscious use of natural resources has led us in a dangerous situation. The researchers, government and citizens globally are finding ways for sustainable production and consumption where economic, environmental and social benefits can be achieved. Most of the sustainable practices are the amalgamations of past methods with present inventions. For sustainable alternatives of many industries, we have to look back into our past to take inspiration. Old methods may serve as a foundation for contemporary sustainable practices.

The handmade paper industry is one such industry which is an amalgamation of arts as well as science and uses renewable, biodegradable, used and unused cellulosic materials with recycling potential. The manufacturing process of handmade paper is also eco-friendly and can be made chemical-free.

2. History of handmade paper development from past to present

History of paper is vibrant and varied, and rests on sustainable practices. Before the invention of paper *Shruti* (Sanskrit word) means the verbal transformation of information was done for the transfer of information. Along with that, many predecessors of paper were also used since ancient time. Various types of hard materials like bones, stone, metal, shells, earthenware, terracotta etc. were used as writing materials. Engraving, embossing, painting and scratching were done on them. Wooden board, barks of trees, palm leaves, leather and cotton clothes are some of the examples of soft writing materials (Tiwari, 2019). History of handmade paper can be described as follows.

2.1. Papyrus in Egypt (3500 BCE/ BC)

Papyrus is a generic botanic term used for tall grass-like plant *Cyperus* of wet origin. A fine paper-like sheet could be achieved by laminating fine strips of pith portion of the plant. Wetting, pressing, hammering and sun drying of the strips were done for lamination of strips (Wiedenmann, 1983). Before the discovery of handmade paper in China, Papyrus was considered as the most appropriate material for writ-

ing especially in Egypt. Egyptian had the monopoly to grow efficient thickness papyrus plant suitable for producing writing material (Bloom, 2017).

2.2. *Parchment and vellum in Europe & Asia (2500BCE/BC)*

During 2nd century BC, animal skin (mainly calf, sheep, goats) was used as writing material in Europe; later it became famous throughout the Islamic region.

Animal skin was limed, scraped and dried under tension so that both the side of the skin can be used as writing materials. Vellum was the superior form of parchment obtained from the skin of young or unborn calf hide (The Intriguing, n.d.). The availability of parchment over papyrus was more and easy, i.e. it was more used, but its spread towards east and central Asia was limited due to Buddhism and Hindu religions.

2.3. *Handmade paper in China (105CE/AD)*

The present-day paper is a modified form of paper invented by China. China was the pioneer of paper making technique for approx. 1000 years and hid this secret to earn monetary benefits. For several years this paper was exported to many countries through Silk Road, and gradually the art of handmade paper making leaked.

The oldest piece of writing paper was excavated from a tomb at Fangmatan in Gansu province, China, and dates back as early as Western Han (179-41 BCE). The occupant of the tomb was buried with a paper map laid on his chest, showing mountains, waterways and roads (The intriguing, n.d.)

According to Chinese record, an official in the imperial Chinese court called Cai Lun (Tshai Lun or T'sai Lun), during the Han Dynasty, presented a report made up of handmade paper to emperor He Di in about 105 AD. This paper was made up of paper mulberry (Kozo) and other bast fibres along with fishnets, old rags, and hemp waste. At around 600 AD woodblock printing was invented in China, and the first newspaper was printed on (740 AD) (Hunter, 1937; Jugaku, 1959; Tsang, H. 2015).

2.4. *Handmade paper in Japan (106CE/AD)*

Approx. after 500 years of handmade paper production in China, paper making technique reached to Japan. During the 6th century AD, the art of handmade paper making first reached to Korea and from their technique was introduced to Japan during 610 AD by a Korean monk named Don-cho (Tsang, H. 2015). A lot of technical developments happened to enhance the quality and uses of paper. Empress Shotoku of Japan in the year 770 ordered approx. one million religious prayers called *Pagodas*. These pagodas were made on handmade papers with wooden block printing. The strips of handmade papers then placed over 4-5 inch strips of carved wooden. Many of the pagodas are surviving till today and maybe the earli-

est evidence of mass printing (Clapperton, 1934; Hunter, 1947; Anon, 1962; Hubbe, 2009).

2.5. *Handmade paper in Arab (715CE/AD)*

The journey of handmade paper towards Islamic and western world was prolonged. Till 715CE papermaking technique was limited to China and Japan. After the battle of *Atlakh* near Talas (present-day Kyrgyzstan), the Chinese army was defeated by Arab forces and this secret was obtained from Chinese prisoners. This led to the introduction of the first paper mill in the Islamic world that was founded in Samarkand, which is modern-day Uzbekistan. After that paper making technique spread to various regions through Silk Road. Paper developed in this reason was known as *Kagaz*. The name *Kagaz* is derived from the Urdu word *Kavas*, which means paper and craftsmen of *Kagaz* manufacturing are called *Kagzi's*. Foldable use of paper in a codex format suitable to write religious books especially *Koran* (religious book of Muslims) was started from Baghdad (Farid, 2003; Hubbe, 2009).

2.6. *Handmade paper in Europe*

Europeans were not aware of the art of handmade paper manufacturing for a long time. During the 10th century AD, this art spread to Egypt through Arabs and then Europe. Papermaking centres mainly flourished in Italy and Spain. Fabriano was the main center where art of handmade paper flourished first and from there it reached to other European countries (Dabrowski, 2008). In Europe, significant technological improvements were done to ease the process of handmade paper making (Hubbe, 2009) use of metal in making fixed screen moulds, the invention of the first printing press by A.D Johan Gutenberg in 1453, development of Hollander beaters in the 1660s or 1670s, watermarks on handmade sheets for their identity by the help of metal screens and development of first industrialised handmade paper making machine by Nicholas- Louis (1798) were some of the significant inventions in the direction of papermaking. By the middle of the 19th-century mechanised wood pulp-based paper industry replaced the handmade paper industry in Europe. European paper manufacturing industry overruled the paper industry of Asia and dominated the market. Only a few craftsmen, artisans and few rebellions against industrialisation tried for the revival of this dying practice.

2.7. *Handmade paper in India*

Handmade paper manufacturing technique reached Tibet at around 650 AD, and from there it was introduced to India (645AD) (Hunter, 1939; Tsang, H. 2015). At the time of Hsuan Tsang's (Chinese Buddhist monk) visit to India, the technique of handmade paper making was known, but it was not so popular, as use of palm leaves was preferred for writing purpose. With the start of Mughal rule (1526), handmade paper industry flourished a lot in India

and gradually became a major centre and a precious export commodity. Many paper manufacturing centres (Kagzipura) were established. Some of them are still surviving. The handmade paper industry is still one of the potential art and craft small scale industry in India, employing nearly 37,000 through its approx. 3000 production units (KVIC India, Dwivedi et al., 2013).

The handmade paper units are scattered throughout the country with concentration most in the Kalapi (Jhansi, Uttar Pradesh), Sanganer (Rajasthan), Pune (Maharashtra), Kurukshetra (Haryana), Mahaboobnagar (Andhra Pradesh) and some clusters are in West Bengal (KVIC, India) (Dwivedi et al., 2009). Sanganer village near (Jaipur, Rajasthan, India) and Kalpi (Jhansi, Uttar Pradesh, India) are considered as the largest handmade paper producing centers in the world.

3. Raw materials used for the handmade paper

Cellulose is the base material for the construction of paper as higher length to width ratio, cohesiveness, pliability, tensile strength, water absorbency, and resistance to tearing, are some of the properties which are desirable in a paper. Various kinds of cellulosic fibres can be used in paper construction. Their origin can be directly from plants or cellulosic waste materials. The blending of plant fibres and waste materials was a more practised option as by the use of a combination of different fibre types and fibre sizes desirable properties could be achieved. For example, long-staple fibres give strength and anti-cracking properties to the paper when used along with short length fibres. It also reduces the cost of paper (Heller, 1978). Evidence of one of the oldest Chinese paper presented by Cai Lun (105 AD) was made up of used rags, along with old rope, fishing nets, hemp, and flax (Clapperton, 1934; Turner and Skiold, 1983).

In India, Gunny bags made from jute (*Corchorus capsularis* or *Corchorus olitorius*), nets and rope made from Sun hemp (*Crotalaria Juncea*) were majorly used as raw materials (Tejgeler, 2001)

It has been suggested that the earliest papermakers mainly used rags as a fibre source. Papers made from cellulosic waste materials were considered inappropriate for religious and ceremonial artwork (Jugaku, 1959; Hubbe, 2009) so later attention turned almost exclusively to locally available fresh vegetative sources (Bloom, 2001). Jute, hemp, flax, ramie, rattan, paper mulberry (kozo), mulberry, and bamboo etc. fibers were used by early Chinese paper makers (Tsien, 1973).

Koreans used the fibres of hemp, rattan, mulberry, bamboo, rice straw, and seaweed to make paper pulp (Hunter, 1936; Tsang, H., 2015). Kozo, Mitsumata and Gampi were the most used bast fibres for handmade papermaking in Japan. The inner bark of Fig tree (Mudakh) was used to get white fibres suitable

for papermaking in Yaman (Bloom, 2017). Flex, jute, banana and bamboo fibres were used by Islamic and Indian handmade paper manufacturers along with used textiles and papers. European paper makers majorly used rags for handmade paper making.

In Nepal, handmade paper is made from the inner bark of Lokta fibers (*Daphne bholua* and *Daphne*) and cotton cutting waste with the ratio of 70% and 30 % respectively. This fiber grows at Himalayan region abundantly and resistant to insect and mildew (Biggs et al., 2005).

A small mountain village Moktu in Arunachal Pradesh India uses locally available raw material similar to Nepal and Tibet called *Daphne Paperacea*, locally called shoughun for paper pulp which requires no chemicals (Bloom, 2017).

Many researchers have worked to standardise the recipe of handmade paper manufacturing through various plant fibers. Hunter (1930), Mason (1963), Lorente (2004) gave paper making recipes from a wide range of common plants. Kumar, V. & Maheswari, R.C. Turner and Skiold (1983) gave detailed descriptions of fibres from seed hairs (cotton, cotton linters), leaf fibres (esparto, manila, grasses, giant nettle, rice straw, rattan), bast fibers (linen/flax, jute, hemp, kozo, gampi, mitsumata, ramie), and wood-derived fibres (made by wasps or by pulping processes) (Hubbe, 2009).

Cotton fibre has an almost insignificant role in paper manufacturing till the 18th century, later large amount of cotton was exported to Europe from India and cotton rags were used to make handmade papers (Bloom, 2017). In present time cotton cutting waste generated by garment manufacturing units is the most usable raw material for the production of handmade paper in India.

Blends of various other materials like dry flowers, pigments, seeds, coloured fibres etc are also used to impart functional and aesthetics properties in the paper. During the 18th century Afshani papers from Daulatabad, Maharashtra was world-famous because of its beautiful blends with gold and silver scraps (Tejgeler, 2001).

3.1. Some new cellulosic materials for the manufacturing of handmade paper

The rising cost and limited availability of cotton cutting waste are escalating problems and to solve this, there are many recent researches to find out the new plant fibres and natural cellulosic materials suitable for the manufacturing of handmade paper pulp which have a superior quality of cellulosic content and easy and cheap availability. Arafat, et al., 2018, researched, to make handmade paper using banana fibres and banana waste fibres which contains lingo cellulosic wastes. According to his research, the properties of handmade paper made from the waste of banana fiber extract are inferior, but the production of handmade paper is possible. Kumar et al., 2013, studied the suitability of Banana (*Musa sapi-*

entum) and ankara (*Calotropis procera*) fibres for the production of handmade papers. Chemical analysis of these fibres showed excellent properties like high cellulose, low lignin and ash. The handmade papers made from these fibers can be used to make tissue paper, bond paper, card sheets and decorative items etc. Ghosh et al., 2009, studies the production of chemical-free handmade paper from date palm (*Phoenix Dactylifera* L) leaves which is a sustainable agro-residue. An attempt was taken by Kulria, 2016; to recycle linen fabric waste to develop handmade papers. Linen Fiber waste (both unbleached and bleached varieties) were collected from a reputed Linen manufacturer. Two varieties of papers, viz., 90 gsm and 130 gsm, were made using the process. Chauhan et al., 2009, experimented to make handmade papers from the currency waste of the Reserve bank of India by bio-enzymatic pulping of currency. This currency handmade made paper gave excellent results in terms of strength and could be used for paper making. Recent research conducted by Kumar Appa National Institute of Handmade Paper, Jaipur, where the handmade paper was produced with the help of 50% single used plastic polythene. Bottle covers made from these papers were specially promoted by the government of India. (Tejgeler, 2001). Asare, et al. (2013) did a research to develop handmade papers with the use of garment cutting waste, old clothes of various fiber types (linen, cotton, wool, nylon, polyester and acetate) and paper mulberry with the ratio of 70% and 30% respectively. Produced handmade papers were also tested with various color mediums. Emmclan et al. (2018) used various aquatic weeds (*Cyperus digitatus*, *Cyperus iria* and *Scirpus grossus*) for the suitable production of handmade paper. Produced handmade papers can be used for production of paper plates, paper boards and decorative paper.

Production of handmade papers with animal dung has become a trendy guild craft. Sri-Lankan paper and paper-mache products made from elephant dung have tremendously flourished. In India handmade papers and some of its products are made by cow dung. Cow is a sacred being in India and respected as *mother*. *Gaukriti* is a brand in India which sells handmade paper products specially made from cow dung. Extensive research took place at Sri Aurobindo Ashram, India to produce handmade papers using algae. Villagers of Pudukuppam, a village near Pondicherry, India were facing the problem of algae growth at saline water, and now these villagers are selling algae to the Ashram (Tejgeler, 2001). Many recent researches are also focused on developing various functional products like cardboard, paper plate, cups, spoons, straw etc. made from handmade paper. Research has been conducted by Indian Institute of Technology, Delhi, India where rice straw waste has been used to make handmade papers, cardboard and paper plates. Every year Approx. 20 million tons of rice straw (locally called *Parali*) is

burned leading to a severe problem of air pollution in some parts of north India which is very hazardous (A startup, 2018).

4. Techniques used for handmade paper production

Present handmade papermaking techniques still follow the traditional way of papermaking with little technical advancement by different countries. Descriptions of these developments are as follows.

4.1. Raw material selection

The first step to make handmade paper is the selection of appropriate raw material according to the availability and end product.

4.2. Sorting

It is one of the most tedious and time-consuming processes. Since ancient times, it was done manually. Sorting was done to separate foreign particles, for example, barks, leaves, stones, dust etc. It was also done to separate similar colour and fiber type of the materials. Recently most of the handmade paper industries use cotton hosiery waste as raw material which does not require an intensive sorting process. Their primary sorting is done on the basis of colours by the supplier of the raw materials. If required, bleaching is done. Earlier bleaching method was to expose the raw materials into the sunlight. Later chlorine and oxidising bleaches were also used to bleach the raw materials and to increase the brightness.

4.3. Pulping

Pulp is a wet or semi-liquid mixture of one or more materials which are made by chemical and mechanical mixing of any component with its solvent. Cellulosic materials of various origins (plants or rags) are mixed with water. Various mechanical and chemical treatments are given to the raw materials to make clear pulp suitable for paper making. Following procedures are used to make a clear paper pulp.

4.3.1 Mechanical treatment of the pulp (Beating and shearing)

Beating and shearing of cellulosic raw materials is done to make appropriate paper pulp. In the case of plant originated fibres, beating process is required to remove lignin and to separate fibres from each other. Various other sub-processes like steaming of stems, peeling the bark, stripping coloured layers away from the bark, chemical retting, fermentation, cooking of fibres in lye or lime, sun bleaching etc. are done to make paper pulp. In the case of cotton hosiery waste, shearing is the most essential and initial step. Some of the procedures (cooking, steaming, retting etc.) are by the past in case of cotton cutting waste. Shearing processes do the delamination within the fibre walls, which provides more fibril-

lated fibrous surface, which generates more surface area for bonding.

Use of human power for beating is the most ancient practice. It was done in various ways: one common way was by lifting and dropping a heavy rod. Fibres were mixed with water in a suitable amount to make a pulp. Hand Beating was a less forceful and tiring process. After that hampers with wooden trip hammers were used for beating purposes which were water-powered. In 1660-1667, Hollander beaters were invented which were wind-powered in which pulp is circulated repeatedly between rotating rolls with metal blades. After the use of Hollander beaters, fermentation procedure was not required to make refined pulp (Hunter, 1947; Cutbush, 1990; Hubbe, 2009).

The duration of the mechanical beating of the fibres again depends on the selection of raw materials and the end product. Finer paper products like tissue; bond paper requires more beating time to make fine pulp. In present time Electric powered Hollander beaters are used to make pulp and cotton cutting waste needs beating operation for approx. 3-4 hours.

4.3.2. Chemical treatment of the pulp (rotting and fermenting)

Chemical treatment is given along with mechanical beating and sharing because the use of chemicals makes the procedure easy and fast. Chemicals are the compound which has either natural or synthetic origin and helps to degrade the natural binding agents by breaking bonds. Chemical treatment shortens the beating time needed for inter-fibre bonding and makes the pulping procedure easy and less time-consuming. Again chemical treatment is essential in case of plant originated fibres.

Ashes (by burning straw, wood), lime powders were mainly used to remove lignin and to soften the fibres. Piles of rags were generally rotted by wetting them and leaving them for several months along with lime (Hunter, 1947; Toale, 1983; Hubbe, 2009).

4.3.3. Other additives in pulp

Certain properties of cellulosic fibres make it self-sufficient for paper making but to impart certain desirable properties and to ease the process of paper making certain additives are added. Experimentation with certain natural and synthetic materials to make paper production more powerful is ancient and interesting. Nagashi-Zuki method is one such method used by the Japanese to make Washi paper where the addition of mucilage was done in paper pulp (Bunsho, 1959; Barrett, 2005). In Japan, these mucilaginous agents are called *Neri*, which were obtained by soaking the roots of Tororo-Aoi plant. Addition of mucilage makes paper firmer, smoother and glossy (Barrett, 2005; Hubbe, 2009).

Before the Islamic world, one side of paper sheets was used. During the Islamic world, both sides of pa-

pers were used for writing with the help of mineral fillers (e.g. clay, ground limestone), which used to increase paper's opacity Clapperton (1934). According to McFarlane (1993) Islamic paper makers sometimes added cooked starch to the vat in order to strengthen the paper. To get colorful paper sheets, some of the natural dyes and mordants were added in paper pulps. Salt, vinegar, sodium carbonate, cream of tartar, brass, iron, tin, copper, alum, and tannic acid are some of the common mordants out of which alum (e.g. aluminium sulfate) was the most used and useful mordant. (Hubbe, 2009). In the beginning of the 18th century, a new practice of internal sizing of paper started to impart hydrophobic properties in paper sheets (Cutbush, 1990). Combination of rosin with aluminum sulfate was used for internal sizing, which had few negative impacts like rapid degradation, resistance to folding and weaker strength (Barrett, 1989; Hubbe, 2009). Use of water is one the essential requirement to make paper pulp, along with that particular natural property of water of specific regions gave extra advantages and properties to the paper of that particular region. Use of clean and clear water gives clean and bright papers sheets. Handmade paper from Nepal is slightly glittery because of mica containing water. In India, many handmade paper artisans use magnet slabs at the bottom of vats to collect iron rust so that brightness of paper can be improved (McFarlane, 1993; Hubbe, 2009).

Fibre Separation, beating, repeatedly soaking, retting, washing, boiling, bleaching, mixing of ingredients and again beating are some of the common steps for paper pulp making.

4.4. Sheet formation

Various time to time inventions also took place to make sheets. Early Chinese used a wove mould and pour method to make paper sheets. In Wove moulds a fabric was stretched on a bamboo frame to make a rectangular mould, and paper pulp was poured on the top of the mould and spread out by the papermaker which is called pour method. After that, sheets were sundried.

In Japan, a new type of mould was developed, which was called Sugeta. Sugeta screens were made from parallel bamboo strips and tiny reeds which were woven with silk thread and horsehair (Pietzcker, 2009). To form a sheet, a screen lifting method was used in which Sugeta is dipped into a vat of paper pulp and lifted. Excess of water is run between the bamboo strips. The paper sheet is immediately transferred on the flat surface because of rollable screens. This entire process is known as the Tame Zuki method of papermaking (Hubbe, 2009).

Papermaking art flourished in the Islamic region after the 12th century. Some of the new fibres and techniques were introduced to make Khurasani paper or Kazaz.

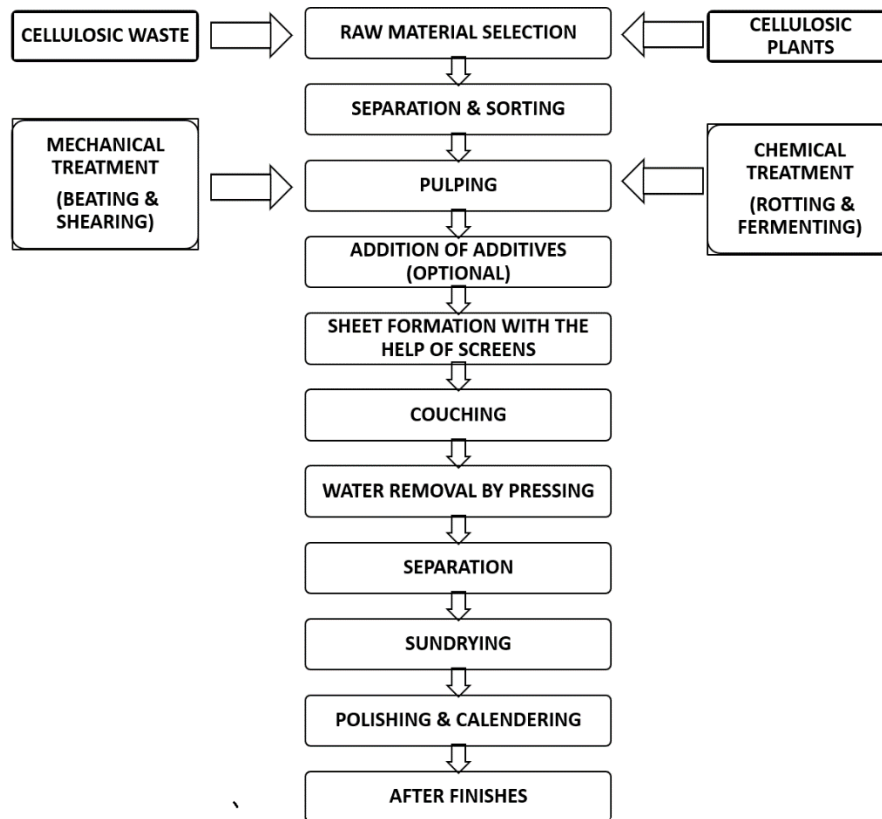


Figure 1.1 various steps of handmade paper production

Laid moulds are the moulds which were used most commonly throughout Asia, Islamic region and even in Europe. In Laid moulds, monofilaments were prominently aligned in one direction to give a specific impression on papers. These moulds were often made from bamboo and grass filaments woven with silk thread, animal hair and other types of thread to make a uniform mat with subtle patterns. In India, patterns made due to thread are called *Chapri lines* or *Chain lines*, often used to distinguish the papers of different sources (Clapperton, 1934; McFarlane, 1993; Hubbe, 2009).

In the 12th century the concept of watermarks started in Italy. Watermarks were the specialised designs or logo to distinguish the papers of different producers. They were made by bending a design in brass wire and attaching it to the mould so that it left an impression on finished sheets (Bloom, 2017). The first watermark was developed by the Fabriano paper mill in Fabriano, Italy and it was in the figure of 8. (Hubbe, 2009). With the availability of finer wires embossing of intricate watermarks were possible. In the present time, most of the handmade paper manufacturers use wooden frames screens made with fine stainless steel wire mesh for corrosion-free metal screens.

4.5. Water removal

Water removal is the tricky step in handmade paper production. To remove the water, first, a bundle of layers of wet handmade paper sheets are prepared.

Each sheet is separated to each other either with nylon or muslin mesh or felt. Once the screen is lifted from paper pulp vat, wet layer of the paper sheet is covered with the mesh/ felt. The screen or mould is then gently flipped to transfer the paper sheet on a flat surface. A thick bundle of sheets is prepared, and this process is called couching. An appropriate size of the bundle is pressed to remove the excess of water (Hubbe, 2009). Earlier pressing was done with the help of some weighty object, mainly stones. They were kept over the bundle of papers. Gradually stones were replaced by hydraulic press machines.

4.6. Drying

Approx. 80% of water is removed by pressing, but for complete drying of the sheets, open-air drying is done. For that purpose, one by one separation of wet sheets from the bundle is done very carefully. Each sheet is separated from each other and dried. The one common way of drying is the use of solar energy. The sheets are transferred on wooden boards and sun-facing walls. Once they are dried, it can easily be removed from the surface. Sometimes powder dusting is done at the surface for easy removal of the paper sheets. Another way of drying is the hanging of the paper in lofts. The most common approach is to hang the sheets over ropes. In case of bad weather conditions, especially in rainy seasons, steam-heated metal surfaces are sometimes used in Japan (Jugaku 1959; Longenecker 1985; Hubbe, 2009). A related

approach has been used by some modern papermakers as well.

4.7. After finishes

Sizing and polishing are the two most important after finishes given to the handmade sheets after drying. Sizing of paper sheets after drying is the common practice adopted by Islamic paper makers. Sizing process improves the strength of paper and makes the surface more suitable for writing. Starch made from rice and sorghum was majorly used. Wheat starch was not preferable due to extraction difficulty and disagreeable odour. In the presence of humidity, starch promotes the growth of microorganism, which is the problem for cold and humid climate areas like Europe. Italian papermakers used Gelatin to size the paper which was made from the hoofs, hides, and horns of the animals (Bloom, 2017). The size solution can be applied to the paper either by dipping the sheets into the solution or by brushing the solution on the surface. After sizing, polishing of the sheets is done to get a smooth and shiny surface. In ancient times stones and shells were rubbed against the paper sheets to get a smooth surface.

German papermakers used water-powered metal hammers for polishing the paper surface. Dutch invented a more advanced method of paper polishing by passing papers between metal rollers under pressure (Turner and Skiold, 1983). The process is called calendering. This process is continuing for polishing the paper surface. Apart from these two basic operations, embossing, printing, embroidery and other surface embellishments are also done to impart specific desirable properties.

5. Variations and Products of handmade paper

Paper is a fantastic material which has unique properties that makes it eligible for multipurpose uses. It can be impregnated, creped, layered, waterproofed, waxed, glazed, marbled, bent, folded, pasted, twisted, cut, torn, moulded, crumpled, embossed, enamelled for various purposes.

In present time approx. 95% handmade paper demand is for consumer-based, and 5% demand is for industrial products like filter paper, cardboard, blotting paper, and tissue paper etc. A lot of variations in quality, thickness, texture and surface embellishments can be seen now.

The history of handmade paper reveals that the spread of this precious technology was very slow and steady from country to country. Various functional and decorative products and the use of handmade paper emerged from time to time. Some of the very creative and innovative uses of handmade paper are as follows.

5.1. Functional handmade paper

Stationary, writing pads, conference folders, computer printouts, drawing, documentation sheets, certificate, wrapping papers, toilet papers, tissue papers

and degree awards etc. are some of the present time practical uses of handmade papers. In the Islamic world, the paper was used for writing, painting, wrapping, offering, and for making kites and playing cards (Bloom, 2001). One fascinating use of handmade paper was done by the Japanese in making balloons to cross the Pacific Ocean during the Second World War (Hunter, 1947; Barrett, 2005; Hubbe, 2009). Selective raw materials and specialised handmade paper artists were selected to make such balloons which were polished with oil to make airtight and water-resistant. Apart from that, Shifu and Paper mache are the art forms where exciting and innovative use of handmade paper has been done.

Shifu: Shifu is an art of making Shifu garment using very fine quality of washi paper in Japan. Very fine strips (not more than 2 mm) of handmade paper are cut which are used as warp and silk threads used in weft direction to weave Shifu. This Shifu fabric was used to make baskets, mats, bags, clothing and other art objects (Bunsho, 1959; Barrett 2005; Hubbe, 2009). Similar to Shifu technique, there are certain recent studies where used garments and cotton rags are used to make handmade paper, and very thin strips of paper are cut (1-2 mm). These strips are used as yarns and woven together with silk yarns to make fabrics and garments (Gambhir, 2011).

Paper Mache: Paper Mache is a 3D art originated from China, which is made with papers. Paper Mache was mainly used to make face masks and dolls in Europe. As its name suggests mashed paper or paper pulp is used to form 3 dimensional objects. Generally some forms of gum (gum Arabica), ceramic or sand are mixed with mashed paper to make a dough which can be used to make 3-dimensional objects. The objects get strength after drying.

5.2. Decorative handmade paper

Umbrellas, wallpapers, wrapping sheets, pen holders, diaries, carry bags, greeting cards, marriage cards and gift boxes etc. are some of the present time decorative uses of handmade paper. Use of handmade papers for invitation cards and gift boxes is one of the major domestic uses of handmade papers in India. Washi paper of Japan was used for various products like umbrellas, fans, screens for windows, fireworks, books, kites, calligraphy paper, letters, envelopes, bags, lanterns, and, of course, toilet paper (Longenecker, 1985; Barrett, 2005, Hubbe, 2009). Apart from various decorative products, handmade papers are also used for Origami, Chiyogami, Quilling, which are Japanese art forms to create beautiful handcrafted products using handmade papers.

6. Advantage of the handmade paper industry

6.1. Eco Friendly process

Handmade paper manufacturing is a 100% wood-free, eco-friendly process, which uses various used

(textile waste, ropes, gunny bags, etc.) and unused (plant fibres) cellulosic raw materials which are locally available. A survey shows that 11 lakh greeting cards made from handmade papers can save approx 500 trees. (A detailed, n.d.). Cellulosic fibres are self-sufficient to make paper but to impart specific desirable properties, mild chemicals (lime, soda as caustic soda, oxalates, oxygen, and peroxides) are used so that a simple effluent treatment plant can treat the effluent, and industry can get *Zero effluent Mill* status easily (Kumar et al., n.d.).

6.2. Waste recovery potential

Handmade paper can be up-cycled and recycled into variegated functional and decorative products. Up-cycling of paper into garments (Shifu), 3-d sculptures (paper mache), and other craft products through Chiogamy and Origami is possible. Recycling of various waste products like garment cutting waste (cotton, linen, jute, and hemp), agro residue waste, animal dung (cow, elephant), plastic, old currency etc. is possible into handmade paper. Recycling of old newspaper, tetra packs and the handmade paper itself into handmade paper or cardboard is also done. In the case of handmade paper, maximum recycling limit is approx eight times (Kumar et al., n.d.). In one of the recent research done by Kulshreshtha (et al., 2013), the sludge of handmade paper and cardboard along with wheat straw was found suitable for the cultivation of mushrooms (*Pleurotus citrinopileatus*).

6.3. The people-friendly industry

Handmade paper industry requires low investment and capital cost with limited machinery. Regular handmade paper industry needs approx. Rs 3 -3.5 lakh as the initial investment. The industry needs only semiskilled or skilled labour (Dwivedi et al., 2009).

6.4. More strength

As compared to machine-made paper, hand-made paper has more tensile strength, bursting as well as tearing strength. In addition, double-fold strength is also higher as fibres of handmade paper can be shaken in all the four direction whereas those of machine-made paper can be shaken side to side (Kumar et al, n.d.; Kulria, 2016).

6.5. Creativity Exploration

Technique of handmade paper manufacturing is an excellent medium of artistic expression where each piece of paper is unique and handcrafted. There are options to explore creativity by way of making infinite designs, textures and products. Currently, a wide variety of handmade papers on the basis of thicknesses and surface embellishments are available.

6.6. Available for various uses

There are unlimited options for paper manipulations like tearing, cutting, mutilating, burning, scorching, stamping, krumping, painting, drawing, packaging, writing, rolling, casting, recycling, upcycling and weaving are possible with the help of handmade paper.

7. Disadvantage of the handmade paper industry

7.1. Erratic Availability of raw material

Supply of raw material for handmade paper is not continuous and uniform, as raw materials for handmade paper are agro and textile waste and are dependent on the production of those industries.

7.2. Slow Production

Production of handmade paper is slow as compared to machine-made paper because of manual work, limited production units and raw materials. One sheet of handmade paper is formed at a time indicating a low productivity

7.3. Non Uniform production

Each sheet of handmade paper is handcrafted, so the bulk amount of uniform production is not possible in case of handmade papers. Due to the handcrafted process, the surfaces of handmade papers are rough and patchy as compared to machine-made paper and not suitable for some works.

7.4. Cost of handmade paper

Cost of handmade paper is high as compared to machine-made paper because of limited handcrafted production, specialised labour and raw materials.

7.5. Handling of handmade paper

Sometimes handling of handmade paper becomes difficult because of chemical-free production. There are huge chances of fungal growth and germination in a moist and humid environment.

7.6. Unstable market demand

Uniform surface, bulk production, maintenance, cost, and easy availability of machine-made paper give tough competition to handmade papers, and there is a problem of non -continuous market demand for handmade paper which creates a problem for the labour-intensive industry to sustain.

Conclusion

Since ancient times to present era, paper is considered as one of the valuable and serviceable commodity. After the industrialization, handmade papers were replaced by wood pulp based machine made papers which destroyed production of handmade pa-

pers. In the present era of sustainability, there is need to recognize and encourage traditional handmade paper production technology for its social, economic and environmental benefits. The current demands of sustainable design suggest value to be generated from waste to move in the cycle of attaining circular economy. This is a painstakingly slow process to implement and varies with scale of production even within the same industry. Handmade paper industry like any other handcrafted industry is socially significant as it employs a rural population with a basic index of skilling. The industry has a strong potential because of the variegated product range, acceptance in the domestic market as well as sustained exports. The production process is in genesis with the ecosystem and aligned to sustainable development goals. It embraces an industrial symbiosis where the waste of one industry becomes the raw material for another industry similar to the handmade industry where the waste of garment manufacturing industries are becoming raw material for the handmade paper industry.

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