An Approach Towards Minimum Fresh Water Consumption In Paper Industries

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ABSTRACT

The paper making process involves huge water consumption and the water requirement depends mainly on raw material usage, process and technology employed and the quality of end product. In recent past, considerable efforts have been made by the mills to reduce water consumption through process optimization for efficient water usage, better housekeeping and increased reuse of back water. In present communication, the effect of contaminants on quality of papers and possible suggestion technologies for minimizing fresh water consumption are discussed Further, reduction in water consumption involves the use of advance technologies.

Introduction

The rapid increase in population and the increased demand for industrial establishments to meet human requirements have created problems such as over exploitation of available resources, leading to pollution of the land, air and water environments. The pulp and paper industry is considered as the third largest polluter among various industries. The effluents from the industry cause slime growth, thermal impacts, scum formation, color problems and loss of aesthetic beauty in the environment. They also increase the amount of toxic substances in the water, causing death to the zooplankton and fish, as well as profoundly affecting the terrestrial ecosystem. The most significant sources of pollution among various process stages are raw materials preparation, pulping, pulp washing, screening, bleaching, and paper machine and coating operations. Among the processes, pulping generates a high-strength wastewater especially by chemical pulping. This wastewater contains wood debris and soluble wood materials. Pulp bleaching generates most toxic substances as it utilizes chlorine for brightening the pulp. Since last two decades, bleaching of pulp has become an issue of great apprehension primarily because of the environmental hazards caused by release of adsorbable organic halides (AOX). The main sources of pollution in paper industry are shown in Figure1.

Fresh water requirement in a paper industry

The source of fresh water in a paper mill is usually surface water and to some extent groundwater, depending on the availability and local conditions. Surface water in particular does not meet the desired quality parameters and therefore, has to be conditioned by filtering and/or chemical coagulation and flocculation and subsequent sedimentation before use. For boiler house use and in specialty papers e.g. photographic base paper, electrical insulation paper or cigarette paper production, the fresh water is softened and/or desalinated/ deionized. With the limited amount of fresh water availability, now-a-days, this resource must be used efficiently. In general, the fresh water taken into a mill is first used

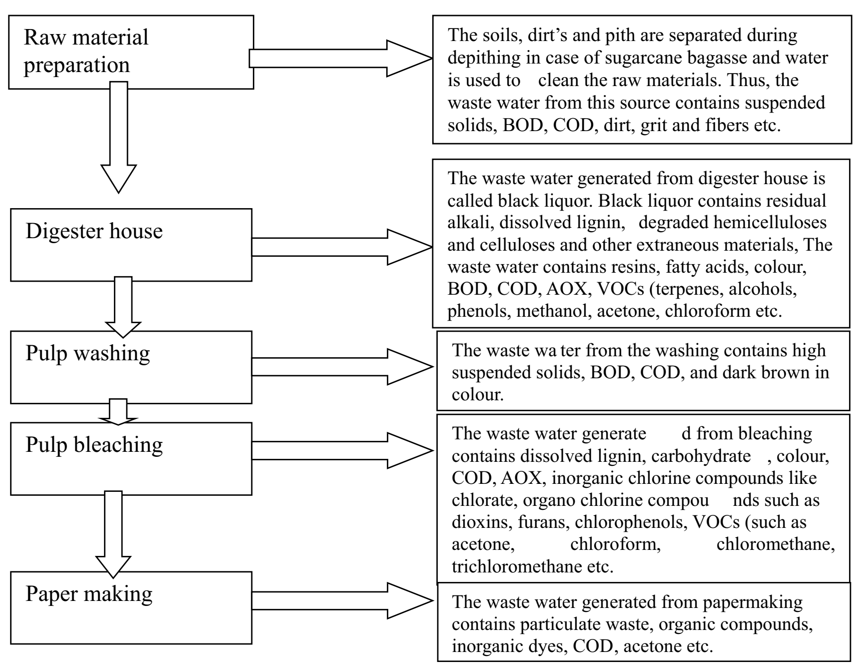

Figure1: Pollution from various sources of pulping and paper making

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for cooling then it is distributed to its process consumers either directly or after further heating. There are only a few fresh water consumers in modern mills:

- Chemical preparation and dilution systems,
- Sealing water consumers (mainly vacuum pumps) and
- High pressure sprays for felt conditioning.

Table 1: Other sources of anionic trash in fresh water

Chemicals	Sources
Sodium silicate	Peroxide bleaching, deinking, recovered paper
Polyphosphate	Filler dispersing agent
Polyacrylate	Filler dispersing agent
Starch	Coated broke, recovered paper
Humic acids	Fresh water
Lignin water, lignosulphonates, hemicelluloses	Chemical and mechanical pulp
Fatty acids	Mechanical pulp, deinking

Contaminants in process water and its effect on quality of paper

The majority of water used in a paper mill is process water or recycled in the different water loops of the water circuit of the system before disposal. The process water is 'produced' in the thickening and dewatering stages of the papermaking process. Due to its contents of solid, colloidal and dissolved substances, the quality of the process water is lower than that of fresh water.

Major process changes in paper production in the last two decades are as under:

- Dearth of cellulosic fibers compels the paper industry for increased use of waste/ recovered paper
- Shifting from acidic (alum-rosin) sizing system to neutral/alkaline (AKD/ASA) sizing system
- Reduction in fresh water consumption and augment use of recycled water wherever, it is possible after treatment

These changes in the process led to various problems due to increasing of detrimental substances in the water loops.

Detrimental substances from different sources

- Raw materials: resin, lignin derivates, bark and pith
- Freshwater: humic acid (increases in rainy season),
- Broke and recovered paper: coating binders, glues and adhesives,
- Additives: fatty acids or silicates, starch and others.
- Some other sources of detrimental substances are described in Table1.

A lot of problems are caused by these detrimental substances throughout the whole paper- making process such as

- Reduction in efficiency of additives,
- Reduction in optical properties like brightness
- Reduction in mechanical strength properties
- Poor sizing (alum-rosin sizing) but not matters in case neutral/alkaline sizing. However, it can be mitigated by reverse sizing i.e. use of paper makers' alum first.
- Bad odour due to microbiological activities and it can be mitigated by proper use of biocides and by proper aeration in water loop.
- Negative effects on drainage and drying: It can be minimized by use of drainage aids

These entire factors are responsible for:

- Reduced paper machine speed.
- Deposits and foam generation causing defects in paper as well as resulting in paper web breaks.
- Detrimental substances (anionic oligomers and poly electrolytes as well as nonionic hydro colloids) are known as anionic trash and are measured as cationic demand by polyelectrolyte titration in a streaming current device or as chemical oxygen demand (COD).
- Inorganic dissolved substances i.e. salts, are measured as increased conductivity.
- Salts (Inorganic) are also detrimental to the process performance and potentially for the paper properties.
- Electrolytes reduce the swelling potential of fibers and
- Chloride especially leads to corrosion of machine parts.

The content of detrimental substances in paper mill water circuit systems depends on the:

- Input of raw materials
- Output by bleeding through waste water disposal as well as by the degree of transfer to the final paper,
- Loop design, and
- Adoption of kidney technologies in the mill.

For different applications, such as sprays in the paper machine, solids (mainly fibers, fines and fillers) in the process water are also disturbing and have to be removed before the water is used.

Minimizing water usage

Cooling water network

The amount of fresh water used for cooling may be around 6 m^3/t of paper. Recycling this water in the fresh water network to the paper machine presents real advantages due to the higher temperature. There are no disadvantages because the only modification in the physico-chemical quality of the water leaving the cooling circuit is an increase of temperature. The cooling water network should be fed by the fresh water system and recycled to the raw water tank of the paper machine. If necessary, the cooling water system can be partially closed; in this case, a cooling tower for reuse is then required.

Preparation and dilution of chemicals

The water quality used for the preparation of chemicals should be free from ionic impurities because pollutants introduced in this step will greatly affect the efficiency of additives added during stock preparation. The preparation of chemicals should be made with clean fresh water. Some chemicals (size chemicals and resins) need dilution prior to sending them to pulp flow. The contact between the water of dilution and the chemicals before their contact with the pulp is very short. It is then possible to use clarified water instead of fresh water for this application.

Paper machine showers

Clear or super-clear white water from the save-all is increasingly used in showers in wet end part of paper machine (Wire pit and couch pit). The use of clarified water to feed wire showers requires adequate showers and nozzles: shower cleaning equipment, with an internal brush or other purging equipment is also necessary. To avoid plugging of the nozzle due to dysfunction of the save-all, water distribution to such showers should go through a protective in-fine strainer, preferably of the slotted type and equipped with an automatic purge. The opening size of this filter should not exceed 1/6th of the spray nozzle diameter. To avoid plugging the nozzle, the particle size is more important than the consistency. The use of clarified water to feed felt showers needs a stronger filtration step and a specific study must be carried out to ensure that the use of process water will not affect the felt plugging. The industry standards for shower water consumption are given in Table 2.

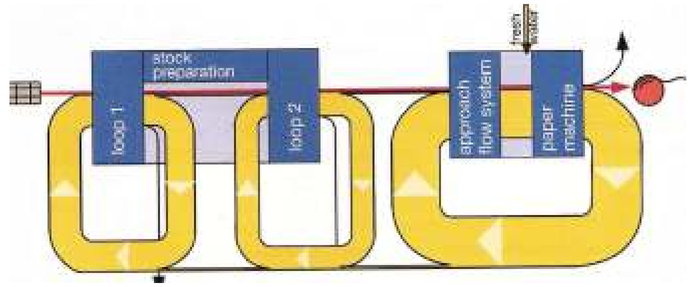


Figure 2: Water loop systems in a paper mill (source: Voith)

Table2: Consumption of showers water by felts in different parts of paper machine

Shower water in liter per min	Pick-up	Pick-up	Top-3	Top-3
High pressure oscillating showers	*	*	*	*
Uhle box lube-I,	*	*	*	*
Uhle box lube-II,	*	*	*	*
Chemical showers	*	*	Not required	Not required
Industry standards shower water liter per kg of felt per min	0.05-0.10	0.04-0.07	0.03-0.04	0.02-0.03

*= Optimize according to felt RPM and felt weight so that value meets the industry standard (Source: Voith).

Sealing waters

Sealing water used for circulating pumps can represent a high use of fresh water. Pump constructors propose interesting alternatives with mechanical seals or dynamic water tightness. Vacuum pumps also need large quantities of sealing water. A recycling loop is recommended for part of the vacuum pump sealing water with integrated cooling and solids removal systems. Paper machine vacuum pumps that recycle used sealing water must have strainers and in the case of a high recycling rate, cooling systems in recycling lines to maintain a high vacuum. It is important to note that some of the paper mills use clarified water as sealing water.

Water loop systems (1)

The objectives of the water loop systems are to offer the required volume rate and quality of water for each consumer and to treat and/or bleed out water containing detrimental substances. Completely closed water loops meaning that there is no waste water produced at all and fresh water (as make-up water) therefore is only fed at the same volume rate as it is removed by evaporation in the dryer section of the paper machine and with the rejects leaving the mill. A water loop systems of a paper mill usually includes different water loops:

- ❖ Paper machine water loop systems include (a) the approach flow system and (b) the white water systems-I (WW-I) and white water systems-II (WW-II) (Figure2)
- ❖ In deinked pulp production, two or three water loop systems are required in the stock preparation.

Water loop systems in a paper mill is shown in Figure2.

End-of-pipe treatment for bled-out water is taken in a waste water treatment plant so that it may be used at appropriate place. There are some main principles have to be followed in order to manage the water loop systems successfully:

- ❖ Efficient loop separation, i.e. transferring stock from one process loop to the following one only at high consistency (preferably 30%), which means at low water content, in order to avoid, to the greatest possible degree, transferring detrimental substances from one water loop to the following one.
- ❖ Application of counter current flow, meaning fresh water is added only at the paper machine, excess water from each loop must only be sent backwards and waste water is disposed of only from the first loop in fiber preparation (lowest quality water).
- ❖ No mixing of water from different production lines in mills where more than one paper machine is operated
- ❖ No mixing of water from different fiber preparation lines and/or pulp preparation plants
- ❖ Use of **kidney technologies** for removal of solids and/or detrimental sub- stances
- ❖ Adequate sizing of the water buffers for each water loop in accordance with the stock storage volumes for avoiding uncontrolled overflows in start-up, shut-down or paper machine sheet break situations.

White water loops system (2)

The white water loop of a paper machine contains (a) white waters loop-I (WW-I) and (b) white waters loop-II (WW-II) and the save-all unit. WW-I coming out from the wire section of the paper machine is directly used to dilute the stock flow after the machine chest or blending chest in the approach flow system and for diluting the pulp coming from constant level box in fan pulp (to bring down the consistency of stock from 3% to 0.7%). WW-II originates also from the forming section (couch pit) but additionally from the press section (after removal of felt hairs, usually with a bow screen), from broke thickening and from the overflow of WW-1. WW-II is sent to a buffer tank and from there it is used at the end of stock preparation to dilute stock from consistency (10-12%) to storage consistency (3-4% in raw pulp chest) and for slushing and diluting broke. An amount of WW-II and the trimmings from the forming section are fed to the save-all unit (Krofta). Save-all has a dual function: (a) stock recovery which is mixed with the pulp present in blending chest and water clarification. **It is recommended to use a disc filter save-all treating a certain volume of WW-II by filtering it through a fiber mat.** In addition to cloudy and clear filtrate, disc filter save-all produces a super clear filtrate with very low solids content. **This super clear filtrate is used as a fresh water substitute for spray applications in the paper machine. The clear filtrate is stored in a buffer tank.** The cloudy filtrate is usually fed directly back to the inlet of the disc filter,the "used" sweetener, including the recovered stock, is fed back to the thick stock in the approach flow system. **Dissolved air flotation type**

save-alls are used now-a-days when a certain degree of ash and fines removal from the process is demanded. In this case, the sludge of the dissolved air flotation is rejected. The advantages of a disc filter save-all compared to a dissolved air flotation save-all are higher filtrate quality, no chemical consumption and less space requirement.

There are two reasons for excess of water present in the paper machine loop. (i) the paper machine loop is continuously fed with fresh water, used for spraying and chemical dilution. (ii) the incoming water content of the stock is higher (consistency 20-22%) than the water content in the sheet after the press section (consistency up to 48% and more). This excess water is sent, in the form of clear filtrate, from the save-all unit backwards, as make-up water, to the stock preparation, thus following the counter current principle. This make-up water is often additionally treated in a dissolved air flotation with coagulation and flocculation chemicals in order to remove detrimental substances before feeding it back-wards.

Water loops systems in stock preparation

Water loop system of a paper mill consists of only one water loop when chemical pulp is the only fiber source or in lower quality packaging paper production. For systems using recovered paper, the strict separation of the water loops in stock preparation from the paper machine loop is essential in order to meet high runability and quality demands because this strategy keeps detrimental substances from the paper machine. Depending on the required quality of the prepared fiber stock and thus on the design of the stock preparation system, the water loop system in the stock preparation can have one to three water loops. The loops are separated by the thickening/dewatering process stages (disc filter plus wire press or screw press). The filtrates of these stages are sent backwards for dilution purposes in the same loop, the excess water (usually clear filtrate from the disc filter) replenishes the preceding loop. A water buffer tank, usually fed by clear filtrate from the disc filter in (Stock Preparation Loop-I) SPL-I, avoids uncontrolled overflow to the waste water treatment plant. Waste water is disposed of from the first water loop as filtrate from reject and sludge thickening, as these filtrates are of low quality. Usually they are treated chemically /mechanically in a dissolved air flotation unit. Depending on the fresh water consumption, a certain amount of this treated filtrate can be recycled into the process.

Limitation of total loop closure

The maximum reutilization of the water employed is limited by the various detrimental substances in the process water. Their concentration in process water is measured as COD concentration. The higher the water l system is closed, the more COD in (kg COD per tonne of paper) is loaded into the paper instead of being bled into the waste water. This leads to a disproportionate increase in various problems due to detrimental substances. Consequently, the multi-loop systems for graphic paper grades now-a-days follow the counter current principle and partly use circuit water cleaning according to the kidney principle. So it is possible to reduce the specific water emissions down to 8-10 l/kg of paper. Further, closing would lead to increased amounts of detrimental substances. This would negatively affect product quality; e.g. decreased optical properties and increased stickies and dirt content as well as runnability problems on the paper machine, such as felt and shower plugging, reduced retention, scaling and slime formation.

Case study: Waste paper based kraft paper mill (3)

Reducing the effluent volumes to zero means that fresh water consumption is reduced to approximately 1.5 L per kg of paper. Zero effluent concept for a packaging paper mill is shown in Figure3. The major problems would arise from the extremely high amount of detrimental substances, which will be bled out of the process only by transferring them into the paper. The only solution to these problems is to remove the detrimental substances from the process with suitable highly efficient kidney technologies. These include, in addition to circuit water cleaning by coagulation and flocculation with subsequent removal in a dissolved air floatation unit, anaerobic/aerobic combinations of biological treatment, and different membrane filtration technologies like micro-, ultra- or nano-filtration down to reverse osmosis or evaporation. Some packaging paper mills in central Europe today run with zero effluent systems using a combination of anaerobic/aerobic biological treatment as kidney technology for COD reduction. The driving forces for reducing the effluent to 0L per kg of paper for these mills were unique to each mill. In one case there was high cost-saving potential by completely avoiding effluent fees for disposal into a public effluent treatment plant. The other reason for complete water loop system closure was the lack of available fresh water due to the local conditions when installing additional production capacity. The other mentioned kidney technologies are membrane filtration and evaporation, are mainly known as pilot scale applications as they are quite cost-intensive and still not proven state-of-the-art.

It is important to note that Vaibhav Paper Mills, (Waste paper based) Vapi (Gujrat) does not discharge a single drop of water from last six years. The analysis results are given in Tables 4-6. It is only possible by achieving over all retention about 90% using retention and flocculation agents with synthetic

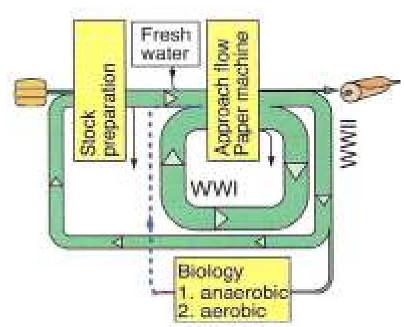


Figure3: Zero effluent concept for a packaging paper mill (Source: Voith)

Table 3: Present limits of system closure

System Application	Specific effluent volume, L/ kg paper	Disturbing effects limiting further closure
Graphic paper grades several water loops counter current flow circuit water cleaning (kidney)	8-10	Decreasing product quality felt shower plugging lower particle retention scaling slime
Board and paper packaging grades	3-5	Odor problems (water and product)
Single or two loops		corrosion
water treatment only for showers		deposits

silica. Due to continuous aeration and short circulation loop, microbiological activities are almost negligible. In kraft paper except burst factor, wet tensile strength and Cobb value other properties are less important. Hence, there is no need of using kidney technology.

Various methods for reuse of paper mill waste water

Combined ozonation and biofilm treatment

A combined ozonation and biofilm treatment reduces COD load by up to 85% with 0.65 g ozone per g of COD. The quality of treated water can be used for the most of grades of papers production. 80-100% treated water can be reused depending upon types of grade. In some cases, the concentration of electrolytes increase therefore, membrane treatment stage (nano-filtration) for desalination would have to be added. The cost of ozone bio-filter process is not as high as expected. The operation cost for a single stage plant will be 0.05 to 0.2 Euro per m^3 of effluent treated depending upon the type of waste water as well as size and technical standard of the plant. The reuse may either may lead to a specific amount of waste water of about 2-4 m^3/t of paper or to a closed system with no effluent and about 1.5 m^3/t of fresh water required due to evaporation.

Membrane filtration of white water

Membrane systems have become widely recommended system for white water purification, especially in light of advances in their durability and throughput. Membrane filters separate various materials from liquid based on their size. In theory, one could employ a one-step filtration with a so-called "nanofiltration" system capable of excluding even some large monomeric ions or a reverse osmosis membrane that can exclude essentially everything except water. Ultrafiltration membranes are rated to exclude very large molecules, such as polyelectrolyte, where as microfiltration systems have pore sizes selected to exclude bacterial cells and fine particulate matter suspended in the water. Throughput is often enhanced by a cross-flow design, as in the case of tubular filters, providing a means for the flow to minimize the caking of excluded materials on the membrane face. A pore-size category of about 10 nm is an ideal choice. The membrane technology can be used in combination with other water treatment measures. Conventional pretreatment strategies, before membrane filtration, include chemical coagulation, adsorption, sedimentation, and flotation.

Several authors compare the efficiency of (i) ultra filtration and (ii) ultra filtration plus dissolved air flotation. The results show 54%, 88%, 100% removal of TOC, color and SS, respectively by ultra filtration alone. Ultra filtration plus dissolved air flotation results in 65%, 90% and 100% removal of TOC, color, and SS, respectively. It is also reported that 88% and 89% removal of BOD, and COD, respectively is achieved by reverse osmosis (RO). It is observed that membrane filtration (MF), and granular membrane filtration (GMF) is suitable for removing heavy metals from the pulp and paper mill wastewater.

Coagulation of white water

Coagulation and flocculation is normally employed in the tertiary treatment in the case of pulp and paper mill wastewater treatment and not commonly adopted in the primary treatment. Paper technologists are often familiar with coagulation phenomena, due to the fact that aluminum sulfate ("alum"), poly-aluminum chloride (PAC), and low-mass, high-charge cationic polymers are commonly used to balance the colloidal charge of a paper machine, the purpose being to stabilize operations and enhance the performance of high-mass acryl amide-type retention aids and other additives. A comparative study is conducted with

Table4: Water balance in Vaibhav Paper Boards Private Limited, Vapi (Gujrat)

Sl. No.	Input			Output		Remarks
	Place	Uses of water	Qty. (kL)	Place	Qty. (kL)	
1	Pulper	Recycle water	2528.5	Thickener	1300	To recycle
2	Refiner	Fresh water	9.1	–	–	–
3	Mixing Chest	Fresh water	56.505	–	–	–
4	Centri cleaning system	Recycle water	5190.965	Centri cleaning system	28.73	To recycle
5	Wire Part	Fresh water	20	Wire Part	6304.74	To recycle
6	Waste Paper	Moisture	6.5	Press part	85.995	To recycle
7	–	–	–	Dryer part	87.945	Evaporation loss
8	–	–	–	In paper	4.16	Moisture go to paper
		Total	**7811.57**	**Total**	**7811.57**	

Table5: Mass balance in Vaibhav Paper Boards Private Limited, Vapi (Gujrat)

Sl. No.	Input			Output		Remarks
	Particular	Qty. (MT)		Particular	Qty. (MT)	
1	Waste paper	65.39		Finished product	66.56	
2	Alum/PAC	1.3		Moisture in paper	4.16	
3	Rosined	0.325		Plastic	0.39	
4	Bentonite	0.195		Process waste	0.26	
5	Water fresh	85.605				
6	Water recycle	7719.47		Evaporation	87.945	
7	Moisture in waste paper	6.5		Water recycle	7719.47	
8	–	–				
9	–	–				
	Total	7878.79		Total	7878.79	

Table6: Characteristics of recycle water

Characteristics of waste water	Usage points
Water in holding tank (Collection tank) pH 6.0 Colour, PCU 400 TDS, mg/L 48520 TSS, mg/L 2680 COD, mg/L 32120 BOD, mg/L 9883	Used in pulper
Decker thickener filtrate tank pH 6.0 TDS, mg/L 48520 TSS, mg/L 2680	Used in decker thickener shower, High density cleaner, Turbo separator, Centricleaner's reject pit dilution
Wire pit silo pH 5.5 TSS, ppm 1200	Used in centricleaner through fan pump
Vacuum seal pit no.1 pH 6.0 TSS, ppm 1400	Used in vacuum pump sealing
Vacuum seal pit no.2 pH 6.0 TSS, mg/L 1000	Used in knockdown shower- a drilled hole shower pipe 1 mm hole
Holding water tank collects water excess water at all the points, press part drainage and vacuum pump drainage i.e. sealing water and hosing of back water in plant	

horseradish peroxide (chitosan) and other coagulants such as ($Al_2(SO_4)_3$), hexamethylene diamine epichlorohydrin polycondensate (HE), polyethyleneimine (PEI), to remove adsorbable organic halides (AOX), total organic carbon (TOC), and color. It is observed that modified chitosan is far more effective in removing these pollutants than other coagulants. Such additives also can be used, at least as a first step, in the clarification of white water. By causing suspended materials to be agglomerated into larger-size units, coagulation can serve as a kind of pretreatment for other kidney operations, such as membrane filtration. The simplest approach, from the standpoint of paper machine operations, is just to add the coagulant to the stock system, and then follow up with addition of a high-mass acrylamide copolymer, i.e. a "retention aid," just before the stock reaches the forming section of the paper machine. In this way, the fine matter becomes incorporated in the product and purged from the aqueous system.

Flotation of white water

Suspended matters present in the pulp and paper wastewater are comprised primarily of bark particles, fiber, fiber debris, filler and coating materials. Such devices use bubbles of air to lift a mat of solid materials, including fibre fines, to the surface of a shallow pool of water, where the solids can be skimmed off and returned to the paper machine system. Most flotation units in paper mills employ pressurized water, to which air has been added. Release of the pressure, as the water enters the bottom of a flotation cell, causes air to come out of solution as very fine bubbles. For purposes of water clarification, it can be expected that dissolved-air flotation (DAF) units will be especially effective in the case of particulate matter having at least some hydrophobic character. A novel idea to enhance the performance of flotation systems, for purposes of water purification, involves the application of direct current to a pair of electrodes near to the entrance to a flotation cell. Tiny bubbles of hydrogen and oxygen, generated by electrolysis at the two electrodes, provide the needed lift to colloidal and particulate matter in the water. 65-95% removal of TSS is reported by dissolved air flotation.

Biological treatment of white water

Biological treatment systems can be designed to run either in the absence of air (anaerobic systems) or with sufficient agitation or air injection to keep the system oxygenated during bacterial or fungal growth (aerobic systems). A further choice may involve the temperature of operation. Paper machines with fully closed white water systems often run at relatively high temperatures, too high for the majority of bacteria to thrive. However, thermophilic aerobic bacteria have been found to perform well in white water treatment systems at temperatures of 55-60ºC. Anaerobic conditions in white water chests, for instance, have been associated with the production of foul smells and corrosion. Even in the absence of biological treatment, it has been recommended to aerate the white water used in mills where the amount of fresh water has been sharply minimized. The combination of aerobic biological treatment, followed by micro flotation has been highly recommended. In another successful installation, aerobic biological treatment was followed by microfiltration.

Integrated treatment processes

An integrated or hybrid system is designed to take advantage of unique features of two or more processes. A combination of coagulation and wet oxidation removes 51% of COD 83% of color and 75% of lignin. A combination of ozone and biofilm reactor removes 80% COD. A combination of chemical oxidation with ozone removed 90% of wood extractives and 50% of the COD from TMP wastewater at 150 ^{0}C. A combination of dissolved air flotation and chemical precipitation removes 93% SS, 50% BOD7, 57% COD, 92% phosphorus, and 52% nitrogen. A combination of activated sludge and with ozonation (as tertiary treatment) removes 87 – 97% COD, and 97% BOD. A combination of a biofilm reactor followed by one anaerobic and two aerobic reactors is found to remove 50% COD, 80 – 90% BOD7, 50% AOX, 90% ClO_3. A combination of aerobic reactor followed by anaerobic reactor removes 94% color, and 66% TOC.

Ways to clean up white water (3)

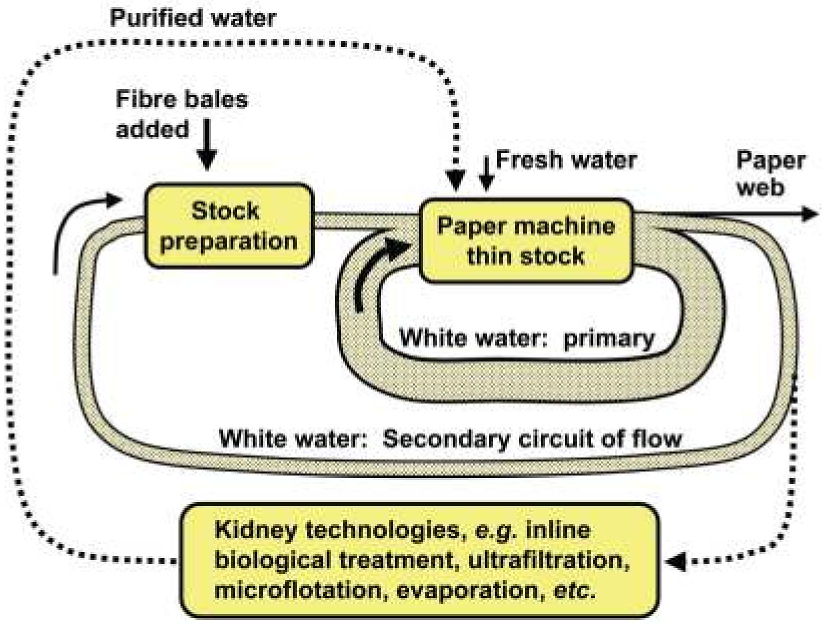
Table 7 summarizes some key strengths and suggested deficiencies of different reported strategies for white water quality improvement. Many of these strategies rely on implementation of one or more "kidneys," i.e. measures to remove dissolved solids, organic matter, or suspended minerals from the water (Figure4).

Conclusions:

Water conservation is now a top priority agenda before pulp and paper industry not only due to high cost of fresh water/ waste water treatment but also due to less availability of water as well as disposal of treated effluent. The pulp and paper industries have already made remarkable efforts to reduce the water consumption through process upgradation, efficient water usage and reuse/recycle of back water and treated effluent for in-house activities. Further, reduction in water consumption can be

Table 7: Summary of strong and weak points of different approaches for cleaning of white water in a paper machine system

White water cleaning technologies	Advantages	Disadvantages
Membrane filtration	Simple; moderate in cost; effective against bacteria	Prone to fouling and low volumetric throughput
Chemical coagulation	Useful as a pretreatment for membrane filtration	By itself not effective for most "non-substantive" substances
Biological treatment	Very effective to reduce biological oxygen demand of the process water	When used alone, there is danger of poor dewatering, brightness loss, salt buildup
Enzyme treatment	A way to more precisely target the desired effects on white water	At most, solves only some of the problems related to white water
	Component	
Oxidative treatment	Accelerates chemical breakdown of organic matter	By itself, does not remove anything; sometimes makes removal more difficult
Evaporation	Most reliable way to achieve high-quality condensate and brine	Tends to set a cost threshold, which competing approaches must beat



achieved through adoption of integrated water management approach and also tertiary treatment options including membrane filtration etc to treat back water/treated effluent and match with the water quality requirement in various process.

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