NATSURV 12

WATER AND WASTE-WATER MANAGEMENT IN THE PAPER AND PULP INDUSTRY

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MANAGEMENT

IN THE

PAPER AND PULP INDUSTRY

PREPARED FOR

THE

WATER RESEARCH COMMISSION

BY

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FOREWORD

The need for guidelines to reduce water intake and waste-water disposal by industry is of national concern in view of South Africa's water scarcity.

To establish norms for water intake and waste-water disposal, the Water Research Commission (WRC) in collaboration with the Department of Water Affairs (DWA), contracted Steffen, Robertson and Kirsten, a firm of consulting engineers, to undertake a National Industrial Water and Waste-water Survey (NATSURV) of all classes of industry. The consultants identified 75 industrial groupings in South Africa, one of which is the paper and pulp industry. The results obtained in the survey of the paper and pulp industry form the basis of the Guide on Water and Waste-water Management in the Paper and Pulp Industry.

It is hoped that this guide will be of value to the industry itself, and to other interested parties such as municipalities, administrators, researchers and consultants in the water and waste-water fields.

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SUMMARY

There are 21 mill sites in the Republic of South Africa ranging from small household tissue mills to the most modern integrated pulp and paper mills, producing approximately 3 million tonnes per annum of pulp and paper products. Specific water intake (SWI) varied between 33 and 136 m^3/t for integrated pulp and paper mills and between 1 and 49 m^3/t for pulp and paper products plants. Specific pollution load (SPL) was found to vary between 9 and 80 kg COD/t and 21 and 183 kg TDS/t for integrated pulp and paper mills, and between 4 and 10 kg COD/t and 2 and 110 kg TDS/t for non-integrated plants.

The variation in water intake and waste-water quality is dependent upon the tree species or pulp material utilized, the efficiency of the mill in terms of process control and operation, the paper product produced and the degree of chemical recovery and waste-water treatment prior to discharge.

Forceful measures have been taken by the Industry in recent years to reduce the water intake and pollution potential of pulp and paper mills. These measures include the tightening up of water using systems, more effective waste-water treatment systems and reuse of treated water sources, new production processes, technically improved machinery and equipment, as well as improved management and operation of production.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

FIGURE

ABBREVIATIONS

COD	Chemical oxygen demand
SPL	Specific pollution load
SWI	Specific water intake
TDS	Total dissolved solids

GLOSSARY

BAGASSE	Waste fibrous residue after the extraction of sugar from cane
BLACK LIQUOR	The black liquid remaining after digestion of timber in a chemical pulping process. Black liquor contains the spent cookery chemicals, lignin, resins and other non-cellulose constituents in solution
BLEACHING	Treatment of cellulosic fibre with chemicals to increase brightness and stability
BROKE	Paper rejects which may be collected and repulped
BROWN STOCK	The mixture of black liquor and pulp produced after digestion of timber
CELLULOSE	A carbohydrate polymer of glucose units
CHEMICAL PULPING	The defibrisation of timber by the use of chemicals such as sulphite, soda and sulphate processes. The yield of pulp is about 50% but the pulp produced is of higher quality than that from mechanical pulping
CLOUDY WATER	Recycle of paper machine water which contains many fine fibres
CROSSFLOW MICROFILTRATION	A pressure-driven filtration process for the removal of suspended and colloidal particles from waste water
DISSOLVED AIR FLOTATION	The use of air, dissolved under pressure, to assist in the flotation of solid material present in waste waters. The solids can then be skimmed from the liquid surface for recovery or disposal

EXTRACTIVES	Wood chemicals that can be removed by extraction with natural solvents such as ethanol or benzene. Contains turpentine, wood resin or rosin, tall oils and soap
HEMICELLULOSE	A carbohydrate polymer of 5 and 6 carbon units
INTEGRATED MILL	A mill where pulping and paper making are integrated on a single site
JUMBO ROLL	The final paper roll from the end of the paper machine
LIGNIN	An organic material occurring in the woody tissues of trees and plants, often combined with cellulose
MECHANICAL PULPING	The mechanical defibrisation of timber, other than for pretreatment, usually without the use of chemicals. The yield of pulp is about 95% but the resulting paper tends to lack strength and to discolour with time
NON-INTEGRATED MILL	A separate pulp or paper mill
PULP	Cellulosic fibre recovered from wood, bagasse, waste paper from which paper is manufactured
PULPING	Recovery of cellulosic fibre from raw materials (wood, bagasse)
SPECIFIC EFFLUENT VOLUME	The waste-water volume for a given period divided by the product mass or volume for the same period
SPECIFIC POLLUTION LOAD	The mass of pollutant for a given period divided by the product mass or volume for the same period

SPECIFIC WATER INTAKE	The water intake for a given period divided by the product mass or volume for the same period
STOCK	The cleaned process pulp suitable for feeding to the paper machines
ULTRAFILTRATION	Separation of colloidal or very fine solid material by filtration through microporous membranes
WHITE WATER	Clarified process water recycled within the paper making process
WIRE	Continuous woven flexible plastic mesh belt on which the paper is formed
YANKEE CYLINDER	Steam heated pressurised roller which reduces the paper moisture content prior to reeling

1 THE PULP AND PAPER INDUSTRY IN SOUTH AFRICA

1.1 Introduction

The pulp and paper industry in South Africa dates back to 1920 when the Klipriver mill near Johannesburg was built to recycle waste paper into wrapping paper at a rate of 3 t/d. It was another 18 years before the first fully integrated chemical pulp and paper operation started operating using wheat straw as the basic raw material, from which it derived its name Enterprise Straw (Enstra) near Springs. Initially two paper machines produced approximately 40 t/d of fine paper. However, the straw process was not a success and in 1948 the mill changed to the pulping of wood as the demand for paper and pulp products escalated.

There are presently 21 mills ranging from small household tissue mills to the most modern integrated pulp and paper mills of world standard, both in terms of size and technology [1].

1.2 Paper and Pulp Production in South Africa

The major raw material is timber for which about 1,3 million hectares are cultivated, at an estimated investment of some R 3 500 million. The Industry offers employment to approximately 60 000 people. Recycled waste represents about 30% of the raw material, with bagasse from sugar cane providing a viable alternative in the cane growing regions. Pulp and paper manufacture represents a direct capital investment of about R 5 000 million, provides direct employment to about 15 000 people, and generates about R 4000 million per annum turnover[1]. Some 3 000 000 t of paper products is produced annually, broken down as shown in Table 1.

The pulp and paper mills in South Africa can be grouped into integrated, non-integrated and secondary fibre mills. Mills which use waste paper as their primary raw material are referred to as secondary fibre mills.

Mills that manufacture paper or paperboard but not pulp are termed non-integrated mills[1]. A generalized flow diagram for the pulp and papermaking process is shown in Figure 1.

Table 1 : Paper Production in South Africa (1988)

Product	% of Production	End-product
Fluting and liner board	42,3	Corrugated board boxes
Newsprint	20,1	Newspapers
Fine paper	19,6	Printing, writing, cover papers, etc
Tissue	5,6	Tissues, wrapping, crèpe, etc
Kraft wrapping	4,3	Package and wrappers, etc

1.3 Water and Waste-water in the Pulp and Paper Industry

The high volumes of water required, have resulted in the majority of the mills in South Africa being situated close to rivers where inexpensive water is readily available. Inland where inexpensive water is less readily available, process water is also derived from treated domestic waste waters. Waste-water disposal often occurs directly to rivers or to the sea with or without prior biological treatment. Other avenues of disposal include irrigation onto pasture land, or discharge to sewer (attracting a local municipal discharge levy).

In the production of approximately 3 000 000 t/a of paper products the Industry uses some 130 million m^3/a of water. The waste water produced is high both in organic material (200 to 17 000 mg/ℓ COD) and inorganic material (500 to 13 000 mg/ℓ TDS).

The variation in water intake and waste-water quality is dependent upon the tree species or pulp material utilized, the efficiency of the mill in terms of process control and operation, the paper product produced, and the degree of chemical recovery or waste-water treatment prior to discharge.

2 THE PULP MANUFACTURING PROCESS

2.1 Raw Materials

The logs arriving at the mill are roughly 1/3 by weight water, 1/3 cellulose, and 1/3 a complex array of lignin compounds, resins, gums and sugars. The output from the factory is cellulose pulp with an absolute minimum of any sort of impurity. The raw materials required to manufacture pulp are indicated in Table 2.

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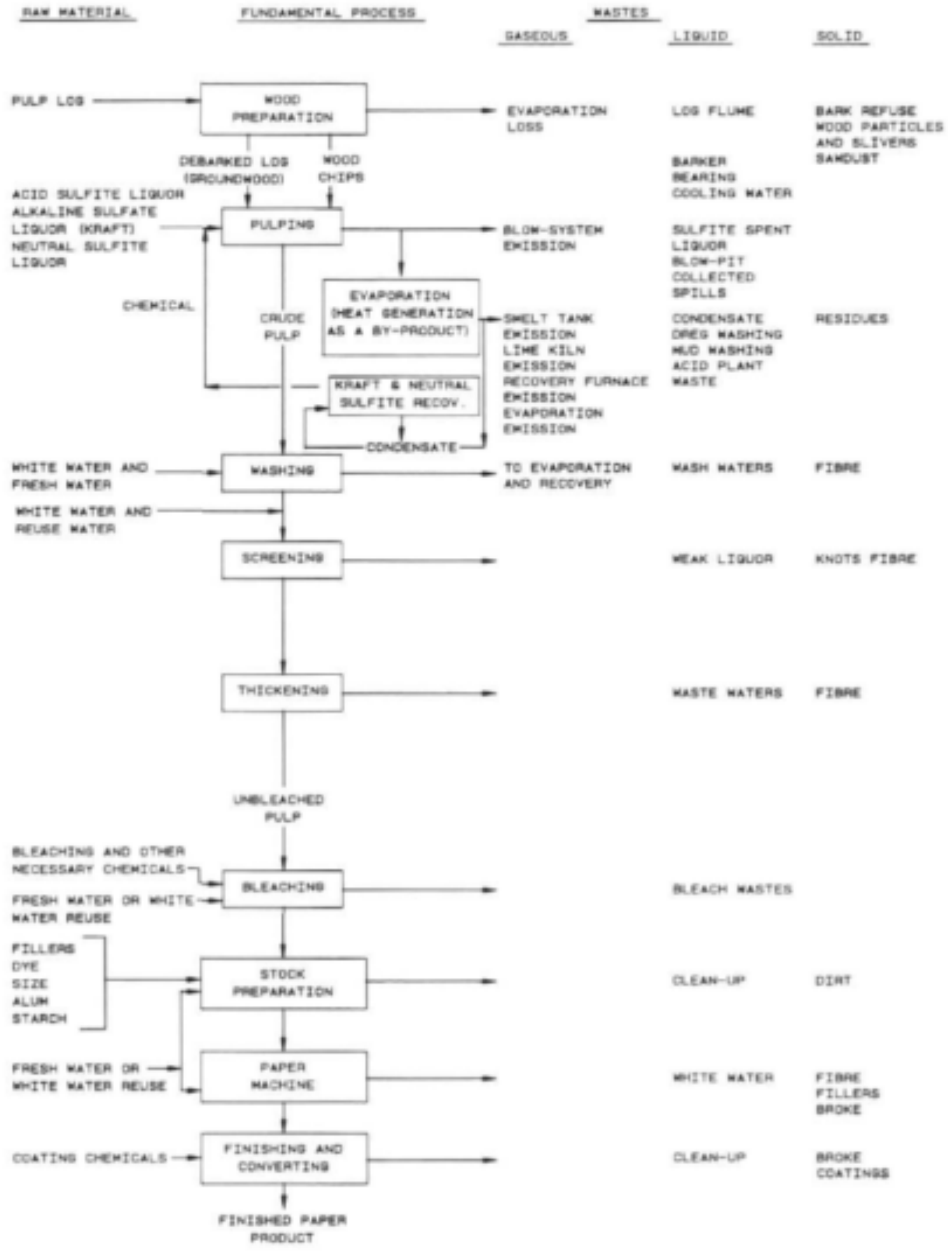

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FIGURE 1: A GENERAL FLOWSHEET FOR THE PULP AND PAPERMAKING PROCESS

Table 2 : Basic Raw Material Requirement

Timber	1.4 - 4 t/t pulp
Water	30 - 130 t/t pulp
Coal	0,5 - 0,75 t/t pulp
Chemicals	Sulphur Chlorine Limestone Caustic soda Numerous bleaching and process chemicals

2.2 Debarking

Drum debarking is the most common way of removing bark in the pulp and paper industry. As the drum rotates, the logs tumble and rub against each other, removing bark by abrasion either in the presence or absence of water (wet or dry debarking).

2.3 Chipping

Debarked logs pass by way of the log flume to the chippers which are large revolving discs equipped with cutting knives. The chips are either conveyed straight into the process or stored in stockpiles.

2.4 Pulping

The chipped wood or bagasse from the sugar industry then proceeds to the pulping process, which may be mechanical or chemical pulping or a combination of the two.

2.4.1 Mechanical Pulping

Mechanical pulping is the defibrisation of timber by mechanical means, usually without the use of chemicals (see glossary). It is normally achieved either by grinding logs of timber against a grinding stone, or by pulverising timber chips between rotating discs.

Water is required in the pretreatment of the wood and fibre, in the pulping and in the screening operations. The screened pulp is thickened to between 2% and 50% consistency dependent upon the process and stages used. The filtrate is partly recirculated and partly discharged from the process. Water is also lost from the process in rejects and through evaporation.

2.4.2 Chemical Pulping

Mechanically produced pulps are essentially wood without the bark. Chemical pulps are mainly pure cellulose, the less desirable constituents of the wood having been removed by the chemical treatment processes.

The earlier soda and sulphite pulp processes have been widely replaced by the Kraft process due principally to the demand for higher pulp strengths and a greater degree of chemical recovery and reduced water pollution. The main steps in the manufacture of chemical pulps are described in the following sections :

(a) Cooking

Chips are cooked for between 2 and 6 hours in digesters at about 10 atmospheres pressure and a temperature of 140°C. During pulping lignin is solubilised releasing individual fibres and extracting resins, alcohols and sugars.

In the batch process, at the end of the cook the pulp and liquor are "blown" under pressure into the blow tank. This is effected by the pressurized steam in the digester, which also serves the function of cleaning the digester, ready for another cook whilst the steam from the blow is utilized to heat water for mill use. Continuous processes are considered to offer more control of product quality and are becoming the norm for the Industry.

The blow tank contains the pulp and black liquor, the latter consisting of the spent cooking chemicals, lignin and other solids extracted from the wood. The pulp and black liquor are diluted and pumped to the brown-stock washers, where the liquor, containing the soluble residue from the cook, is washed out of the pulp.

(b) Washing and screening

To achieve high brown stock washing efficiency, multi-stage, counter-current washing systems are employed. The circulating water of the washing-screening system may also be connected with oxygen bleaching (delignification). In a closed system, fresh water may only be introduced to the washing stage after oxygen bleaching[2].

After washing and screening the pulp is sent to the bleach plant or paper mill.

(c) **Chemical recovery system**

The black liquor from the brown-stock washers, containing about 16% solids, is evaporated in multiple-effect evaporators to up to 65% solids. The condensate is recovered for reuse or disposal. During evaporation, resinous soaps are separated and recovered as a by-product. In the older mills the liquor may be partially concentrated in a direct evaporator. Combustion takes place in special furnaces. Combustion of lignin and other extracts produces heat which is able to maintain combustion and produce steam.

In the Kraft process the recovery furnace further serves the purpose of reducing sulphate to sulphide. The smelt formed from the chemicals in the furnace is dissolved to produce green liquor containing mainly sodium sulphide and sodium carbonate. The green liquor may then be treated with lime to convert the carbonate present to hydroxide. The calcium carbonate produced is kilned to produce calcium oxide which is slaked to reform calcium hydroxide. The white liquor containing the sodium hydroxide and sulphide is reused as cooking liquor.

Lignin extraction during chemical pulping may be as high as 50% of the pulp production of an integrated mill. This may be recovered for conversion to by-products such as adhesives, resins and epoxys.

3 BLEACHING

3.1 Conventional Bleaching

A typical bleaching process of a pulp mill is a multi-stage (5 - 7 stages) system consisting of bleaching towers for each stage and drum washers for washing the pulp between the stages.

A common sequence in Kraft bleaching is CEDED with each chemical stage followed by a washing stage.(C is Chlorination, D is Chlorine Dioxide, E is Alkali). Sulphite pulps require a shorter bleaching sequence. Mechanical pulps are usually brightened in a single stage with sodium hydrosulphate, sodium peroxide or hydrogen peroxide.

Displacement bleach plants have also been built to replace conventional systems, where the various bleaching stages can be performed in the same bleaching tower.

3.2 Oxygen Bleaching

In the **Sapoxal** process, which was developed in South Africa, the unbleached pulp from the digesters is reacted with oxygen under high pressure and temperature together with caustic soda and magnesium oxide for approximately 45 minutes to obtain semi-bleached pulp.

Fully bleached pulp is obtained by further treatment with chlorine and chlorine dioxide. Between each stage the pulp is thoroughly washed.

3.3 Bleach Effluent Quality

In bleaching Kraft pulp, the waste-water volume leaving an old bleach plant may be as high as 80 - 120 m^3/t pulp. In modern four- and five-stage bleach plants the waste-water volume is 30 - 40 m^3/t pulp. In displacement bleaching the waste-water volume can be as low as 10 - 15 m^3/t pulp, depending on the consistency of the chlorination stage[3].

Bleach waste waters are not normally recovered and become the major pollution source of most pulp and paper mills, containing degradation products originating from the lignin, carbohydrates, simple phenols and neutral and acidic compounds. These are generally regarded as not readily biodegradable, due to the presence of bio-toxic constituents such as chlorphenolics[1]. A typical bleach plant waste-water analysis is shown in Table 3.

3.4 Colour

The colour pollution arising from a modern conventional pulp mill principally originates from the first alkali stage of the bleaching process due to the lignins, tannins and hemicelluloses present from the wood processing.

Technologies for colour removal and by-product recovery include :

- Pre-bleaching with oxygen
- Ultrafiltration
- Cross-flow microfiltration
- Carbon adsorption
- Lime addition and precipitation

Table 3: Bleach Plant Waste-water Analysis (example for a Kraft pulp process)

Parameter	Concentration
COD mg/ℓ	1 400
pH	2,8
PO_4 mg/ℓ	1,4
NO_3 mg/ℓ	<0,5
NH_4 mg/ℓ	<0,1
Sodium mg/ℓ	820
Potassium mg/ℓ	39
Calcium mg/ℓ	27
Magnesium mg/ℓ	90
Sulphate mg/ℓ	229
Chloride mg/ℓ	1 830
Aluminium μg/ℓ	100
Boron μg/ℓ	654
Chromium μg/ℓ	100
Cobalt μg/ℓ	45
Copper μg/ℓ	410
Mercury μg/ℓ	<1
Lead μg/ℓ	105
Manganese μg/ℓ	7 100
Nickel μg/ℓ	64
Zinc μg/ℓ	1 822

4 PAPER MANUFACTURE FROM PULP AND WASTE PAPER

4.1 Stock Production

The paper machines may draw wet or slush pulp direct from a pulp mill or baled pulp from associated pulp mills, and from waste-paper plants. The slush pulp passes to the stock preparation section where the various types of pulp are blended, the proportions being used depending on the grade of paper being made.

At this stage various chemicals and additives are mixed with the pulp to give the desired finished paper product qualities, the stock is diluted progressively from 4% to 0,5% then cleaned and screened to remove grit and dirt particles. Sizing agents are added to increase the resistance of paper to water and fillers such as calcium carbonate are added to increase the density of the paper, making it less transparent and better suited to printing.

4.2 Paper Machine Feed

The clean, diluted stock is pumped into a head or flow box which has a narrow opening across its width. The head or flow box jets a wide, thin sheet of stock on the fast moving "wire". This "wire" is a continuous woven flexible plastic mesh belt.

Water drains from the stock through the wire, helped by foil elements and vacuum suction boxes, leaving a web of pulp fibres on the wire at about 65% moisture. This is known as the "wet end" of the machine. The press section further dewaters the web with the aid of roll pressure and felts to about 48% moisture content. The remaining moisture is removed in the dryer section by close contact with steam heated cylinders.
The calender stack of steel rolls further smooths the sheet and improves surface properties. The paper is reeled up into large reels, known as jumbo rolls, prior to trimming, finishing and sale.

4.3 Coating

Coating with a clay slurry may be used to create a smooth, even surface for printing purposes. Gloss paper is created by passing the coated paper through the alternate metal and synthetic rolls of a super calender.

4.4 Tissue Paper

Tissue paper is created in a similar fashion to conventional paper with slushed pulp being blended and dyed in the stock preparation section prior to dilution from about 4% to 0,2%. Clean, screened stock is pumped onto the moving synthetic wire. The wet web of paper at about 85% moisture content is picked up from the wire by the pick-up roll which runs inside a felt. The pressure rolls transfer the paper onto the steam heated and pressurized Yankee cylinder which reduces the moisture content from 80% to 6% in one rotation. The tissue paper is reeled up into large reels at the end of the machine, either single or two ply.

4.5 Paper Production from Waste Paper

Wastepaper is principally utilized as pulp for the production of corrugated board, liner and fluting for cardboard packaging.

The raw material is slushed with water, blended and fibre sorted and passed through density cleaners and thickeners to a preparation chest. The cleaned pulp from the preparation chest passes to the wire press, forming table and vacuum box. The initial presses prepare the pulp for the couch roll, prior to further pressing, drying, and rolling into a Jumbo roll, which is rewound and trimmed for sale. Dyes, starch, alum, retention aids and fillers (clay) are added during the process.

5 SURVEY RESULTS

5.1 Introduction

Water intakes and waste-water qualities obtained during the survey of several of the major pulp and paper manufacturers in South Africa are presented in Tables 4, 5 & 6. Considerable variation was found due to the variety of production processes undertaken and recovery or reutilization of water sources, as well as the different waste-water treatment processes employed.

5.2 Water and Waste-water Management

The results of this study reveal that although a degree of water management is practised in many mills, and that the water use figures are generally impressive in terms of international practice, there is still considerable variation in water intake between factories producing the same commodities.

In many cases this occurs because:

- the mill has ample process water available;
- historically the installed plant has not been designed or managed for optimum water intake;
- discharge of mill waste water to high volume rivers close to sea outfalls has generally been considered acceptable;
- until recently optimization of water intake, chemical and fibre recovery, and minimizing pollutant loads have not been allocated a consistently high level of priority by the Industry.

In terms of water and waste-water management, the mills in South Africa perform between average and highly efficient in relation to international practice. The pressure to improve efficiency in production coincides with advances in product loss control and chemical recovery, reduced bleach plant waste-water discharges and improved process sequences.

Table 4: Specific Water Intake (SWI) for Various Mills

Mill	Production t/d	Water Intake m^3/d	SWI m^3/t
1	650	44 840	70
2	1 200	39 320	33
3	290	20 000	69
4	900	122 400	136
5	145	2 700	19
6	120	1 000	8,0
7	900	32 600	36
8	22	230	11
9	185	145	0,8
10	15	740	49
11	148	2 800	19

Mills 1 - 5 are integrated mills (pulping and papermaking)
Mills 6 - 11 are non-integrated (papermaking only)

Table 5: Waste-water Quality Discharged (mg/ℓ)

Mill	COD	SS	TDS	Na	Cl	SO_4
1	100	100	1 470	250	308	290
2	674	342	999	230	320	300
3	2 201	2 284	2 224	203	433	173
4	780	408	1 782	-	-	-
5	3 393	3 200	13400	177	127	349
6	2 353	3 200	12 965	157	103	258
7	259	227	2 760	495	503	526
8	2 216	1 750	1 082	132	-	-
9	17 402	81 380	9 690	920	100	345
10	521	550	563	66	106	78
11			1 788	125	62	690

Table 6 : Specific Pollution Load

Mill	Production t/d	Waste-water Discharge m^3/d	SEV m^3/t	SPL		
				kg COD/t	kg TDS/t	kg SS/t
1	650	27 200	42	9	62	4
2	1 200	27 250	23	15	23	8
3	290	17 300	60	131 *	132	136 *
4	900	92 260	103	80	183	42
5	145	2 300	16	54	21	51
6	120	890	8,0	9,2	110	24
7	900	25 000	28	7	77	6
8	22	45	2	5	2	4
9	185	63	0,3	6	3	28
10	15	280	19	10	11	10
11	148	1 900	13	4,4	23	1,1

* Outlying results
Mills 1 - 5 are integrated mills (pulping and papermaking)
Mills 6 - 11 are non-integrated (papermaking only)

These improvements include reduced water consumption by closing loops throughout the production line, and by pretreatment and total treatment of final waste water prior to re-utilization or discharge.

Water intake

Specific water intake was found to vary between 33 and 136 m^3/t for pulp and paper mills and between 1 and 49 m^3/t for paper products factories.

The following points were noted:

- The SWI varies widely amongst factories processing the same commodity.
- Water of higher quality is sometimes selected where water of lesser quality could be used.
- Individual process steps within the overall processing cycle consume different quantities of water at different factories even if similar plant is employed.
- Due to the complexity of an integrated paper mill imbalances sometimes occur between different parts of the process, leading to loss of reusable water.
- The absence of water meters and flow recorders on each process line at some of the factories, makes record keeping and hence control of water use difficult.
- Internal water conservation measures include extended white water collection systems, high-pressure machine cleaning showers, reuse of decontaminated evaporator condenser water and fibre-recovery save-alls. External treatment includes clarification, fibre-recovery and dewatering as well as biological treatment.
- In view of the diversity of the Industry it is recommended that targets are set by the management of each plant based on their individual circumstances and that programmes are implemented to monitor and improve on these targets on an on-going basis.

Waste water

The following points are noted:

- Waste-water qualities vary widely between factories processing the same commodity.
- Recovery of chemicals used in the processing of pulp and paper leads to greater economy in production, and significantly reduces inorganic and organic loads discharged as waste water.

- Suspended solids lost to drain represent a product loss in terms of fibre, and a pollutant loading to the receiving catchment or treatment system in terms of COD *and TDS as well as suspended solids.*
- Bleach waste waters are not normally recovered and become the major pollution source of many pulp and paper mills.
- Chlorinated compounds and alkali extraction liquors from pulp bleaching contribute significantly to the toxicity of waste waters.
- Recent technological advances aimed at higher yield pulping processes may result in deviations from standard waste-water pollution control practices.
- As for water intake Industry targets are considered inappropriate. Rather, each plant should set targets based on its own unique circumstances and programmes should be implemented to monitor and improve on these targets on an on-going basis.

6 WATER REUSE

6.1 Reducing Water Consumption

The water consumption of a paper or board mill can be reduced by tightening the water system of the mill. This has the advantage that lower levels of suspended solids, suitable for paper raw material are discharged to drain. With less fresh water being introduced to the system, the temperature of the white water rises, which makes it easier to remove water from the paper web, so that energy can be saved.

Increased tightening of the white water system, however, causes some problems in paper and board mills, preventing total closure of the water circulation system. The accumulation of salts and organic compounds dissolved from the fibre raw material increases significantly, which causes problems due to microbiological activity, corrosion and growth of slime, which must be controlled.

6.2 Reuse of Water

White water from the paper or board machine may be first treated mechanically by flotation, sedimentation or filtration, or a combination of processes. The flotation treatment, is suited to the recovery of fine suspended solids. Sedimentation is better suited to white waters that contain large amounts of filler. Filtration is suitable for white waters that contain low levels of solids and filler.

Generally, the brown grades of paper are most tolerant of recycled water, followed by newsprint and tissue types. Fine papers (high whiteness) are very sensitive to colour and certain metal ions, particularly with respect to aging and colouring. The colloidal chemistry involving paper sizing and resin applications is sensitive to phosphate and other dispersants and some metal ions.

7 WASTE-WATER CHARACTERISTICS OF PULP AND PAPER MILLS

7.1 Suspended Solids

The presence of suspended solids in mill waste waters is due to the fine bark particles and silt from pretreatment, the overall retention on the paper machines, which is affected by the use of retention aids and save-alls, and the loss of fibre/filler in spillages or during wash-ups and grade changes (see Table 6).

The load of suspended solids in untreated mill waste waters varies over the range 1,1 - 51 kg/t of product. At a number of mills, however, waste-water suspended solids are not a genuine loss, as the waste-water clarification plant is operated as a save-all to recover material for reuse in the mill, particularly in the recovery of fibre in waste-paper-based paper production. The settleable solids portion is usually in the range of 75-95% of the total suspended solids. Much of the non-settleable solids is fines and colloidal material which are difficult to remove by conventional means[5].

The composition of suspended solids is equally varied depending on the type of fibre (waste paper or pulp) and filler (clay or chalk) used, whilst the ash content of mill sludges varies from 5 to 50%.

Of particular importance to secondary biological treatment is the concentration of non-settleable, colloidal solids present in the clarified waste water. The concentration of colloidal solids increases with increasing use of waste paper and starch and with decreasing specific water intake. Both inorganic filler and non-biodegradable lignins represent an inert load on treatment systems.

7.2 Dissolved Solids

Organic matter

Depending upon the pulping procedure and yield coefficient of pulp from the wood, bagasse or waste paper, up to 60% of the raw material is suspended or dissolved and becomes a potential organic pollutant load. The loss of dissolved organic matter in mill waste waters also arises from non-retained wet-end additives and materials dissolved from pulp or recycled broke and waste paper. In practice the majority of this material is recovered for reuse.

As measured by the COD of the mixed waste water, the specific loss of dissolved organics ranged from 4,4 - 80 kg/t (Table 6). The strength of the waste water depends on the load loss and the specific water intake and varies over an extremely wide range (200 - 20 000 mg/ℓ COD).

Inorganic matter

Total dissolved solids loads ranged from 2 - 183 kg/t of product (Table 6). Pulp liquors containing discharges from the black liquor, washing liquors, overflows and storage residue contribute to the high TDS levels in the form of salt cake, sodium, calcium, carbonates and sulphates.

Bleaching liquors are usually high in chloride content. The concentration of soluble cations (particularly sodium, calcium and magnesium) can reach high levels in closed water systems.

Sulphides occur in mill systems as a result of microbial reduction of sulphate and contribute to corrosion of the system. As with anaerobic decomposition of organic solids, sulphate reduction to sulphide occurs in attached slimes or stagnant, quiescent zones of the machine system. The sulphide levels measured in waste waters arise from soluble sulphides that have diffused from the generation zone or insoluble sulphides that have been scoured from surfaces by changes in water velocity[6].

8 WASTE-WATER TREATMENT PRACTICES

8.1 Waste-water Treatment Technologies

The pulp and paper industry utilises a wide range of technologies in the treatment of waste water. Most mills utilise primary methods of treatment such as screening and settling, while there are several secondary and tertiary methods that are also in use to various degrees. These include flotation, micro-straining activated carbon absorption, steam or air stripping, polymeric resin treatment, and biological treatment.

8.2 Biological Waste-water Treatment of Pulp and Paper Waste Waters

Aerobic treatment

The conventional treatment of pulp and paper industry waste water has been by means of aerated biological systems with sedimentation. These have been in the form of aerated lagoons, aeration stabilization and settling basins, activated sludge treatment, or biofiltration plants. These processes differ primarily in the manner in which the organisms come into contact with the organic material.

Aerobic treatment does have certain disadvantages, namely the high energy demand that is required for efficient aeration, and the excess biological sludge that is produced, requiring disposal.

Efficiencies regarding COD removal employing purely aerobic processes vary greatly and are naturally dependent on the exact nature of the influent and bleaching processes applied. Efficiencies of 45 to 57% COD reduction are not uncommon(7), and can be as low as 20% for chlorinated compounds from bleach plants(8). A recommended route for the biological treatment of pulp and paper effluent is the use of a two-stage aerobic treatment rather than a single treatment stage(7)(9), or combining aerobic and anaerobic treatment.

Anaerobic treatment

Since the early 1980s interest has been growing in the paper industry in the use of anaerobic systems for the treatment of waste water from pulp and paper mills, coinciding with improvements in papermaking practice and closing up of water and effluent systems which have resulted in lower volumes of effluent but of high organic content.

There are at least 20 systems operating internationally in the Industry and several more are at pilot or design stage [10]. The most common systems utilised in the paper industry are the Upflow Anaerobic Sludge Blankets (UASBs) and Anaerobic Contact Filters (ACF).

Anaerobic processes have the advantages that comparatively little sludge biomass is generated, and that they do not require energy for aeration although they do require some form of recycling to maintain optimal loading conditions. Anaerobic systems also produce methane gas which can be utilised within the factory.

Effluents from high-yield pulping processes containing levels of COD and sodium sulphite of 4 000 - 8 000 mg/ℓ have been successfully anaerobically treated at removal efficiencies of 50 - 80% for COD and higher than 90% for sulphate and H_2S [2]. Anaerobic digestion has also been applied to pulp bleaching effluents where simultaneous reduction of chlorate (100%) and sulphate (>90%) has been achieved [2].

9 POLLUTION CONTROL - RESEARCH AND DEVELOPMENT

The following topics are receiving attention from researchers and in some cases have already been implemented by the Industry in South Africa and internationally on a limited scale and are undergoing further development in order to improve plant productivity, water use and effluent quality parameters [1 - 5]. Research and development areas include:

- extended delignification without the use of chlorine, including prolonged cooking and oxygen bleaching
- partial substitution of elemental chlorine by oxygen, peroxide, ozone or chlorine dioxide in the bleach plant, and integration with low-multiple chlorination
- replacement of hypochlorite by chlorine dioxide or chlorine-free bleaching chemicals to prevent the formation of chloroform
- change of bleaching sequences, e.g starting with a combined extraction-bleaching stage to reduce waste-water pollution
- ultrafiltration of extraction stage waste waters and recycle of the permeate for reuse and disposal of the concentrate via the black liquor system
- increased recycling of bleach waste waters to the recovery system or to a separate system for destruction

- aerobic and anaerobic biological purification of waste-water side streams (evaporation condensates, bleach waste waters and final plant waste waters as well as final effluents)
- chemical flocculation or precipitation of organic pollutants in effluents (by lime, iron or aluminium salts and organic polyelectrolyte)
- removal of organic pollutants, particularly hazardous substances, by adsorption processes using activated carbon, pyrolysis coke, aluminium oxide, magnetite or adsorber resins
- recovery and reuse of sulphite and sulphur, or biological reduction to reduce hydrogen sulphide and sulphur dioxide discharges
- application of new technology for the removal of suspended and colloidal solids, eg dissolved air flotation, crossflow microfiltration, ultrafiltration, floating media filtration
- closed-loop recycle of process waters with improved purging of chlorides, salts, and organics
- use of neutral sizing, as opposed to alum-sizing, to reduce sulphate discharges and also inhibition of anaerobic pretreatment
- neutralization of spent liquor in order to bind organic acids as non-volatile salts
- use of fungi for the degradation of bleach plant residues and other components resistant to conventional biological treatment.

10 BIBLIOGRAPHY

1	CSIR (1988)	Chemical aids for the South African Paper and Paperboard Manufacturing Industry. Wood. 7. Special report W T Gore.
2	Vlok A G J et al. (1989)	The role of anaerobic digestion in treating effluent in the pulp and paper industry. Pres. 2nd Anaerobic Digestion Conference. Bloemfontein, Sept 1989.
3	Virkola N et al. (1985)	Wastewater Characteristics. Wat. Sci. Tech.,17, 1-28.
4	Wood A et al. (1989)	Pilot scale experience in the anaerobic treatment of pulp and paper effluent. Pres. 2nd Anaerobic Digestion Conference. University of Orange Free State, Bloemfontein, September 1989.
5	Water Research Commission (1987)	Investigations into water management and effluent treatment in the processing of pulp and paper. Water Research Commission No 106/1/87, Pretoria.
6	Webb L J (1985)	Characteristics of paper/board mill wastewaters relevant to anaerobic treatment. Wat. Sci. Tech.,17, 29-38.
7	Galrão J B et al. (1988)	Treatability studies and toxicity reduction in pulp and paper mill effluents. Wat. Sci. Tech. 20, 1, 149 - 160.
8	Norrström H A (1988)	Reducing the discharges to water technical objectives. Wat. Sci. Tech., 20, 9-18.
9	Mehler A et al. (1988)	Process alternatives for enhanced biological treatment efficiency at forest industry effluents. Wat. Sci. Tech., 20, 1, 241 - 250.
10	Pearson J et al.	Major anaerobic plants start up. Pulp and Paper Industry, March 1989.