# Water and Wastewater Management in the Paper and Pulp Industry

(Edition 2)

Marlene van der Merwe-Botha,
Bertie Steytler, Peter Wille

WATER RESEARCH COMMISSION

TT 704/16

# NATSURV 12
# Water and Wastewater Management in the Paper and Pulp Industry
# (Edition 2)

**Marlene van der Merwe-Botha, Bertie Steytler, Peter Wille**

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# EXECUTIVE SUMMARY


The purpose of the NATSURV 12 Study is to review the status of the South African Paper and Pulp Industry with specific focus on national production capacity, specific water use and effluent generation rates, specific energy consumption rates and best practices in the management of water and effluent. The study provides an overview of the most pertinent legislation that regulates the industry on national and local levels.

The research methodology included a literature review, discussions with the regional environmental managers, site specific surveys and site visits, and processing of data and information. The NATSURV Report should be read in conjunction with the '***Best Practice Guideline for Water and Effluent Management in the Paper and Pulp Industry***', developed by the Department of Water and Sanitation (2016).

The research confirmed that 29 paper and pulp mills are operational in South Africa. The bulk of production is performed by the five largest Paper and Pulp manufacturers, namely Kimberly-Clark, Mondi, Mpact, Sappi and Twinsaver Group. These companies operate 15 mills of which 8 are paper and pulp mills and the remaining 5 are paper mills. The study included 11 independent tissue manufacturers and 3 independent packaging material manufacturers that also operate in this sector. Two further packaging material manufacturing companies were identified at a stage too late for inclusion in the study. The big manufacturers, as well as the independent packaging material manufacturers, participated fully in the study. Only four of the independent tissue manufacturers responded to the study survey.

Raw water intake to the manufacturing process is usually derived from a water resource where the abstraction is authorised by the Department of Water and Sanitation, or from the local municipality. The Specific Water Intake (SWI) for the 22 participating sites varied between 3.5 and 76.1 $m^3/t$. For the Paper and Pulp mills the SWI varied between 11.9 and 76.1 $m^3/t$ and for Paper mills between 3.5 and 38.8 $m^3/t$. This represented a marked decrease from the 1990 NATSURV Survey which was between 33 and 136 $m^3/t$ for Paper and Pulp Mills and between 1 and 49 $m^3/t$ for Paper mills.

Different volumes and quality of wastewater (effluent) is produced during the manufacturing processes. Effluents are treated via a range of treatment technologies which include clarification, activated sludge, dissolved air flotation and belt presses. The treated effluents are discharged to the receiving environment or reused / recycled to the manufacturing process where technically feasible. The Specific Effluent Volume (SEV) generated varied between 0.08 and 84.5 $m^3/t$. For Paper and Pulp mills the SEV varied between 10.5 and 84.5 $m^3/t$ and for Paper mills between 0.08 and 38.2 $m^3/t$.

The variations between water intake and effluent generation is a function of a range of factors such as feed material used, technology selection, product produced and the age of the facility.

Comparison of NATSURV Surveys (1990 vs. 2015):

- A larger sample of mills participated in the 2015 survey;
- Differentiation between integrated Paper and Pulp mills and non-integrated Paper mills was added to the 2015 survey;
- Average SWI decreased from 40.0 $m^3/t$ to 25.2 $m^3/t$ and the maximum SWI decreased from 136 to 76.1;
- Average SEV decreased from 28.6 $m^3/t$ to 22.8 $m^3/t$ and the maximum SEV decreased from 103 to 84.5;
- Average and maximum COD, Conductivity and SS levels have decreased.
- The reduction in SWI and SEV is a reflection of actions taken by the industry to recover and re-use water, thereby reducing fresh water intake. This awareness was confirmed by the improvement in effluent treatment technologies and equipment at a number of the sites surveyed. The use of water foot printing and risk management were key considerations when undertaking facility expansion studies and selecting appropriate technologies.

**Table 1: Comparison of water and effluent management practises in 1990 and 2015 based on NATSURV survey results**

| | 1990 Survey results | | | 2015 Survey results | | |
|---|---|---|---|---|---|---|
| **Parameter** | **N** | **Range** | **Average of N Companies** | **N** | **Range** | **Average of N Companies** |
| **Specific Water Intake ($m^3$/t)** | 11 | 0.8-136 | 40.0 | 21 | 3.5-76.1 | 25.2 |
| Paper and Pulp SWI ($m^3$/t) | | | | 8 | 11.9-76.1 | 40.8 |
| Paper SWI ($m^3$/t) | | | | 13 | 3.5-38.8 | 15.6 |
| **Specific effluent volume ($m^3$/t)** | 11 | 0.3-103 | 28.6 | 21 | 0.08-84.5 | 22.8 |
| Paper and Pulp SEV ($m^3$/t) | | | | 8 | 10.5-84.5 | 37.4 |
| Paper SEV ($m^3$/t) | | | | 13 | 0.08-38.2 | 12.2 |
| **COD (mg/ℓ)** | 10 | 100-17 402 | 2 990 | 12 | 165-3 853 | 1 773 |
| **Conductivity (µS/cm)*** | 11 | 840-20,000 | 6 610 | 10 | 211-4 970 | 2 073 |
| **SS (mg/ℓ)** | 10 | 100-81 380 | 9 344 | 12 | 34-2 260 | 561 |
| **pH** | 0 | | | 11 | 6.5-8.5 | |

Note:
N = Number of companies contributing data
* Where only TDS was specified a factor of 0.67 was applied for conversion to Electrical Conductivity.

Increasing electricity costs and the damaging impact of load shedding has also resulted in and increased energy awareness across the industry. The data indicate that the South African Paper and Pulp Industry is performing on par or exceeding international standards. Most of the sites confirmed that continuous improvement on energy consumption is a focus and energy consumption values are reported to management on a daily or weekly basis against target values. The generation of renewable energy from waste products is a consideration at larger sites and has already been incorporated at some of the plants. Specific Energy Consumption (SEC) ranges from 1.6 to 6.3 GJ/ADt, as Eskom electricity. Total SEC ranges for 3.7 to 11.3 GJ/ADt) which includes Eskom electricity, steam, renewable/recoverable energy, coal to steam and gas.

When benchmarked against international SWI, SEV and energy consumption guidelines, the South African Paper and Pulp sector generally performs at the lower range of values.

The participating companies listed a range of best practices that have been implemented or are being implemented. These practices generally correspond to the recommendations made in international publications on best environmental practices in the Paper and Pulp industry. Typical BAT principles include:

- **Better overall management**: refers to an integrated water management plan combined with continuous improvement initiatives. Integrated management is already the model of water use reduction widely used by the South African Paper and Pulp Industry. Monitoring of flows and quality takes place on a continuous basis and forms the basis of reporting against DWS effluent quality limits, municipal trade-effluent charges, and internal reuse or conservation targets.
- **Design stage procedures**: refer to the consideration of water savings during the initial design phase of a mill or a modification at a mill. Based on feedback received from mills this already forms an important part of risk based technology selection criteria in South Africa.
- **Low-cost improvements**: relates to the awareness of water savings during the execution of daily production activities. These types of activities were listed by almost all South African mills.
- **Process modifications**: Relates to smaller optimisation modifications that can be performed. The mills in South Africa are aware of these opportunities and implementing them where feasible.
- **Process redesign**: refers to more capital intensive options. Most South African mills already utilise one or more of the recommended technologies to treat their effluent and recycle it for re-use in equipment

and processes. Technologies such as activated sludge, clarification, DAF and filter belt presses are widely used to treat effluent and monitor performance against compliance standards set by DWS.

- **Total system closure**: Experience shows that it is not viable to indefinitely close the system, since concentration of undesirable components result in off-specification product. Although theoretical system closure could be achieved, the life cycle costing of implementation of these types of technologies may be prohibitive. Energy scarcity and cost will in the current South African energy scarcity scenario prohibit the use of most of these technologies. Furthermore the final waste product from a fully closed system will be classified as a hazardous waste with disposal implications.

The industry is extensively regulated through the application of national legislation (in particular water use authorisations), municipal trade-effluent bylaws, as well as national and international norms and standards such as ISO and SANS. The study shares perspectives by the industry and the regulatory authorities pertaining to the use of water and effluent targets and compliance with norms, standards and specifications.

It is recommended that continuous improvement focusing on improved SWI and SEV target continue to be used in this industry; and that research continues to explore the energy and resource recovery potential associated with the industry.

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    - Ms M Odayar — Mpact Felixton
    - Mr S Pillay — Correll Tissue (Pty) Ltd
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    - Ms B Singh — Mpact Springs
    - Ms R van Hoeve — Sappi Southern Africa
    - Mr J Viviers — Mpact Piet Retief
    - Ms C Webb — Mondi Richards Bay

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## List of Abbreviations

| | | |
|---|---|---|
| BAT | : | Best Available Technology (or Technique) |
| BM | : | Board Machine |
| COD | : | Chemical Oxygen Demand |
| DAF | : | Dissolved Air Flotation |
| DEA | : | Department of Environmental Affairs |
| DWR | : | Durban Water Recycling |
| DWS | : | Department of Water and Sanitation |
| ECF | : | Elemental Chlorine Free |
| Enstra | : | Enterprise Straw |
| HW | : | Hardwood |
| IP | : | Intellectual Property |
| ISO | : | International Organisation for Standardisation |
| GDP | : | Gross Domestic Product |
| K-C | : | Kimberly-Clark |
| KPI | : | Key Performance Indicator |
| LPG | : | Liquefied Petroleum Gas |
| NSSC | : | Neutral Sulfite Semi Chemical |
| OECD | : | Organization for Economic Cooperation and Development |
| PAMSA | : | Paper Manufacturers Association of South Africa |
| PFD | : | Process Flow Diagram |
| PM | : | Paper Machine |
| PRASA | : | Paper Recycling Association of South Africa |
| RCF | : | Recycled Cellulose Fibre |
| RISA | : | Resource Information Systems Inc. |
| SA | : | South Africa |
| SASAQ | : | Semi-chemical Alkaline Sulphite Anthroquinone |
| SATMA | : | South African Tissue Manufacturers Association |
| SEV | : | Specific Effluent Volume |
| SS | : | Suspended Solids |
| SW | : | Soft Wood |
| SWI | : | Specific Water Intake |
| TCF | : | Total Chlorine Free |
| TDS | : | Total Dissolved Solids |
| TM | : | Tissue Machine |
| tpa | : | metric ton per annum |
| UK | : | United Kingdom |
| USA | : | United States of America |
| US$ | : | United States Dollars |
| WRC | : | Water Research Commission |

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# 1. INTRODUCTION

The NATSURV series of publications have been developed by the Water Research Commission of South Africa from the mid-1980s onwards. The intention of the publications was to review and document water and wastewater management and best practice within different important industrial sectors in the South African economy.

The 12th document in the series was the 1st edition of "Water and Wastewater Management in the Paper and Pulp Industry" and was issued in December 1990. Since Steffen, Robertson and Kirsten Consulting Engineers have developed this document, many changes have occurred in the world and South African society and industry necessitating an update of the document.

## 1.1. Project Objectives

The aim of this project is to undertake an assessment of the South African Paper and Pulp Industry to obtain an overview of the operations, water use, effluent production and best practice implementation, as well as the legislative environment in which this industry is regulated.

The scope of work is summarised as follows:

1. Provide a detailed overview of the Paper and Pulp Industry in South Africa, its changes since 1980 and its projected change(s). It is important that representative samples of the respective industries are used as case studies.
2. Critically evaluate and document the "generic" industrial processes of the Paper and Pulp Industry in terms of current practice, best practice and cleaner production.
3. Determine the water consumption and specific water intake (local and global indicators, targets; benchmarks, diurnal trends) and recommend targets for use, reuse, recycling and technology adoption.
4. Determine wastewater generation, and typical pollutant loads (diurnal trends) and best practice technology adoption.
5. Determine local electricity, water, and effluent prices and bylaws within which these industries function and critically evaluate if the trends and indicators are in line with water conservation demand management and environmental imperatives.
6. Critically evaluate the specific industry water (including wastewater) management processes adopted and recommend fundamental principles and guidelines that are important for the water users.
7. Evaluate the industry adoption of the following concepts: cleaner production, water pinch, energy pinch, life cycle assessments, water footprints, wastewater treatment and reuse, best available technology and ISO 14 001 to name a few. Provide and outline the manner in which industries may prevent, minimize and mitigate possible water pollution.
8. Provide recommendations on the best practice for this industry with the aim of developing a comprehensive guide to the industrial sector to meet the Department of Water and Sanitations regulatory requirements.

## 1.2. Methodology Summary

The methodology followed in the execution of the study was as follows:


1. **Literature survey and review**

A literature survey and review was undertaken to cover the South African Paper and Pulp Industry, the technologies, growth and changes before and after 1980, inclusive of a list of paper and pulp industries in South Africa.

2. **Identification of main role-players**

The main role-players in the industry as well as a shortlist of potential case studies were done, to best represent the industry and the regional boundaries of SA.

3. **Induction meetings**

One-on-one discussions took place with the Group Environmental Manager or equivalent main contact person in the specific company, to relay the purpose and proposed approach being followed and to get their buy-in into the process. Confidentiality Agreements were signed where required. 'SurveyMonkey' or electronic questionnaire surveys were not considered based on the general poor responses normally received when using these media.

4. **Case Study Assessment Schedule**

A 'NATSURV Case Study Assessment Schedule' was developed to prepare the selected companies for the site visit and to focus information gathering. The schedule consisted of processes, practices related to water, energy and wastewater, national industry-specific targets, benchmarks and the legislative framework. The schedule was also used to gather information from other sites which would not be visited. The Assessment Schedule was prepopulated as far as possible, prior to circulating to the industry representatives in order to optimise the data gathering process.

5. **Site visits and interviews, data collation**

Site visits were undertaken to those companies who were open to participate in the study. During this site visit, information and data were gathered, using the Assessment Schedule as guidance. This information was used to perform data processing, develop schematics and flow diagrams, and conduct comparative analysis specific to the following fields of study:

a. Water use and water quality
b. Energy use and efficiency
c. Wastewater generation / use and quality
d. Management of all the above
e. Status quo and targets in each area
f. Technology applied or planned in each area

Close collaboration continued with the managers, to ensure that any outstanding data be collected, and that any uncertainties be clarified where required. Comparison studies were established to follow trends across the different time spheres of the industry:

a. 1980 (NATSURV edition1)
b. Status quo 2015 (baseline)
c. Planned – >2020 future horizon

6. **Circulate draft report to managers, sensitivity / IP analysis:**

The draft report was sent to case site managers for their respective input and to allow managers to remove any data or information that may be regarded as 'sensitive' or as 'Intellectual Property', where so required by the respective companies' policies. Each company received only their 'site-specific' extract from the overall Report to protect privacy and IP.

7. **Circulate 1st draft NATSURV 12**

The draft NATSURV report was circulated to the WRC Reference Group and DWS for input and guidance.

8. **Circulate 1st draft Best Practice Guideline**

The draft BPG was presented (in parallel to the NATSURV report) to the WRC Reference Group and DWS for input and guidance.

9. **Finalise NATSURV 12 and BPG**

The NATSURV and BPG were updated to a final draft by incorporating input and recommendations received from role players, and re-circulated for final perusal.

10. **Workshop at WISA 2016**

The NATSURV report and Best Practice Guideline are presented and distributed at the WISA Biannual Conference in May 2016.

11. **Finalise NATSURV 12 and the BPG**

The final report and guideline incorporated input from the WISA Conference, followed by quality assurance, printing and release via the WRC and DWS knowledge distribution networks.

## 1.3. Research Output

The study delivered two main outputs:

1. NATSURV 12: Water and Wastewater Management in the Paper and Pulp Industry (2nd Edition, 2015)
2. Best Practice Guideline for Water and Wastewater Management in the Paper and Pulp Industry (2015)

# 2. INDUSTRY OVERVIEW

## 2.1. History of Paper and Pulp

Paper has been with mankind for a long time. However, the use of wood to make paper is a relatively new technological development(1). Originally cotton and linen was used in paper making, followed by fibrous crops such as flax.

The parallel development of mechanical pulping of wood in Germany and Canada in the 1840s resulted in the development of paper as we know it. Chemical processes to enhance pulping followed and by 1900 sulphite pulping was the predominant technique used in producing wood pulp(1).

The development of the recovery boiler resulted in the recovery of almost all chemicals in the Kraft pulping process. This, together with the ability of the Kraft process to utilise a wider variety of woods to produce stronger fibres resulted in it being the dominant process used by the 1940s (1).

The South African Paper and Pulp Industry is much younger, with Premier Paper being the first mill commissioned in 1920 at Klipriver near Johannesburg with the purpose to recycle waste paper. In 1938, two additional mills were commissioned at SA Board Mills in Durban and Sappi's Enstra mill in Springs. The Enstra mill processed straw, hence the name Enterprise Straw, and was the first fully integrated chemical Paper and Pulp operation in SA. The straw process was unsuccessful and in 1948 the mill was converted to wood as feedstock(2, 3). These mills were followed by the Cellulose Products mill in Johannesburg in 1949 and the Trans African Paper Products mill in Benoni in 1950(3).

Between 1950 and 1984 a further 13 mills were built across South Africa. In addition to the development of new mills, a number of the mills were also significantly expanded during this period(3).

Limited new development occurred after 1985, with the focus shifting from building new facilities to upgrading of existing facilities (3). Some mills have also been shut down.

There are five main players in the South African Paper and Pulp sector. Most of these companies are no longer only limited to activity within South Africa, but are operating in the international market. The five largest companies are:

- Kimberly-Clark,
- Mondi,
- Mpact,
- Sappi, and
- Twinsaver Group (previously part of Nampak).

## 2.2. Current Global Paper and Pulp production

In 2013 approximately 403 million tons of paper was produced in the world, up approximately 1% from the 399 million tons produced in 2012(6). Asia is the world's largest paper producer at ± 45% (182 million tons) of paper production, followed by Europe (106 million ton) and North America (85 million tons).

The pie chart in Figure 1 reflects the global pulp production per region for the same period and indicates a 1.6% decrease in pulp production (6).

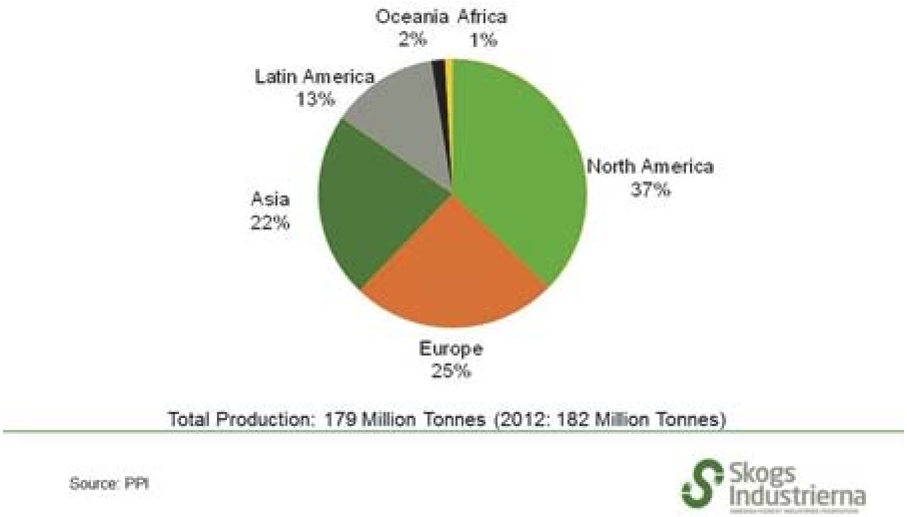


**Figure 1: Global 2013 Pulp Production by Region [6]**

The countries with the highest paper and paperboard, excluding pulp, production in the world in 2011 are summarised in Table 2 (RISI[7]).

**Table 2: Countries with Highest Paper Production in 2011[7]**

| Rank 2011 | Country | Production in 2011 (1,000 ton) | Share (%) |
|---|---|---|---|
| 1 | China | 99 300 | 24.9 |
| 2 | United States | 75 083 | 18.8 |
| 3 | Japan | 26 627 | 6.7 |
| 4 | Germany | 22 698 | 5.7 |
| 5 | Canada | 12 112 | 3.0 |
| 6 | South Korea | 11 492 | 2.9 |
| 7 | Finland | 11 329 | 2.8 |
| 8 | Sweden | 11 298 | 2.8 |
| 9 | Brazil | 10 159 | 2.5 |
| 10 | Indonesia | 10 035 | 2.5 |
| **Total** | | **398 975** | **100** |

The Top Ten global Forest, Paper & Packaging Industry Companies as well as the other South African companies in this sector based on sales in US$[8] are listed in Table 3.

**Table 3: Top 10 Forest, Paper & Packaging Industry Companies based on 2012 sales [8]**

| Rank 2012 | Rank 2011 | Company name | Country | Sales 2012 (Million US$) | Sales2011 (Million US$) |
|---|---|---|---|---|---|
| 1 | 1 | International Paper | US | 27 833 | 26 034 |
| 2 | 2 | Kimberly-Clark | US | 21 063 | 20 846 |
| 3 | 4 | Oji Paper | Japan | 15 161 | 14 193 |
| 4 | 5 | UPM – Kymmene | Finland | 13 423 | 14 019 |
| 5 | 3 | Stora Enso | Finland | 13 398 | 15 268 |
| 6 | 6 | Nippon Paper Group | Japan | 13 030 | 13 251 |
| 7 | 7 | Svenska Cellulosa | Sweden | 12 619 | 12 543 |
| 8 | 8 | Smurfit Kappa | Ireland | 9 432 | 10 244 |
| 9 | 16 | Rock-Tenn | US | 9 208 | 5 400 |
| 10 | 9 | Mondi Group | UK | 7 468 | 7 991 |
| 12 | 11 | Sappi | South Africa | 6 347 | 7 286 |
| 91 | 78 | Nampak | South Africa | 804 | 1 042 |

NOTE: Sales have been adjusted to exclude non-forest paper and packaging revenue

The per capita consumption of paper varies significantly between the developed and developing world. Typical 2010 per capita consumption [9] is summarised in Table 4. Developed countries have high consumptions with Austria at 274 kg/person per annum and the USA at 236 kg/person per annum. India is on the other end of the scale with a consumption of 9.3 kg/person per annum.

**Table 4: Paper and Pulp Consumption [9]**

| Country | Pulp Consumption (Million tpa) | Paper Consumption (Million tpa) | Per Capita (kg/person/annum) |
|---|---|---|---|
| China | 32.4 | 91.6 | 70.7 |
| USA | 46.7 | 74.3 | 236.0 |
| Japan | 10.7 | 27.9 | 220.5 |
| Germany | 7.0 | 19.7 | 237.4 |
| Canada | 9.3 | 6.3 | 169.8 |
| Finland | 8.8 | 1.5 | 255.9 |
| Sweden | 9.2 | 2.0 | 231.3 |
| South Korea | | 9.4 | 182.0 |
| Indonesia | 4.6 | 6.1 | 33.6 |
| Brazil | 6.1 | 9.5 | 47.7 |
| India | 4.5 | 10.8 | 9.3 |
| Italy | | 10.8 | 175.6 |
| France | 3.5 | 9.2 | 149.4 |
| Russia | 5.8 | 6.6 | 43.5 |
| Spain | 1.8 | 6.5 | 168.1 |
| Austria | 2.0 | 2.2 | 274.0 |
| Mexico | | 7.3 | 80.3 |
| Thailand | | 4.8 | 62.6 |
| UK | | 10.5 | 170.5 |
| Taiwan | | 4.0 | |

## 2.3. Current Paper and Pulp Production in South Africa

The Forestry and Paper sector contributed 0.6% to the total SA GDP in 2013 and 3.8% to the Manufacturing GDP [10]. Its contribution to the agricultural GDP was 26.1%[10]. The total SA Paper and Pulp production for 2003, 2012 and 2013 is summarised in Table 5.

**Table 5: Annual South African Paper and Pulp Production (10)**

| Item | 2003 Production ('000 tpa) | 2013 Production ('000 tpa) |
|---|---|---|
| Printing and Writing Paper produced | 920 | 740 |
| Packaging Paper produced | 1 265 | 1 356 |
| Tissue Paper produced | 152 | 222 |
| Total Paper produced | 2 337 | 2 318 |
| Total Pulp produced | 2 317 | 2 016 |
| Total Paper imported | 371 | 825 |
| Total Pulp imported | 71 | 144 |

According to PAMSA statistics, the South African paper consumption for 2013 was 2 532 244 t [50]. Based on the 2013 SA census information and the 2012 paper consumption statistics, the per capita consumption of paper in South Africa is 50.0 kg/person per annum [11]. Annualised per capita consumption for various paper grades as well as total per capita consumption for the period 2006 to 2014 is reflected in Figure 2.

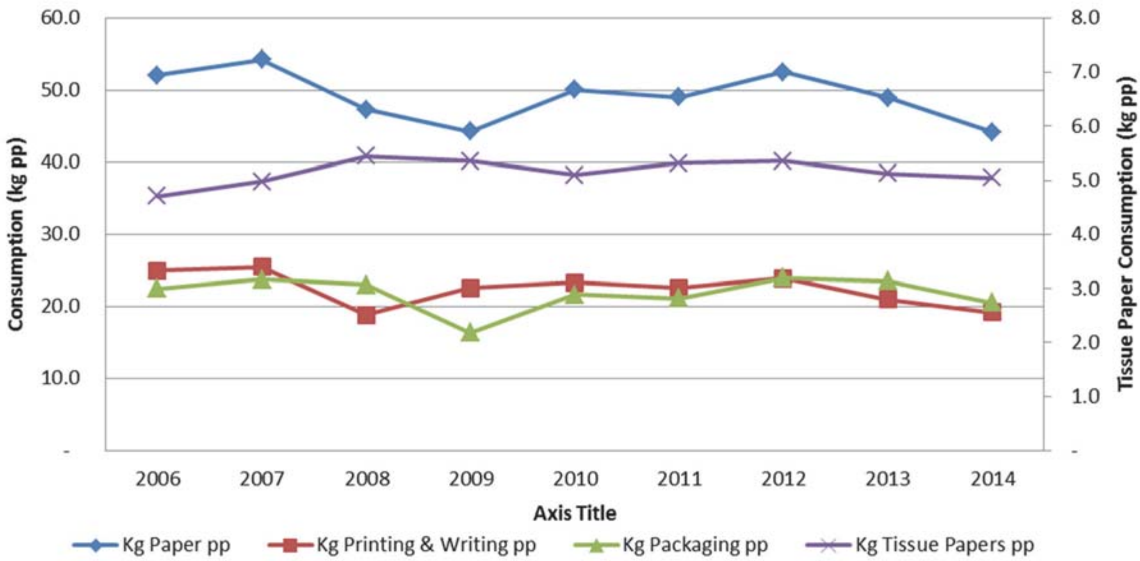


**Figure 2: Annualised per Capita Paper Consumption per Category and Total**

Kimberly-Clark has facilities in:

1. Springs manufacturing tissue; and
2. Epping manufacturing absorbent hygiene products.

Mondi produces approximately 753,000 t/a of pulp, 234,000 t/a Uncoated Fine Paper (UFP) and 258,000 t/a container board. Mondi has the following paper and pulp mills [5]:

1. Merebank, Durban that produces paper; and
2. Richards Bay that produces linerboard.

MPact has three mills, namely at Felixton, Piet Retief and Springs producing approx. 507,000 t/a of different grades of packaging material.

SAPPI produces approximately 950,000 t/a paper and 750,000 t/a pulp[4]. Specialised cellulose production is approximately 1 010,000 t/a [35]. SAPPI currently has five paper and pulp mills in South Africa, as well as chemical cellulose (dissolving pulp) production capacity, with production as follows[4]:

1. Cape Kraft Mill in Cape Town that produces paper;
2. Enstra Mill in Springs, Gauteng that produces paper;
3. Ngodwana Mill in Mpumalanga that produces pulp, Chemical Cellulose, newsprint and linerboard;
4. Stanger Mill in KwaZulu Natal, that produces pulp, tissue and paper;

5. Tugela Mill in KwaZulu Natal, that produces Paper and Pulp; and
6. Saiccor Mill in KwaZulu Natal that produces Chemical Cellulose.

The Twinsaver Group has three mills, namely Bellville, Klipriver and Riverview producing approximately 59,000 t/a of tissue paper.

Independent tissue manufacturers have 11 mills (excluding tissue mills listed above), located at various points in the country, with most located in KwaZulu-Natal and Gauteng.

The five independent packaging manufacturers are:

1. Gayatri in Germiston
2. Huhtamaki with mills in Springs and Atlantis
3. Lothlorien in Wadeville.
4. South African Paper Mills in Jacobs and
5. Neopak in Rosslyn, Pretoria.

## 2.4. Historical Trends in Water Consumption

Historically the Paper and Pulp Industry were perceived to have had a high specific water intake (ton water/ton product) industry. Much has been done to improve this image. Historically, consumptions as high as 156 $m^3$/t were reported in 1975 in Canada [(3)]. The improvement in specific water intake is illustrated in Table 6.

**Table 6: Change in Water Use of a recycled fibre mill in Canada [(3)]**

| Year | Paper Production (t/d) | Water Use ($m^3$/d) | Specific Water Use ($m^3$/t) |
|---|---|---|---|
| 1950s | 100 | 10,000 | 100 |
| 1960s | 150 | 7 500 | 50 |
| 1970s | 400 | 10,000 | 25 |
| 1980s | 500 | 2 500 | 5 |
| 1990s | 1000 | 3,000 | 3 |
| 2003 | 1200 | 2 400 | 2 |

According to the 1st edition of the NATSURV study, the water consumption per mill varied significantly depending on the process used and the type of products produced as presented in Table 7. The specific water intake was found to vary between 33 and 136 $m^3$/t for integrated mills and between 1 and 49 $m^3$/t for paper mills [(2)].

**Table 7: Specific Water Intake for Various Mills from NATSURV 12 1st Edition [(2)]**

| Mill | Production (t/d) | Water Intake ($m^3$/d) | Specific Water Intake ($m^3$/t) |
|---|---|---|---|
| 1 | 650 | 44 840 | 70 |
| 2 | 1 200 | 39 320 | 33 |
| 3 | 290 | 20,000 | 69 |
| 4 | 900 | 112 400 | 136 |
| 5 | 145 | 2 700 | 19 |
| 6 | 120 | 1,000 | 8 |
| 7 | 900 | 32 600 | 36 |
| 8 | 22 | 230 | 11 |
| 9 | 185 | 145 | 0.8 |
| 10 | 15 | 740 | 49 |
| 11 | 148 | 2 800 | 19 |

The continuous improvement trend in SWI can be observed in historical data as presented in Table 7 for 1991, Table 8 for 2000 and Table 9 and Table 10 for 2004. Current data is presented in Chapter 5. Typical specific water intake values for different Paper and Pulp production technologies in 2000 (European Commission) are summarised in Table 8. In general, a non-integrated pulp mill is observed to have a higher effluent load than a non-integrated paper mill.

**Table 8: Historical (2000) Specific Water Intake per Processing Type (12)**

| Processing Technology | Specific Consumption ($m^3$/t) | | |
|---|---|---|---|
| | Lower | Upper | Norm |
| Unbleached Kraft including woodyard | 9 | 20 | 12 |
| Bleached Kraft including woodyard (conventional or ECF) | 27 | 42 | 32 |
| Unbleached NSSC including woodyard | 1 | 34 | 6 |
| Bleached Sulphite including woodyard (Calcium based) | 70 | 130 | 75 |
| Bleached Sulphite including woodyard (Magnesium based) | 40 | 100 | 45 |
| Recycled fibre based carton board (uncoated) | 2 | 10 | 5 |
| Recycled fibre based carton board (coated) | 7 | 15 | 8 |
| Recycled fibre based packaging papers | 1.5 | 10 | 5 |
| Recycled fibre based newsprint | 10 | 20 | 15 |
| Recycled fibre based tissue | 5 | 100 | 20 |
| Recycled fibre based fine paper | 7 | 12 | 12 |
| General printings and writings not integrated | 7 | 20 | 12 |
| General linerboard/packaging papers | 3 | 20 | 10 |
| General corrugating medium including unbleached pulp mill | 12 | 30 | 15 |
| Newsprint/paper | 6 | 30 | 16 |

Some interpolation has taken place to determine the norm where this was not available in the literature

In a 2004 study evaluating water consumption in South Africa, Macdonald has further divided the specific water intake into two categories for larger (see Table 9) and smaller (see Table 10) mills, with a total water consumption of 10,000 $m^3$/d used as the guideline for the split[(3)].

**Table 9: Historical Specific Water Intake at Larger Water Using South African Mills (3)**

| Mill | Production (t/d) | Water Use ($m^3$/d) | Specific Water Use ($m^3$/t) |
|---|---|---|---|
| Sappi Saiccor | 1 600 | 112,000 | 70.0 |
| Mondi Richards Bay | 2 300 | 55,000 | 23.9 |
| Sappi Tugela | 1 170 | 52,000 | 44.4 |
| Sappi Ngodwana | 1 851 | 35,000 | 18.9 |
| Mondi Merebank | 1 755 | 34 500 | 19.6 |
| Sappi Enstra | 590 | 25 500 | 43.2 |
| Sappi Stanger | 290 | 21,000 | 72.4 |

**Table 10: Historical Specific Water Intake at Smaller Water Using South African Mills [3]**

| Mill | Production (t/d) | Water Use ($m^3$/d) | Specific Water Use ($m^3$/t) |
|---|---|---|---|
| Mondi Felixton | 300 | 5 900 | 19.6 |
| Mondi Springs | 400 | 4,000 | 10.0 |
| Kimberly Clark Enstra | 140 | 2 700 | 19.2 |
| Mondi Piet Retief | 340 | 2 500 | 7.3 |
| Nampak Bellville | 91 | 2 200 | 24.1 |
| Nampak Klipriver | 69 | 1 700 | 24.6 |
| Sappi Adamas | 108 | 1 700 | 15.7 |
| Sappi Cape Kraft | 163 | 1 400 | 8.6 |
| Nampak Rosslyn | 115 | 1,000 | 8.7 |
| Nampak Riverview | 28 | 700 | 25.0 |

*Note: The above is historical data and the current status of water consumption within the industry in South Africa will be reviewed in later sections of the report (Chapters 5 and 6).*

## 2.5. Effluent Generation

As with water consumption, the amount of wastewater (effluent) generated is strongly dependant on the technology used on site and whether it is an integrated or non-integrated mill. For a non-integrated paper mill (no pulp), the water consumed and thus effluent produced is significantly lower. Effluent production is typically 1.5-3 $m^3$/t less than water consumption depending on the mill type [29].

From the 1st edition of NATSURV 12, the specific effluent volumes for different mills in South Africa were as per Table 11 below.

**Table 11: Historical Specific Effluent Volumes for South African Mills [2]**

| Mill | Production (t/d) | Effluent Discharge ($m^3$/d) | Specific Effluent Volume ($m^3$/t) |
|---|---|---|---|
| 1 | 650 | 27 200 | 42 |
| 2 | 1 200 | 27 250 | 23 |
| 3 | 290 | 17 300 | 60 |
| 4 | 900 | 92 260 | 103 |
| 5 | 145 | 2 300 | 16 |
| 6 | 120 | 890 | 8.0 |
| 7 | 900 | 25,000 | 28 |
| 8 | 22 | 45 | 2 |
| 9 | 185 | 63 | 0.3 |
| 10 | 15 | 280 | 19 |
| 11 | 148 | 1 900 | 13 |

A significant portion (approximately 89%) of water extracted by the Paper and Pulp Industry is treated and returned to the environment [13]. The use of second class water (such as treated sewage) to replace potable water intake has also been implemented at some facilities [14].

## 2.6. Energy Requirement

Focus on expanding the use of renewable energy sources has resulted in Sappi and Mondi becoming the largest energy producers from renewable biomass in South Africa. This has resulted in the SA paper industry avoiding the use of 1.3 million tons per annum of fossil fuels such as coal, oil and gas [23].

The increased collection of biomass for power generation could result in 15-20% more value being recovered from existing plantations, while stimulating job creation. The currently discarded branches, sawdust and offcuts can serve as a sustainable and renewable biomass energy source that is less susceptible to seasonal variations and drought than other alternatives. A life cycle analysis is however required since the collection and transport to the mills may not be economically viable and the greenhouse gases generated during transport may offset the benefits. Up to 50% of waste from a sawmill can be used as biomass for bio-energy [(23)]. This approach is however contentious as some foresters prefer a portion of this biomass to stay in the fields where it returns nutrients to the soil.

## 2.7. Pulp Manufacturing Process

The pulp utilised for the manufacturing of paper is typically derived from either wood, bagasse or recycled paper. The pulping of wood is a much more extensive process than the use of recycled paper, requiring additional treatment processes, as well as larger quantities of raw materials. Since the pulping of wood is more intensive, the description below will focus on this option, more than the recycling of paper.

### 2.7.1. Raw Materials

The main requirements for Paper and Pulp production are wood, water and energy. In the first edition of NATSURV 12 (1990), the raw material requirement as at that stage was summarised as per Table 12 below.

**Table 12: Raw Material Requirements from NATSURV 12 1st Edition [(2)]**

| Material | Specific Consumption (t/t pulp) |
|---|---|
| Timber | 1.4-4 |
| Water | 30-130 |
| Coal | 0.5-0.75 |

### 2.7.2. Debarking

The wood utilised in the pulping process can be received either as logs (Figure 3) or as wood chips (Figure 4). The first treatment step is the debarking of the logs. If the wood is received as chips, the debarking step is not required at the pulping facility. Hardwood is debarked in the plantations and softwood is debarked at the mills.

**Figure 3: Wood Logs in Woodyard [(16)]**

**Figure 4: Wood Chips [(16)]**

Debarking is the process of removing bark from the untreated logs, which can either be a manual or mechanised process. Debarking is performed either in the plantations after felling of the trees, or in the woodyard at the pulping facility. The stripped bark is a good fuel and can be used in boilers to generate steam. It also serves as good feed material for composting. For manual debarking a sharpened hatchet, debarking spud or shaped spades are typically utilised. The bark is stripped either as long or short strips or as small plates [(17)].

Mechanical debarking is typically done by mechanical debarker systems such as drum debarkers, ring debarkers, Rosser head debarkers, flail debarkers and hydraulic debarkers. Only drum debarkers are used in South Africa. The drum debarker (Figure 5) utilises a slightly inclined rotating drum (15). Logs are batch fed linearly into the drum debarker. The drum rotates and tumbles the logs and the bark is removed by rubbing against the drum walls and other logs in the drum (18).

### 2.7.3. Chipping

Depending on the pulping technology used on site, the debarked logs can be either ground to fibres for mechanical pulping sites or chipped with multi-knife chippers on chemical pulping sites or refiner mechanical sites (16). The chips are screened to remove oversized chips, since chips that are too thick are undesirable. Such chips will limit the speed and thoroughness of cooking chemical impregnation on the chips (15).

**Figure 5: Drum Debarker**

**Figure 6: Chipped Wood**

### 2.7.4. Pulping

The pulping process is broadly divided in two categories, namely mechanical and chemical pulping, although some hybrid categories such as thermo-mechanical and chemical-thermo-mechanical pulping processes also exist. The type of technology selected is subject to the type of product being produced at a specific site. Chemical pulping includes chemicals utilised in the bleaching process (for bleached pulps) and hence can have a larger environmental impact than mechanical pulping that will result in an unbleached pulp being formed. Thus, mechanical pulping is typically selected for non-fine paper type of applications such as packaging material production where chemical pulp will be used in fine paper production.

The different pulping processes operate at different pH ranges as per Figure 7.

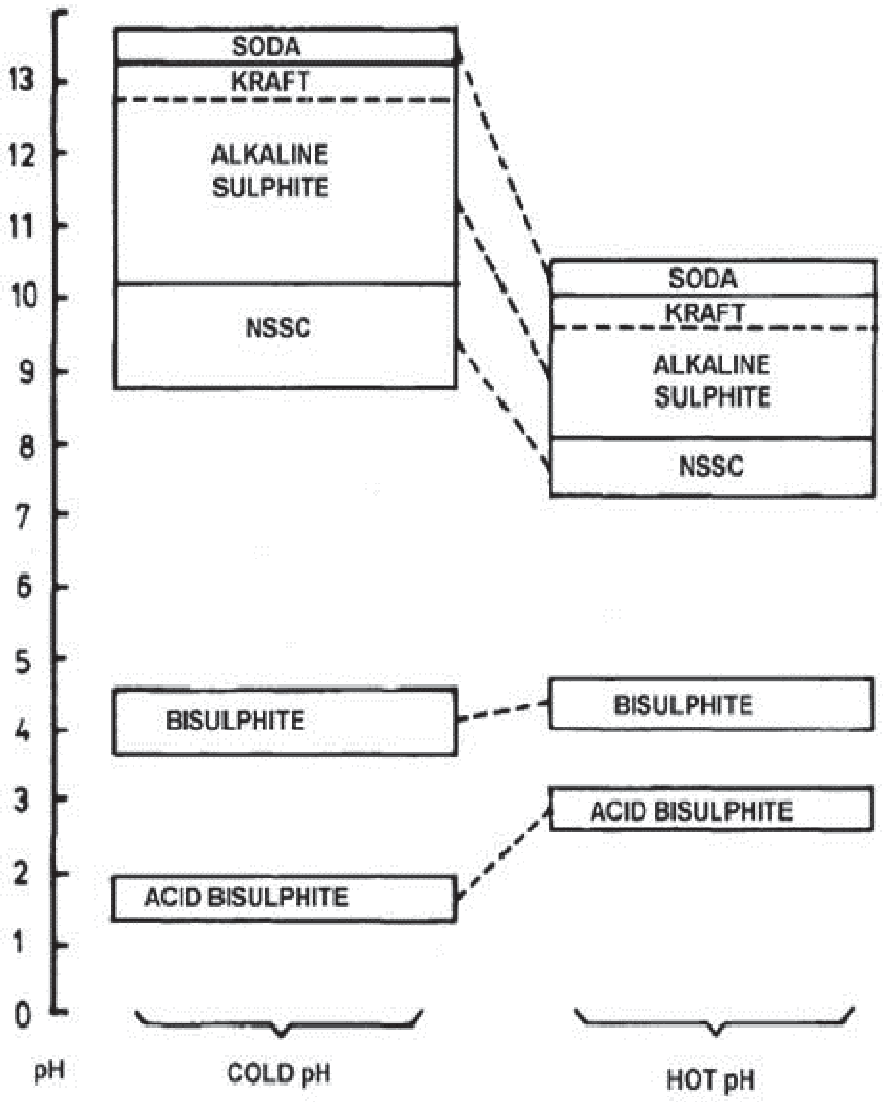


**Figure 7: The range of pulping processes against pH**

#### *2.7.4.1. Mechanical Pulping*

In groundwood pulping the logs together with water are fed to a rotating stone grinder which breaks them down into fibres called pulp. The process has a high yield of approximately 90 -96%[16]. Water is used to wash the pulp if required, followed by pulp thickening [19]. The unbleached pulp is then either processed further or used as unbleached pulp depending on site specific application.

Mechanically produced pulp can be used in various applications such as to produce short life papers such as newspaper, board and lightweight coated paper [19], but also for applications requiring unbleached pulp such as packaging material, ceiling tiles, etc.

#### *2.7.4.2. Refiner Mechanical Pulping*

In Refiner Mechanical Pulping (RMP) wood feedstock is ground between two grooved discs. The process keeps the high yield advantages of the groundwood pulping process, while producing somewhat longer fibres with greater strength. This permits lighter weight paper to be used for printing and results in more print media per ton of feedstock. The RMP process can use wood feedstock other than logs, such as wood scraps and sawdust from lumber mills [48].

#### *2.7.4.3. Thermo-Mechanical Pulping*

In Thermo-Mechanical Pulping (TMP) wood chips are first steamed to soften them before being ground in the same manner as the RMP process. The TMP process generates the highest grade mechanical pulp but is also a high-energy intensity process due to its steam use. This process can also produce a darker pulp that is more costly to bleach. Despite these drawbacks, TMP is commonly used as a mechanical pulping process [48]. The yield achieved is similar to mechanical pulping at 90-96%[16].

#### *2.7.4.4. Chemi-Thermo-Mechanical Pulping*

Chemi-thermo-mechanical pulping (CTMP) combines chemical impregnation of the wood with mechanical processing. The wood chips are first partially softened chemically in a neutral sulphite solution and then mechanically pulped [19]. The yield is slightly lower than for mechanical pulping at approximately 85-90%. The fibre length and strength of the paper is better controlled [16].

The benefits of the process are that it achieves higher yields and requires less chemical addition than full chemical pulping. The process is typically used for the production of high quality, strong fluting for packing cases from hardwoods. Since the chemicals are more diluted, the recovery and re-use of the chemicals is more costly than with chemical pulping [19].

#### *2.7.4.5. Chemical Pulping*

During the chemical pulping process, lignin, the natural 'glue' that holds the wood fibres together, is dissolved, freeing the wood fibres [25]. This results in a typical lignin concentration of 3-8% by mass for unbleached pulp (0-1% if bleached) vs. 25-31% for mechanical pulp. The yield from chemical pulping is lower (typically between 43 and 52%) [16] than with mechanical pulping. Chemical pulping creates either a sulphate (Kraft) or sulphite pulp, depending on the chemicals used. The fibre obtained in this way is quite clean and undamaged. The paper made from chemical pulp is called coated fine paper (or woodfree paper) [35].

The sulphate (or Kraft) process is an alkaline process used for strongly resinous wood types. It requires more expensive installations and a more intensive use of chemicals [16]. The Kraft process can be either batch or continuously operated. The wood chips are cooked for 1-2 hours in a solution of sodium hydroxide and sodium sulphide which is called the white liquor [19]. To achieve reasonable cooking time, the temperature required is in the range of 150-165°C. The wood is then disintegrated into fibres by a sudden pressure decrease of the pressure cooker [15]. The chemical liquor recovered from the pulp is called the black liquor and is screened and cleaned of residual impurities. The treated black liquor can then be recycled to the white liquor circuit [19], after burning in a recovery boiler for combined heat and power generation.

The sulphite process can be across the whole range of pH’s. Magnesium and calcium sulphite are acidic. The sulphite liquor penetrates the wood and decomposes the lignin during a process called cooking [16]. Cooking takes place batch wise under elevated temperatures and pressures with cooking times of up to 9 hours [19]. The lignin becomes a water-soluble substance that can then be washed out of the wood pulp and remains in the cooking liquor. The strength of sulphite pulps is less than that of sulphate pulps. The pulp produced still has a brownish colour and needs to be bleached for the production of white paper [16]. The chemicals used in the magnesium sulphite process can be recovered and recycled [19], after burning in a recovery boiler for combined heat and power generation. Lignosulphonate can be produced as a by-product from the black liquor.

For non-wood fibres, a weaker chemical pulping liquor, consisting of sodium hydroxide. Chemical recovery is not possible in this process [19].

#### *2.7.4.6. Recycled Fibre Pulping*

The practise of recycling paper has increased in popularity as the environmental awareness of communities has increased. Collection schemes for waste newspaper, board and office waste paper have been initiated in many centres.

The recycling process entails sorting, followed by re-pulping of the waste paper. Once re-pulped, the pulp typically undergoes centrifugal cleaning and then coarse and fine screening to remove residual impurities such as metal (staples), plastics and adhesives [19]. Depending on the quality of the end product produced, de-inking of the pulp may be required. This entails washing of the pulp, followed by chemical flotation [19].

In South Africa, paper recycling trends are monitored and reported by the Paper Recycling Association of South Africa (PRASA). The 2014 figures for this sector are summarised in Table 13,

Table 14 and Figure 8.

**Table 13: 2014 Quantity and Source of Recycled Paper in South Africa (metric tons/annum) [33]**

| Category | Paper Recovered in South Africa | Recovered Paper Imports | Recovered Paper Exports | Consumption of Recycled Paper in SA |
|---|---|---|---|---|
| Newspapers | 109 973 | 300 | 22 839 | 87 434 |
| Magazines | 53 729 | 1 431 | 11 246 | 43 914 |
| Corrugated, solid cases, Kraft papers | 734 804 | 32 975 | 18 280 | 749 499 |
| Office, graphic papers | 60 239 | 9 772 | 8 989 | 61 021 |
| Mixed and other papers | 104 385 | 11 155 | 10 760 | 104 780 |
| **TOTAL** | **1 063 129** | **55 633** | **72 114** | **1 046 648** |

**Table 14: South African Recycling Rates [33]**

| | % recycled |
|---|---|
| Recyclable paper recovered as % of paper consumption | 46.4% |
| % Recycled paper used in paper produced in SA | 46.3% |
| Recovered paper as % of recoverable paper | 63.6% |

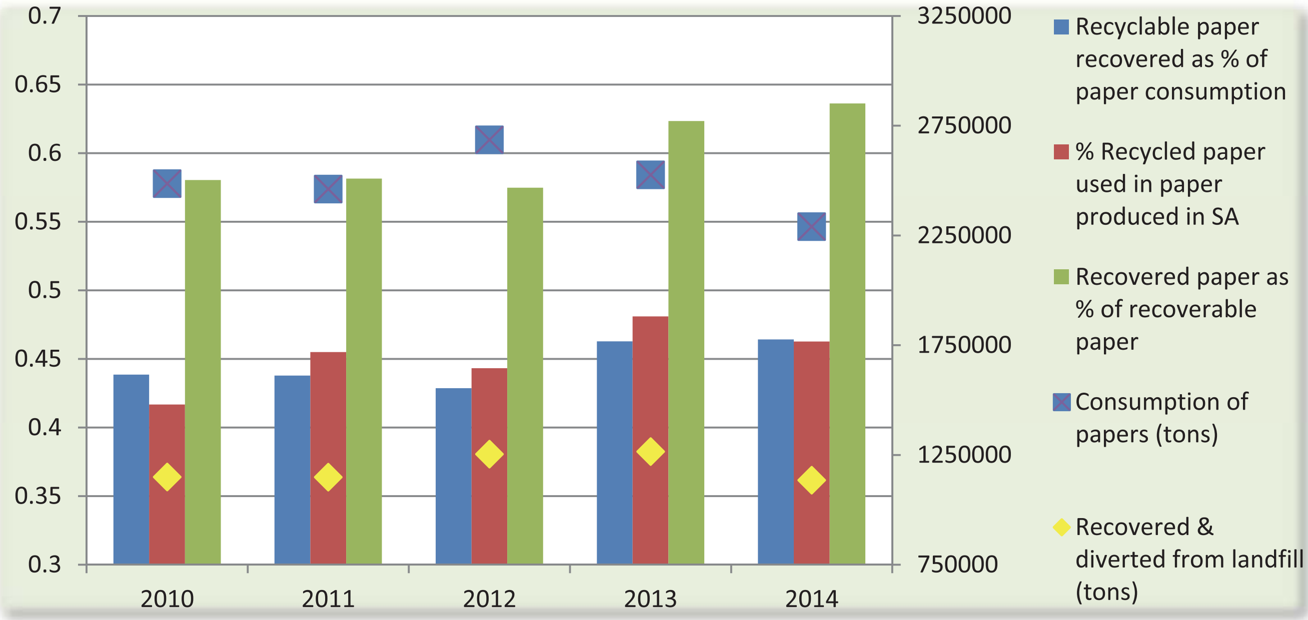


**Figure 8: South African Consumption and Recycling Rates [33]**

### 2.7.5. Pulp Washing

Due to the large amounts of chemicals used in the chemical pulping process, it is important to optimally recover the chemicals. This is achieved by washing the pulp. Recovering the chemicals, reduces the cost of replacing chemicals, facilitates downstream processes and prevents potentially harmful chemicals from entering the environment [15].

Most washing processes utilise hot water to displace the chemicals from the pulp, but mechanical processes such as drum screens and presses can be used to squeeze the chemical liquor from the pulp [15].

### 2.7.6. Black Liquor Recovery

Black liquor is formed in alkaline pulping processes and contains the cooking chemicals, lignin and other organic components extracted from the wood. Material in this stream is recovered by evaporating the bulk of the water, resulting in a fuel source. The black liquor is burned in the Kraft recovery boiler to generate energy and to recover the chemicals in the black liquor for re-use. By performing this form of chemical recovery, the quantity of fresh chemical make-up is drastically reduced.

The energy generated by burning the black liquor is used to generate steam that can be used on site for process purposes as well as for power generation.

The composition of the black liquor is a function of the pulping chemicals used, the type of wood and the pulping process used.

### 2.7.7. Bleaching

After pulping and washing, the pulp is typically a brownish colour and therefore needs to be bleached to produce white paper. The purpose of bleaching is to remove residual lignin from the pulp. For the production of corrugated boxes, brown bag paper, etc. bleaching is not required.

The bleaching process consists of a number of sequential chemical processing steps, with washing between the different steps [16].

Various chemicals such as chlorine or chlorine based compounds [35], ozone/oxygen based chemicals and hydrogen peroxide can be used for bleaching chemical pulp [16]. Historically Chlorine was widely used. Chlorine however results in the formation of some undesirable decomposition products making the use of chlorine-based bleaching methods undesirable from an environmental perspective [16]. Chlorine-based processes have fallen out of favour because of their environmental impact [35] and are no longer utilised in South African mills. Consequently, elemental- and totally-chlorine free processes are now more frequently used. For mechanical and recycled fibre pulp, hydrogen peroxide, sodium hydrosulphite or formamidine sulphuric acid, together with complexing agents for heavy metals such as manganese, can be used for bleaching [19].

The bleaching process is effectively split in two processes, namely oxygen delignification and final bleaching. In oxygen delignification about half the remaining lignin is removed, with the balance removed in final bleaching [15].

Prior to oxygen delignification, the pulp is washed to remove as much of the black liquor as possible in order to reduce the chemical requirement. Sodium hydroxide is used to produce an alkaline solution that ionises the phenolic group in the lignins. Magnesium salts are included in the blend to inhibit metal ion activity that could damage the cellulose structure of the pulp resulting in reduced pulp strength. Following the oxygen delignification process, the pulp is again washed to remove the bulk of the soluble organics produced in order to reduce chemical consumption during the final bleaching step [15].

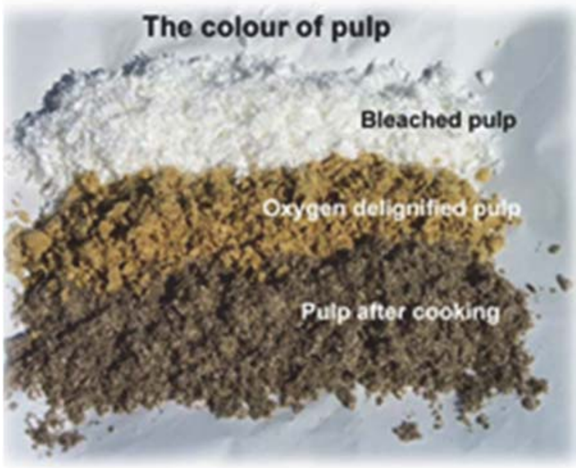


**Figure 9: Pulp Colour before and after bleaching steps [16]**

Oxygen delignification produces significantly less water pollution than chlorine based bleaching and is an effluent free process since the effluent is recovered in the black liquor. Although the initial capital cost is high the operating cost of oxygen delignification is fairly low [15].

Final bleaching is a multi-step process to improve efficiency. Historically elemental chlorine was widely used, but is now virtually eliminated. Chlorine dioxide has a reduced environmental footprint, but is not as effective a bleaching agent. If the incoming lignin levels are low enough as with oxygen delignification, chlorine dioxide can still be used. There are various bleaching sequences used in industry e.g. the use of chlorine dioxide as a three-step bleaching process using chlorine dioxide, followed by a blend of caustic soda, oxygen and hydrogen peroxide, followed by a second chlorine dioxide bleaching step. Chlorine dioxide has been globally accepted as environmentally acceptable [50]. In such cases, only oxygen, hydrogen peroxide and ozone together with caustic soda and chelating agents are used [15].

Following bleaching, the pulp is washed and thickened. Where chlorine based chemicals were used, the free chlorine is removed chemically [19].

If the pulp must be transported to another site, the pulp is thickened and/or pressed to remove the bulk of the water [19]. For transportation purposes the pulp is either baled or rolled.

## 2.8. Paper Manufacturing Process

In the papermaking process, the pulp produced as per the previous section, is treated and processed further to produce different paper-based products.

### 2.8.1. Pulp Refining

As the first step of paper manufacturing, the bleached or unbleached pulp (depending on final product produced) is reconstituted in water to form a slurry. The slurry is then mechanically treated to separate fibres and roughen their surfaces to increase surface area and improve adhesion [19]. The mechanical refiner (Figure 10) typically consists of two revolving metal discs through which the reconstituted pulp is passed.

**Figure 10: Pulp Refiner**

### 2.8.2. Paper Machine Feed

The first modern paper machine was developed in the early 1800s and was named the Fourdrinier paper machine (Figure 11). For this machine the reconstituted pulp is diluted to 0.5-1.0% consistency and then fed under pressure on a flat travelling wire screen. The water is extracted through the screen and recirculated to the feed stock since it still contains a significant concentration of fines, while the remaining material is referred to as the web. The web is removed from the screen at approximately 20% solids [(15)].

In order to eliminate so-called two-sidedness since water is only drained from the bottom of the web, twin-wire machines, called twinformers, were developed. These machines utilise synthetic fibre fabrics between which the stock is injected [(15)]. Suction boxes are utilised to suck the water from the top, in addition to water removal under gravity at the bottom. The processing time is significantly reduced, resulting in a more efficient process [(16)].

**Figure 11: Fourdrinier Paper Machine**

The web is then further pressed to 35-40% solids [(15)] and as high as 50-55% [(16)]. The pressing process is a mechanical process using a series of rollers possibly with shoe presses through which the web is fed. The removed water is absorbed by felts and transported away from the presses [(16)].

It is then fed over a number of heated cylinders (Figure 12) and dried to approximately 95% solids by evaporation of the water [(15)].

After drying and depending on the type of paper produced, the paper can be glazed before being rolled onto steel cores or tambours at a constant circumferential speed [(16)].

**Figure 12: Paper Dryer Cylinders**

As the paper moves along the paper machine, there are various measuring frames at different positions, measuring and controlling quality parameters such as basis weight, moisture and ash content, brightness and opacity [(16)].

Sizing is to impart water resistance in order to increase strength under humid or damp conditions. This is achieved with aluminium sulphate, rosin, and various other sizing agents. Fillers are added to give better opacity and a better printing surface. Dyes and other additives can also be added on the paper machines [(19)]. The processes used will differ and are selected at each site depending on final product requirements.

### 2.8.3. Coating

Coating entails adding a layer of pigments, binding agents and/or process materials to the surface of the paper. Coating of paper is performed to improve printing behaviour, yield more colour in thinner ink layers, produce more contrast and also to enhance paper properties such as whiteness and shade, gloss and smoothness [16]. The paper is typically coated to fill the pores and smoothen the whitened paper. This is achieved by the addition of calcium carbonate and Titanium trioxide.

The paper sides are coated sequentially with a drying step after coating of each side. Drying can be by infrared dryers, air foils or drying cylinders. There are two main coating techniques used, namely film and blade coating (Figure 13). During film coating, a uniform coating layers is applied to the paper, retaining the paper contours. In blade coating the coating layer is partially scraped off with a blade, to result in a smooth surface [16].

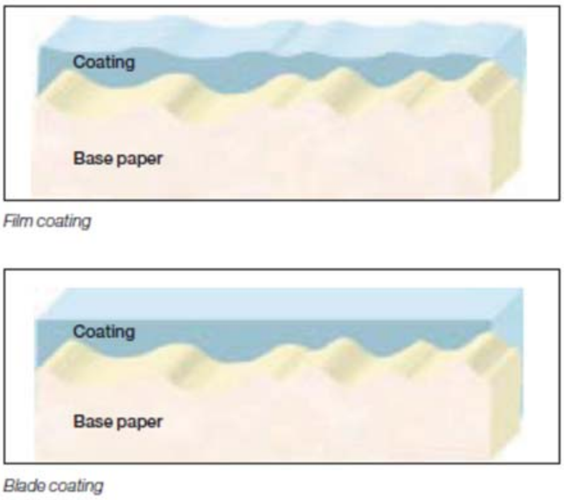


**Figure 13: Film Coating vs. Blade Coating [16]**

### 2.8.4. Finishing

Depending on the type of paper produced, it is ready for use after coating or may require further processing in a calendar to make the surface extra smooth and glossy [16].

**Figure 14: Slitter Rewinder Machine**

The full-width paper roll is then cut into smaller reels using a slitter rewinder machine either for delivery to the customer or for further cutting into sheets by a cross cutter machine [16]. Sheeting is carried out to produce reams of cut sheets [50].

## 2.9. Growth Projections

### 2.9.1. Global Growth Projections

In general, certain growth projections are viewed by industry as part of their competitive advantage and industry representatives are therefore reluctant to disclose such information. This section only contains information currently available in the public domain.

Several factors are impacting on the Paper and Pulp sector in the current global economic and social environment. Seven main reasons underlie these shifts in consumption and production [20]:

1. For the first time in history, communication paper (printing, writing paper and newsprint) consumption is decreasing in OECD member countries. The main cause of the decrease is the increased popularity of using electronic social media for communication purposes;
2. There is a contrast between non-OECD member countries where the use and production of paper and paperboard is increasing as opposed to the decline in OECD member countries;
3. For the past decade, the real price of paper and paperboard has been declining;
4. The share of hardwood pulp from South America, Asia and Oceania is increasing rapidly;
5. International Paper and Pulp trade is increasing in absolute and real terms;
6. Diversification into new markets such as bioenergy and biorefining is taking place in OECD member countries to offset declining markets in conventional products; and
7. Increased globalisation has resulted in industry consolidation with increased multinational companies.

The Paper and Pulp Industry is however still a large industry with 400 million tons of paper and paperboard products produced in 2010 at a market value of $ 360 billion. In comparison, the global aggregate 2011 sales of Apple Inc., Microsoft Inc. and Nokia Inc. was $ 228 billion or approximately 63% of the global Paper and Pulp Industry [20].

The percentage of different categories of paper produced is reflected in Figure 15.

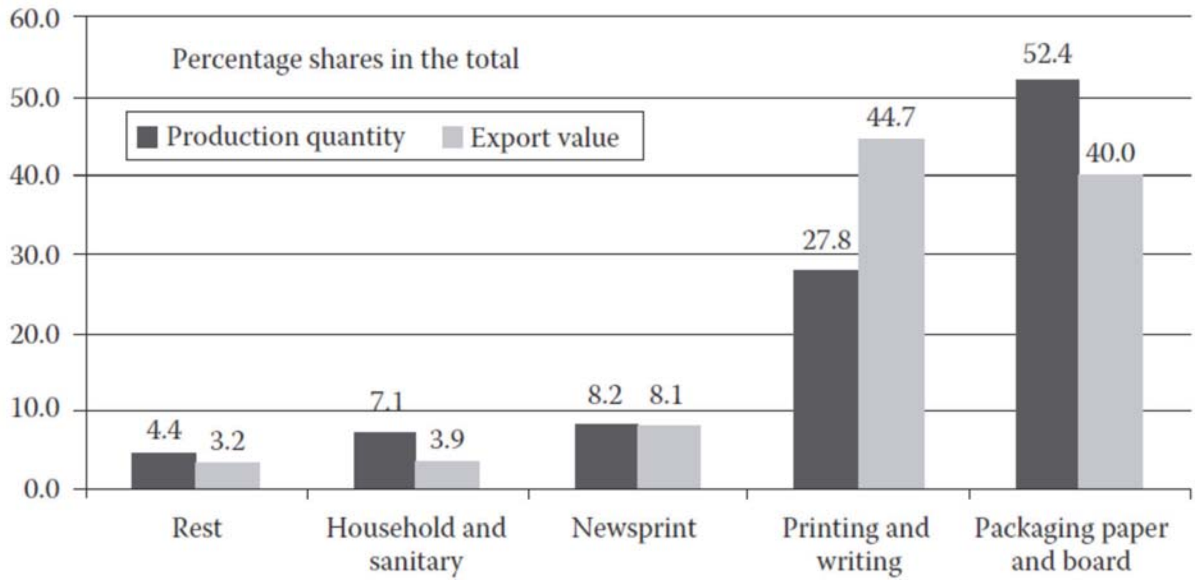


**Figure 15: Global production of Paper Product Groups in 2010[20]**

In 2011 the global pulp consumption reached an all-time high of 407 million tons. Recovered paper serves as the main source at a peak of 223 million tons, with wood pulp totalling 166 million tons. Non-wood fibre consumption was marginal at 17 million tons [21].

It is expected that the global growth in paper consumption will be slower than the global GDP growth. From 2013 to 2025 the average global GDP growth is projected to be 3.6% per annum, whilst the growth in paper production is expected to average 1.6% per annum [21].

The increased consumption in overall paper and paperboard results in an anticipated increased consumption of pulp. The consumption is expected to increase from 2013 levels of 407 million ton to 510 million ton by 2025. The main growth sector is expected to be in packaging board contributing 85% of the expected growth in fibre demand. Tissue paper will contribute approximately 15% in growth, whilst the use of graphic paper is expected to decline marginally [21].

The use of recovered paper has increased, but in markets such as North America, Western Europe and Japan full potential of economically recoverable waste paper collection is being approached. Thus the marginal cost of increasing waste paper recovery will result in an increase in cost, resulting in increased paper prices for recycled paper [21].

Developments in China also impact significantly on the global Paper and Pulp markets. Between 2000 and 2010 Chinese paper and paperboard consumption increased by 143%, but this was still superseded by the increase in Chinese production of paper and paperboard which increased by 182%[20].

From the above it is clear that regional differences will play an important role in future paper production trends. Thus the regional expected growth in paper production and consumption is summarised in Table 15. In 2010 Asia was the largest consumer of paper and paperboard at about double that of either the North American or Western European regions which are the 2nd and 3rd largest consumers. This gap is however expected to widen as Asian consumption increases. On the other end of the spectrum is Africa which, although its population size is approximately the same as that of North America and Western Europe, only consumes about 10% of these region's consumption in 2010.

**Table 15: Regional Historical and Predicted Paper and Paperboard Consumption and Production from 2000 to 2030 (in million metric ton/annum) [20]**

| Region | | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|
| Asia | Consumption | 109.4 | 178.1 | 250.7 | 323.7 |
| | Production | 96.0 | 164.4 | 238.8 | 313.3 |
| North America | Consumption | 100.7 | 81.5 | 67.0 | 49.4 |
| | Production | 106.8 | 88.6 | 75.2 | 59.4 |
| Western Europe | Consumption | 81.4 | 75.9 | 75.3 | 72.2 |
| | Production | 88.6 | 90.5 | 96.0 | 99.0 |
| Eastern Europe | Consumption | 13.1 | 24.0 | 37.0 | 48.9 |
| | Production | 12.8 | 19.0 | 25.9 | 32.1 |
| Latin America | Consumption | 19.4 | 27.1 | 35.3 | 43.7 |
| | Production | 14.9 | 20.3 | 26.3 | 32.0 |
| Africa | Consumption | 4.8 | 8.0 | 11.1 | 14.2 |
| | Production | 3.3 | 4.3 | 5.6 | 6.7 |

The rate of internet penetration in developing countries such as China is foreseen to be a major factor to reduce the predicted rate of increase in paper consumption in these countries [20].

### 2.9.2. South African Growth Projections

As mentioned in the previous section, the South African Paper and Pulp sector is small when compared to the total global industry. However, it still remains a significant contributor to the South African economy and hence the future prospects of this sector are important. In 2013, R18.2 billion (or 0.6% of SA's GDP) was added to the South African economy due to the forestry-to-paper value-add. A total of 150,000 people is employed in the sector's value chain – from forestry, Paper and Pulp manufacturing to recycling [33]. The paper industry not only makes a significant contribution to the South African economy, but is also a growing source of export income for the country. The growth in ZAR value of exported goods from the industry is reflected in Figure 16.

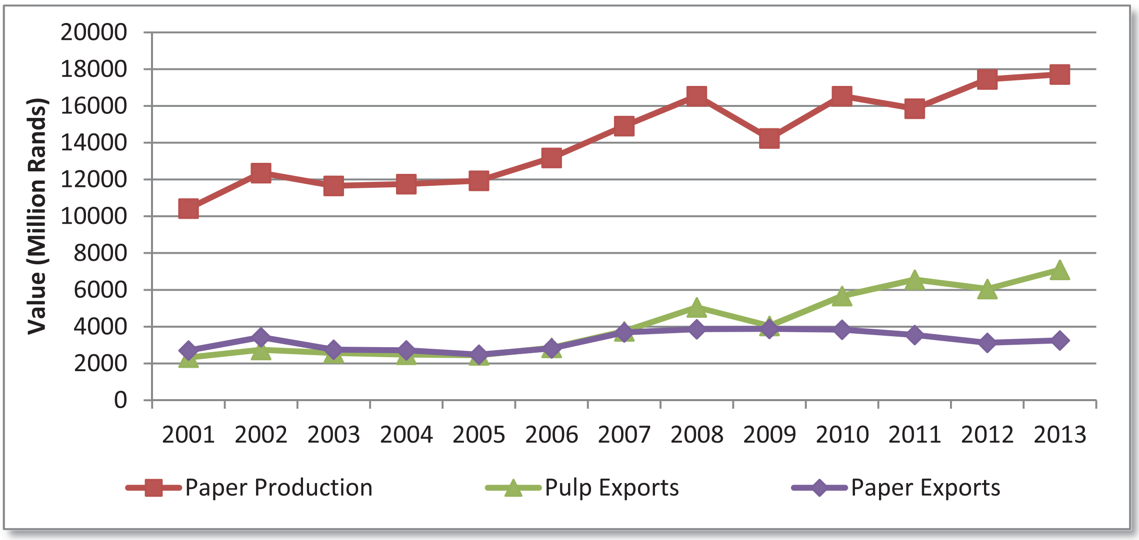


**Figure 16: Growth in ZAR value of locally produced paper and exported Paper and Pulp [10]**

Many of the factors discussed in the previous section, will also impact on the South African industry, but other external factors also need to be considered according to a global industry review by Deloitte. Sappi and the other South African producers are proactively taking measures on high growth opportunities as well as their core capabilities. External factors that have a further negative impact on the South African paper and pulp sector include electricity supply shortages, labour unrest and higher energy costs. These factors also contribute to reluctance to further investment in this sector in South Africa [22].

The country's Paper and Pulp Industry is however utilising the good relations with China to export wood chips to the East, mostly from smaller cooperative producers [22].

However, as the global recession has been slowing down, certain grades of South African produced pulp, packaging and tissue paper have been showing a slight increase in demand. Worldwide overproduction of products such as newsprint, together with increased costs and rising imports could negatively impact on the SA industry [23].

An increase has been experience in SA per capita paper consumption in certain categories (Figure 17), mostly due to increased living standards which in turn resulted in increased consumption of packaging and tissue paper. This trend is expected to continue. Printing and writing paper consumption are however showing signs of a decline in demand. In line with, but slower than the global trend, the consumption of newsprint has been declining at 1.57% per annum in SA in the four years prior to 2013[23].

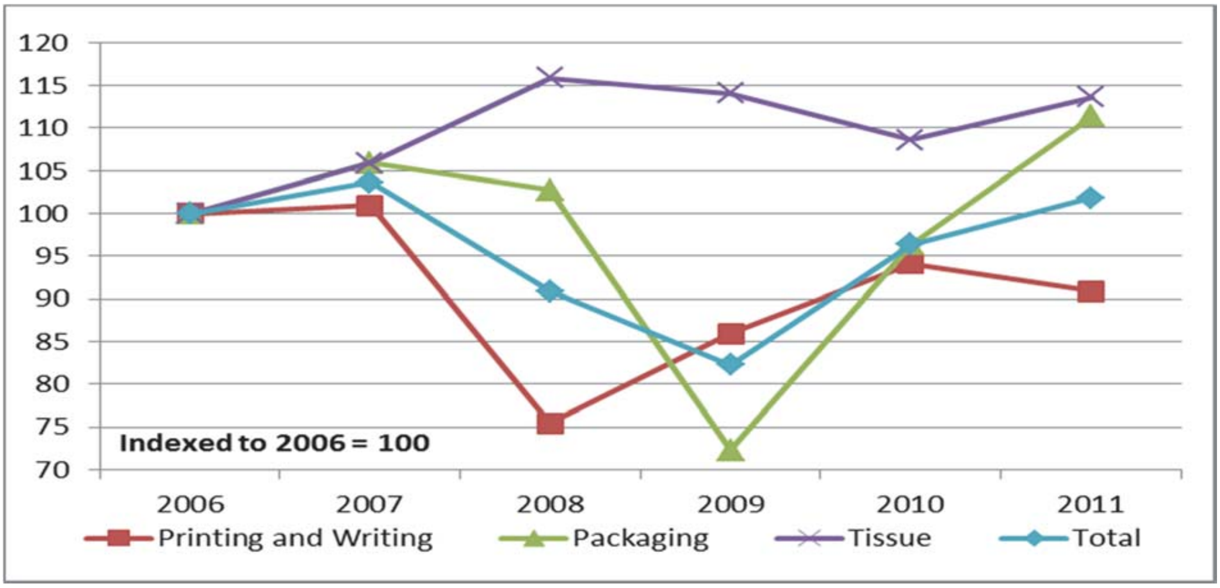


**Figure 17: South African Paper Consumption relative to 2006[32]**

The international market trends are also impacting on the type of trees grown. Increased demand for hardwood pulp with a decrease in demand for softwood pulp has resulted in increased eucalyptus to pine plantation ratios. This is seen as beneficial for southern hemisphere pulp producers who typically produce higher yields of hardwood [23].

In line with global diversification trends, Sappi has identified a market opportunity to produce dissolving wood pulp, or specialised cellulose, which is used in the production of fibre used in textile that can breathe, unlike polyester and other oil-based textiles. Other uses of this type of pulp include cell phone screens, pharmaceuticals and household products. Sappi anticipates that the shortfall in global cotton production will create a gap for chemical cellulose to fill. They have invested $ 340 million in their GoCell expansion project at Ngodwana (Figure 18) to supply this need [23].

Mondi is considering a € 25 million project to debottleneck its Richards Bay mill as well as to increase pulping capacity by 8% [23].

The shift towards green chemicals also presents a number of opportunities to the SA Paper and Pulp Industry. Significant research has been done on the recovery of chemicals found in pulping liquors and waste streams.

Calcium lignosulphonate is produced at the Sappi Saiccor mill in Umkomaas from the specialised cellulose production process. It is used in various applications for its binding properties. The Sappi Tugela mill in Mandeni produces sodium lignosulphonate which is also used for bonding properties in various applications [23].

**Figure 18: Sappi Ngodwana GoCell Project [34]**

## 2.10. Generic Water Flow Schemes

Different Paper and Pulp mills utilising different technologies e.g. in pulping techniques and producing different types and grades of paper will have different flow schemes. Thus, it is not possible to compile a single flow scheme that represents all mills in South Africa. However, the technology used can be divided into broad groups and some typical schemes for such groups are presented in this section. Care must however be taken that these flow schemes cannot be used without considering the actual unique facility configuration and adapting to a per case basis.

### 2.10.1. Kraft Pulp Mills

The data reported in this section is historical data from 2001 and is based on EU Mills' operating performance. Variations may occur when compared to South African Mills.

The main wastewater contaminants originating from the Kraft process are:

- Organic substances (COD, BOD),
- Compounds extracted from the wood such as resin acids, etc.,
- Chlorinated organics (AOX), chlorate (depending on bleaching agent used),
- Nitrogen and phosphorus based compounds,
- Suspended solids,
- Metals, salts and
- Coloured substances.

A typical water flow scheme for a bleached Kraft mill is shown in Figure 19.

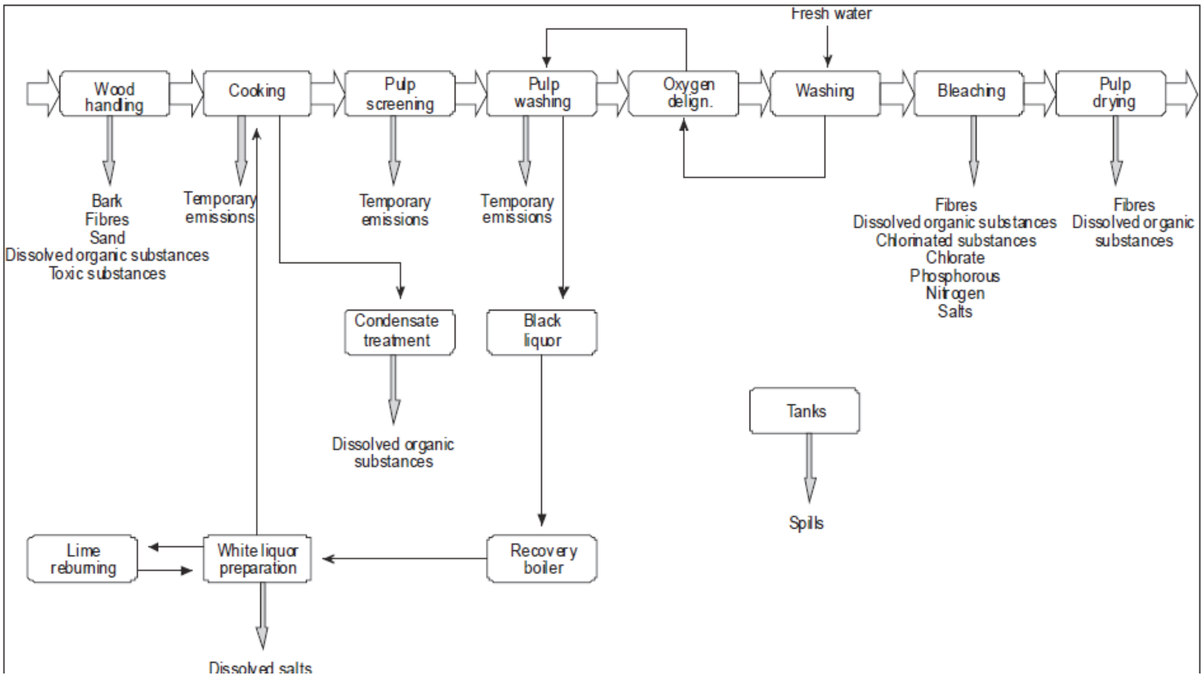


**Figure 19: Typical Water Flow Scheme for a bleached Kraft pulp mill [40]**

Typical effluent generation rates for the various main contaminants are summarised in Table 16, Table 17 and Table 18.

**Table 16: Generic COD production rates before external treatment from bleached Kraft pulp mills [40]**

| Process stage | COD kg/ADt |
|---|---|
| Wood handling | 1-10 |
| Condensates | 2-8 |
| Spillage | 2-10 |
| Washing loss | 6-12 |
| Bleaching | 15-65 |
| **Total from mills** | **31-105** |

**Table 17: Phosphorus and Nitrogen in kg/t from bleached Kraft pulp mills [40]**

| Process | Phosphorus kg/ADt | Nitrogen kg/ADt |
|---|---|---|
| Unbleached | 0.01-0.04 | 0.2-0.4 |
| Bleached | 0.04 -0.06 | <0.1* |
| **Total from mill** | **0.05 -0.10** | **0.2-0.4*** |
| Note: * Use of chelating agents can increase this figure of nitrogen by about 0.1-0.2 kg/t. Chelating agents will normally end up in the white water. Some mills also add the chelating agents in the closed part of the process. In this case the complexing agents end up in the recovery boiler i.e. are incinerated. | | |

**Table 18: Metals released from Kraft pulp mills [40]**

| | Cd | Pb | Cu | Cr | Ni | Zn |
|---|---|---|---|---|---|---|
| Unbleached pulp | 0.03 | 0.3 | 0.5 | 0.2 | 0.4 | 5 |
| Bleached pulp | 0.1 | 0.4 | 1 | 0.7 | 0.9 | 15 |

The effluent generated in Kraft mills can be treated microbiologically by either aeration lagoons or activated sludge processing. Typical contaminant removal rates that can be achieved by these processes are summarised in Table 19.

**Table 19: Percentage Reduction in Contaminants by Effluent Treatment [40]**

| Reduction rate of | $BOD_5$ [%] | COD [%] | AOX [%] | P [%] | N [%] |
|---|---|---|---|---|---|
| Aerated lagoon | 40-85 | 30-60 | 20-45 | 0-15 | 0 |
| Activated sludge | 85-98 | 40-70 | 40-65 | 40-85 | 20-50 |

### 2.10.2. Sulphite Pulp Mills

The data reported in this section is historical data from 2001 and is based on EU Mills' operating performance. Variations may occur when compared to South African Mills.

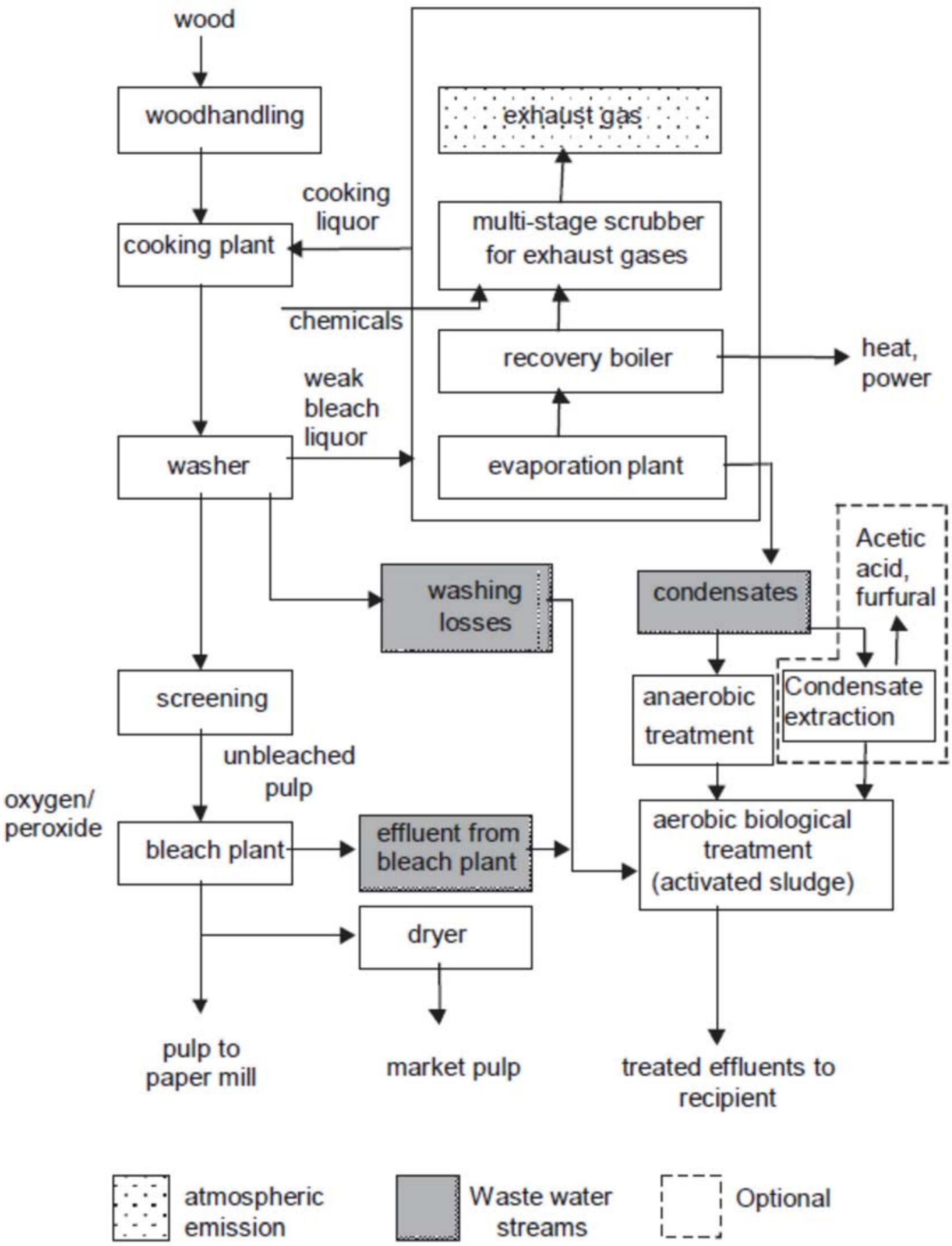


**Figure 20: Typical Process Flow Scheme for a bleached Sulphite pulp mill [40]**

The main wastewater contaminants originating from the Sulphite process are:

- Organic substances (COD, BOD),
- Compounds extracted from the wood such as resin acids, etc.,

- Chlorinated organics (AOX), chlorate (depending on bleaching agent used),
- Nitrogen and phosphorus based compounds,
- Suspended solids,
- Metals, salts and
- Coloured substances.

Figure 21 represents a typical flow scheme for a Magnesium Sulphite pulp mill with the recovery cycles reflected in Figure 22.

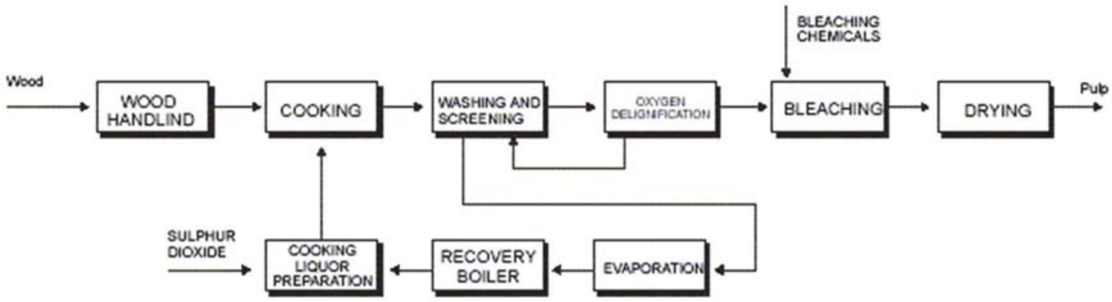


**Figure 21: Main Unit Processes of Manufacturing of Magnesium Sulphite Pulp [53]**

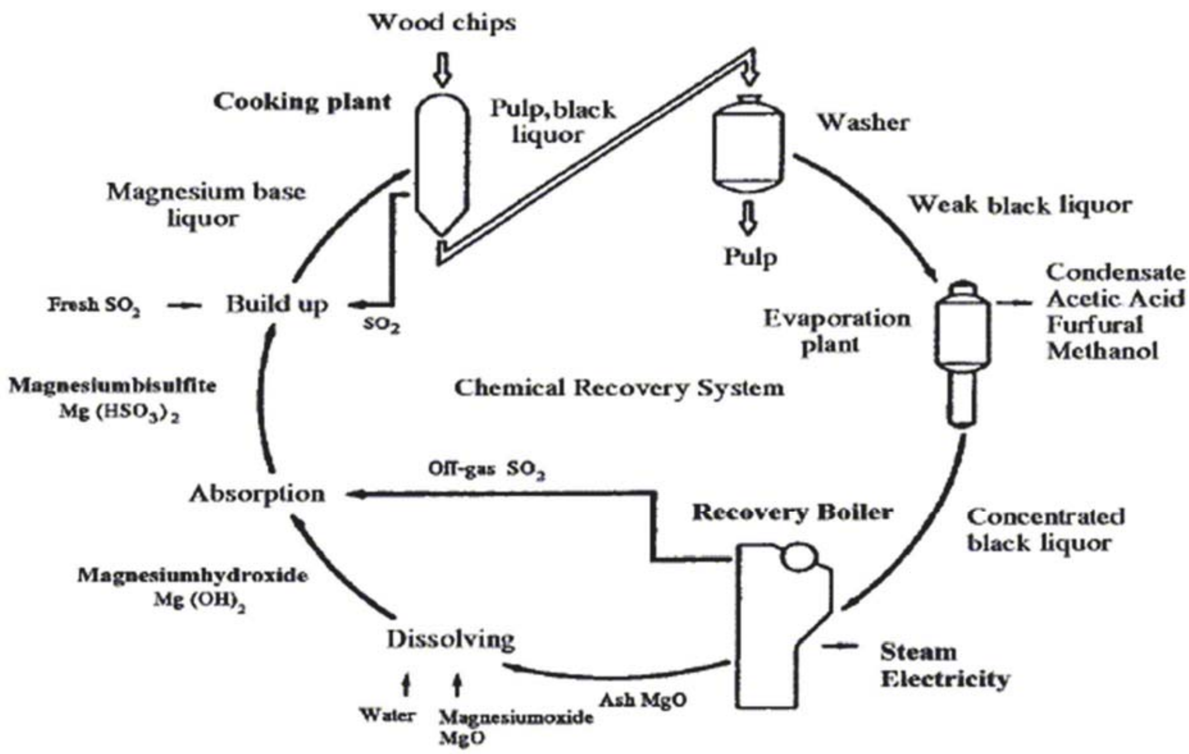


**Figure 22: Recovery Cycles for a Sulphite Mill [53]**

As per Kraft mills, the effluent generated in Sulphite mills can be treated microbiologically. Typical discharge qualities after treatment vary significantly within Europe.

**Table 20: Typical treated effluent discharge qualities achieved at Sulphite Pulp Mills [40]**

| Sulphite pulp | BOD5 kg/ADt | COD kg/ADt | AOX kg/ADt | tot-P g/ADt | tot-N kg/ADt | TSS kg/ADt |
|---|---|---|---|---|---|---|
| Bleached and unbleached | 0.5-75 | 10-190 | 0-1 | 15-150 | 0.18-1 | **1.7-10** |

### 2.10.3. Mechanical and Chemi-Mechanical Pulping

The data reported in this section is historical data from 2001 and is based on EU Mills' operating performance. Variations may occur when compared to South African Mills.

The process flow scheme for a Refiner Mechanical Pulping unit is shown in Figure 23 and for a Groundwood Pulping unit in Figure 24. The bleaching step is optional, dependent on the final application of the pulp produced.

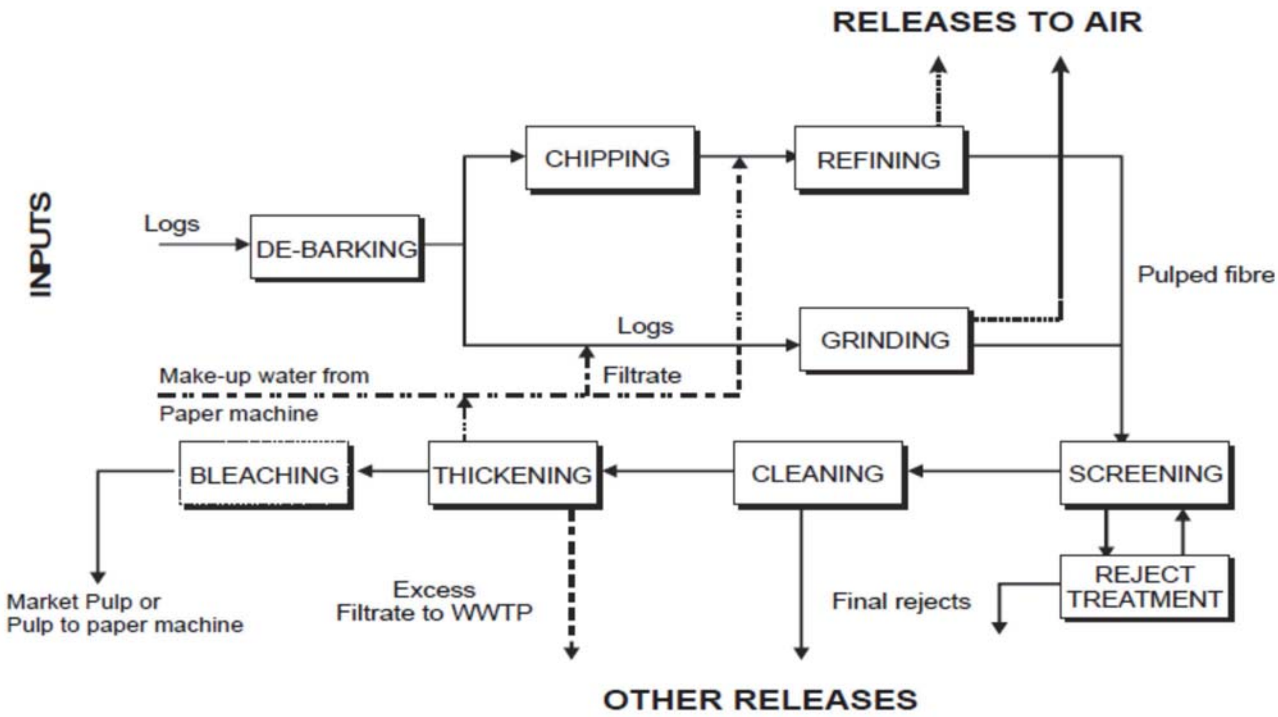


**Figure 23: Typical Process Flow Scheme for a Mechanical pulp mill [40]**

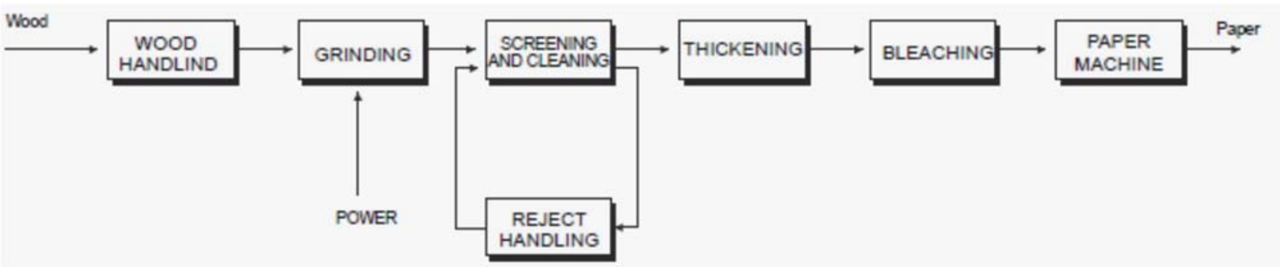


**Figure 24: Typical Process Flow Scheme for a Groundwood pulp mill [40]**

The main wastewater contaminants originating from the Refiner Mechanical pulping process are:

- Organic substances (COD, BOD),
- Nitrogen and phosphorus based compounds,
- Suspended solids,
- Salts and
- Coloured substances.

The effluent generated in a Mechanical pulp mill can be treated microbiologically. Typical discharge qualities after activated sludge treatment of both Thermo-Mechanical and Chemi-Thermo-Mechanical pulping are listed in Table 21. Again, the range of qualities achieved varies significantly within Europe.

**Table 21: Typical treated effluent discharge qualities achieved at mechanical pulp mills [40]**

| Pulping process | $BOD_5$ (kg/t) | COD (kg/t) | tot-P (g/t) | tot-N (g/t) | TSS (kg/t) |
|---|---|---|---|---|---|
| CTMP | 0.5-9 | 12-30 | 5-50 | 200-500 | 0.1-12 |
| TMP | 0.2-1.7 | 2- 8 | 5-15 | 60-160 | 0.5-1.5 |

Figure 25 presents a typical flow sheet for a semi-chemical pulp mill. Both the Semi Alkaline Sulphite Anthraquinone (SASAQ) and Neutral Sulphite Semi-chemical (NSSC) processes are semi-chemical processes.

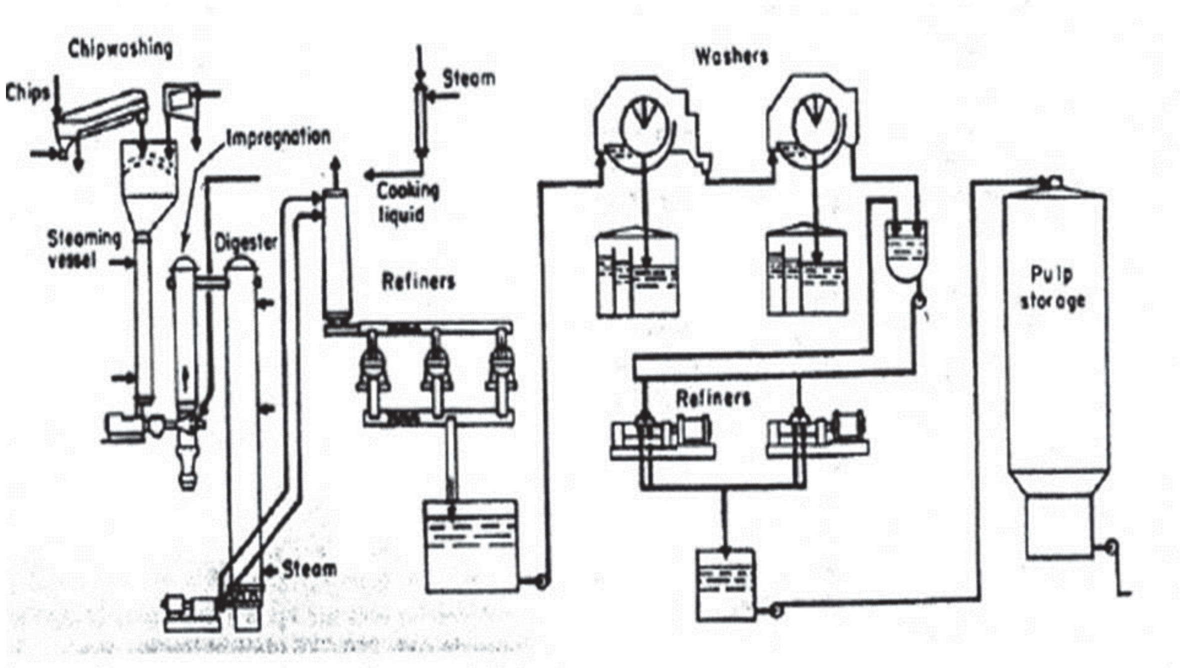


**Figure 25: Semi-Chemical Pulp Mill flow sheet [54]**

The SASAQ process results in an alkaline sulphite pulp with good bleaching properties and relatively high strength. The process results in a 10-15% higher yield than the Kraft pulping process.

The NSSC process produces a high yield of pulp with good bonding capabilities but with an inherent stiffness, making it highly suitable for production of packaging materials. The process uses sodium sulphite neutralised with sodium carbonate.

### 2.10.4. Recovered Fibre Processing

Recovered Fibre processing entails the re-suspension of the recovered fibre as well as various processes to remove impurities. Various flow scheme configurations can be used and each recycling facility is individually designed depending on the type of recycled fibres use and the end product produced, etc. A typical flow scheme is included in Figure 26.

Typical processing areas/steps are:

- Recovered paper storage,
- Repulping of the recovered paper,
- Mechanical removal of impurities e.g. by screens, centrifuges and hydrocyclones,
- Deinking (optional) typically by chemical addition and flotation,
- Washing deinking and ash removal (optional),
- Bleaching (optional),
- Process water purification,
- Fine screen final cleaning and dewatering and
- Reject and sludge handling.

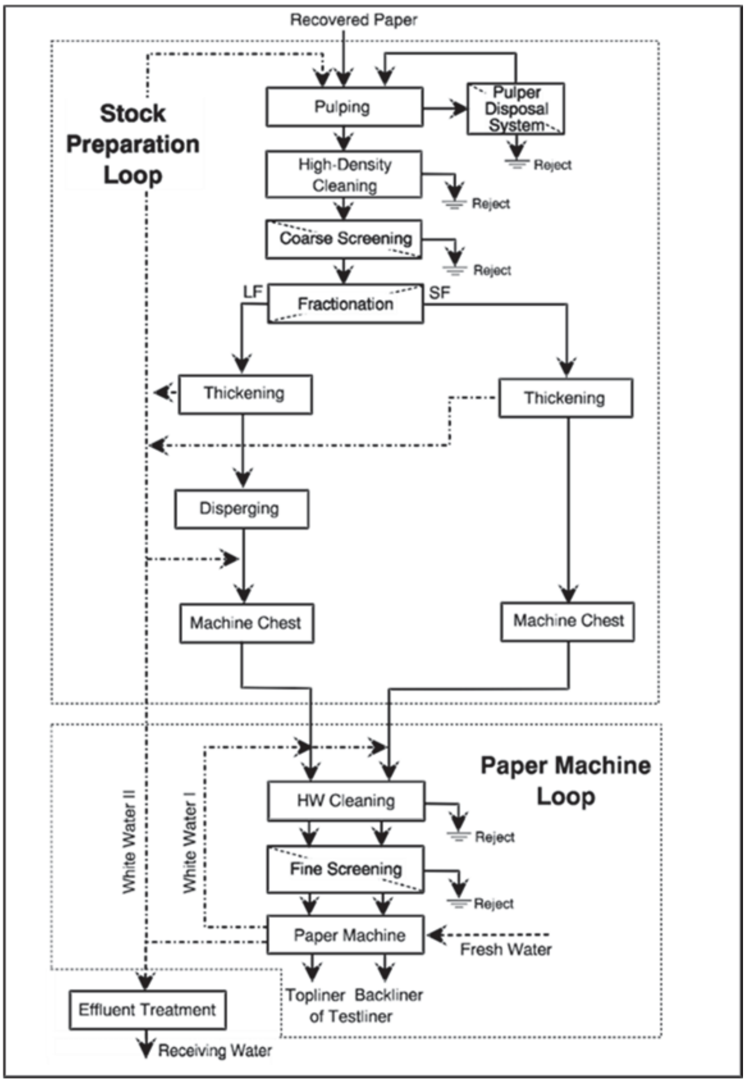


**Figure 26: Typical Process Flow Scheme for a Recycled Fibre Processing Facility [40]**

The main wastewater contaminants originating from the mechanical pulping process are:

- Organic substances (COD, BOD),
- Compounds extracted from the wood such as resin acids, etc.,
- Chlorinated organics (AOX) (depending on bleaching agent used, if any),
- Nitrogen and phosphorus based compounds,
- Suspended solids,
- Salts and
- Coloured substances.

### 2.10.5. Papermaking

Papermaking entails stock preparation followed by the paper machine. A paper mill typically has three process water circuits namely the primary circuit, the secondary circuit, and the tertiary circuit. A generic configuration is shown in Figure 27.

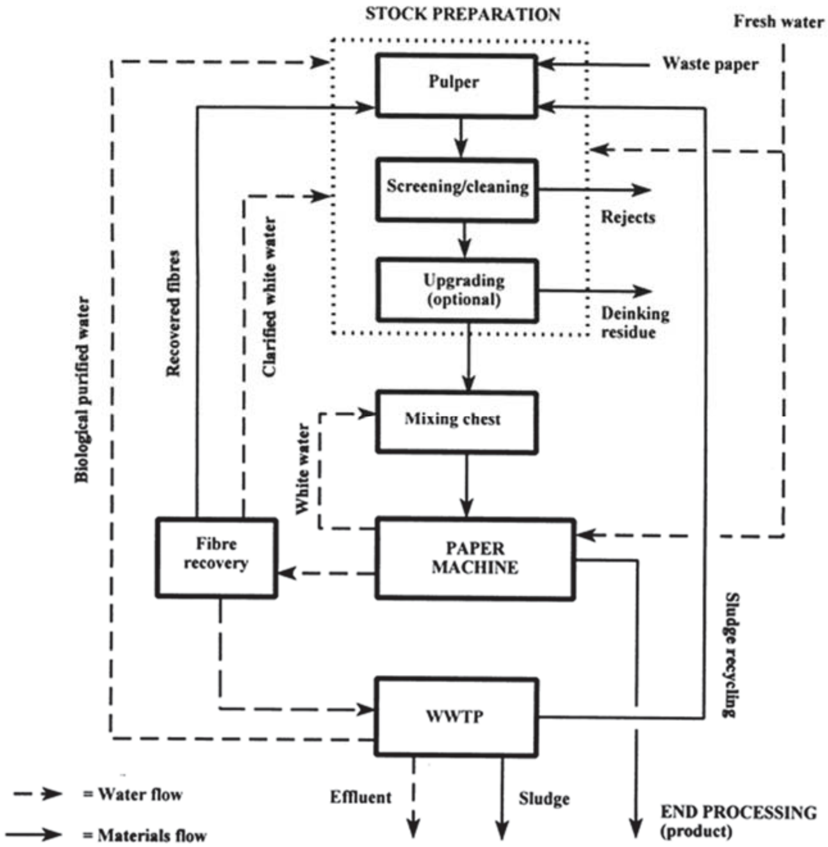


**Figure 27: Simplified schematic illustration of global water flows in a paper mill** [40]

In the primary circuit fibre, fines and filler-rich water obtained in the sheet-forming zone of the wire section (white water I) is recycled for stock dilution in the stock approach flow system. The primary circuit is maintained as closed as possible [40].

Excess water from the sheet-forming section, suction and press water, as well as cleaning water is called white water II and is circulated in the secondary circuit. The white water draining from the wire is typically treated through a so-called save-all, which may be a sedimentation or flotation plant or a filtration unit such as a drum or disc filter. This water is then called clarified water [40].

The tertiary circuit contains excess water from the secondary circuit and, in addition all other process water which is not directly reusable because of its degree of contamination. It is treated in chemo-mechanical and/or biological wastewater treatment plants. Re-use of purified water is not fully applicable for all paper grades. In some cases, purified water is partially returned to the process depending on product quality and local conditions [40].

The main wastewater contaminants originating from the papermaking process are:

- Organic substances (COD, BOD),
- Compounds extracted from the wood such as resin acids, etc.,
- Chlorinated organics (AOX) (depending on bleaching agent used, if any),
- Nitrogen and phosphorus based compounds,
- Suspended solids,
- Salts and
- Coloured substances.

## 2.11. Potential for Energy from Wastewater

A study was conducted by the WRC in 2009 into the generation of power from various wastewater sources in different industries. The study investigated the anaerobic digestion of various wastewater streams in the Paper and Pulp Industry. Assuming an 80% reduction in COD and a methane yield of 0.35 $m^3$ $CH_4$ per kg COD digested, the industry's total energy recovery potential using anaerobic digestion was calculated as summarised in Table 22 (38).

**Table 22: Total potential figures for energy recovery from South Africa's pulp & paper industry sector's wastewaters using anaerobic digestion (38)**

| Mill | COD removed (ton) | $CH_4$ $\times 10^3 (m^3)$ | Energy (GJ) | Electric power (MW) |
|---|---|---|---|---|
| **Mondi** | | | | |
| Merebank | 3862-13620 | 1352-4767 | 53712-189446 | 1.7-6.0 |
| Richards Bay | 23914 | 8370 | 332621 | 10.55 |
| **Mpact** | | | | |
| Felixton | 35329 | 12365 | 491397 | 15.58 |
| Piet Retief | 2728 | 954 | 37942 | 1.2 |
| Springs | 1623 | 568 | 22575 | 0.72 |
| **Sappi** | | | | |
| Saiccor | 16384-81920 | 5734-28672 | 227885-1139425 | 7.23-36.13 |
| Stanger | 1593-5872 | 557-2055 | 22152-81680 | 0.7-2.59 |
| Enstra | 3506-11707 | 1227-4097 | 48764-162834 | 1.55-5.16 |
| Adamas | 343-1304 | 120-456 | 4777-18136 | 0.15-0.58 |
| Ngodwana | 10152-38375 | 3553-13431 | 141211-533763 | 4.48-16.92 |
| Tugela | 4437-16145 | 1553-5651 | 61711-224563 | 1.96-7.12 |
| Cape Kraft | 204-1427 | 71-499 | 2835-19843 | 0.10-0.63 |
| **Twinsaver Group** | | | | |
| Bellville | 384-1280 | 134-448 | 5341-17804 | 0.17-0.56 |
| Kliprivier | 288-960 | 101-336 | 4006-13353 | 0.13-0.42 |
| Riverview | 120-400 | 42-140 | 1669-5564 | 0.05-0.18 |
| Rosslyn | 160-1120 | 56-392 | 2225-15578 | 0.07-0.49 |
| **Kimberly-Clark** | | | | |
| Enstra | 576-1920 | 202-672 | 8012-26705 | 0.26-0.85 |
| **New Era** | | | | |
| Gayatri | 180-1260 | 63-441 | 2504-17525 | 0.08-0.56 |
| Other | 764-3016 | 267-1056 | 10626-41950 | 0.34-1.33 |
| **Total** | **106 547-243 921** | **37 292-85 372** | **1 481 965-3 392 703** | **47.0-107.6** |

Some of the mills have also executed resource recovery projects that recover fibres from the wastewater as well as other solid waste and use that as feed to boilers for electricity generation. Thus current capacity values may be lower than reported above.

Furthermore, the Paper and Pulp industry has been identified as a potential source of renewable fuels, chemicals and materials. Biomass Gasification for Syngas production could be a tool to reduce the Greenhouse Gas Emissions and increase revenues. A typical syngas production flow scheme is included in Figure 28. The syngas can in turn be utilised for power generation, methanol production, synthetic natural gas production, Fischer-Tropsch crude production, etc. (51). Potential constraints to the implementation of gasification would be plot space availability, controllability and of course life-cycle cost.

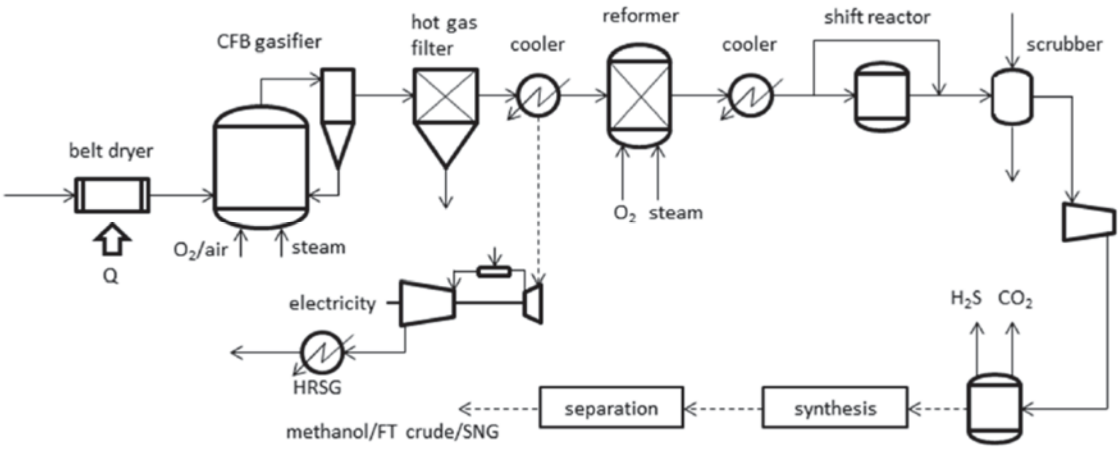


**Figure 28: Biomass to Syngas Process Flow Diagram** (51)

# 3. PROCESS OVERVIEW

The Paper and Pulp Industry is unique in the sense that no two mills are identical. Different feedstocks, pulping techniques and product ranges can result in vastly varying ranges of water use and effluent production. Thus, a single generic description will not serve to cover the differences between the different mills, hence this section contains a short description of each of the mills participating in the study. The industry further consists of a number of discreet fairly large production facilities rather than many smaller production facilities distributed across the country.

## 3.1. South African Industry Overview

### 3.1.1. Feed Sources

In South Africa five main feed sources are typically used in pulp mills, namely:

1. Hardwood, typically eucalyptus trees in SA,
2. Softwood, typically pine trees in SA,
3. Bagasse from sugarcane,
4. Imported pulp and
5. Pre- and post-consumer waste paper.

Depending on the feed source, mills are divided in pulp mills, paper mills and integrated Paper and Pulp mills with varying water requirements and effluent production rates.

### 3.1.2. Pulping Process

As discussed in section 2.7.4 various pulping techniques have been developed. The techniques used in South African pulp mills vary depending on the feedstock, age of the mill, product being produced, etc. The specific techniques used will be discussed later in this section on a per mill basis.

### 3.1.3. Products Produced

A wide range of products from fine paper to packaging material and specialised cellulose are produced by the different mills. Again, the type of product produced, will impact on the water and environmental footprint, e.g. is bleaching required, etc.? The products produced will be discussed later in this section on a per mill basis.

## 3.2. South African Mills

In this section of the report, each mill is briefly described in terms of its feed and product spectrum, production capacity, water consumption and effluent generation.

### 3.2.1. Kimberly-Clark Enstra

The Kimberly-Clark Enstra mill is located at Enstra in the Springs area, Gauteng province.

Enstra Mill is the site where Kimberly-Clark started producing toilet and facial tissue in SA. Today the mill produces toilet tissue, facial tissue and paper towel products. Also, located on this site are a de-inking plant for processing of waste paper and various types of tissue converting equipment[24].

Both virgin and recycled fibre based tissue products are manufactured. For virgin tissue products, pulp is bought in from other mills. For recycled fibre tissue products, waste paper of different grades is bought in for different quality products.

The plant consists of two sections, namely the

1. Recycled Fibre Plant: Produces the wetlap required for the recycled fibre based grades. Processing includes pulping, bulk screening, coarse screening, fine screening, washing, flotation, bleaching and wetlap formation via a press; and

2. Tissue manufacturing: Uses combinations of fibre ranging from 100% virgin to 100% recycled. Fibre goes through pulping, blending, refining, screening, formation and drying.

Fresh water is supplied by the local municipality based on the internal recycled water quality. Fresh water up-take range is 24-19% of total monthly water requirements with the balance of water demand supplied from treated recycled water.

Currently only primary treatment of all process effluent is done via single stage clarification with a flow rate of between 8 600 and 11 500 $m^3$/d. Any overflows are sent for external treatment at the municipality.

### 3.2.2. Mondi Merebank

Mondi Merebank (Figure 29) is located at Merebank which is to the south of Durban, KwaZulu-Natal. The site is an integrated mechanical (TMP) and recycled Paper and Pulp mill.

The Mondi Merebank Mill produces a range of office paper including the brand, Mondi Rotatrim. Mondi Shanduka Newsprint is also located in Merebank, and produces newsprint primarily for the South African market [(25)].

The site produces two main products, namely:

1. Uncoated wood-free paper using fibre from responsible wood sources at approximately 260,000 t/a; and
2. Newsprint using TMP pulp and recycled paper at approximately 120,000 t/a.

**Figure 29: Aerial Photograph of Mondi Merebank**

The mill obtains its process water from the Durban Water Recycling plant. The DWR facility was commissioned in May 2001 and is designed to treat 47 500 $m^3$/d of domestic and industrial wastewater to a near potable standard for sale to industrial consumers for direct re-use in their processes. By doing this, potable water that would have been consumed by industry is made available for human consumption. The main treatment processes are screening, degritting, primary settling, activated sludge treatment, lamella settling, dual media filtration, ozonation, activated carbon filtration and chlorination. As a result of various water consumption reduction projects, Mondi Merebank consumes less than their quota of this water, although there is a take-or-pay agreement in place with the municipality. Thus, if the excess treated water could be re-assigned to another industrial user currently operating on municipal potable water, potable water could be freed up for human consumption.

In addition, the mill consumes some municipal potable water for domestic use, as well as for chemical make-up and fresh feed to the cooling towers. Studies have however been conducted to use lower grade water for the chemical and cooling tower make-up and it is expected that these consumptions will be eliminated by July 2015 thus reducing the site's potable water consumption.

The mill has various drainage systems which collect all the wastewater generated on site. These drains flow towards two main channels which direct the wastewater via a pump station to the wastewater treatment plant. The first part of the wastewater treatment consists of two rotating screens, which remove plastics and objects larger than the screen slots. The screened wastewater flows to one of three mixing channels, which direct wastewater to one of three clarifiers. In the clarifiers solids are removed from the wastewater by sedimentation. A portion of the treated water is used by the Durban Water Recycling plant and the balance is routed to the sea outfall.

The settled solids from the clarifiers, consisting of mainly fibre are pumped to belt presses for de-watering, where the sludge is de-watered to a moisture content of approximately 40%. The de-watered sludge feeds to a Multi-Fuel Boiler where it is burnt together with bark, sawdust, coal ash and coal to generate stream and electricity [25].

### 3.2.3. Mondi Richards Bay

Mondi Richards Bay (Figure 30) is located at Richards Bay, Northern KwaZulu-Natal. The site is an integrated Kraft Paper and Pulp mill. The site produces two products namely Bleached Chemical Pulp (partly exported to other sites) and white top linerboard. The total site production capacity is 750,000 t/a.

**Figure 30: Mondi Richards Bay Mill**

The Kraft process involves the cooking of wood chips in a solution of sodium hydroxide and sodium sulphide (called liquor). The alkaline attack causes the lignin molecules (the molecules in the wood which bond the fibres) to fragment into smaller segments. These smaller molecules are then soluble in an alkali liquor and can be removed from the wood, thus leaving the wood fibres (pulp). The liquor and dissolved lignin is burnt and the alkaline chemicals are recovered for re use, and steam and energy are generated for use in the Paper and Pulp making processes.

The Paper and Pulp process is one where water is reused and recycled continuously in a counter-current fashion throughout the mill and the only genuine water consumers are those processes which remove water altogether (i.e. contained in products, effluent, recovery boilers, cooling towers etc.). The fresh water used is supplied as treated raw water by Mhlathuze Water.

All effluents generated on site are combined and routed to a two-stage effluent treatment plant (Figure 31 and Figure 32).

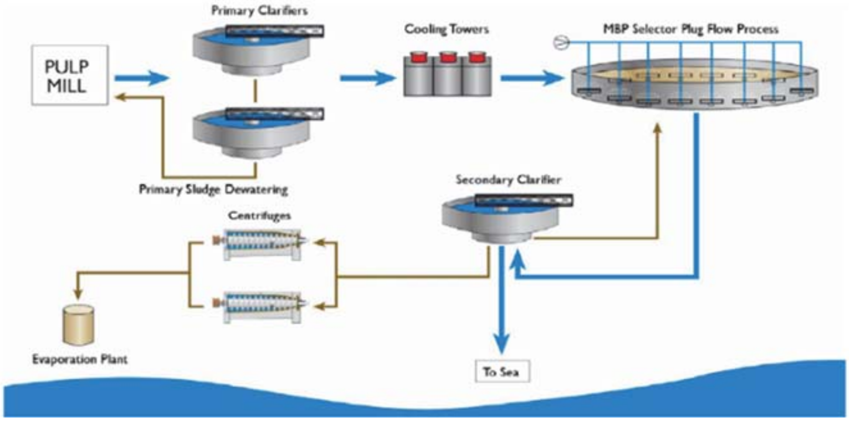


**Figure 31: Mondi Richards Bay Effluent Treatment Plant Schematic**

Acid and alkali streams mix in the first chamber, i.e. the pre-neutralization chamber, with the purpose of controlling the pH to the subsequent stages. The flow division chamber where the flow is split into two clarifiers, which serve to recover any solid matter in the mill effluent. This solid matter is mainly fibre. The efficiency of the clarifiers is 60-90%, depending on the mill effluent flow and solids concentration. The underflow of the primary clarifiers is pumped to a sludge dewatering system that recovers the solids.

Prior to secondary treatment the effluent is cooled down through a set of cooling towers. The secondary effluent treatment plant (SETP) is an aerobic process that utilizes biological means to reduce organic loading of the effluent from the mill. The activated sludge is settled out in the secondary clarifier and only clarified effluent is sent to sea via a marine outfall managed by Mhlathuze Water.

**Figure 32: Mondi Richards Bay Effluent Treatment plant**

### 3.2.4. Mpact Felixton

Mpact Felixton is located at Felixton, close to Richards Bay, Northern KwaZulu-Natal (Figure 33). It is an integrated Paper and Pulp mill founded in 1953 and became part of Mondi Group in 1984, and was later split from Mondi to become part of the Mpact group.

The mill uses sugar cane bagasse and recycled paper as main fibre sources for the papermaking process. Since bagasse is a seasonal raw material, it has to be preserved and stored in a stock pile for use through the year. The mill employs the Soda pulping process for producing bagasse pulp. In the soda pulping process the only active cooking chemical is caustic soda. The recycled fibre is delivered in the form of bales to the mill, from Mpact Recycling, and consists of various grades. An additional feed stream is recycled fibre in the form of effluent sludge from Mondi Richards Bay which contains 60-75% fibre. The main processing steps (Figure 34) are raw material preparation, pulping operations and the paper making operations.

The production capacity of the paper machine is currently about 165,000 t/a. The mill produces packaging material specialising in general purpose fluting and liner used for box manufacturing.

**Figure 33: Aerial Photograph of Mpact Felicton Mill**

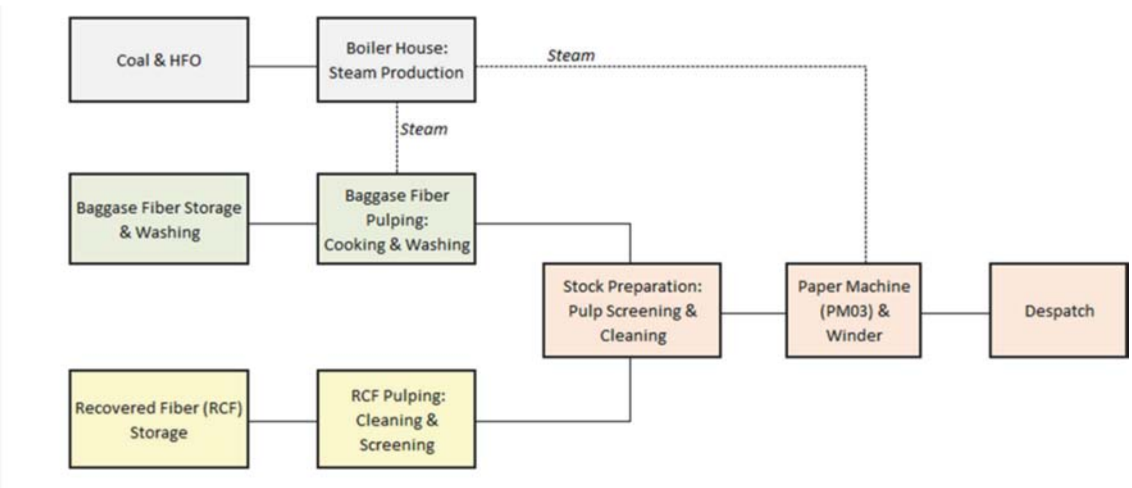


**Figure 34: Mpact Felixton Mill Process Block Diagram**

Two grades of water are used on site, namely raw water from the Mhlathuze River and potable water from the adjacent Tongaat Hulett sugar mill. Some processes need the latter good water quality for selected applications such as chemical make-up. A significant part of the water is recycled back into the process at various steps of the pulping process and for dilution of the pulp before the paper machine.

Effluent and black liquor from the site is combined, pre-treated on site by clarification and then released to a marine outfall pipeline. The effluent treatment plant is shown in Figure 35.

**Figure 35: Mpact Felixton Wastewater Treatment Works**

### 3.2.5. Mpact Piet Retief

Mpact Piet Retief is located at Piet Retief in the south-eastern part of Mpumalanga (Figure 36). The mill is an integrated Paper and Pulp production facility. SASAQ (semi-chemical alkaline sulphite anthroquinone) pulp is produced on site from a mixture of eucalyptus and pine.

**Figure 36: Aerial Photograph of Mpact Piet Retief**

The mill manufactures approximately 132,000 t/a linerboard and fluting, which is the raw material for the corrugated packaging industry. Linerboard is produced from pulp derived from the following processes:

- SASAQ pulp produced on site from eucalyptus and pine;
- Market pulp; and
- Recycled fibre sources – internal recycles and purchased post customer waste corrugated boxes (K4).

The various grades of pulp are pumped to blending chests and mixed to predetermined recipes depending on the grade of linerboard to be manufactured (Figure 37 for the mill flow scheme). The blended pulp is diluted and pumped to a paper machine where the sheet is formed and dried using vacuum, pressure and heat.

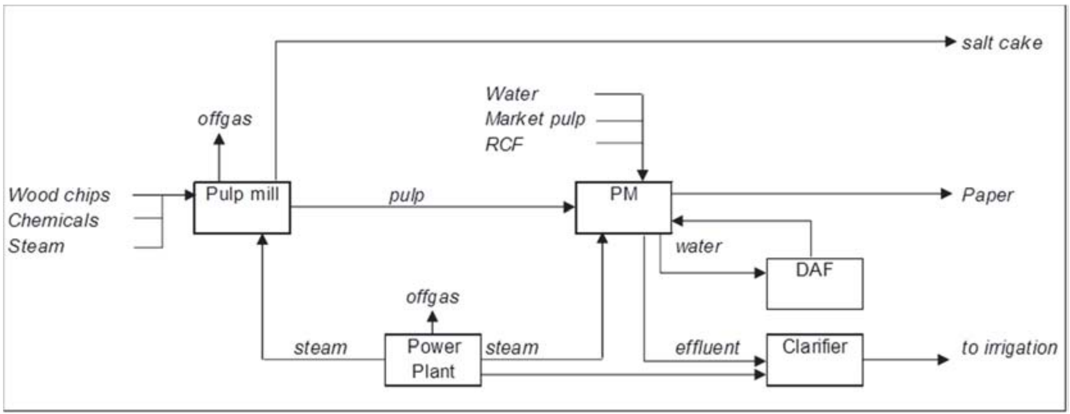


**Figure 37: Mpact Piet Retief Mill Process Flow Diagram**

Water to the facility is extracted from the Hlelo River. The extracted water is treated by flocculation to a quality suitable for process use. When problems are experienced with product quality, more fresh water is used.

The effluent (back water) produced in the mill is treated by dissolved air flotation (DAF) and is then re-used in the paper machines (Figure 38 for the mill Water flow scheme). Effluent from other areas is sent to a clarifier where the water and fibre are separated.

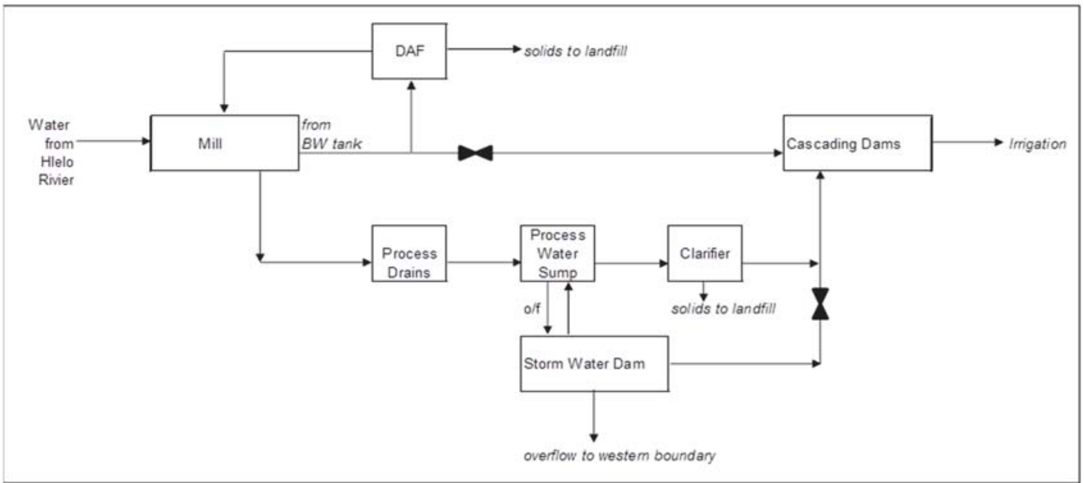


**Figure 38: Mpact Piet Retief Water and Effluent Diagram**

The sludge from both processes is sent to landfill. The product water from the clarifier is used to irrigate eucalyptus plantations. Black liquor is burnt in the Copeland fluidised bed reactor to produce salt cake. The salt cake consists of a mixture of sodium carbonate and sodium sulphate. This salt cake is used as a make-up chemical in Kraft mills.

### 3.2.6. Mpact Springs

As indicated by the name, Mpact Springs Mill is located in the Springs area, Gauteng province. It is a paper mill only, utilising recycled paper and imported pulp. The imported pulp is Topliner hardwood virgin pulp from Mondi Richards Bay.

Mpact Paper Springs Mill has always been a packaging board production facility (previously Mondi Board Mills and Mondi Packaging). The maximum production capacity is approximately 175,000 t/a on Board Machine 6 and 35,000 t/a on Board Machine 3. The final board on BM6 includes white coated folding carton board, plaster board liner and industrial uncoated grades. BM3 produces match board, core board, chip board and divider board.

Recycled pulp, of different grades, is used in the production process. A 7-ply board is produced using 4 different stock preparation systems on BM6 and 2 different systems on BM3. Each system is independent of the other and utilise different blends of the recycled raw material. Each system undergoes its own process of highly intensive stock preparation before being sent to the board machine.

Each system may contain different technology and equipment; however, a generic flow sheet is included in Figure 39. This explains BM3 and BM6 overall process on a high level.

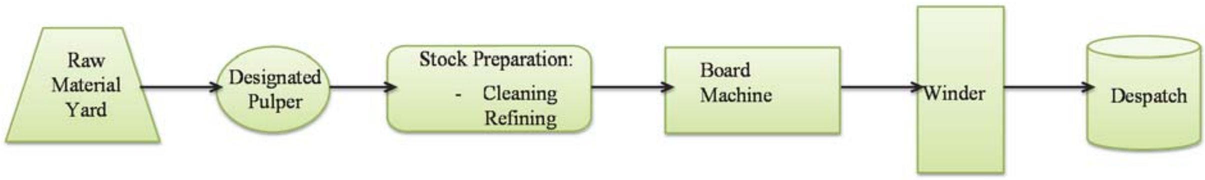


**Figure 39: Mpact Springs Mill Process Flow Diagram**

The facility receives fresh water from the municipality. Treated effluent is also recycled internally and the excess is discharged to the municipality.

Fresh water is used on the machine without any treatment; however, it undergoes a softening stage before boiler application.

The process water returned from the machines is treated in 2 primary clarifiers (Figure 40), a drum screen and chemical treatment before the effluent is sent back to the machines for re-use or discharged to the municipality. The recycling of water depends on the product grade running on the respective BM's. When Topliner is produced, the process requires more fresh water. If the effluent quality is poor, the machine runability is compromised. As a result, the fresh water usage is increased to compensate for this reduction in source quality.

**Figure 40: Mpact Springs Water Treatment Plant**

Limiting factors on the re-use of the water are the presence of colour and COD in the effluent. Certain product grades require the addition of colourants to the pulp, but the water produced during these periods is then not suitable for direct re-use from the current treatment process.

The TDS and SS in the return water are also monitored and could limit re-use if limits are exceeded. Excessive SS in the return water could result in blockages of filters on the BM's due to high concentration of fibres in the water.

### 3.2.7. Sappi Cape Kraft

Sappi Cape Kraft (Figure 41) is located in Milnerton, Cape Town in the Western Cape. It is a paper mill only that buys pre- and post-consumer waste paper, re-pulps the paper and uses it on the paper machine to produce waste-based linerboard and corrugating medium. The mill is an exception to the other mills in Sappi Southern Africa as it produces fluting and linerboard from 100% recycled paper.

The mill converts approximately 67,000 t/a of waste paper to produce 60,000 t/a paper per year. This can be divided approximately equally between fluting (30,000 t/a) and linerboard (30,000 t/a).

Potable water and treated wastewater from the municipality is used in the paper manufacturing process.


Figure 41: Regional Setting of Sappi Cape Kraft

Effluent is generated from different processes in the manufacturing process. The effluent is treated by means of dissolved air flotation (DAF) and clarification (Figure 42) before being discharged to the municipal sewer.

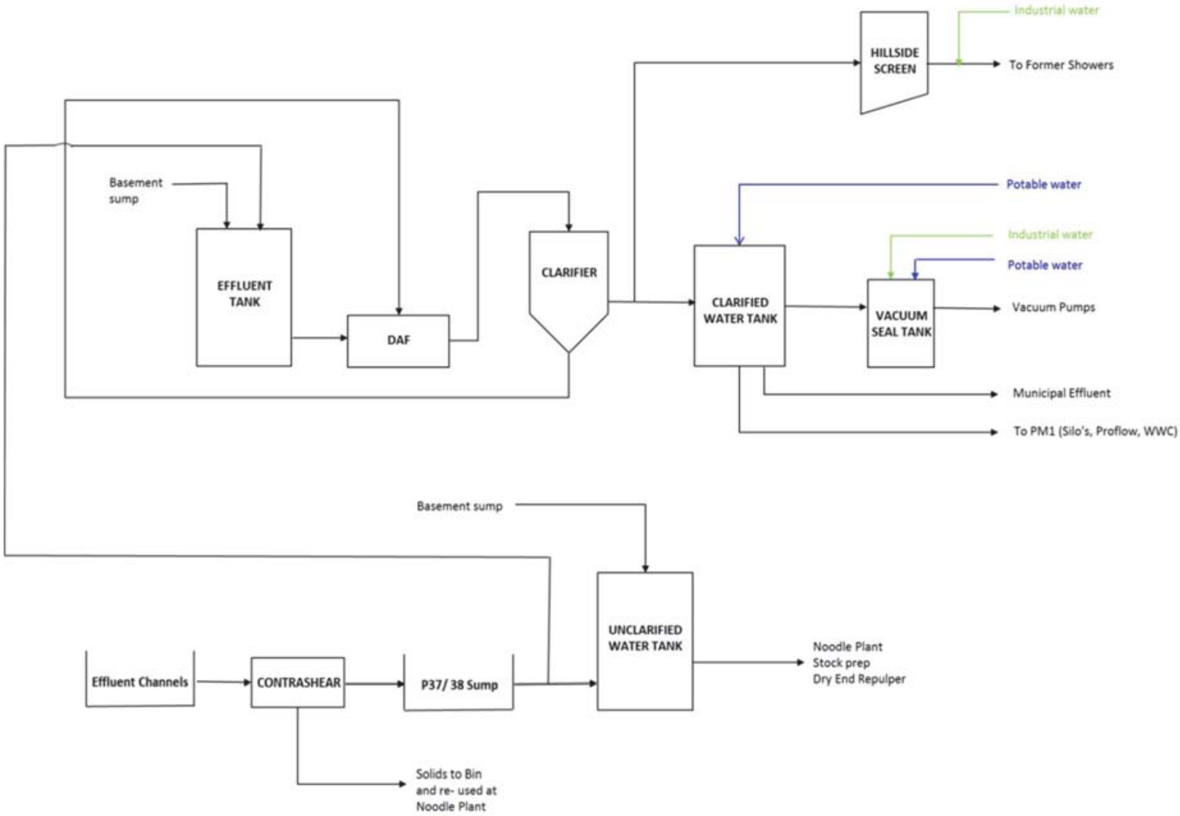


Figure 42: Sappi Cape Kraft Process Flow Diagram

### 3.2.8. Sappi Enstra

The Sappi Enstra mill is a non-integrated paper mill located in Enstra, in the Springs area, Gauteng province (Figure 43). The mill was the first mill built in what was to become Sappi.

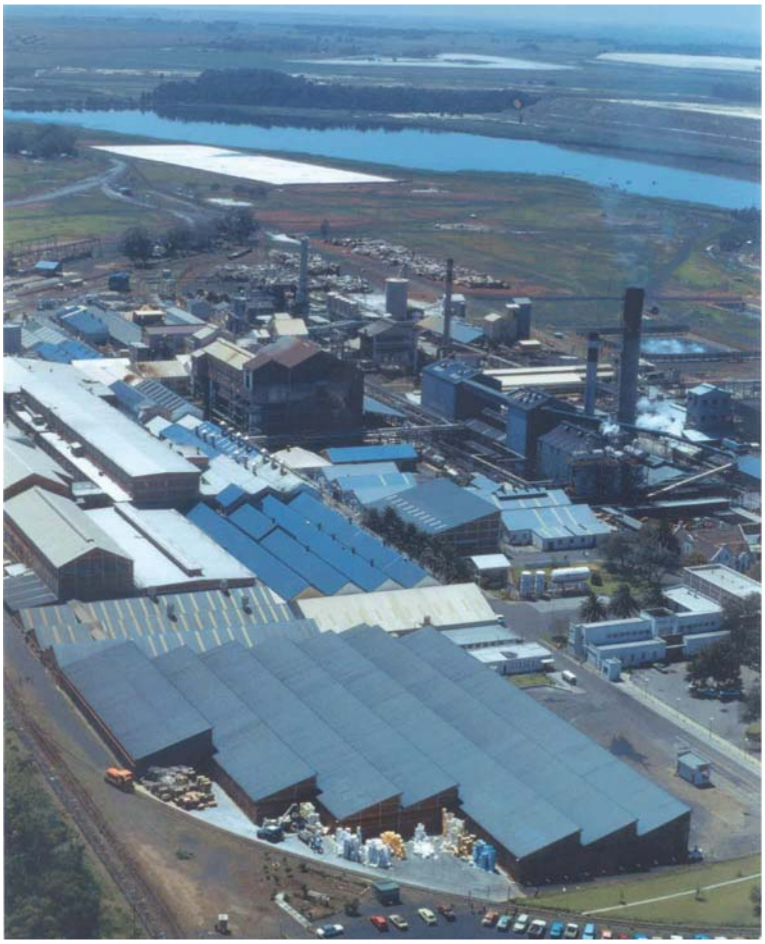

**Figure 43: Aerial Photograph of Sappi Enstra Mill**

The mill is a non-integrated paper mill which produces approximately 200,000 t/a uncoated office paper from bleached pulp as well as fluting and linerboard grades from both recycled and virgin unbleached pulp.

The mill uses two water sources, namely potable water from Rand Water and treated municipal wastewater. By re-using treated municipal wastewater, the need for potable water consumption is reduced and the equivalent quantity of potable water is made available for human consumption. The water is then used for re-pulping and paper making. Rand water is used in the boilers for steam generation and for certain paper grades.

Effluent is generated through the papermaking process. This effluent is treated in two stages in the wastewater treatment plant (Figure 44). The effluent goes to a clarifier from where the overflow is treated in the aeration lagoon or activated sludge process in a 50:50 ratio. The discharges of these two processes are then combined and discharged to the receiving water resource.

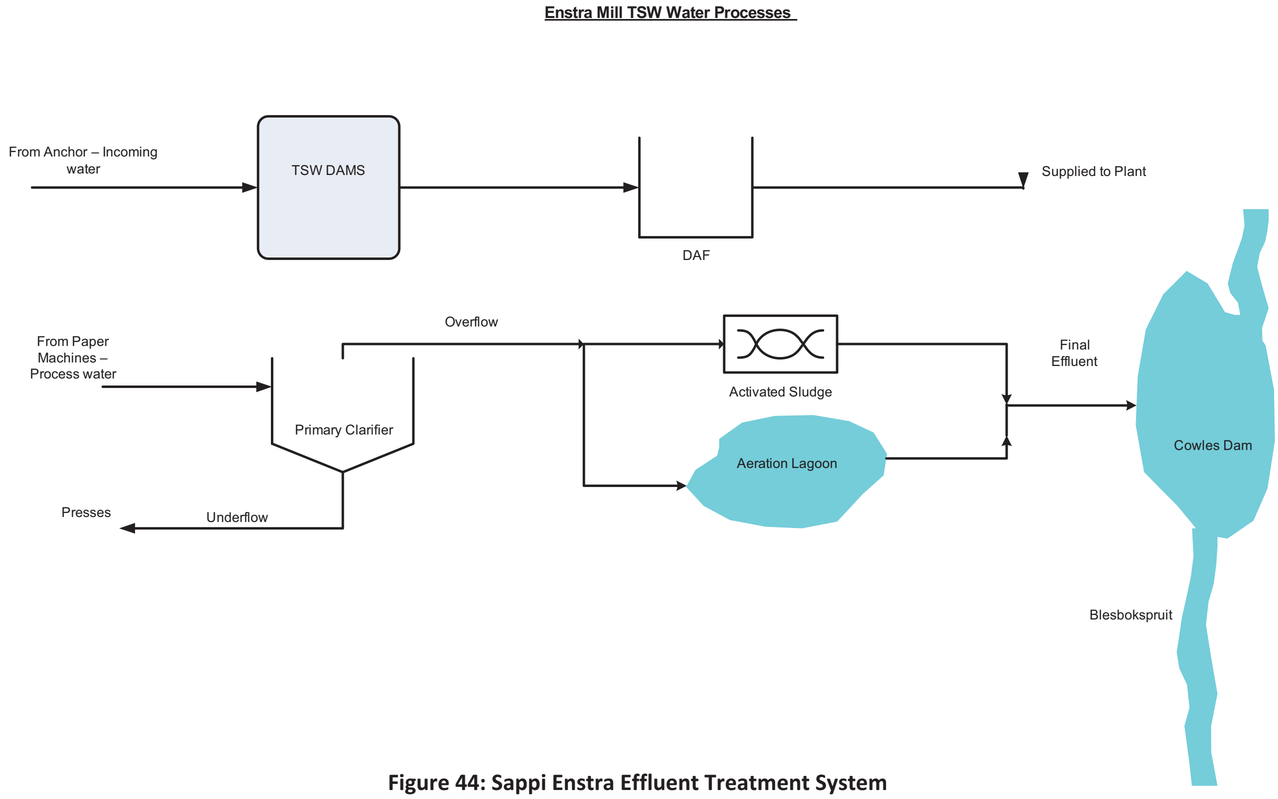


**Figure 44: Sappi Enstra Effluent Treatment System**

### 3.2.9. Sappi Ngodwana

The Sappi Ngodwana mill (Figure 45) is an integrated Paper and Pulp mill located at Ngodwana, to the west of Mbombela in Mpumalanga. The mill has been operational since 1966. Sappi Ngodwana contributes R4.5 billion to the economy of Mpumalanga and more than 42 400 people in Mpumalanga depend on Sappi for their livelihood.

**Figure 45: Sappi Ngodwana Mill**

The Kraft process entails the treatment of wood chips with a mixture of sodium hydroxide and sodium sulphate (Strong White Liquor) that breaks the bonds that link lignin to the cellulose. The process allows the recovery and reuse of the inorganic pulping chemicals resulting in a nearly closed-cycle process with respect to inorganic chemicals (Figure 46). The mill also has a groundwood pulp mill, producing groundwood pulp for newsprint production. In groundwood pulping the logs together with water are fed to a rotating grinder which breaks them down into pulp fibres.

The mill produces unbleached and bleached chemical pulp and unbleached groundwood pulp.

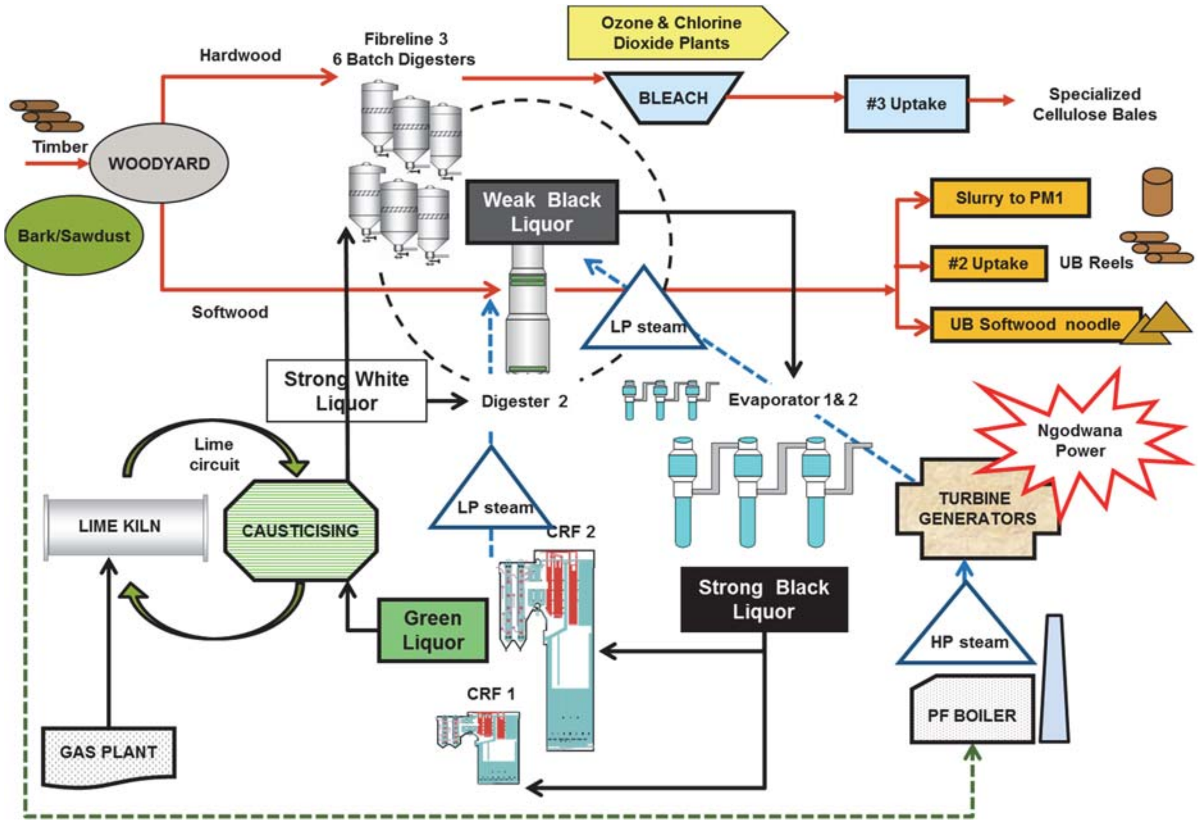


**Figure 46: Sappi Ngodwana Kraft Pulping Process Flow Diagram**

The mill produces a range of products as per Table 23. The production of specialised cellulose commenced after the installation of the GoCell unit. The plant was commissioned in 2013. Previously only approximately 10% of the pulp production was exported, where-as now, all specialised cellulose produced is for the export market, thus contributing positively to the South African trade balance.

**Table 23: Sappi Ngodwana Product Range**

| Product | Type | Quantity (t/a) |
|---|---|---|
| Total Pulp | Total | 405,000 |
| | Unbleached | 195,000 |
| | Specialised Cellulose | 210,000 |
| Total Paper | Total | 370,000 |
| | Newsprint | 140,000 |
| | Kraft Linerboard | 230,000 |

Ngodwana mill uses water from the Ngodwana River, flowing into and stored in the Ngodwana Dam (owned and managed by Sappi). The river flows through Sappi plantations and is thus a pristine source of water with no external pollution sources such as sewage or mine water decant. The water from the Ngodwana Dam is then treated at the fresh water treatment facility by flocculation followed by clarification (Figure 47). Lime addition for pH control occurs before the water is filtered through a sand filter. Disinfection is achieved by chlorination. This facility also supplies potable water to the surrounding communities. From the mill reservoir, the water is routed to the different processing activities.

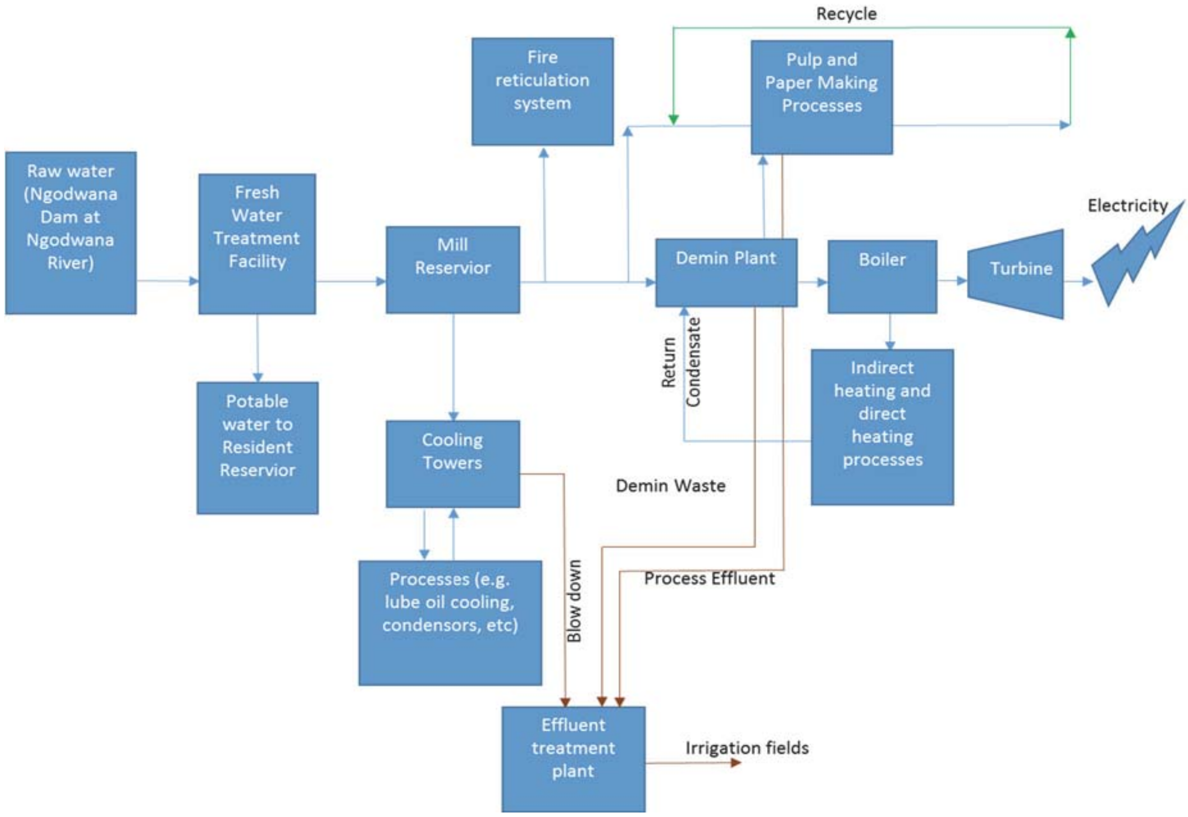


**Figure 47: Sappi Ngodwana Mill Water Process Flow Diagram**

Effluent is generated from different processing steps in the manufacturing process. All effluent streams report to the general effluent flume before entering the effluent treatment plant. Solids are removed and the pH is neutralised by mixing acid and alkaline effluent streams. The effluent is then allowed to settle in clarifiers. Defoamer and biocide are added prior to transfer to two retention dams on an irrigation farm. Lime is added to correct the pH while Gypsum ($CaSO_4$) is added to improve the SAR (Sodium Absorption Ratio). The pastures act as a bio-filter where COD and organics are biodegraded. These pastures are grazed by up to 1,000 head of cattle at any given time.

Bark from the woodyard is crushed in a hammer mill prior to use as a renewable energy source, in bark boilers, on site. The strong black liquor stream from the process is also used as renewable energy source. Some of the wood waste products have been composted by an external party, but since this enterprise is no longer profitable it will be closing down. The option of using this material as an alternative boiler fuel is being investigated.

#### 3.2.10. Sappi Saiccor

The Sappi Saiccor mill is a dissolving pulp mill producing specialised cellulose and is located at Umkomaas in KwaZulu-Natal (Figure 48). The mill produces approx. 800,000 t/a elemental chlorine free specialized chemical cellulose only.

Cellulose is produced from hardwood by first cooking wood chips in pressure vessels (digesters) and then bleaching and drying the pulp produced. Two cooking processes are used at Saiccor, one based on acid calcium bisulphite, and the other on acid magnesium bisulphite. In order to remove lignin from the timber, wood chips are “cooked” in the digesters at 145° C and at a pressure of 8.5 bar using either calcium or magnesium cooking liquor. Most of the lignin is dissolved forming calcium or magnesium lignosulphonate. A portion of the calcium lignosulphonate is recovered by LignoTech, located adjacent to the mill, and the remainder is pumped to sea as effluent via a 6.5 km pipeline.

**Figure 48: Sappi Saiccor Mill**

The 5-stage bleaching process is an Elemental Chlorine Free (ECF) process. No pure chlorine is used in the process, only Chlorine dioxide ($ClO_2$). The five stages are $O_2$, $ClO_2$, NaOH, $ClO_2$ and NaOCl. The bleached pulp is then screened and dried.

The dried pulp is cut into sheets (bales) either wrapped or unwrapped, tied with wire (unitised), or reeled (rolls). This end product of bales or rolls are transported to the harbour via road.

The magnesium based black liquor, removed from the magnesium bisulphite pulping process, is thickened by evaporation and burned in a recovery boiler where magnesium oxide and $SO_2$ are recovered and reclaimed to form cooking liquor (magnesium bisulphite).

Water from the Umkomaas River is pumped from the intake pump house via an overhead pipeline to the grit chambers at the waterworks plant (Figure 49). The water is flocculated and clarified followed by the sand filters and finally a reservoir. From here the water is distributed to various parts of the factory as domestic and process water.

The water used for pulp washing has to be pure with no dissolved salts and silica. If it is contaminated, then the contaminants will remain on the pulp after drying. The Demineralisation Plant was designed to remove unwanted ions from the raw water and thus purify it of agents that can contaminate the pulp in the pulp washing process.

The effluent system consists of three main channels that combine before a settling pond, a surge pit, an emergency spill pond and emergency channel, an effluent pump house and an 11 km pipeline. Effluent from various process plants throughout the mill, as well as the outflow from the septic tanks, drains into these channels.

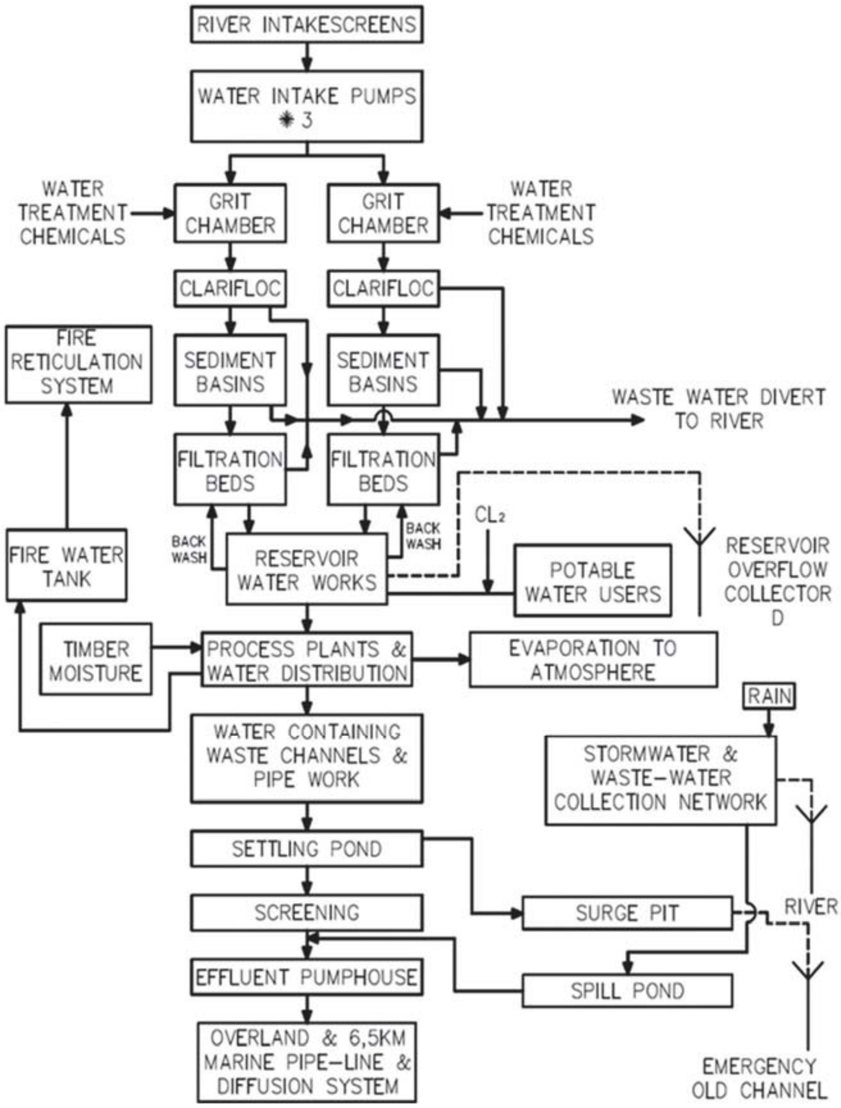


**Figure 49: Sappi Saiccor Water Process Flow Diagram**

### 3.2.11. Sappi Stanger

The Sappi Stanger mill is an integrated Paper and Pulp mill and is located at Stanger in KwaZulu-Natal (Figure 50). It utilises the soda pulping process. Stanger manufactures pulp from bagasse and bought in bleached pulp. The bought in pulp is re-pulped and the bagasse pulp is bleached (DEPP sequence) and used on the paper machines to produce uncoated office papers, as well as tissue paper. The pulp produced is for own use only and no pulp is sold from the site.

The following are typical production quantities for the mill:

- Uncoated paper – 30,000 t/a will increase to 60,000 t/a pending market demand;
- Tissue – 30,000 t/a.

Water from the Umvoti River and Mbozambo Lake is pumped to the Water Clarifier (Figure 51). The raw water is flocculated, followed by sedimentation. The supernatant water is pumped to the Process Filter Station. Chlorine is added to disinfect the water before it is fed to six filters. Backwash water from this plant gravitates to the Mbozambo Lake. The filtered water, now called process water, is then utilized by all production units of the mill. Process water is also further treated and used for onsite potable purposes. The Demineralisation Plant produces deionised feed water for the boilers.

Figure 50: Aerial Photograph of Sappi Stanger Mill

Effluent is generated from different processing steps in the manufacturing process. The effluent is directed to the total effluent sump and pumped to the primary clarifier for removal of solids and subsequent flow to the aeration lagoon and secondary clarifier before discharge into the Ntshaweni River. The volume of effluent that is discharged to the River is monitored and recorded daily.

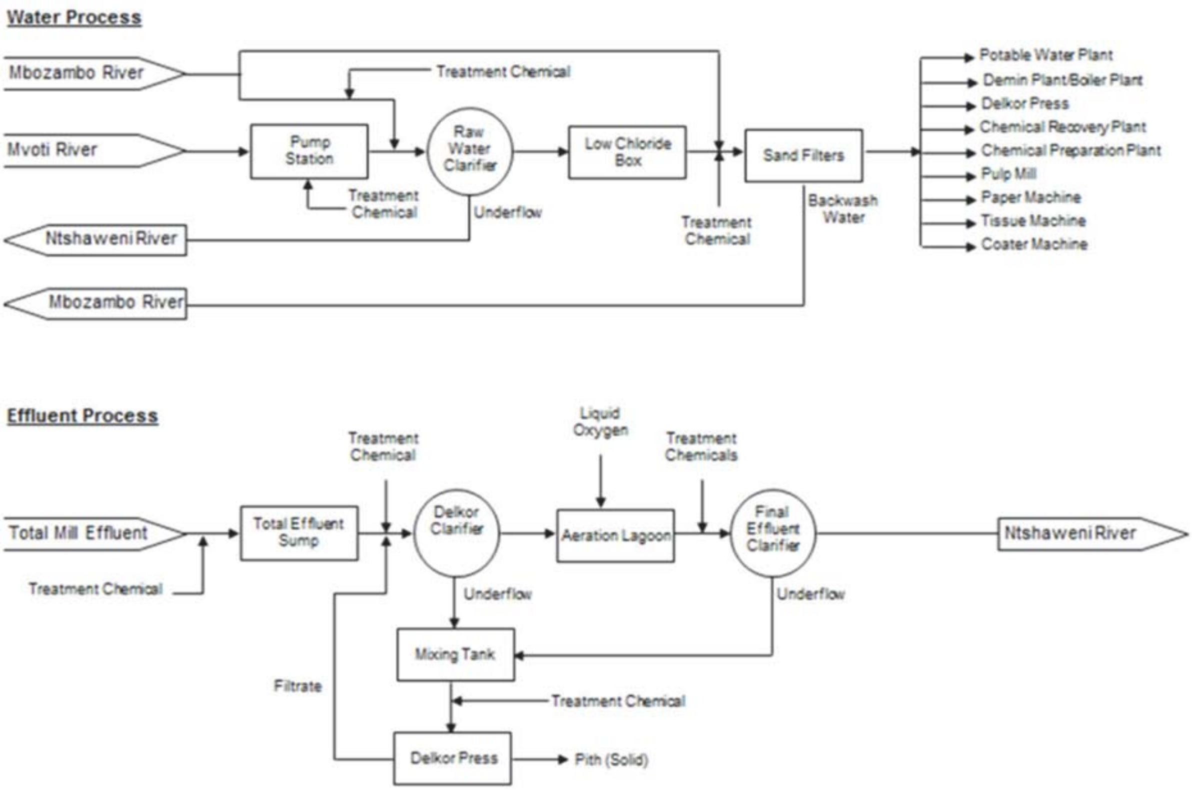


Figure 51: Sappi Stanger Process Flow Diagram

### 3.2.12. Sappi Tugela

The Sappi Tugela mill is an integrated Paper and Pulp mill located at Mandeni in KwaZulu-Natal (Figure 52). The mill produces approximately 210,000 t/a fluting and liner board packaging grades from a combination of wood and pre-and post-consumer waste paper.

**Figure 52: Aerial Photograph of Sappi Tugela Mill**

Water from the Tugela River is pumped into the clarification plant where it is flocculated and clarified (Figure 53). The supernatant water from the clarifier is pumped into the Mill reservoir. 75% of the water from the mill reservoir is gravity fed into the mill as process water and the rest is used to produce potable water in the filter plant. The local community is supplied with this potable water from Sappi Tugela.

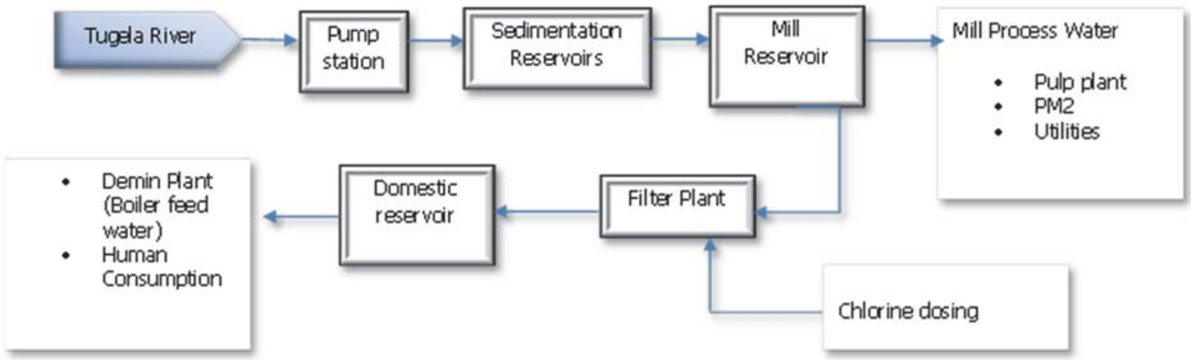


**Figure 53: Sappi Tugela Fresh Water Process Flow Diagram**

Effluent is generated from different sections in the manufacturing process. This effluent is directed to a second clarifier where it is treated and discharged to the Tugela River. The final effluent is monitored and recorded on a daily basis (Figure 54).

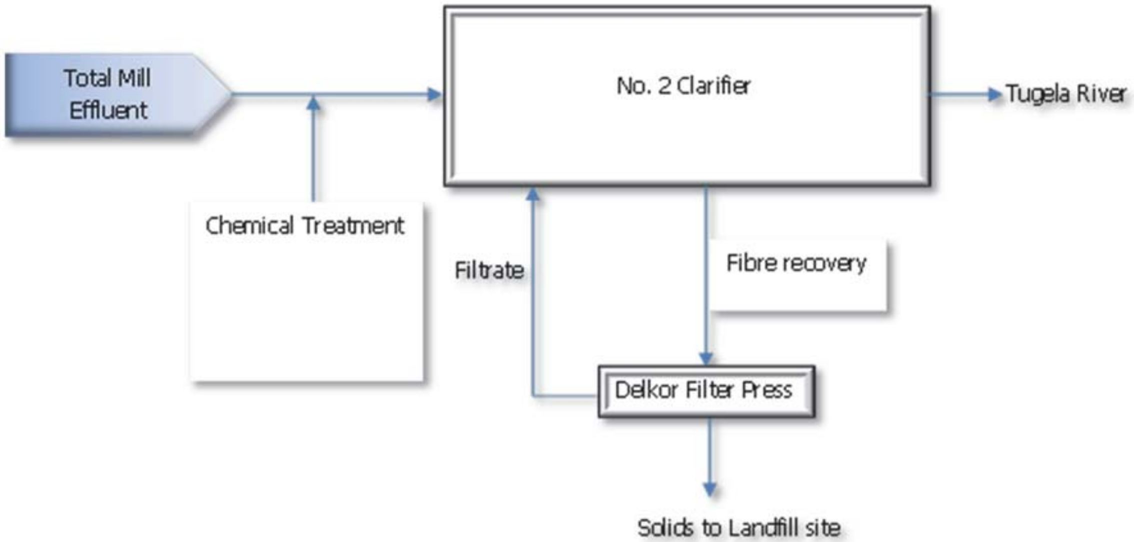


**Figure 54: Sappi Tugela Effluent Treatment Process Flow Diagram**

### 3.2.13. Twinsaver Bellville

Twinsaver Bellville (Figure 55) is located in Bellville in the Western Cape. The mill produces approximately 25,000 t/a tissue paper from recycled fibre and virgin pulp.

**Figure 55: Twinsaver Bellville Site**

The fresh water source for the facility is potable water from the municipality. Effluent generated is treated on site by means of sedimentation and DAF clarification of internal process water and recycled for re-use. Solids from the sedimentation process are separated by centrifugation and the solids are disposed. Excess clarified water is released to the municipal sewer.

### 3.2.14. Twinsaver Klipriver

Twinsaver Klipriver (Figure 56) is located in Klipriver in the Gauteng province and produces 24,000 t/a of tissue paper.

**Figure 56: Twinsaver Klipriver Mill**

The mill has two types of stock preparation plant namely a virgin line and a de-inking line. In the virgin line hardwood (HW) and softwood (SW) pulps are re-pulped in a high intensity pulper. After repulping the pulp is pumped to refiners i.e. HW and SW refiners for strength development before it goes to the tissue machine.

The de-inking line takes recovered fibre and processes it in the de-inking line where contraries such as sand, plastics and staples are removed in the process. During the process ink is also removed from the pulp before bleaching. Clean pulp at the correct brightness is then pumped to the tissue machine for tissue production.

Only one stock preparation plant from the two listed above runs at a time. Pulp is pumped into a crescent former where water is drained through the wire before being pressed for extra water removal. After this the tissue is transferred onto the Yankee dryer which is heated with steam evaporating more water from the sheet. Gas fired hoods are used to remove further water from the sheet. An on-line scanner controls the final sheet properties like basis mass and moisture. Paper is also tested in the lab for basis mass, strength and stretch before being passed.

Two sources of water are used, namely borehole water and potable water from Rand Water. Water is typically used at the boiler house and on the tissue machine, as well as peripheral areas such as workshops and offices.

Effluent generated is treated by clarification which removes part of the COD and a portion of the treated effluent is re-used in the process. The balance of the treated effluent is released to the municipal sewer.

### 3.2.15. Twinsaver Riverview

Twinsaver Riverview is located in Verulam in the KwaZulu-Natal province and produces 10,000 t/a tissue wadding from 15 to 35 gsm.

The mill utilises a combination of fresh water and recycled process water. Water is typically utilised at the pulper, stock preparation equipment and paper machine.

Excess water from the paper machine and stock preparation is sent to a main sump and from there to a centrifuge and a DAF unit. Treated effluent from the DAF unit and sand filters is recycled for re-use in the paper machine. Excess process water is discharged to the eThekwini municipal sewer.

### 3.2.16. Independent Tissue Manufacturers

There are a number of independent tissue manufacturers operating within South Africa. This section gives a brief overview of the operations of the manufacturers that did participate in the survey.

#### *3.2.16.1. Correll Tissue*

Correll is based in Phoenix in the KwaZulu-Natal province and produces approximately 10,000 t/a of tissue paper.

The mill uses a combination of fresh water and recycled treated water in its process. Water is used for the pulping of paper, in paper production and for steam generation.

The mill is planning an expansion project that will double its production and hence also approximately double its total water consumption rate. The impact of the expansion on its specific water intake will be confirmed post commissioning.

#### *3.2.16.2. Green Tissue*

Green Tissue is based in Bellville in the Western Cape and produces between 22 -27 t/d of tissue paper.

The mill utilises municipal water as the fresh supply source, but also treats and re-uses effluent on site.

#### *3.2.16.3. SAMS Tissue Products*

SAMS Tissue is based in Langlaagte in Gauteng and produces approximately 6,000 t/a of toilet tissue.

The mill uses a combination of fresh water and recycled treated water in its process. Water is used in the Wire HP shower, boiler, trim jets, Yankee spray boom shower and suction press roll internal showers.

The mill has installed an effluent treatment plant in March 2015 to save water, improve quality and improve productivity.

### 3.2.17. Independent Packaging Material Producers

Three independent packaging material manufacturers have production facilities in South Africa.

#### *3.2.17.1. Gayatri*

Gayatri Paper Mill is located in Germiston, Gauteng and produces Kraft Liner and Fluting from 100% recycled paper for cardboard box manufacturing.

Municipal potable water from Ekurhuleni Municipality is used in the paper manufacturing environment in the following sections:

- Boilers: Steam Generation;
- Stock Preparation: Washing and Dilution, cooling for Pulpers; and
- Paper Machine: Washing of screens.

Effluent is generated from excess process water and washing processes during the paper production, as well as from any overflows of tanks. Suspended solids are removed from excess water by a DAF unit. Solids that are skimmed off are returned to the process and the water is then pumped through a spray filter for additional solid removal. Water from the spray filter is split for re-use as washing water and any excess is discharged into the municipal sewer system.

#### *3.2.17.2. Huhtamaki*

Huhtamaki has two mills, one in Springs, Gauteng and the second in Atlantis, Western Cape. They produce a range of packaging material such as egg cartons, egg trays, fruit trays and bottle dividers from recycled paper.

Mostly municipal water is used for the pulping of waste paper and in the production process. At the Atlantis mill the municipal water is supplemented with ground water.

The facility is operated as a closed loop, with minimal effluent generated, once per year upon cleaning and flushing of the system. This effluents releases into the municipal sewer.

#### *3.2.17.3. Lothlorien*

Lothlorien Mill is located in Alberton, Gauteng and produces Brown Kraft paper from recycled fibres.

Mostly municipal potable water, supplemented with groundwater, is used for Fourdrinier showers, fibre recovery equipment showers and drinking water.

Liquid effluent is treated by screening. A portion of the treated effluent is re-used on site and the excess water is released to the municipal sewer.

# 4. REGULATORY ENVIRONMENT

## 4.1. Legislative and Regulatory Framework

The Department of Water and Sanitation is the custodian and national regulator of water and water services in South Africa, in accordance with the National Water Act (Act 36 of 1998) and the Water Services Act (Act 108 of 1997). The Department of Water and Sanitation bases its licences, authorisations and policy on the principles of resource protection and the waste management hierarchy. This approach also encapsulate newer global trends around business seeking alternative opportunities around resource recovery and beneficiation.

**RESOURCE PROTECTION AND WASTE MANAGEMENT HIERARCHY**

**Step 1: Pollution Prevention**

↓

**Step 2: Minimisation of Impacts**

Water reuse & reclamation

Water treatment

↓

**Step 3: Discharge or disposal of waste and/or wastewater**

Site-specific risk based approach

Polluter pays principle

At local level, it is the responsibility of a Water Services Authority to set local standards pertaining to water and effluent management, and to enforce such standards through municipal bylaws and its associated tariffs.

Industry has their own self-regulatory management instruments to ensure best management practice and compliance to environmental and water management performance imperatives. As example, ISO 14001 is the only component of the ISO 14000 series of environmental standards that is required for certification. Before an organisation can obtain ISO 14001 certification, one of the criteria is that it has considered all legal requirements. By promoting the certification, the Department of Water and Sanitation is able to extend its water quality management capacity.

The section that follows provide a high level overview of the most pertinent legislation and regulations pertaining to water and effluent management, and also provide an extract of typical industrial effluent charges and conditions as pertaining to the paper and pulp industry in South Africa. The section concludes with the key findings from the case study sites that participated in the NATSURV study.

### 4.1.1. Industry Standards and Specifications

A number of standards and specifications applies to the industry which includes inherent properties which drive water use improvement in the Paper and Pulp industry. Typically, standards used in the paper and pulp industry include:

- ISO 9001: Quality Management
- ISO 14001: Environmental Management
- OHSAS 18001: Occupational Health and Safety

- ISO 31000 – Risk Management
    - For new projects, HAZOP studies are performed by a multi-disciplinary teams
- ISO 50001 – Energy Management
- ISO 55000 – Asset Management
- ISO 22301 Business Continuity Management System
- SANS 10330:2007: Hazard Analysis and Critical Control Point System (HACCP System).
- BRC Global Standards: a safety and quality certification programme to guarantee the standardisation of quality, safety and operational criteria and ensure that manufacturers fulfil their legal obligations and provide protection for the end consumer
- SABS 17025 – Sampling (one company did indicate that their technology centre is 17025 accredited).
- Various Forest Stewardship Council (FSC) certificates ensuring that products come from well managed forests that provide environmental, social and economic benefits.

### 4.1.2. National Legislation

National government promulgates Acts, Regulations, Policies and Frameworks, and set norms and standards whereby compliance is monitored and regulated.

**Table 24: A summary of the select legislation which impact on water management in the Paper and Pulp Industry**

> Refer to the "Best Practice Guidelines for Water and Wastewater Management in the Paper and Pulp Industry" for detailed description of legislation, strategies and regulations, guidelines and WUL application process.
>
> [DWS, 2015]

| Responsible Government Department | Regulation | Sector covered and Applicable area to Industry | Main aspects | Of note to Industry |
|---|---|---|---|---|
| Department of Justice and Constitutional Development | The Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) ("the Constitution") | All industries: All aspects of water use and discharge | Supreme law of the Republic of South Africa providing and confirms a number of rights as well as provides the overarching legislative foundation for environmental management in South Africa. | Enshrines the concept of sustainability; specifying rights regarding the environment, water, access to information and just administrative action. |
| **Responsible Government Department** | **Regulation** | **Sector covered and applicable area to Industry** | **Main aspects** | **Of note to Industry** |

| | | | | |
|---|---|---|---|---|
| **Department of Environment** | Environment Conservation Act, 1989 (Act 73 of 1989) | All industries: All aspects of water use and discharge | This Act has largely been replaced by the National Environmental Management Act, 1998 (NEMA). | Sections specifically relevant to the industrial water and wastewater management are:<br>• 21. Identification of activities which will probably have detrimental effect on the environment;<br>• 26. Regulations regarding environmental impact reports. |
| | National Environmental Management Act, (Act 107 of 1998) | All industries: All aspects of water use and discharge | Reinforces the constitutional rights and promotes reasonable legislative and other measures that:<br>• prevent pollution and ecological degradation;<br>• promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development | • Development must be socially, environmentally and economically sustainable;<br>• Environmental management must be integrated, pursue the selection of the best practicable environmental option, e.g. option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society – in the long- and short term;<br>• "Polluter pays" principle, whereby the 'Waste Discharge Charge System' applies;<br>• Pollution prevention is everybody's responsibility and environmental pollution or degradation, in so far as it is authorized by law or cannot reasonably be avoided or stopped, must be minimized and rectified;<br>• Management of Emergency incidents |
| | National Environmental Management: Waste Act, (Act 59 of 2008) | All industries: Production process, waste & wastewater minimisation, resource recovery, waste & wastewater discharge | Reforms the law regulating waste management in order to protect health and the environment by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development; It provides for compliance and enforcement; and for matters connected therewith. | • Sets norms and standards on a national and provincial level;<br>• Outlines the requirements for waste management plans;<br>• Outlines waste management measures such as reduction, reuse, recycling and recovery;<br>• Storage collection and transportation;<br>• Treatment, processing and disposal;<br>• Licensing requirements; Remediation of contaminated land and registration on the waste information system. |

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|---|---|---|---|---|
| | - No.35572 – Notice 614 Of 2012: Waste Classification and Management Regulations, 10 Augustus 2012 | All industries: Production Process, waste & wastewater minimisation, resource recovery, waste & wastewater discharge | • Defines the regulation of the classification and management of waste in a manner which supports and implements the provisions of the Act;<br>• Establishes a mechanism and procedure for the listing of waste management activities that do not require a Waste Management Licence;<br>• Prescribes the requirements for the disposal of waste to landfill;<br>• Prescribes the requirements and timeframes for the management of certain wastes; and<br>• Prescribes the general duties of waste generators, transporters and managers. | • Requirement to classify waste ito SANS 10234 and period of re-classification;<br>• Management of waste and recording of hazardous waste e.g. safety data sheet, labelling etc.;<br>• Conditions of mixing and treating waste is linked to the potential for re-use, recycling and waste recovery;<br>• Assessment and disposal of waste in accordance with the *Standard for Assessment of Waste for Landfill Disposal;*<br>• Motivation for- and consideration of listing Waste Management Activities that do not require a Waste Management Licence;<br>• Requirements regarding record keeping and waste manifest system;<br>• Prescribes the general duties of waste generators, transporters and managers. |
| | National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014) | All industries: Production process, waste & wastewater minimisation, resource recovery, waste & wastewater discharge | To amend the National Environmental Management: Waste Act, 2008, so as to:<br>• to establish a pricing strategy for waste management charges and to provide for the content and application of the pricing strategy;<br>• to establish the Waste Management Bureau and provide for the objects, functions, funding, financial management, reporting and auditing, immovable property and manner of operation thereof. | The amendment of the Waste Act, brought with it changes to key definitions contained therein. Most notable in this respect were the changes to the definition of 'waste' itself, as well as that of 'recovery'.<br><br>The definition of waste has been amended to remove the previously applied exclusion of 'by-products' from the definition thereof, and has furthermore been linked to two non-exhaustive lists of hazardous (Category A) and general (Category B) waste streams/industry sectors under "Schedule 3 Defined Wastes" to the Waste Amendment Act. |
| | National Environmental Management: Integrated Coastal Management Act (No24 of 2008) (and amendments) | All water users impacting on coastal environment and or utilising coastal resources | The ICM Act establishes the statutory requirements for integrated coastal and estuarine management in South Africa and include norms, standards and policies associated with it. | Of specific interest to the industry is *Chapter 8: Marine and Coastal Pollution Control section 69: Discharge of effluent into coastal waters*, relating to Authorisation and action required for obtaining authorisation & the conditions under which authority for discharging of effluent that originates from a source on land into coastal waters may be granted. |

| | | | | |
|---|---|---|---|---|
| | National environmental management: air quality act, 2004 (act no. 39 of 2004) | All industries: All aspects of production | To reform the law regulating air quality in order to protect the environment by providing reasonable measures for the prevention of pollution and ecological degradation; to provide for national norms and standards regulating air quality monitoring, management and control by all spheres of government. | • Encourages the implementation of cleaner production and clean technology;<br>• Identifies priority areas and the management thereof;<br>• Listing of activities resulting in atmospheric emissions;<br>• Pollution prevention plans;<br>• Measures in respect of dust, noise and offensive odours;<br>• Licencing of listed activities. |
| | No 1210 - National ambient air quality standards, 24th December 2009 | All industries | Sets limits for $SO_2$, $NO_2$, particulate matter (PM10), Ozone, Benzene, lead and carbon monoxide emissions. | |
| | Act No. 20 of 2014: National Environmental Management: Air Quality Amendment Act, 2014 | All industries | To amend the National Environmental Management: Air Quality Act, 2004, so as to substitute certain sections. Some of the changes relate to:<br>• the establishment of the National Air Quality Advisory Committee;<br>• to provide for the consequences of unlawful commencement of a listed activity;<br>• to provide for monitoring, evaluation and reporting on the implementation of an approved pollution prevention plan;<br>• to clarify that applications must be brought to the attention of interested and affected parties soon after the submission to the licensing authority;<br>• to provide for a validity period of provisional atmospheric emission licence;<br>• to create an offence for non-compliance with controlled fuels standards;<br>• to provide for the development of regulations on climate change matters and the procedure and criteria for administrative fines. | Of specific note to industry is the following:<br>• Industries operating without the required atmospheric emissions licences (AELs) will now be required to apply for retrospective authorisation of their activities and could be liable for a maximum administrative fine;<br>• Where an air emission activity is also classified as a Listed EA Activity and a waste management activity under the Waste Act, potential for an integrated licence if the competent authority is authorised to issue EAs and WMLs under NEMA and the Waste Act respectively;<br>• Time period placed on the validity of a provisional atmospheric emission licence. |
| **Responsible Government Department** | **Regulation** | **Sector covered and Applicable area to Industry** | **Main aspects** | **Of note to Industry** |
| Department of Water and Sanitation | National Water Policy for South Africa - White Paper (April 1997) | All water users | Sets out the policy of the Government for the management of both quality and quantity of South Africa's water resources. The first step in the review of the National Water Act of 1956. | |
| | National Water Act - 1998 (No. 36 of 1998) | All water users | It is the primary statute providing the legal basis for water management in South Africa and has to ensure ecological integrity, economic growth and social equity when managing and using water. | Of specific interest to Industry are:<br>• Chapter 1 Interpretation and fundamental principles;<br>• The section dealing with how water will be protected, used, |

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|---|---|---|---|
| | | Provides the legal framework for the effective and sustainable management of SA water resources that is rivers, streams, dams, and ground water. It contains rules about the way that the water resource (surface and ground water) is protected, used, developed, conserved, managed and controlled in an integrated manner.<br>The NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality (quality of the aquatic biota and in-stream and riparian habitat). The IWRM approach provides for both resource directed and source directed measures:<br>• Resource directed measures aim to protect and manage the receiving environment;<br>• Source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms.<br>The integration of resource and source directed measures forms the basis of the hierarchy of decision-taking aimed at protecting the resource from waste impacts. | developed, conserved, managed and controlled;<br>o Chapter 2 Water management strategies<br>o Chapter 3 Protection of water resources<br>o Chapter 4 Use of water<br>o Chapter 5 Financial provisions<br>• Chapter 14 Monitoring, assessment and information;<br>• The section dealing with Mechanisms to address appeals, offences and remedies;<br>o Chapter 15 Appeals and dispute resolution<br>o Chapter 16 Offences and remedies. |
| National Water Amendment Act - 1999 (No. 45 of 1999) and National Water Amendment Bill - 1999 | All water users | To amend the National Water Act, 1998 so as to effect contextual improvements; and to change the procedure for the appointment of members of the Water Tribunal; and to provide for matters connected therewith. | |
| Water Services Act - 1997 (No. 108 of 1997) | All water users | Deals mainly with water services or potable (drinkable) water and sanitation services supplied by municipalities to households and other municipal water users. It contains rules about how municipalities should provide water supply and sanitation services. | The sections of specific pertinence to Industry are:<br>• Section 7 - Industrial use of water;<br>• Section 9 - Standards;<br>• Section 10 - Norms and standards for tariffs. |
| - General and special effluent Standards-Regulation no. 991 _18 May 1984 - Requirements for the purification of wastewater or effluent | All industries | Prescribes the requirements for the purification of wastewater or effluent produced by or resulting from the use of water for industrial purposes and sets limits for effluent characteristics such as pH, temperature, COD, suspended solids, metals etc.<br><br>Also, identifies the test method to be used, and Areas where the special standards must be applied are provided. | |

| | | | |
|---|---|---|---|
| | - No.1191 General and Special Authorisation - Discharge limits and conditions set out in the National Water Act, Government Gazette No. 20526, 8 October 1999 | | Defines the General and Special Authorisation - Discharge limits and conditions |

The regulation of water use is based on the likely risk, nature, and extent of potential impact of the proposed activity on a water resource. The level of potential risk of impact determines the choice of regulatory means. Water use can be authorised in various ways, including:

Refer to the "Best Practice Guideline" for MORE detail pertaining to Section 21 authorisation, as well as effluent discharge standards and limits

- ***Schedule 1*** water uses where minimal risk or no risk exists and water can be used without a license or registration of the use. The category allows people to use water for a garden, animals or small-scale non-commercial food garden;
- ***General Authorisations*** are issued to permit the use of raw water without a license in specific areas or catchments, and implies water use with low risk impact;
- ***Water Use Licenses*** are applied for medium to high risk impacts and have conditions attached which state how long it is valid; and
- ***Existing Lawful Use (ELU)*** allows commercial users of raw water before the new Act came into effect in 1998 to carry on using that water until such time as they are called upon to apply for a license under compulsory licensing. Such users must have registered the use and apply for verification of the water use when requested by DWS. Verification confirms how much water may be used lawfully.

### 4.1.3. Municipal Bylaws

The Section 21 of the Water Services Act require all municipalities (water services authorities) to implement bylaws which contain conditions for the provision of water services at local level. The bylaws must set standards and tariffs and the municipality must monitor compliance and enforce adherence to the bylaws. A selection of bylaws and tariffs from seven (7) municipalities: (4 metropolitan, 1 district and 2 local municipal areas) are described in this section.

**eThekwini Metropolitan Municipality**

Important policy documents from the eThekwini Municipality include the Policies and Practices of the eThekwini Water and Sanitation Unit (EWS, 2013) which outline the policy related to provision of water and sanitation services, the Water Services Development Plan (EWS, 2011) and the Sewage Disposal Bylaws (EWS, 1999). The tariff schedule provides the related costs (EWS, 2014).

Refer to the "Best Practice Guidelines for Water and Wastewater Management in the Paper and Pulp Industry" for more detail pertaining to bylaw requirements.

[DWS, 2015]

Any industry wishing to discharge to a wastewater treatment works must apply for a trade effluent permit. Requirements for this permit include the undertaking of a cleaner production assessment to identify measures to reduce the consumption of water and generation of wastewater at source. Trade effluent will not be accepted if it contains concentrations of substances above stated limits and separate limits are provided for sewerage works with a capacity both greater than, and less than, 25 ML/day. A third set of limits is applicable for industry discharging directly to one of the two sea outfalls (EWS, 2011).

Industrial, commercial and institutional customers are charged for the acceptance of sewage into the Municipal sewerage system by means of a volume based sewage disposal charge which replaced sewerage rates from 1 July 2010.

In addition to the above charge, Industries that are permitted to discharge trade effluent and with a COD greater than 360mg/ℓ and SS greater than 9ml/l (pollution loading exceeding that of 'normal' domestic sewage) are charged for their high strength effluent at the rate calculated as given in Equation 1 (EWS, 1999).

**Equation 1:** $$\textbf{Volume based charge} + V\left(\frac{COD}{360} - 1\right) + Z\left(\frac{SS}{9} - 1\right)$$

***Where:***

COD : Chemical Oxygen Demand in mg/ℓ

SS : Settleable Solids in l/l

V : rate for the treatment in the treatment works of standard domestic effluent having a prescribed COD value

Z : rate for the treatment in the treatment works of standard domestic effluent having a prescribed settleable solids value

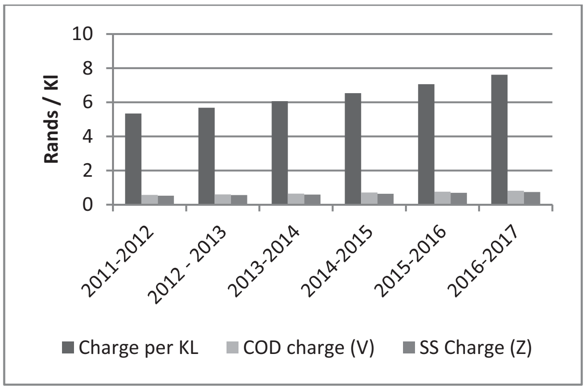
The volume of trade effluent discharged is determined by either a trade effluent meter, which is read every month and readings forwarded to the municipality, or through a water balance questionnaire which is filled in by the company. The water balance questionnaire subtracts the volume of domestic effluent, water used in product, in the process and loss due to evaporation from the incoming volume to give a percentage of trade effluent produced. Limits for effluent quality are set depending on the size of the receiving wastewater treatment works.

Data on basic unit cost for water and effluent and the values for V and Z are provided in Table 25.

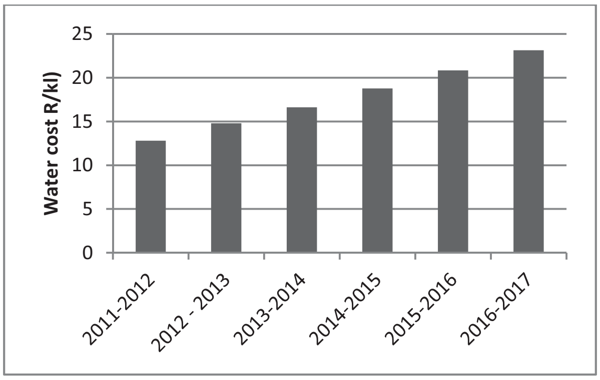
**Table 25: Basic unit costs for water and effluent in eThekwini Municipality (EWS, 2014)**

| Period | Effluent | | | Water |
|---|---|---|---|---|
| | Rand / Kl | COD charge (V) | SS Charge (Z) | R /Kl |
| **2011-2012** | 5.34 | 0.57 | 0.52 | 12.8 |
| **2012-2013** | 5.68 | 0.6 | 0.56 | 14.79 |
| **2013-2014** | 6.07 | 0.65 | 0.59 | 16.63 |
| **2014-2015** | 6.54 | 0.71 | 0.64 | 18.78 |
| **2015-2016** | 7.06 | 0.76 | 0.69 | 20.84 |
| **2016-2017** | 7.62 | 0.82 | 0.74 | 23.14 |

The trends on water and effluent costs from 20211/2012 to 2015/2016 are shown below.




**(a): Trends in charges for eThekwini Municipality with predicted increase**




**(b): Trends in water price for eThekwini Municipality with predicted increase**

**City of Johannesburg Metropolitan Municipality**

The Water Services Bylaws provide a description of the policy related to the provision of water and the discharge of industrial effluent. Limits are set for effluent quality with which industry must comply. An application for relaxation on these limits can be made, but this is dependent on a number of criteria being met including the use of best available technologies and the implementation of a waste minimisation programme (CoJ, 2008).

Trade effluent tariffs are calculated based on the formula given in Equation 2.

**Equation 2**

$$\left[C + T\frac{COD}{700}\right] + \left[T\ \frac{(Metal - factor)}{factor}\right] + C(7 - pH) + (C + T)\frac{FOG - 200}{200}$$

***Where:*** (CoJ, 2014)

C = 492.42 c/Kl

T = 537.00 c/Kl

COD = Chemical Oxygen Demand

FOG = Fats, Oils and Grease

- All concentrations of metals (mg/ℓ) must be greater than the factor for the formula to apply
- pH term applies if pH is less than 4
- FOG term applies if FOG is greater than 200 mg/ℓ

| Metal | Factor | Metal | Factor | Metal | Factor | Metal | Factor |
|---|---|---|---|---|---|---|---|
| **As** | 2.5 | **Hg** | 1 | **Se** | 2.5 | **Cr** | 20 |
| **Cd** | 2.5 | **Mo** | 5 | **Zn** | 20 | **Cu** | 20 |
| **Pb** | 10 | | | | | | |

**City of Tshwane Metropolitan Municipality**

The relevant policies within the City of Tshwane are the Sanitation and Water Tariff Policies which outline the approach taken by the Municipality when setting water and sanitation charges. There are three different categories for industrial effluent charge (Tshwane, 2014):

1. **Normal conveyance and treatment cost**: Applies to effluent of the same quality as domestic wastewater discharged to sewer and is calculated by multiplying the combined unit conveyance and treatment cost by the volume discharged. Industrial consumers will be charged the tariff cost with a rebate of 10%.

2. **Extraordinary Treatment Cost:** Applies when the pollution loading exceeds that of normal wastewater and the cost is calculated as given in Equation 3

**Equation 3:**

$$Tc = Qc.t[0.6\ \frac{(CODc-CODd)}{CODd} + 0.25\ \frac{(Pc-Pd)}{Pd} + 0.15\ \frac{(Nc-Nd)}{Nd}]$$

**Where:**

$T_c$ = extraordinary cost to the consumer
$Q_c$ = wastewater volume (Kl)
t = unit treatment cost of wastewater (R/Kl)
$COD_c$ = total COD in mg/ℓ of wastewater including biodegradable and non-biodegradable
$COD_d$ = total COD of domestic wastewater in mg/ℓ
$P_c$ = orthophosphate concentration of wastewater in mg phosphate/l
$P_d$ = orthophosphate concentration of domestic wastewater in mg phosphate/l
$N_c$ = ammonia concentration of wastewater in mg nitrogen/l
$N_d$ = ammonia concentration of domestic wastewater in mg nitrogen/l

**2014 tariffs:**

t = R 0.94 / Kl
$COD_d$ = 710 mg/ℓ
$P_d$ = 10 mg/ℓ

3. **Non-compliance with Bylaw limits**: where the limits are exceeded, the tariff given in Equation 4 will apply:

**Equation 4:**

$$T_C = Q / D.N\ [C_{AIP} – B_{LL}/W_{PL}]t_{NC}$$

**Where:**

$T_c$ = charge for non-compliance
Q = monthly volume in Kl
D = working days in the month
N = number of days exceeding bylaw
$C_{AIP}$ = average concentration of parameter exceeding bylaw
$B_{LL}$ = bylaw limit
$W_{PL}$ = Water Affairs standard limitation on parameter exceeding bylaw
$t_{NC}$ = tariff ( R 0.65 / Kl

**Table 26: Basic unit costs for water and effluent in Tshwane (Tshwane, 2015)**

| | Water Tariff R/Kl | | | Effluent Tariff R/Kl | | |
|---|---|---|---|---|---|---|
| | 2012-2013 | 2013-2014 | 2014-2015 | 2012-2013 | 2013-2014 | 2014-2015 |
| **0-10,000 kℓ** | **11.89** | **13.08** | **14.39** | | | |
| **10 001-100,000 kℓ** | **11.29** | **12.42** | **13.66** | | | |
| **More than 100,000 kℓ** | **10.52** | **11.57** | **12.73** | | | |
| **Charged at 60% of incoming water** | | | | **4.66** | **5.13** | **5.64** |

## City of Cape Town Metropolitan Municipality

The City of Cape Town has bylaws relating to Wastewater and Industrial Effluent (COCT, 2013, promulgated 2014) which sets out the requirements and limits for industrial effluent discharge which outlines the permitted use of treated effluent (e.g. for irrigation etc.). The City defines industrial effluent as follows: "any liquid, whether or not containing matter in solution or suspension, which is given off in the course or as a result of any industrial trade, manufacturing, mining or chemical process or any laboratory, research, service or agricultural activity, and includes matter discharged from a waste grinder and any liquid other than domestic effluent…"

Limits are set for effluent discharge with respect to general pollution loads such as COD and electrical conductivity, as well as for chemical substances, heavy metals, and inorganic content (Schedule 1 of the Wastewater and Industrial Effluent). Failure to comply with these limits results in the application of a surcharge factor (CoCT, 2013).

**Equation 5:**

$$Vw\ (SVC) + VieT\ (COD\text{-}1000)/1500 + VieT\ (SF)$$

**Where:**

Vw = total volume, expressed in kilolitres, of wastewater discharged from the premises during period concerned.
SVC = sewerage volumetric charge in terms of the sanitation tariff.
Vie = total volume, expressed in kilolitres, of industrial effluent discharged from premises during period concerned.
T = cost, as determined by the council, of treating 1 kilolitre of wastewater.
COD = chemical oxygen demand of the effluent in milligrams per litre. (If COD < 1,000, the COD factor falls away).
SF = surcharge factor of the effluent calculated according to the formula:
SF = (X-L)/L
**where**
X = concentration of one or more of the parameters listed in Schedule 2.
L = limit applicable to that particular parameter.

### Amajuba District Municipality:

Industrial effluent discharged into the Council's sewage disposal system incurs a treatment charge, based on the volume effluent discharged, the strength of the effluent and the permitted (allowed) concentrations of the industrial effluent on a monthly basis, in accordance with the following formula:-

**Equation 6:**

$$Ti = Tt\left(\frac{Qi}{Qt}\right)\left[a + b\left(\frac{CODi}{CODt}\right) + c\left(\frac{Pi}{Pt}\right) + d\left(\frac{Ni}{Nt}\right) + e\left(\frac{SSi}{SSt}\right)\right]$$

Where:

Ti = Charges due per month for the treatment of industrial Effluent.

Tt = Total charges for Wastewater Treatment

Qi = sewage flow (*as defined in the Council's Wastewater bylaws*) originating from the user in kilolitres per day determined for the relevant month;

Qt = annual total sewage inflow (*as defined in the Council's Wastewater bylaws*) to the Council's sewage disposal system in kilolitre per day;

CODi = average chemical oxygen demand of the settled sewage originating from the user in milligrams per litre determined for the relevant month;

CODt = annual average chemical oxygen demand of the settled sewage in the total inflow to the Council's sewage disposal system in milligrams per litre;

Pi = average Ortho-phosphate concentration originating from the user in milligrams phosphorus per litre determined for the relevant month;

Pt = annual average ortho-phosphate concentration of the sewage in the total inflow to the Council's sewage disposal system in milligrams phosphorus per litre;

Ni = average ammonia concentration originating from the user in milligrams nitrogen per litre determined for the relevant month;

Nt = annual average ammonia concentration of the sewage in the total inflow to the Council's sewage disposal system in milligrams nitrogen per litre;

SSi = average suspended solids concentration originating from the user in milligrams per litre determined for the relevant month;

SSt = annual average suspended solids concentration of the sewage in the total inflow to the Council's sewage disposal system in milligrams per litre;

a = portion of the fixed cost of treatment;

b = portion of the costs directly related to the removal of chemical oxygen demand;

c = portion of costs directly related to the removal of phosphates;

d = portion of the costs directly related to the removal of ammonia;

e = portion of the costs directly related to the removal of suspended solids.

Where:

| a | b | c | d | e |
|---|---|---|---|---|
| 0.29 | 0.26 | 0.16 | 0.15 | 0.14 |

The owner or occupier of an industrial premise is also liable for a sewer collection charge based on its portion of the total sewer collection cost. The formulae promote the principle of the 'polluter pays'. Hence, customer with high concentrations of organic pollutants will be charged more than customer with lower concentrations of such pollutants, for the same quantity of wastewater.

The maximum concentration limits of substances contained in any sewage, industrial effluent or other liquid discharged to the sewer are specified in the schedule below. An additional tariff is payable in respect of the discharge of industrial effluent having a value which exceeds the discharge limits. The additional charge being the higher of R0-50 per kilolitre industrial effluent discharged during the relevant month or R500-00 per month for each individual parameter deviating from the acceptable parameters.

**Table 27: Amajuba Schedule for limits and maximum concentration of substances that may be contained in discharged effluent**

| Parameter | Allowed Specification |
|---|---|
| Electrical conductivity not greater than | 500mS/m at 20 degrees Celsius |
| Substances not in solution including fat, oil, grease, waxes and like substances –<br>(a) of mineral origin<br>(b) of vegetable origin | (a) < 50 mg/l<br>(b) (b) < 200 mg/l |
| Chlorides (expressed as Cl) | 1,000 mg/l |
| Anionic surface active agents | 250 mg/l |
| Sulphates (expressed as $S0_4$) | 250 mg/l |
| Iron (as Fe) | 200 mg/l |
| Manganese (as Mn) | 50 mg/l |
| Nitrates (as N) | 50 mg/l |
| Chrome (expressed as Cr) | 20 mg/l |
| Cobalt (expressed as Co) | 20 mg/l |
| Copper (expressed as Cu) | 20 mg/l |
| Titanium (as Ti) | 20 mg/l |
| Cyanides (as CN) | 20 mg/l |
| Zinc (expressed as Zn) | 20 mg/l |
| Lead (expressed as Pb) | 10 mg/l |
| Phenols (expressed as phenol) | 10 mg/l |
| Nickel (expressed as Ni) | 10 mg/l |
| Sulphides (as S) | 10 mg/l |
| Boron (expressed as B) | 5 mg/l |
| Fluoride (expressed as F) | 5 mg/l |
| Molybdenum (expressed as Mo) | 5 mg/l |
| Arsenic (expressed as As) | 2.5 mg/l |
| Cadmium (expressed as Cd) | 2.5 mg/l |
| Selenium (expressed as Se) | 2.5 mg/l |
| Mercury (expressed as Hg) | 1.0 mg/l |

### Newcastle Local Municipality

The municipality's Tariff of Charges for 2015/2016 states that the monthly charge payable by the owner or occupier of any trade premises in respect of any industrial effluent discharged into the Council's sewers, shall be assessed by uThukela Water at half yearly intervals. The formula applied in Newcastle is dated, and the municipality and the WSP are in the process of updating the tariff.

**Equation 7:**

$$Charge\ payable = 30.8 * \frac{(\mathrm{OA}\ -\ 50)\ \text{cents per kilolitre}}{20}$$

Where:

- OA is the oxygen absorbed, expressed in milligrams per litre, from acidic N/80 potassium permanganate in 4 hours: (OA mg/ℓ 4hr $KMnO_4$)
- OA is determined by uThukela Water on the well shaken sample in accordance with the method of chemical analysis given in Schedule D of the Council's Industrial Effluent Bylaws

Basic sanitation services are charged in accordance with:

| Description of basic sewer charge | Actual 2014/2015 Tariff | Actual 2015/2016 Tariff |
|---|---|---|
| Business and Industry (per kilolitre of water consumed) | R3.00 | R3.21 |

**uMhlathuze Local Municipality (Richards Bay)**

Industrial users are required to discharge industrial effluent in accordance with the standards and criteria set out in specific Schedules. A separate Schedule specifies the standards and criteria for discharge of effluent to a sea outfall.

Relaxation of or varying the standards prescribed in the Schedules can be authorised, provided that compliance with any national standards is not affected and the authorised official is satisfied that any such relaxation represents the best practicable environmental option. A risk aversion and caution philosophy is maintained by the municipality, taking into consideration a number of factors:

- whether the applicant's plant is operated and maintained at optimal levels;
- whether technology used by the applicant represents the best available to the applicant's industry and, if not, whether the installation of such technology would entail unreasonable cost to the applicant;
- whether the applicant is implementing a program of waste minimization which complies with national and local waste minimization standards to the satisfaction of the authorised official;
- the cost to the Municipality of granting the relaxation or variation; and
- the environmental impact, or potential impact, if the relaxation or variation is granted.

At present (2015), the municipality does not use a specific trade effluent tariff, but is the subject of investigation for future implementation. Current charges for wastewater discharge is based on a generic sewer discharge formula, which produce a monthly charge per developed erf or connection point, in respect of the usage of the sewage disposal system:

**Equation 8:**

$$\mathrm{C} = \frac{b\ (V}{360(eb_V} + \frac{B}{eb_B} + \frac{S\ )}{eb_S)}T$$

The symbols represent the following descriptions:

**Where:**

| | |
|---|---|
| C | = Monthly charges per erf or connection point |
| b | = Calculated, measured or as agreed upon monthly discharge per connection point of the sewerage, industrial effluent and or other substance. |
| $eb_V$ | = Estimated daily capacity of sewerage disposal system |
| $eb_s$ | = Daily capacity purchased in the sea (outfall) |
| V | = Annual estimated capital cost of the sewerage disposal system |
| B | = Annual estimated operating cost of the sewerage disposal system |
| S | = Annual estimated capital cost of the sea (outfall) |
| T | = A surcharged determined by the Council (for 2015/2016 it is proposed to be 0.0894 R/kl excl VAT) |

The monthly discharge is calculated, measured or as agreed upon per month and in accordance with the table below. The discharge figures in the respective tables are for Primary Uses in accordance with the proposed City of uMhlathuze Land Use Scheme in course of preparation. The discharge is set at a minimum of 20 $m^3$ or as determined below (provided that for Underdeveloped Erven the maximum erf size shall be 10,000 $m^2$):

**Table 28: Discharge Figures: Monthly Discharge Figures for Undeveloped Erven & Developed Erven**

| Industry | Undeveloped Erven | Developed Erven |
|---|---|---|
| Service Industrial | 0.240 cubic m./$m^2$ | *100% of water consumption or per agreement* |
| Low, medium & high impact industrial | 0.075 cubic m./$m^2$ | *100% of water consumption or per agreement* |

uMhlathuze present strict condition pertaining to constituents that exceed the special limits stated below, which is differentiated based on the size of the treatment plant:

- No calcium carbide, radioactive waste or isotopes
- No yeast & yeast wastes, molasses spent or unspent
- No cyanides or related compounds capable of liberating HCN gas or cyanogen
- No degreasing solvents, petroleum spirit, volatile flammable solvents or any substance which yields a flammable vapour above 20°C

**Table 29: Discharge Figures: Monthly Discharge Figures for Undeveloped Erven & Developed Erven**

| General Quality | Limits Large Works > 25 Ml/d | Small Works < 25 Ml/d | Units |
|---|---|---|---|
| 1. Temperature (°C) | <44°C | <44°C | Degrees Celsius |
| 2. pH | 6 < pH < 10 | 6.5<pH< 10 | pH units |
| 3. Oils, greases, waxes of mineral origin | 50 | 50 | mg/ℓ |
| 4. Vegetable Oils, greases, waxes | 250 | 250 | mg/ℓ |
| 5. Total sugar and starch (as glucose) | 1000 | 500 | mg/ℓ |
| 6. Sulphates in solution (as $SO_4$) | 250 | 250 | mg/ℓ |
| 7. Sulphides, hydrosulphides and polysulphides (as s) | 1 | 1 | mg/ℓ |
| 8. Chlorides (as C') | 1,000 | 500 | mg/ℓ |
| 9. Fluoride (as F1) | 5 | 5 | mg/ℓ |
| 10. Phenols (as phenol) | 10 | 5 | mg/ℓ |
| 11. Cyanides (as CN) | 20 | 10 | mg/ℓ |
| 12. Settle-able Solids | Charge | Charge | mg/ℓ |
| 13. Suspended Solids | 2,000 | 1,000 | mg/ℓ |
| 14. Total dissolved solids | 1,000 | 500 | mg/ℓ |
| 15. Electrical Conductivity | - | 400 | mg/ℓ |
| 16. Anionic Surfactants | - | 500 | mg/ℓ |
| 17. C.O.D. | Charge | Charge | mg/ℓ |
| 18. Copper (as Cu) | 50 | 5 | mg/ℓ |
| 19. Nickel (N) | 50 | 5 | mg/ℓ |
| 20. Zinc (Zn) | 50 | 5 | mg/ℓ |
| 21. Iron(Fe) | 50 | 5 | mg/ℓ |
| 22. Boron (B) | 50 | 5 | mg/ℓ |
| 23. Selenium (Se) | 50 | 5 | mg/ℓ |
| 24. Manganese (Mn)§ | 50 | 5 | mg/ℓ |
| 25. Lead(Pb) | 20 | 5 | mg/ℓ |
| 26. Cadmium (Cd) | 20 | 5 | mg/ℓ |
| 27. Mercury (Hg) | 1 | 1 | mg/ℓ |
| 28. Total Chrome (Cr) | 20 | 5 | mg/ℓ |
| 29. Arsenic (As) | 20 | 5 | mg/ℓ |
| 30. Titanium (Ti) | 20 | 5 | mg/ℓ |
| 31. Cobalt (Co) | 20 | 5 | mg/ℓ |
| Total Metals | 100 | 20 | mg/ℓ |

**Table 30: Conditions for discharge into the sea outfall**

| Sea Outfall Quality Limited | Value | Units |
|---|---|---|
| 1. Temperature (°C) | 44°C | Degrees Celsius |
| 2. pH | 5.5 < pH < 9.5 | |
| 3. Settle-able Solids | 2 | mg/ℓ |
| 4. Oils, greases, waxes of mineral origin | 50 | mg/ℓ |
| 5. Arsenic (expressed as As) | 5 | mg/ℓ |
| 6. Cadmium (expressed as Cd) | 1.5 | mg/ℓ |
| 7. Total chromium (expressed as Cr) | 3 | mg/ℓ |
| 8. Copper (expressed as Cu) | 3 | mg/ℓ |
| 9. Lead (expressed as Pb) | 5 | mg/ℓ |
| 10. Mercury (expressed as Hg) | 0.05 | mg/ℓ |
| 11. Cyanides (expressed as CN) | 10 | mg/ℓ |
| 12. Nickel (expressed as Ni) | 10 | mg/ℓ |
| 13. Zinc (expressed as S) | 20 | mg/ℓ |
| 14. Sulphide (expressed as S)) | 1 | mg/ℓ |
| 15. Sulphates in solution (as SO4) | 250 | mg/ℓ |

## 4.2. Industry Conformance to Standards and Specifications

### 4.2.1. Conformance with Industry Standards

The Paper and Pulp industry is aware of the best management practice and the various norms and standards that are required to conduct business in this discipline. The standards and specifications that are generally conformed to by the industry include:

*Note: Norms and standards are legally enforceable. Specifications are normally followed by industry but are not enforced by law.*

- ISO 9001: Quality Management
- ISO 14001: Environmental Management
- OHSAS 18001: Occupational Health and Safety
- ISO 22000: Food Safety Management System (where applicable)

In general, companies have indicated that they do not ascribed to:

- ISO 31000 – Risk Management. However, for new projects HAZOP studies are performed by a team from different disciplines.
- ISO 55000 – Asset Management
- SANS 17025 – Sampling (one company did indicate that their technology centre is 17025 accredited)
- ISO 50001 Energy Management.
- SANS 10330:2007: Hazard Analysis and Critical Control Point System (HACCP System).
- BRC Global Standards: a safety and quality certification programme to guarantee the standardisation of quality, safety and operational criteria and ensure that manufacturers fulfil their legal obligations and provide protection for the end consumer.

Industry confirmed that risk management, as well as water footprints, are used as selection tools for both best practice application and site modification and expansions. An integrated SHER approach is followed. An additional tool being implemented by one of the companies surveyed is the British Standards Institution BS 25999-1 & 2:2006 and the ISO 22301 Business Continuity Management System.

### 4.2.2. Raw Water Specifications

Biofouling, corrosion and scaling are three of the highest risks associated with the water systems in the paper manufacturing industry [39].

Biofouling is the predominant fouling mechanism in paper production. The relevant parameters leading to biofilm accumulation derive from microbiological mechanisms, e.g. temperature, pH, dissolved oxygen and redox potential, nutrient concentrations such as COD, total N, total P, etc. (39)

Corrosion in the paper industry can occur in the wet process equipment, each manufacturing step having its specific corrosion problem. Temperature, chemical constituents, concentration, size and quality of the wood fibres and metals used are some of the factors affecting corrosion. Different forms of corrosion can be experienced. One of the most frequent types of corrosion in the Paper and Pulp industry is microbiologically induced corrosion (39).

Scaling problems can also occur in the Paper and Pulp industry. Scaling can occur in different areas in the process e.g. pipes, pumps or in the wastewater treatment plant. Most frequent depositions are calcium carbonate depositions. The potential of the deposition of calcium carbonate can be predicted and assessed on the basis of the Langelier saturation index.

A large number of South African sites have indicated during the study that they utilise municipal potable water as the fresh water source for their processing activities. In these cases, the water quality generally complies with quality specifications in the water use agreement. Where municipal drinking water supply is used as raw input water, SANS 0241 usually applies. Where excursions such as too high chloride concentrations have been found in a specific case, the water supply authority provided support in rectifying the problem.

Where raw water is obtained from water abstracted from a river, the site generally has to treat the water to a suitable quality for processing purposes and often also as potable water supply. A rising concern is the impact of upstream municipal wastewater treatment plants that are not complying with the discharge limits. This is resulting in a continuing deterioration of incoming water quality that is affecting the mills' operations.

Different grades of product produced, results in the need for different water qualities during processing with high grades of paper such as graphic paper requiring a higher grade of water than, for instance, brown packaging material. Typical water specifications in the Paper Machine Loop for some grades of paper are summarised in Table 31,

Table 32,

Table 33 and

Table 34. The tables list a range within which many existing non-South African mills are working. However, the maximum values also listed indicate that there are some mills operating at considerably higher loadings in their process waters.

**Table 31: Water quality for graphic papers (39)**

| Parameter | Unit | Location | | | |
|---|---|---|---|---|---|
| | | Process Water PM Loop | 1st Loop Deinked Pulp | 2nd Loop Deinked Pulp | Mechanical Pulp |
| pH | - | 7.0-8.5 | 7.5-8.5 | 7.5-8.5 | 6.0-7.0 |
| Temperature | °C | 40-60 | 40-60 | 40-60 | 60-80 |
| TDS | mg/ℓ | 1,000 | 3 500 | 2,000 | 1 500-2,000 |
| COD | mg/ℓ | 1,000 | 3 500 | 2,000 | 2,000-3,000 |
| Chloride | mg/ℓ | 100 | n.a. | n.a. | n.a. |
| Sulphate | mg/ℓ | 100 | 300 | 200 | n.a. |
| Hardness | mg/ℓ ($CaCO_3$) | 50 | 200 | 150 | n.a. |
| Ammonia | mg/ℓ - N | 1 | 1 | 1 | n.a. |
| Nitrate | mg/ℓ - N | 1 | 1 | 1 | n.a. |

| Parameter | Unit | Location | | | |
|---|---|---|---|---|---|
| | | Process Water PM Loop | 1st Loop Deinked Pulp | 2nd Loop Deinked Pulp | Mechanical Pulp |
| Nitrite | mg/ℓ - N | 1 | 1 | 1 | n.a. |
| Total P | mg/ℓ | 1 | 1 | 1 | n.a. |
| Fungi | UFC/mℓ | 2 | 2 | 2 | n.a. |
| Algae | UFC/mℓ | 2 | 2 | 2 | n.a. |
| Microorganisms | per mℓ | 10 | 10 | 10 | n.a. |

**Table 32: Water quality for packaging papers from recovered fibres without deinking [39]**

| Parameter | Unit | Typical Range in PM Loop | Maximum Reported |
|---|---|---|---|
| pH | - | 6.3-7.3 | 7.5 |
| Temperature | °C | 35-48 | 48 |
| TDS | mg/ℓ | 2,000-6,000 | 13,000 |
| COD | mg/ℓ | 1,000-8,000 | 25,000 |
| Chloride | mg/ℓ | 100-700 | 1 200 |
| Sulphate | mg/ℓ | 200-900 | 1 600 |
| Calcium | mg/ℓ | 200-200 | 3 800 |
| Langelier Stability Index | - | < 0.5 | |

**Table 33: Water quality for sanitary papers from fresh fibre [39]**

| Parameter | Unit | Typical Range in PM Loop | Maximum Reported |
|---|---|---|---|
| pH | - | 7.1-8.1 | 8.1 |
| Temperature | °C | 36-44 | 44 |
| TDS | mg/ℓ | 500-1 700 | 3 500 |
| COD | mg/ℓ | 150-450 | 1,000 |
| Chloride | mg/ℓ | 50-350 | 700 |
| Sulphate | mg/ℓ | 80-200 | 900 |
| Calcium | mg/ℓ | 50-400 | 1 800 |

**Table 34: Water quality for sanitary papers from recovered paper [39]**

| Parameter | Unit | Typical Range in PM Loop | Maximum Reported |
|---|---|---|---|
| pH | - | 7.1-8.3 | 8.3 |
| Temperature | °C | 30-46 | 46 |
| TDS | mg/ℓ | 1,000-2 500 | 4,000 |
| COD | mg/ℓ | 500-1 500 | 2 500 |
| Chloride | mg/ℓ | 60-250 | 700 |
| Sulphate | mg/ℓ | 150-350 | 600 |
| Calcium | mg/ℓ | 80-250 | 330 |
| Langelier Stability Index | - | < 0.5 | |

### 4.2.3. Effluent Release Specifications

Generally, the effluent release quality and quantity specifications are based on municipal bylaws or the Water Use Licence. Most mills have indicated that they achieve a high level of compliance of between 95-100%.

For smaller facilities where the cost of effluent treatment is prohibitive, the level of compliance is lower in some cases with one site reporting 83% compliance to a specific parameter.

### 4.2.4. Contaminants of Emerging Concern

In general, the South African Paper and Pulp industry does not see itself as a contributor to this category of pollutants.

A concern was however raised on the impact of upstream municipal wastewater treatment plants that are not complying with the discharge limits and thus increased level of these types of contaminants entering sites via river water abstraction.

## 4.3. Industry Compliance with National Legislation

### 4.3.1. Water Use Licences

The Paper and Pulp Industry in general have either a Water Use Licence in place or have an agreement in place with the local municipality or water agency with regards to both water usage and effluent release for each mill operated. One of the mills do not have a WUL and explained that an extended processing period with DWS is experienced.

The authorisations have been made available by industry for the study purposes but are too extensive to include for the purposes of this report. The Water Use Licenses were analysed to establish the typical content of such authorisations and are summarised in the "Best Practice Guideline for Water and Wastewater Management in the Paper and Pulp Industry" (DWS, 2015).

### 4.3.2. Compliance with Water Use Licences

The feedback from industry is as follows:

- ✓ Industry report that the WUL requirements are generally complied with;
- ✓ Industry often have own internal targets that are set at management/corporate level that drives the mills to do better than required by the WUL's;
- ✓ Internal sustainability goals set long term environmental targets that are reported to management on a regular basis and also at corporate level (both in SA and internationally);
- ✓ Industry in general is confident in achieving compliance with the specifications to which they need to comply with; and
- ✓ Varying levels of compliance to licence conditions have been reported by different mills and are in general between 95 and 100%.

## 4.4. Industry Perspective

### 4.4.1. Challenges Experienced

Since the global paper industry is under severe pressure due to the reduced consumption of paper, challenges are experienced in economically justifying some upgrades to equipment. Despite this, significant capital investments have been made by the Paper and Pulp Industry to continue reducing water consumption and improving effluent quality.

Various mills identified challenges with the regulatory processes involving water and wastewater management. The most pertinent issues are:

1. Delayed responses or a lack of feedback by DWS with regards to the licence application/transfer/renewal process;

2. Certain mills perceive that unreasonable conditions are enforced which stems mainly from a lack of understanding of industry by government, e.g. the perception that further expansion is not supported by the Reserve;
3. General lack of cooperation, questionable competence and high staff turnover at DWS – at specific DWS offices only. Many mills did not identify this as a problem;
4. A lack of sensitivity and knowledge by government officials is alleged to impact on the industry's reputation, which create a negative perception of the industry's water use practices by members of local water forums and interest groups and negatively affect attitudes and decision making;
5. The cost of compliance to water legislation proposed will risk a number of the mills to shut down due to the fact that targets cannot be achieved economically. The independent tissue and packaging material manufacturers are particularly impacted by cost derivatives;
6. Lack of data and understanding of the volume of water abstracted and returned to the reserve by paper mills;
7. Industry experiences discernment towards the manufacturing sector with regard to water usage, as opposed to for example the agricultural sector (irrigation boards).

### 4.4.2. Use of Targets

Apart from the licensed specifications, no other targets are set for the industry by the DWS.

The Paper and Pulp Industry expressed the following perspectives regarding the use of targets:

- Setting of targets, if done in a scientific way, is seen as both useful and required and is already done voluntarily at all the mills visited;
- The basis for targets need to focus on continuous improvement for a specific site since no single target value can be set for the whole industry, due to the extreme variability between different sites as will be discussed in later sections of this report;
- A more realistic target methodology need to focus on specific water intake and effluent generation rates and continuous improvement on these values;
- Concerns were expressed on the repercussions if targets are set arbitrarily without a full understanding of what is achievable in the specific industry; and
- A number of production facilities indicated that they have already developed internal targets for especially specific water intake and that they are measured by their management against these targets. In general, this system is found to work well.

### 4.4.3. Use of Incentive Based Regulation

The Paper and Pulp Industry expressed the following perspectives regarding the use of incentives to regulate water use in the SA water industry:

- Incentive based regulation could be considered, but causes a concern of excessive penalties being imposed for occasional non-compliance in an industry that is already experiencing financial difficulty due to a global decrease in demand for their product;
- Some of the major companies supported the concept in principle, but would want an opportunity to comment in more detail on the merit of specific proposals should incentive based regulations be proposed;
- Any incentive based regulation will only prove an effective tool if incentives are significant enough to motivate capital investment;
- Some mills have used internal incentives for effluent quality improvement with great success;
- Industry acknowledged that the paper industry is a highly water intensive industry, though not as intensive as e.g. farming. Water is becoming an expensive commodity and availability will continue to become scarcer, therefore the efforts toward proper water management are imperative; and

- Compliance to WUL's could already be seen as an incentive and that industry does not need more regulation.

# 5. RECENT WATER USE AND MANAGEMENT

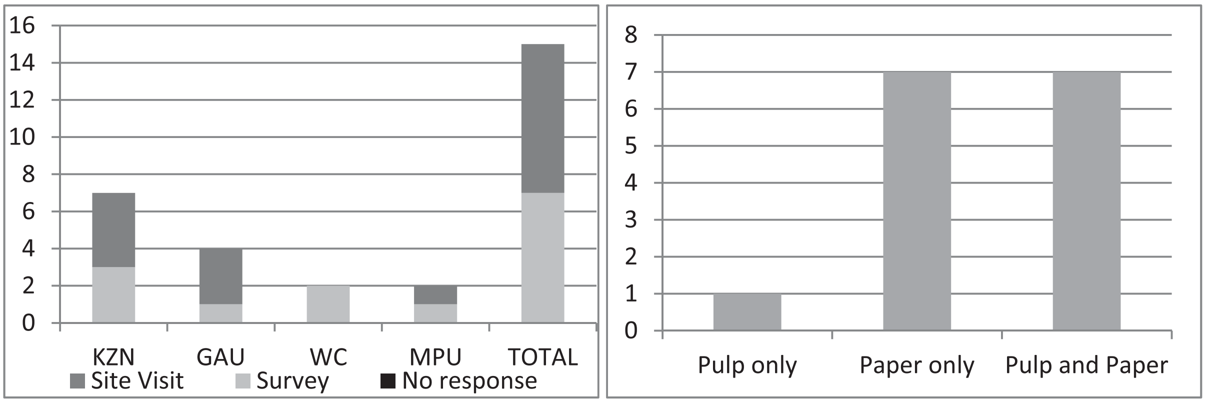
## 5.1. Assessment Schedule Response Overview

The large paper and pulp manufacturers in South Africa are members of the Paper Manufacturers Association of South Africa (PAMSA) and were in general extremely supportive of the study and willing to assist in enabling the development of a NATSURV document that was of use to industry, government and the public in general. A summary of the respective PAMSA member mills is listed in Table 35. Not all mills were visited, but assessment schedules were sent to all participating mills.

**Table 35: Mills operated by PAMSA members**

| Mill | Level of Involvement | | Province |
|---|---|---|---|
| | Survey | Site Visit | |
| a | | X | GAU |
| b | | X | KZN |
| c | | X | KZN |
| d | | X | KZN |
| e | X | | MPU |
| f | | X | GAU |
| g | X | | WC |
| h | | X | GAU |
| i | | X | MPU |
| j | X | | KZN |
| k | | X | KZN |
| l | X | | KZN |
| m | X | | WC |
| n | X | | GAU |
| o | X | | KZN |

**NOTE: Lowercase alphabetical Mill Numbering in Table 35 is not the same order as uppercase mill numbering in Table 37**




**(a) Location and level of Participation** **(b) Type of Mill**

**Figure 57: Profile of Companies Participating (a) Location and Level of Participation and (b) Type of Mill**

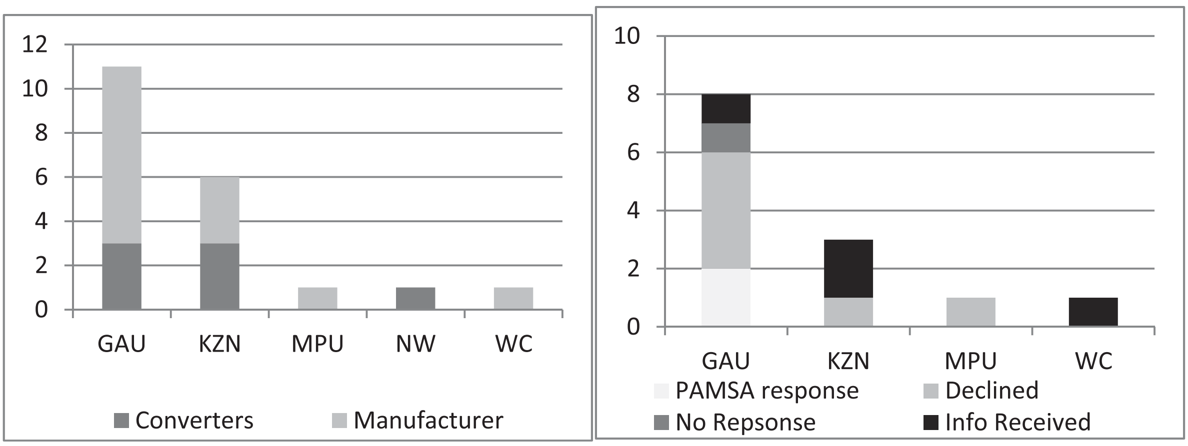
From the information contained in Table 35 and Figure 57 it can be seen that 100% participation from the Paper and Pulp Industry members who are registered at PAMSA was received.

The independent tissue manufacturers were represented by the South African Tissue Manufacturers Association (SATMA). It was ascertained that SATMA has been disbanded and hence could not be used as a body to approach their members. The membership list was however obtained from PAMSA. The list could be divided in tissue converters who obtain pre-manufactured tissue material and only cut it to size for re-use and thus do not consume water in their processing steps and actual tissue manufacturers (Figure 58). Assessment schedules were sent to tissue manufacturing companies (excluding the PAMSA members who have already responded and these companies all were also contacted telephonically to engage them in the process.

Responses received were mixed. Some tissue manufacturers declined to participate with no value being seen in the study. The categories of responses received is summarised in Table 36 and Figure 58. The first response category was the two companies that are also PAMSA members and have thus already responded via this route. The declined category relates to tissue manufacturers who received the survey, reviewed it and decided to decline to participate. The third category refers to companies where no read reply was received and the telephone number no longer exists. The last category refers to companies who have submitted information. Thus 46% of the tissue manufacturers contacted participated in the survey and a further 46% officially declined to participate, with the remaining 8% not responding in any way.

**Table 36: Summary of Tissue Manufacturers**

| Company | Location | Province | Type of Mill | | Response Type | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Cvt. | Mnf. | PAMSA | Declined | No Response | Response Received |
| Mill 1 | Heidelberg | GAU | | X | | X | | |
| Mill 2 | Vereeniging | GAU | X | | | | | |
| Mill 3 | Parow | WC | | X | | | | X |
| Mill 4 | PMB | KZN | | X | | | | X |
| Mill 5 | Springs | GAU | | X | X | | | |
| Mill 6 | Umhlali | KZN | X | | | | | |
| Mill 7 | Kwadukuza | KZN | X | | | | | |
| Mill 8 | Tongaat | KZN | | X | | X | | |
| Mill 9 | Langlaagte | GAU | | X | | | | X |
| Mill 10 | Mafikeng | NW | X | | | | | |
| Mill 11 | Middelburg | MPU | | X | | X | | |
| Mill 12 | Phoenix | KZN | | X | | | | X |
| Mill 13 | Empangeni | KZN | X | | | | | |
| Mill 14 | Johannesburg | GAU | | X | X | | | |
| Mill 15 | Alberton | GAU | X | | | | | |
| Mill 16 | Spartan | GAU | | X | | X | | |
| Mill 17 | Springs | GAU | X | | | | | |
| Mill 18 | Pretoria | GAU | | X | | | X | |
| Mill 19 | Kempton Pk. | GAU | | X | | X | | |
| Mill 20 | Garankuwa | GAU | | X | | X | | |




**(a) Location and Type of Company** **(b) Location and Level of Response**

**Figure 58: Profile of Tissue Industry Participation (a) Type and Location of company (b) Level of Participation**

Five independent packaging material manufacturers also operate in South Africa. The manufacturers are located in Gauteng with one also having an operation in the Western Cape. Support from this sector for the study was excellent and all three companies participated in the survey, resulting in 100% participation in this sector of the industry as well.

## 5.2. Factors Affecting Water Use

Water use in the Paper and Pulp Industry is heavily dependent on a number of factors, namely:

1. Age of facility – Older facilities are typically not as water efficient as a newly designed facility. Due to the physical size of these facilities it is also often not economical to retrofit more water-wise processes in these facilities.
2. Type of facility – Whether a mill is an integrated Paper and Pulp mill or only a pulp or paper mill has a significant impact on water consumption with an integrated mill having more processing steps and thus requiring more water. Also, a pulp mill with a bleach plant will be more water intensive than one without. A highly bleached pulp like dissolving pulp will require the most water.
3. Processing technology used – Different technologies are utilised in the industry worldwide and impacts directly on the water requirement of the site. Significant differences between the requirements for different types of pulping processes apply.
4. Feed source used – Varying feed sources such as hardwood, softwood, bagasse and recycled paper are used in the SA Paper and Pulp Industry. Different feed sources require different processing steps, impacting directly on water requirements. The footprint of using recycled paper is also much smaller than for using virgin material.
5. Variety of products produced – The larger the range of products produced at a mill, the larger the water consumption would typically be in order to also allow for cleaning of equipment between different product runs, etc.
6. Type of product produced – Again a range of different products are produced in SA that will impact on the water consumption. The higher the grade of paper produced, the more processing steps, e.g. bleaching is required.
7. Size of the mill – Generally economy of scale in a larger mill will beneficially impact on specific water intake when compared to a small mill using the same processes, etc.

Hence it can be seen that it is almost impossible to compare the consumption of water in different mills, since each mill represents a different permutation of the different factors listed above and is thus unique in its own right. Best practise would thus likely require an evaluation of continuous improvement for a specific mill rather than comparing different mills and attempting to set a single industry standard.

## 5.3. Water Consumption at South African Mills

Based on the 2014 results for the different mills in SA, the specific water intake is summarised in Table 37. From the table, it can be seen that specific water intake per air dried ton of product can vary significantly as a result of the factors listed. Considering the total water consumption per site would also be misleading, since a large facility producing more product at a better water efficiency could utilise a larger quantity of water. A better approach would be to consider historical specific water intake on a per site basis.

By dividing the mills into two main categories, namely Paper and Pulp (which includes the one pulp only producing mill in SA) and Paper only mills, an indication of the impact of the more extensive processing required for pulp production can be obtained.

**Table 37: Specific Fresh Water Intake for Different Mills**

| Mill Code | Specific Water Intake ($m^3$/t product) | |
|---|---|---|
| | Paper and Pulp Mills | Paper Only Mills |
| A | 68.2 | |
| B | | 21 |
| C | 18.7 | |
| D | | 8.7 |
| E | 71.7 | |
| F | 22.3 | |
| G | | IP |
| H | | 20 |
| I | | 38.8 |
| J | 76.1 | |
| K | 32 | |
| L | 25.2 | |
| M | | 16 |
| N | 11.9 | |
| O | | 8.0 |
| P | | 11.0 |
| Q | | 22.2 |
| R | | 20 |
| S | | 14.6 |
| T | | 3.5 |
| U | | 6.7 |
| V | | 12 |
| Min | 11.9 | 3.5 |
| Average | 40.7 | 15.6 |
| Max | 76.1 | 38.8 |

### 5.3.1. Mill A

Fresh water (approx. 31 600 $m^3$/d) to mill A is obtained from river abstraction. Historical water consumption information is included in Figure 59.

The mill is currently busy with a water balance study – the focus is to reduce COD and there is not much direct focus on water usage reduction. The main water usage is for dilution to keep the COD in spec. If the COD is under control, there will be a significant reduction in water usage. The mill is also investigating water substitution. Reduction of water ingress into the system and the use of paper backwater for washing on the belt washer are also under investigation.

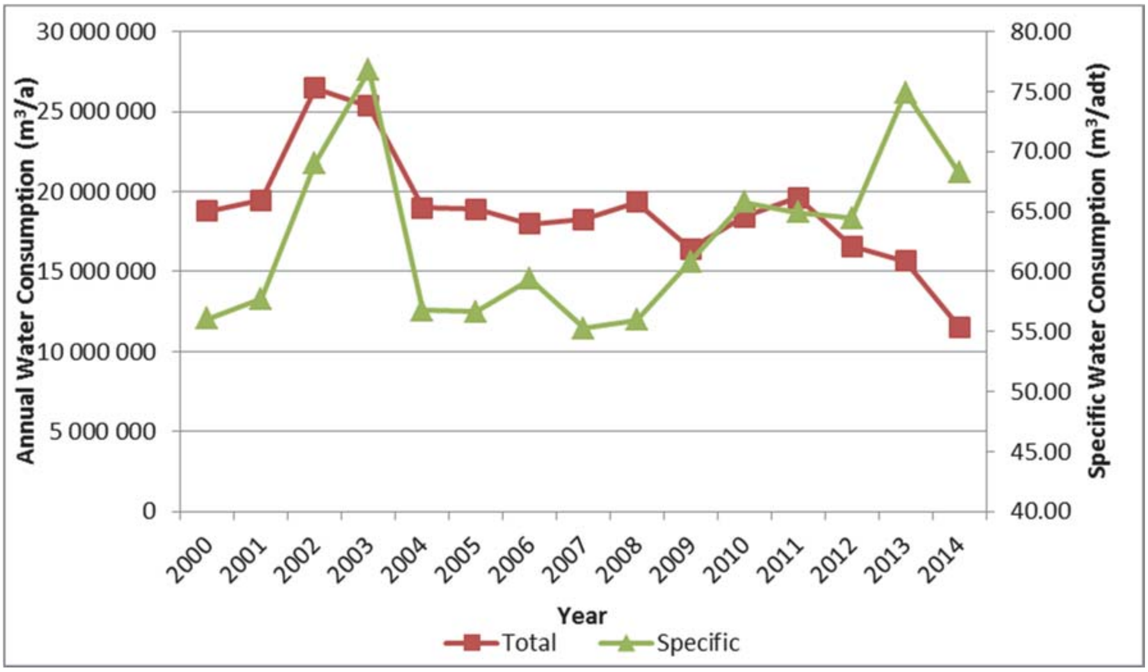



**Figure 59: Mill A Historical Water Consumption**

### 5.3.2. Mill B

The site uses a combination of raw water and potable water at approx. 1 500 $m^3$/d. The specific fresh water consumption rate for the site is 21 $m^3$/t product. Treated effluent is also re-used at a rate of 11 $m^3$/t product.

The historical water consumption rate has been decreased by practices such as the increased internal rate of recycle and increased Condensate return to boilers.

New effluent processing equipment installation is planned which will result in a predicted reduction of specific fresh water consumption to 17 $m^3$/t paper.

### 5.3.3. Mill C

Mill C utilises water from two sources namely potable water and second class water for the bulk of processing requirements.

Through water saving activities the rate of consumption of water has also been decreased to an average of approx. 18,000 $m^3$/d. In addition, the mill consumes approximately 1 200 $m^3$/d of municipal potable water resulting in a specific water intake of 18.7 $m^3$/t product.

### 5.3.4. Mill D

The facility receives municipal water (approx. 4 500 $m^3$/d) as fresh feed. Treated effluent is also recycled internally. If the effluent quality is poor, fresh water usage is increased to compensate for this reduction in source. Drinking water and auxiliaries have a dedicated water meter that is reported separately.

There has been an observable decrease in the average fresh water usage (Figure 60 for total and Figure 61 for specific consumption rates).

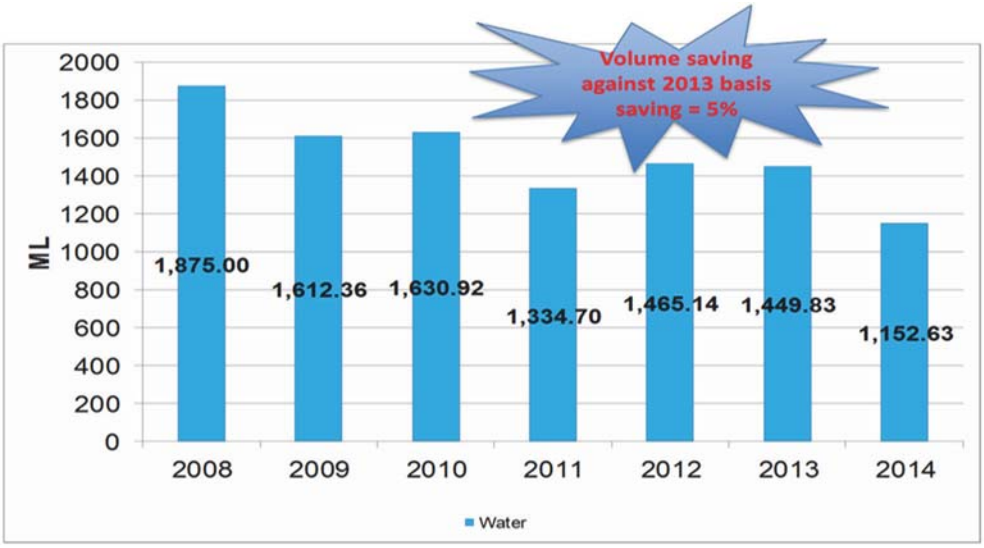



**Figure 60: Mill D Historical Annual Water Consumption**

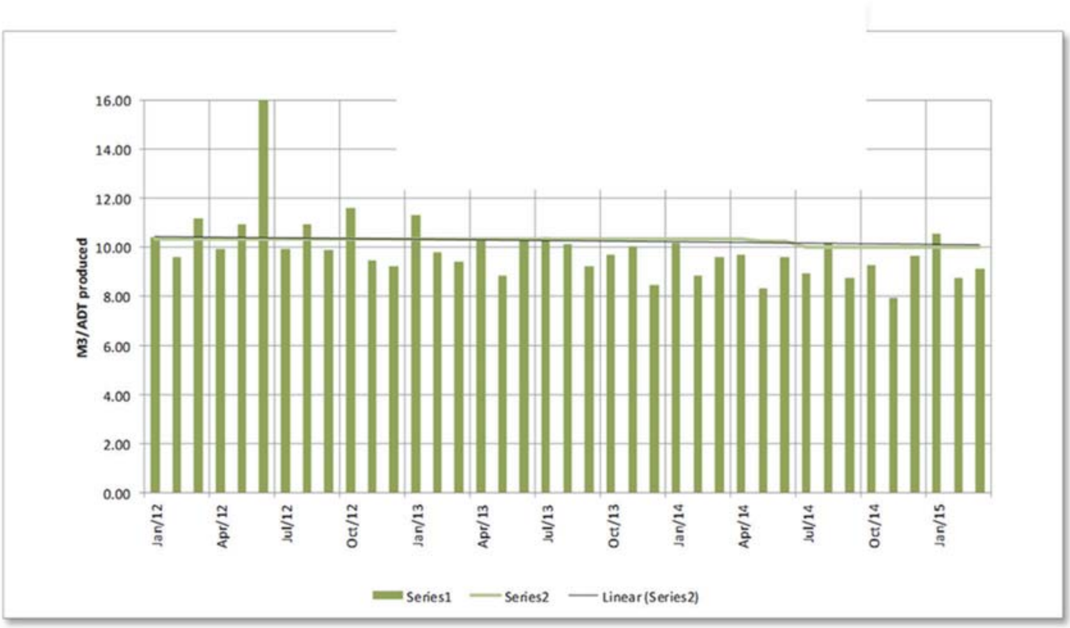



**Figure 61: Mill D Historical Specific Water Intake**

The decreased consumption is largely due to many mill improvements, projects and optimisation such as:

- Installation of more efficient screening equipment on machines to utilise more process water without blocking the screens (fresh water usage reduction),
- Improvement in chemical treatment of clarifier water thus effluent improvement increasing ability to recycle,
- Replacement of fresh water for ash quenching with process water,
- Optimisation of cleaning systems to reduce the water usage,
- Improvement of sludge dewatering to reduce water being lost from the system.

### 5.3.5. Mill E

The mill uses (approx. 17 500 $m^3$/d) river water as fresh water source. Historical water consumption information is included in Figure 62.

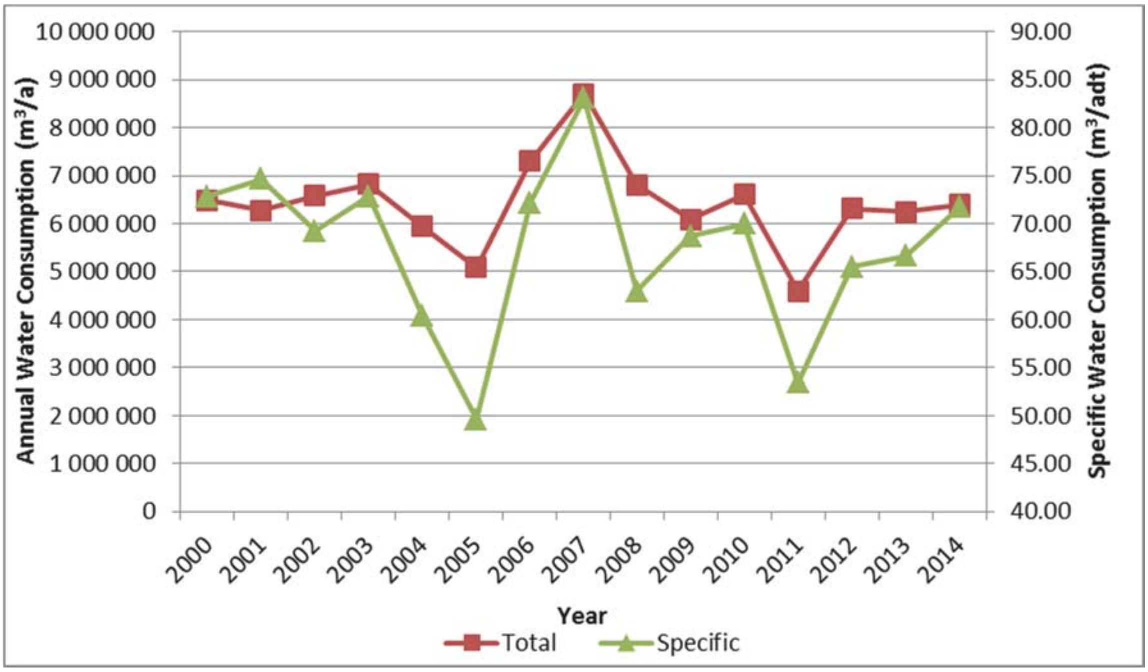



**Figure 62: Mill E Historical Water Consumption**

The mill plans to continue reducing its fresh water consumption by continuing investigations and implementation of water reduction projects and process optimizations with a combined potential reduction of 4 100 $m^3$/d, such as:

- Reuse of Vacuum Pump sealing water,
- Reduction of Back Water,
- Reduction of process water make up,
- Reduction of Screw Feeder Flush Water,
- Reuse of Screw Feeder Water,
- Reduction of Sealing Water to Black Liquor Pumps,
- Reduction of process water in the Bleach Plant,
- Reuse of white water for pulp dilution,
- Reuse of white water for chemical dilution,
- Reduction in Cooling Tower make up water,
- Reduction in water tank make up water,
- Reduction of shower water in the Wire and Felt Section,
- Reduction in Breast Roll shower water,
- Reduction of water at the Coating Pans,
- Reduction of spray water on the filter press.

### 5.3.6. Mill F

Two water sources are used, namely flocculated raw water and treated internally recycled water. Water is used for dilution, chemical make-up and -carrier water, domestic purposes and steam production. Water uses such as abstraction, process water use, non-process water use (domestic) are all monitored and reported to management.

Fresh water usage is approx. 4 600 $m^3$/d at a specific water intake of 12.6 $m^3$/t product. Recycled water usage represents a further 9.7 $m^3$/t product. Use of recycled water eliminates the use of fresh water for this purpose.

A specific water intake of 10 $m^3$/t product has been achieved in the past, but this was not sustainable as internal water loops increased in concentration and affected product quality.

### 5.3.7. Mill G

Fresh water consumed by Mill G is sourced from the municipal potable water supply infrastructure. Effluent is also treated on site and recirculated internally for re-use. Each department is metered. Balances can be done using this and process conditions.

Water is managed on site through:

1. Daily tracking at level one meetings – each machine has a water usage target which must be achieved. Usage is measure by meters which link to the DCS or are read in the field.
2. Daily tracking at level 2 meetings.
3. Monthly tracking against KPIs at steercom and environmental committee meeting,
4. International tracking using an in-house database.

Points of water use include offices, canteen, the tissue machines, recycle fibre plant, boiler, chemical make-up, fire hydrants, cooling towers and converting – all metered. The tissue machines and RFP are the biggest water users; where water is used for vacuum sealing, fresh water is used, since the seals cannot tolerate the contaminants in process water. On the tissue machines the closed loop recycle treatment is via a DAF system.

The monthly fresh water consumption is approximately 80,000 $m^3$/month. No specific water intake was reported since this is considered to be intellectual property.

### 5.3.8. Mill H

The site utilises a combination of imported fresh water and recycled treated effluent for re-use. The typical daily fresh water consumption is 650 $m^3$/d. The specific fresh water consumption rate for the site is 20 $m^3$/t product. Treated effluent is also re-used at a rate of 30 $m^3$/t product.

Following the installation of treatment equipment, treated effluent could be re-used as process water. This resulted in a decrease in specific fresh water consumption from 45 $m^3$/t to the current 20 $m^3$/t.

A water separation project is being introduced which is predicted to further lower the fresh water intake to approx. 15 $m^3$/t.

### 5.3.9. Mill I

Mill I utilises approx. 19 900 $m^3$/d municipal water as fresh water source. Historical water consumption information is included in Figure 63.

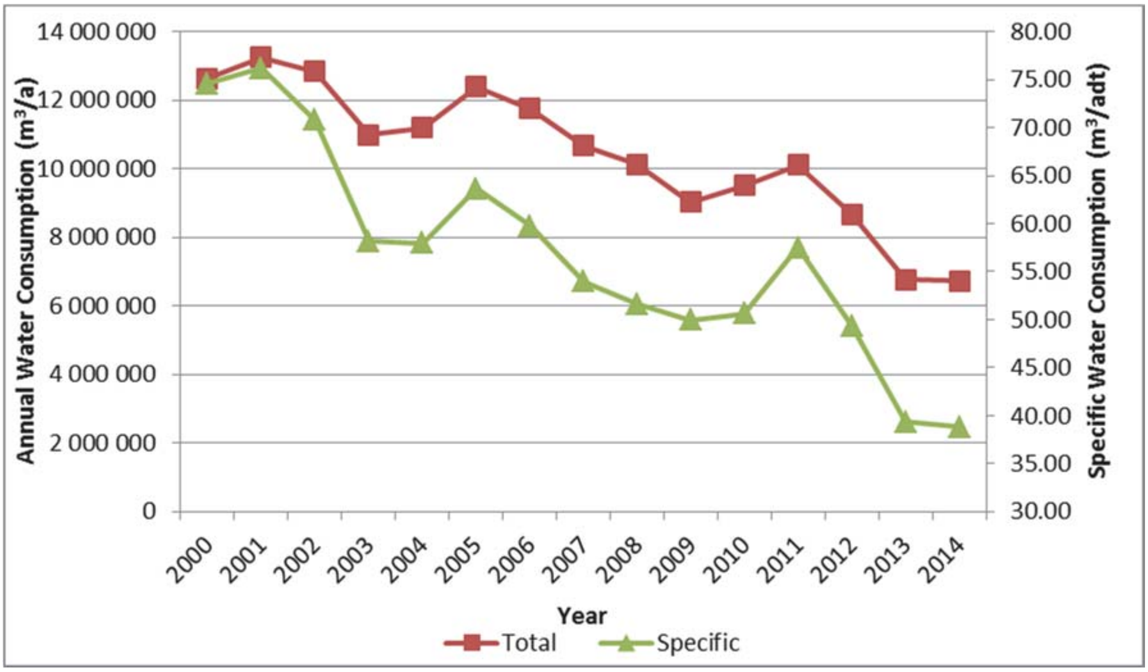



**Figure 63: Mill I Historical Water Consumption**

The following are typical examples of projects implemented to reduce water consumption:

- Unclarified water set-point change,
- A solenoid valve was installed to automate the opening and the closing of cooling water supply,
- Broke thickener showers – adjusted operating procedures,
- Screen overflow – redirected to Back water chest,
- Forward roll lubrication – Install solenoid valve and interlock with fan pump,
- Refiner cooling water – Re-direct to back water chest,
- Back-water to standpipe – Tie-in to deliver water from BW to stand pipe.

The mill will continue improvement of the mill water balance to allow more internal reuse, therefore leading to less incoming water. Improvement of internal recycle quality will be a further focus to allow some fresh water applications to have a changed source.

### 5.3.10. Mill J

River water (approx. 151,000 $m^3/h$) is extracted and treated as fresh water source. Historical water consumption information is included in Figure 64.

Specific projects implemented to reduce water consumption include:

- Replace nip flooding on belt washer with pre-ox,
- Recovery Seal Pot Water saving project,
- Woodyard – review flume auto level control system,
- Recycle sand filter back wash.

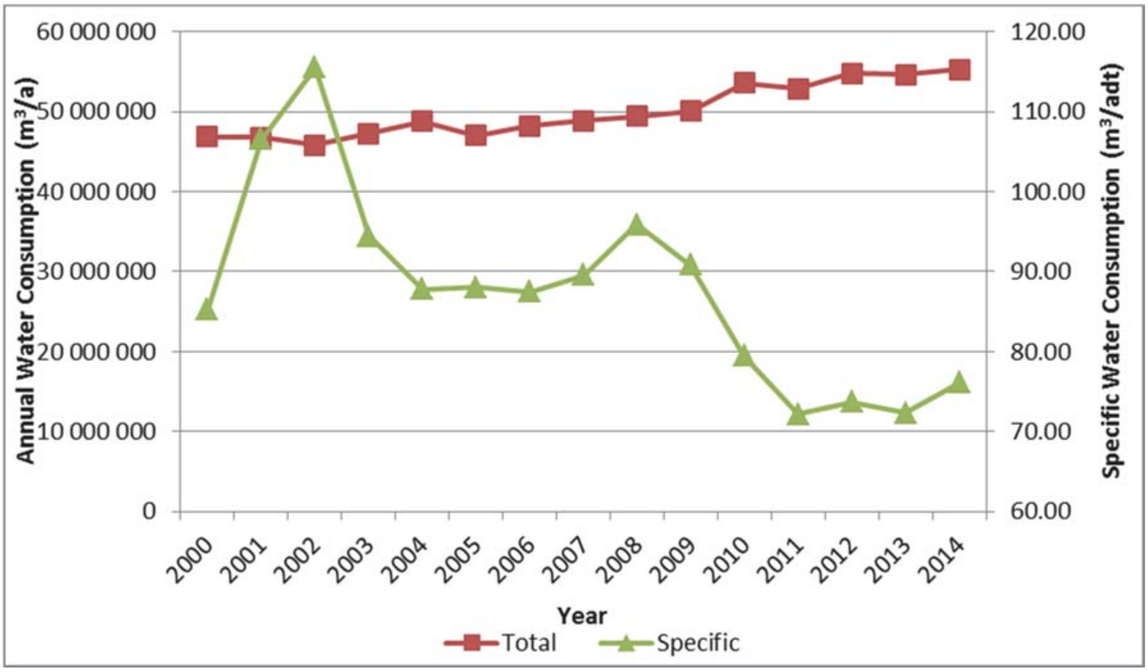



**Figure 64: Mill J Historical Water Consumption**

The mill plans to continue reducing its fresh water consumption by continuing investigations and implementation of water reduction projects and process optimizations, such as:

- Replace organ pipe dilution with thin liquor,
- Liquor plant softener backwash water recovery,
- Cooling tower water to Woodyard flumes,
- Use pre-ox filtrate to replace liquor plant water in the repola head tank,
- Repola 1-3 wire wash sprays on pre-ox filtrate,
- Eliminate Karbate coolers,
- Optimise Ramens coolers,
- Plant wide seal water collection,
- Recover Belt washer Hydraulic Oil Cooling Water.

### 5.3.11. Mill K

Mill K uses treated river water at a typical rate of 64,000m$^3$/d.

Water is typically utilised for:

- Domestic use e.g. in kitchens, toilets and bathrooms,
- Cooling tower make-up,
- In boilers for steam production and
- In the process for washing and as product input.

Used water is also recycled internally as far as possible, but the quantities are not measured. Condensate from the evaporator plant is also recovered and gets re-used on site.

Due to the installation of more efficient processes, the specific water intake has decreased since 2008 (Figure 65).

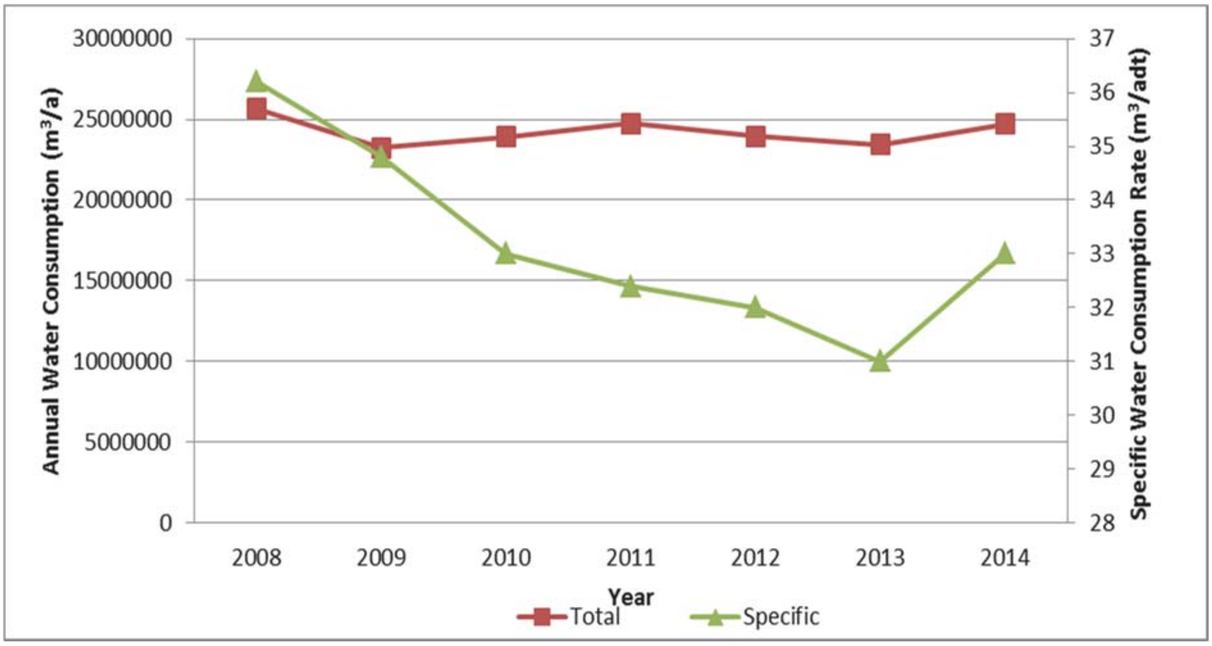



**Figure 65: Mill K Historical Water Consumption**

The increased water consumption post 2014 can be attributed to the installation of an additional steam condensing turbine for electricity generation and the increase in water consumption is as a result of the water used to generate the additional electricity.

Some examples of water conservation projects that have been implemented include:

- Reboiler project – 1 200 $m^3$/d reduction in water consumption,
- Bleach Plant Project -1 500 $m^3$/d reduction in water consumption,
- Installation of Bleach $ClO_2$ heat exchanger – 500 $m^3$/d savings,
- Installations of new mechanical seals – 1 871 $m^3$/d savings.

The facility is currently implementing a technology upgrade in the woodyard which is expected to decrease water consumption by a further 350 $m^3$/d.

A water reduction task team has been appointed to identify further possible water savings projects.

### 5.3.12. Mill L

Mill L uses river water as fresh water source at approx. 36,000 $m^3$/d. Historical water consumption information is included in Figure 66.

The increased total water consumption (Figure 66) can be largely attributed to expansion of the facility. Other lesser factors also contribute, e.g. shrinkage has decreased from 11% to 2% due to improved equipment availability resulting in less downtime and thus increased production. Consolidation of product range also requires less frequent product changes and thus improved availability of equipment.

Specific projects implemented to reduce water consumption are:

- Storm water reduction project,
- 9 projects (2 capex and 7 operational) presently being addressed -

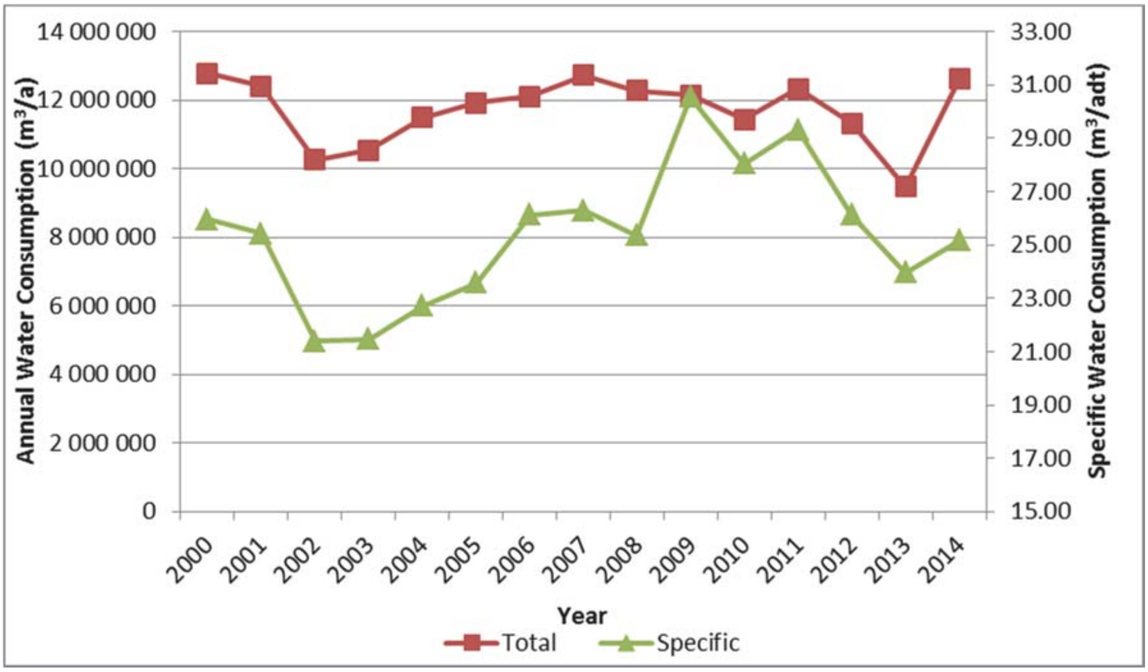



**Figure 66: Mill L Historical Water Consumption**

Potential future projects to be implemented will result in a further increase in total water requirement. Parallel actions to reduce fresh water intake and re-use as much water as possible for these projects are being considered to off-set part of this impact.

### 5.3.13. Mill M

The mill utilises municipal potable water as fresh water source (Figure 67). Before 1997, the site-specific water intake was ± 40 m$^3$/t paper. In 1997 a clarifier was installed to improve clarification and treated water re-use. In 2001 the water system was optimized by compiling a water balance, rerouting mill sealing water supply and re-using pulper sealing water into the process. These modifications resulted in a specific water intake reduction of 16 m$^3$/t paper.

Historical water consumption for the site has shown a decreasing trend as below:

- Before 1997: - ± 2 720 m$^3$/day @ ± 40 m$^3$/t paper
- 1997-2001: ± 1 700 m$^3$/day @ ± 25 m$^3$/t paper
- 2001 to 2015: ± 1 088 m$^3$/day @ ± 16 m$^3$/t paper

It is further foreseen that a planned 5% improvement in production will reduce specific water intake further. Fresh water consumption is predicted to reduce by 54 m$^3$/d in the process.

Recycled treated effluent represents a specific water intake of 24 m$^3$/t paper and thus a corresponding prevention of fresh water consumption.

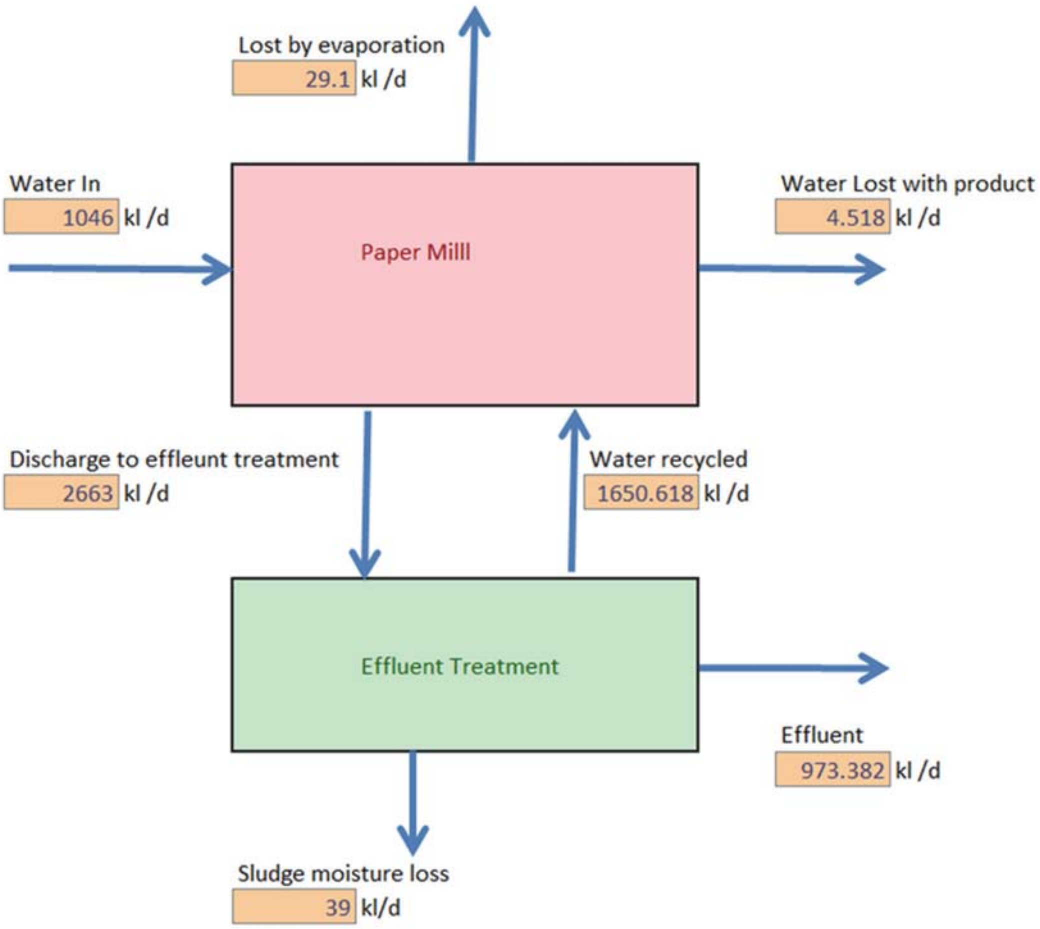



**Figure 67: Mill M Water Flow Diagram**

### 5.3.14. Mill N

Two grades of water are used on site, namely raw water from river (approx. 5 500 m$^3$/d) and potable water (approx. 700 m$^3$/d). A process of continuous improvement and daily monitoring and deviation reporting to management is used to drive improved water consumption on site.

The specific consumption of raw water (excluding potable water use) has decreased from 13 m$^3$/t product in 2013 to 12 m$^3$/t product in 2014 and is targeted to reduce to 11 m$^3$/t product in 2015. Due to the low rainfall to date in 2015 it is also expected that water restrictions will be implemented, so the reduction in consumption is done proactively to be ready for such a scenario. Prior to 2005 the SWI was in excess of 20 m$^3$/t product (Figure 68).

A further 1.55 m$^3$/t product of potable water is consumed for production processes where a higher grade water is required, such as chemical make-up. A water balance diagram is included in Figure 69.

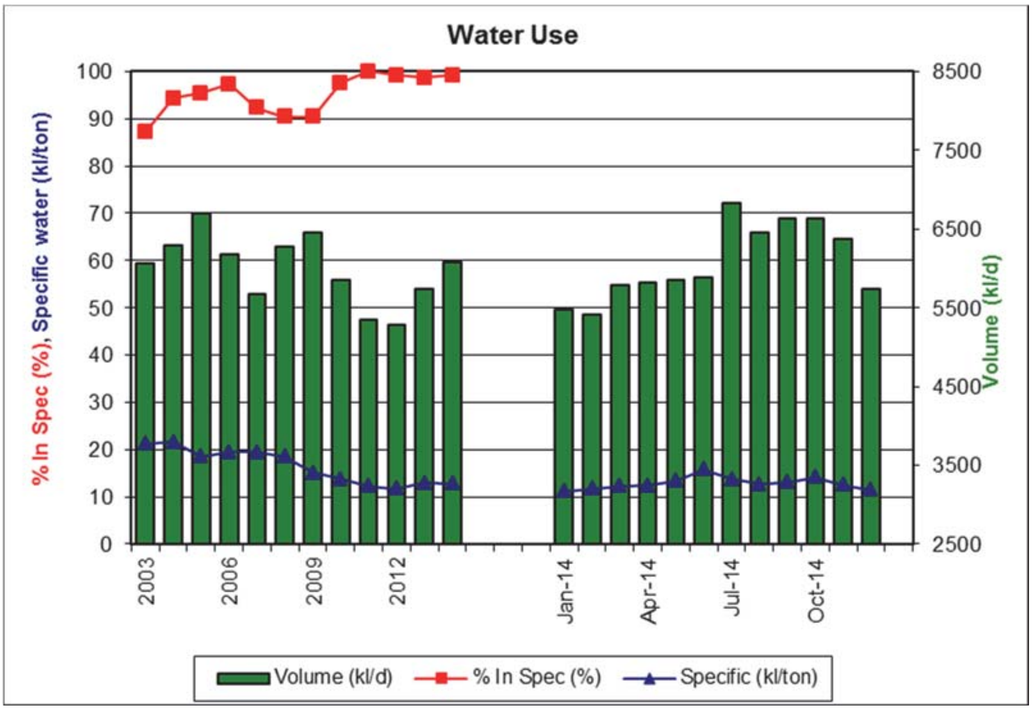



**Figure 68: Mill N Historical Water Consumption**

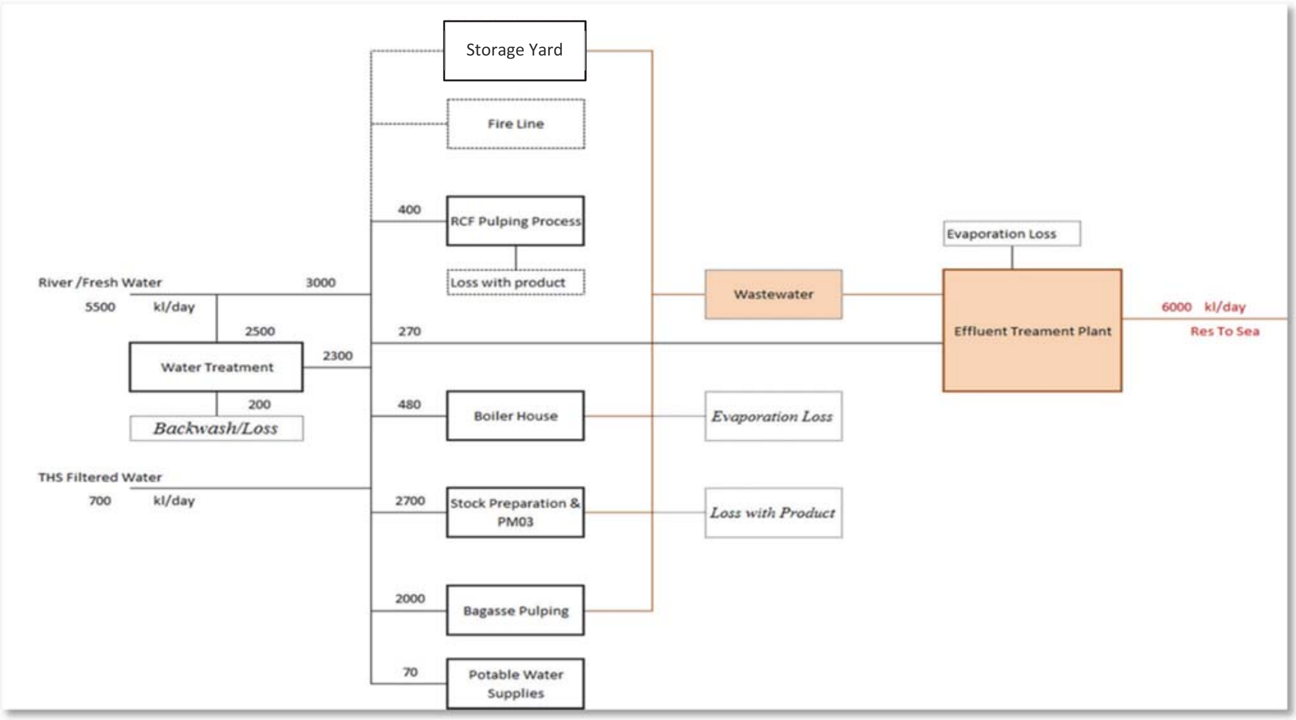



**Figure 69: Mill N Water Balance Diagram**

The reduction in specific water intake was a result of a number of different projects which included:

- Awareness drives, monitoring (incl. installation of metering devices) and reporting,
- Installation of Water and Fibre Recovery Process for process water recovery & reuse,
- Gradual cleanout & de-sludging of effluent ponds,
- Improved shower and spray water application on paper machines,
- Gland-water use optimisation,
- Vacuum ring water modifications,
- Paper machine white-water reticulation modifications,

- On-going awareness training of washing crews on efficient water use,
- Increased output from the paper machine without increasing water use.

The mill endeavours to continuously improve on water consumption and water conservation task teams meet periodically to brain storm new methods of improvement.

### 5.3.15. Mill O

Mill O uses approx. 1 350 $m^3$/d municipal water. Historical water consumption information is included in Figure 70.

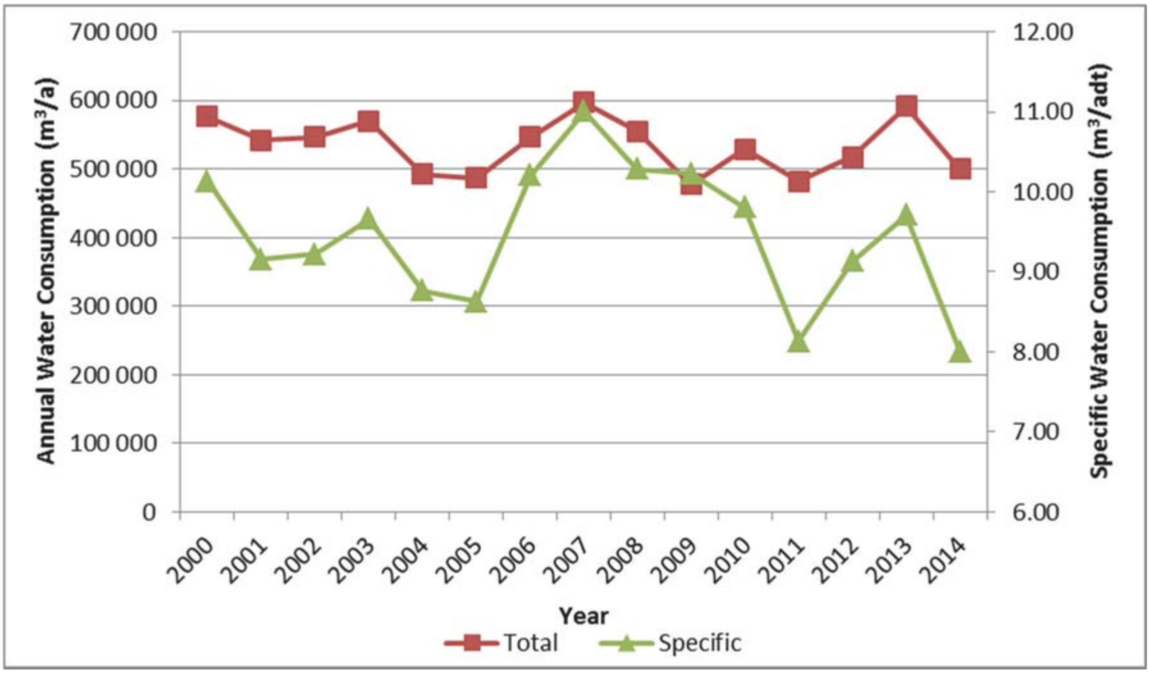



**Figure 70: Mill O Historical Water Consumption**

The following projects have been executed to reduce water consumption:

- Substituted treated effluent water with process water (re-cycled water used in other processes),
- Reduced consumption by various equipment upgrades,
- Re-used cooling water blowdown in the process instead of discharging to the municipality.

Further equipment upgrades are planned in the future, including improved control, replacing treated effluent with process water, improved water cleaning possibly with a disk filter.

### 5.3.16. Mill P

Mill P consumes municipal water as make-up source at a rate of between 120 and 180 $m^3$/d. This results in a specific water intake of between 10 and 15 $m^3$/t of product, but typically in the region of 11 $m^3$/t product.

The mill is in the process of commissioning a newly installed effluent treatment unit that will result in between 50 and 80 $m^3$/d of water being recycled and re-used, thus reducing the future specific water intake to approx. 5 $m^3$/t product.

### 5.3.17. Mill Q

Mill Q utilised about 600 $m^3$/d of municipal water resulting in a specific water intake of approx. 22.2 $m^3$/t paper.

### 5.3.18. Mill R

Mill R consumes 20 $m^3$/t paper of water. No further information was made available.

### 5.3.19. Mill S

Mill S utilises approximately 400 $m^3$/d of municipal water resulting in a specific water intake of 14.6 $m^3$/t paper. Through recycling projects marginal improvements in water consumption have been achieved.

### 5.3.20. Mill T

Mostly Municipal water is used at Mill T, but it is supplemented with groundwater. The total daily water consumption is 147 $m^3$/d which results in a specific water intake of 3.5 $m^3$/t paper. Of this 110 $m^3$/d or 2.6 $m^3$/t paper is fresh water.

### 5.3.21. Mill U

Mostly Municipal water of potable water quality is used at Mill U, but it is supplemented with groundwater. The total water consumption is 679 $m^3$/d with a specific water intake of 6.7 $m^3$/t paper. Of this 162 $m^3$/h or 1.6 $m^3$/t paper is fresh water.

The mill has also installed a microfilter which has increased output, while at the same time reducing the SWI from the historical level of 7.1 $m^3$/t paper to the current level of 6.7 $m^3$/t paper.

Further modifications are planned that is expected to reduce the specific water intake to about 5 $m^3$/t paper.

### 5.3.22. Mill V

Water of potable water quality from the municipal supply is used at Mill V. The total water consumption is 2 500 $m^3$/d with a specific fresh water consumption rate of between 10-12 $m^3$/t paper.

As a result of both effluent treatment and production technology upgrades, the historical water consumption was reduced by 500-600 $m^3$/d, i.e. 2.5-3 $m^3$/t paper.

A project is also underway to install additional gravity strainers on the process water resulting in increased water recycling and reduced fresh water import. A saving of 500 $m^3$/d or 2 $m^3$/t paper is anticipated.

# 6. EFFLUENT GENERATION AND MANAGEMENT

## 6.1. Factors Impacting on Effluent Generation

As with water use, effluent generation in the Paper and Pulp Industry is heavily dependent on a number of factors. The amount of effluent generated is generally slightly less than the raw water intake and thus it can be expected that similar factors impact on both water use and effluent generation. Typical factors to consider in effluent generation are:

1. Age of facility – Many modern-day techniques to reduce effluent generation cannot be cost effectively retrofitted on an existing mill. All South African mills are fairly old and were built in the previous century and thus this is a common limitation for all SA mills.
2. Type of facility – Whether a mill is an integrated Paper and Pulp mill or only a pulp or paper mill has a significant impact on water consumption and thus also on effluent generation, with an integrated mill having more processing steps and thus requiring more water.
3. Processing technology used – Different technologies are utilised in the industry worldwide and impacts directly on the effluent generation of the site.
4. Feed source used – Different feed sources require different processing steps. Generally, all mills attempt to maximise internal recycling in their processing steps to reduce effluent generation.
5. Type of product produced – Again a range of different products are produced in SA that will impact on effluent production. The higher the grade of paper produced, the more processing steps, e.g. bleaching is required.

Thus, as with water consumption, it is almost impossible to compare the generation of effluent between different mills, since each mill represents a different permutation of the different factors listed above and is thus unique in its own right. Since effluent generation is linked to water consumption, best practise would have to be linked to continuous improvement on specific water intake for a specific mill rather than comparing different mills and attempting to set a single industry standard.

## 6.2. Effluent Generation at South African Mills

Based on the 2014 results for the different mills in SA, the specific effluent volume rates are summarised in Table 38.

From Table 38 it can be seen that specific effluent volume per air dried ton of product can vary significantly as a result of the factors listed. Considering total effluent generation per site would be misleading, since a large facility producing more product at a better water efficiency could produce more effluent, but have a lower specific effluent volume. Thus, historical specific effluent volume on a per site basis is a better parameter to consider.

By dividing the mills into two main categories, namely Paper and Pulp (which includes the one pulp only producing mill in SA) and Paper only mills, an indication of the impact of the more extensive processing required for pulp production can be obtained.

**Table 38: Specific Effluent Volume for Different Mills**

| Mill Code | Specific Effluent Volume ($m^3$/t product) | |
|---|---|---|
| | Paper and Pulp Mills | Paper Only Mills |
| A | 64.9 | |
| B | | 10 |
| C | 17.2 | |
| D | | 10 |
| E | 84.5 | |
| F | 10.5 | |
| G | | IP |
| H | | 17 |
| I | | 38.2 |
| J | 64.6 | |
| K | 26.2 | |
| L | 18.9 | |
| M | | 14 |
| N | 12.0 | |
| O | | 7.4 |
| P | | 11 |
| Q | | DNS |
| R | | DNS |
| S | | 10.6 |
| T | | 0.08 |
| U | | 6.7 |
| V | | 9 |
| Min | 10.5 | 0.08 |
| Average | 37.4 | 12.2 |
| Max | 84.5 | 38.2 |

Typical Chemical compositions of the treated effluent from different mills are summarised in Table 39.

**Table 39: Treated Effluent Composition**

| Mill | COD (mg/ℓ) | Conductivity (µS/cm) | SS (mg/ℓ) | pH (mg/ℓ) | N (mg/ℓ) | P (mg/ℓ) | $SO_4$ (mg/ℓ) | Cl (mg/ℓ) | Na (mg/ℓ) |
|---|---|---|---|---|---|---|---|---|---|
| Mill B | - | 210 | - | 8.1 | 0.27 | - | 16 | 11 | 10 |
| Mill C | 666 | 1 690 | 38 | 7.0 | - | - | 182 | 103 | - |
| Mill D | 1 898 | 2 730 | 2 260 | 6.5 | - | - | 194 | 90 | 174 |
| Mill E | 238 | 2 220 | 62 | 7.7 | - | - | 360 | 340 | 347 |
| Mill G | 1 358 | 1 640 | 34 | 7.5 | 0.1 | 0.1 | 224 | - | - |
| Mill H | 2 663 | - | 338 | 7.1 | - | - | - | - | - |
| Mill I | 165 | 1 210 | 59 | 7.3 | 1.2 | 0.5 | 98 | 136 | 97 |
| Mill K | 378 | 4 970 | 41 | 8.4 | - | - | - | - | 740 |
| Mill L | 1 648 | 2 770 | 189 | 7.2 | - | - | 565 | 224 | 582 |
| Mill N | 3 853 | - | 1 790 | - | - | - | - | - | - |
| Mill O | 3 598 | - | 1 220 | - | - | - | - | - | - |
| Mill T | 2 600 | 1 710 | 300 | 8.5 | 0.4 | - | - | - | 100 |
| Mill V | 2 210 | 1 580 | 399 | 6.8 | 0.1 | 0.1 | - | - | - |
| Average | 1 773 | 2 070 | 561 | | 0.4 | 0.2 | 234 | 151 | 293 |

### 6.2.1. Mill A

At Mill A approx. 30,000 $m^3$/d effluent is generated at the pulp mill, paper machine, cooling tower blowdown and utilities (boilers, demin plant, etc.). This effluent is clarified prior to river release. Current effluent generation is at 30 100 $m^3$/d (vs. historical 53 500 $m^3$/d) and a specific effluent volume of 64.9 $m^3$/adt (vs. historical 58.4 $m^3$/adt). Refer Figure 71 for the effluent generation trend.

The mill will continue to strive towards reducing its environmental impact by investigating and implementing effluent improvement projects.

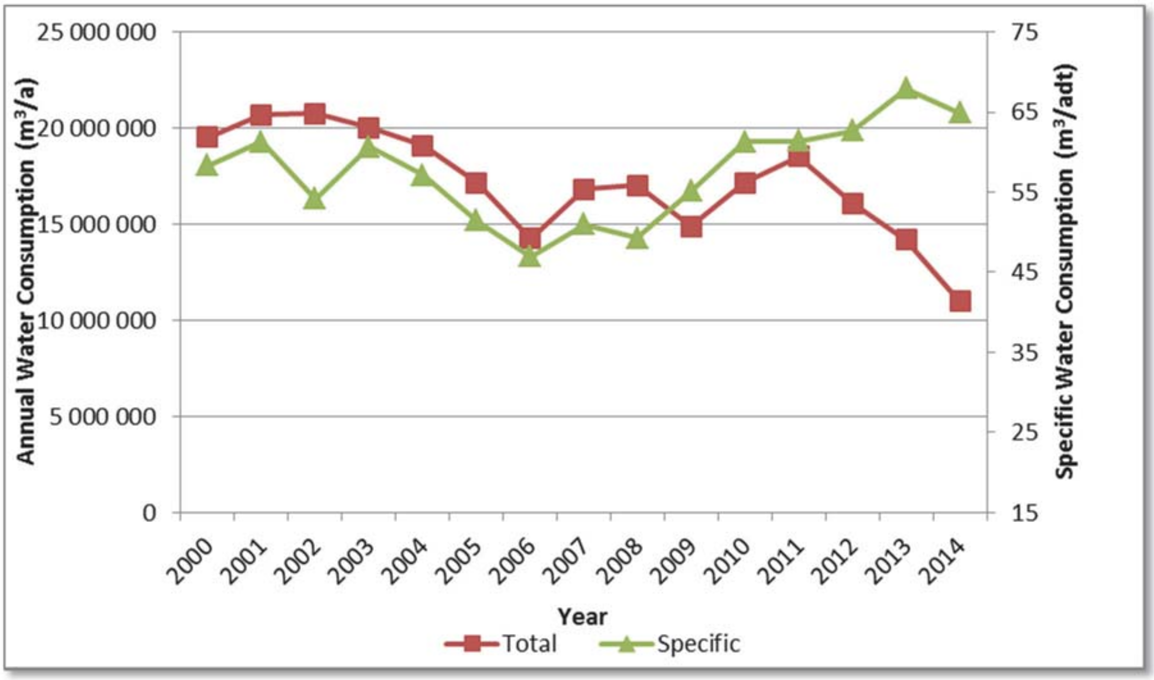



**Figure 71: Mill A Historical Specific Effluent Volume**

### 6.2.2. Mill B

The main effluent streams from the site are boiler blowdowns, paper machine DAF Units and Water Treatment Plant Back Wash. The effluent treatment plant utilises clarification to achieve solids removal and COD reduction. Approximately 800 $m^3$/d is recycled to the process. The balance of the treated effluent (approx. 700 $m^3$/d) is released to the municipal sewer.

The current specific effluent volume for the facility is approx. 10 $m^3$/t paper, but has been steadily decreasing as reflected in Figure 72.

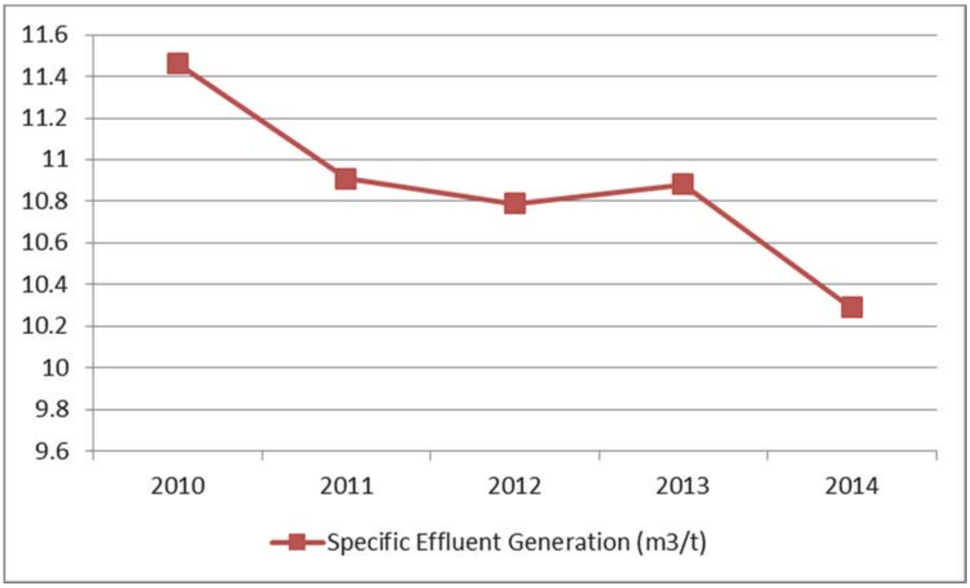



**Figure 72: Mill B Historical Specific Effluent Volumes**

This has been achieved by increasing the rate of internal recycling. All the water used in the pulping process originates from mill effluents that are re-used. The mill only discharges excess process water that cannot be re-used. The released effluent generally complies 100% with the municipal limits, with the exception of free chlorine where a 98% compliance was achieved.

Further actions are planned to increase the quantity of effluent that can be re-used in the process with a target future specific effluent volume of 5 $m^3/t$ paper.

### 6.2.3. Mill C

The mill produces approx. 18,000 $m^3/d$ of effluent split approximately equally between the two production lines. For the combined mill production, the specific effluent volume is 17.2 $m^3/t$ product. Historical effluent production rates are presented in Figure 73.

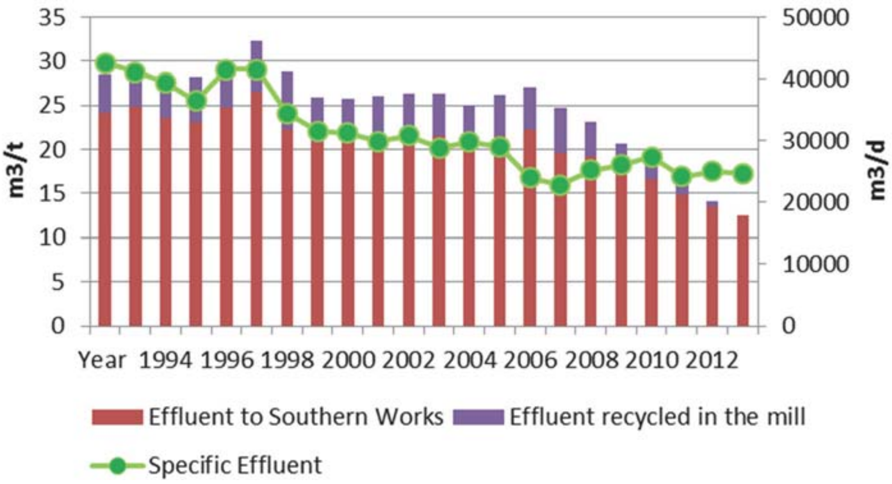



**Figure 73: Mill C Historical Effluent Volumes**

De-watered sludge from the effluent processing plant is dewatered and sent to a Multi-Fuel Boiler where it is burnt together with bark, sawdust, coal ash and coal to generate stream and electricity.

The facility has no current planned activities for effluent reduction.

### 6.2.4. Mill D

The bulk of effluent generated (approx. 15 500 $m^3$/d) is treated and recycled internally with the excess (< 3 500 $m^3$/d) discharged to the municipal sewers at a specific effluent volume of approx. 10 $m^3$/t (refer Figure 74 for a historical trends). The effluent parameters are as per the municipality specifications. Critical effluent parameters for both effluent discharge and machine operability include N, P, pH, TSS, COD, sulphates and conductivity.

The sludge produced from the treatment plant is dewatered by belt press. The Sludge (approximately 400 ton per month) is supplied to a cattle feedlot as a ground cover that is then incorporated with cattle dung and composted. The mill also gives about 750 dry ton per month to the informal block making industry.

An effluent improvement project is currently in the benchmarking phase, but the anticipated improvements have not yet been quantified.

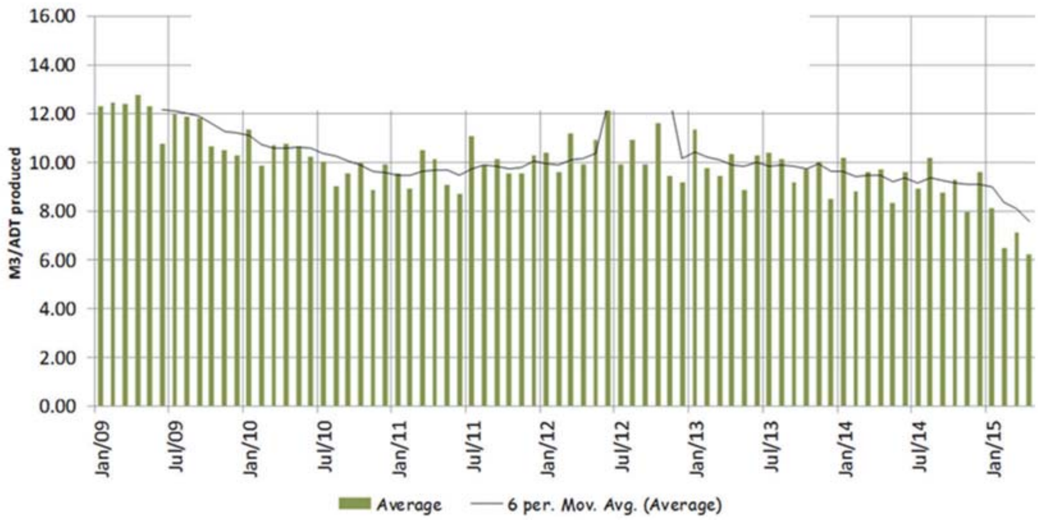



**Figure 74: Mill D Historical Specific Effluent Volumes**

### 6.2.5. Mill E

Mill E effluent originates from the pulp mill, paper machine, tissue machine, cooling tower blowdown and utilities (boilers, demin plant, etc.). The combined effluent is treated by clarification, aeration and secondary clarification prior to discharge to the river. Current effluent generation is at 20 600 $m^3$/d (vs. historical 19 100 $m^3$/d) and a specific effluent volume of 84.5 $m^3$/adt (vs. historical 78.2 $m^3$/adt). Refer Figure 75 for the effluent generation trend.

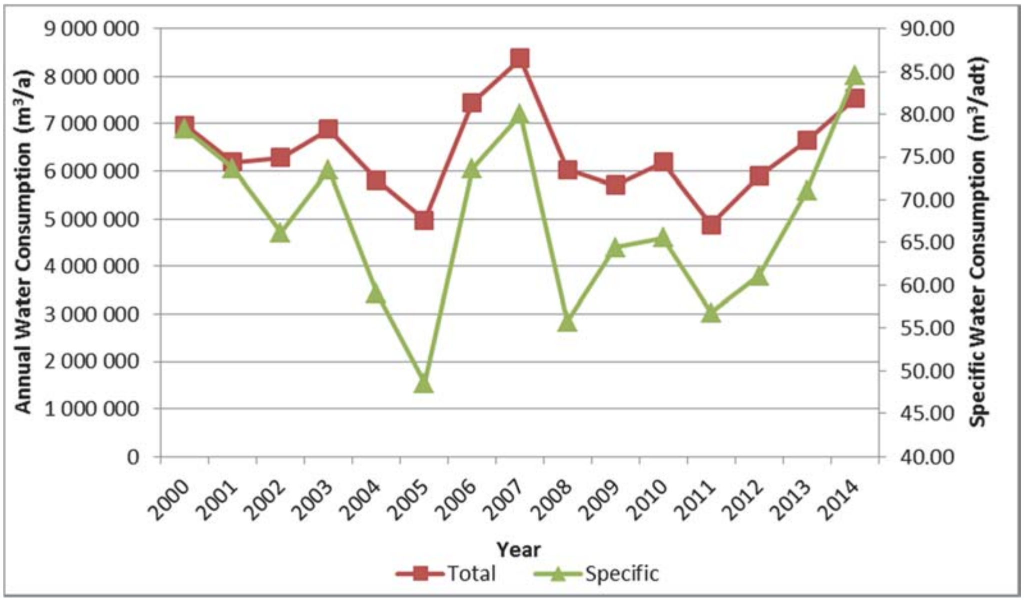



**Figure 75: Mill E Historical Specific Effluent Volumes**

The mill is in the process of applying for a new water use and effluent discharge licence. The mill will continue to strive towards reducing its environmental impact by investigating and implementing water use and effluent improvement projects as listed in 5.3.5. Future specific water intake is expected to remain similar to current levels.

### 6.2.6. Mill F

Mill F generates approx. 3 500 m$^3$/d of effluent mostly from the paper machine and power plant at a specific generation rate of 10.5 m$^3$/t product (Figure 76). The treated effluent is used for irrigation purposes.

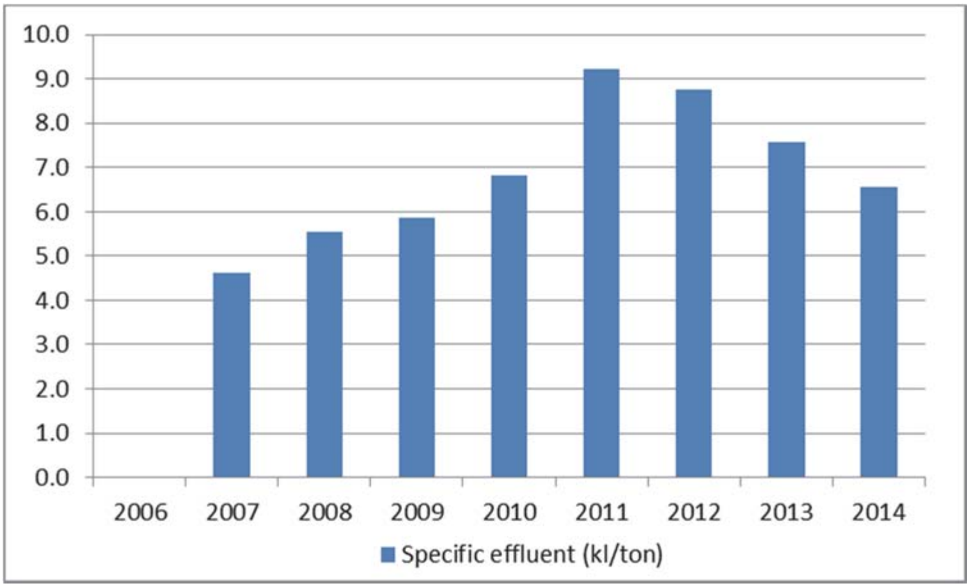



**Figure 76: Mill F Historical Specific Effluent Volumes**

Significant work was done in the 1990s to reduce effluent volumes and vastly improve quality:

- Elimination of black liquor spills to effluent,
- Attempted Reverse osmosis plant to treat effluent (failed),
- New clarifier installed,
- DAF unit installed,
- Many process optimisations.

No future effluent treatment or reduction activities are planned.

### 6.2.7. Mill G

Effluent from the tissue machines, recycled paper yard and boiler basement drains are routed to a buffer tank at the effluent treatment plant where they are combined for treatment. Re-use of the treated effluent in the process is maximised. Any overflows are sent for external treatment at the municipality. The effluent treatment plant treats between 8 600 and 11 500 $m^3$/d. The specific effluent volume is classified as intellectual property and was not released for this study.

### 6.2.8. Mill H

The main sources of effluent are the stock preparation area and the paper machine water. Some of the treated effluent is re-used and any excess treated effluent is discharged into the municipal sewer.

The site specific effluent volume is 17.6 $m^3$/t paper and the effluent re-used is 5.6 $m^3$/t product. Significant improvement of effluent quality discharge has been achieved from 1994 to 2015 regarding suspended solids, settable solids, sulphides and pH. Effluent quality standards have been as required by municipal bylaws.

The site is planning a water separation of the stock preparation and machine water circuits, with more re-use of process water internally in the mill. Therefore, less effluent will be discharged and fresh water usage will reduce.

The mill has also achieved maximum capacity regarding production and therefore future effluent discharge will not exceed current output. It is however expected to reduce as more process water is re-used.

### 6.2.9. Mill I

At Mill I effluent from the papermaking process is treated in an activated sludge effluent treatment plant. The discharge is re-used or released to the environment. Current effluent generation is at 16 400 $m^3$/d (vs. historical 31,000 $m^3$/d) and a specific effluent volume of 34.5 $m^3$/adt (vs. historical 66.8 $m^3$/adt). Refer Figure 77 for the effluent generation trend.

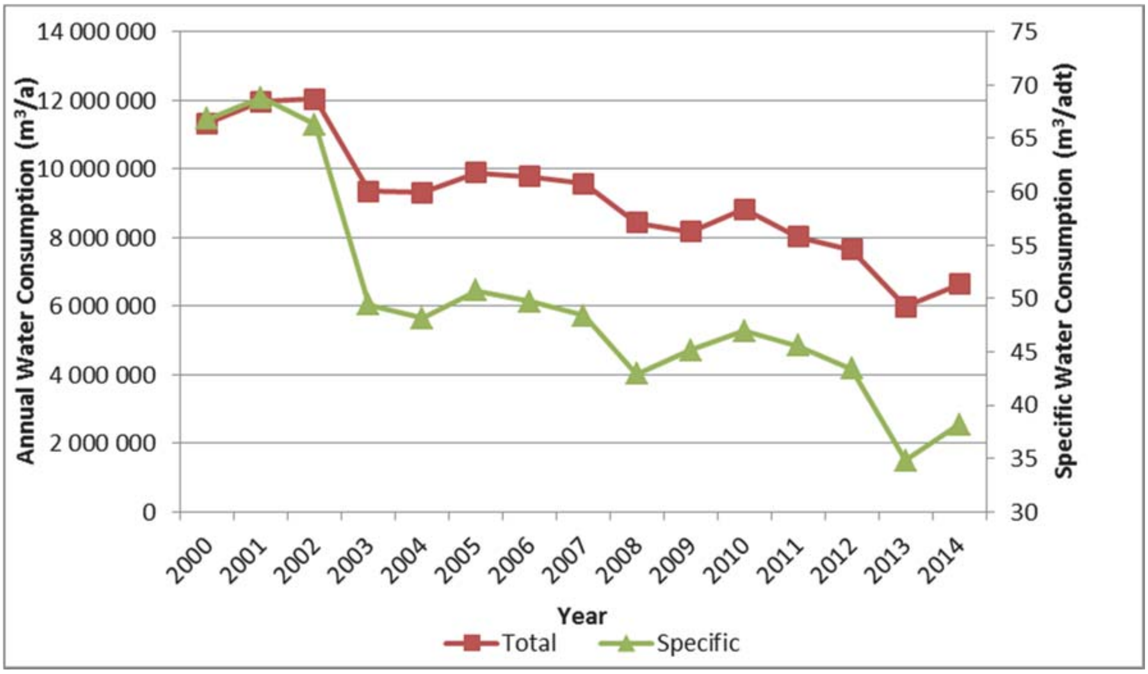



**Figure 77: Mill I Historical Specific Effluent Volumes**

Reductions in effluent generation were achieved as a result of closure of the pulp mill recycle implemented and closure of paper machine water loops.

Water consumption and effluent generation is expected to reduce further towards end 2015. Further optimisation is planned by improved water balance on the paper machine and further closure of mill loops.

### 6.2.10. Mill J

At Mill J effluent is generated at the woodyard, liquor plant, boilers, bleaching, digesters, pulp washing plants, recovery plants and pulp drying machines. The effluent streams combine before a settling pond, a surge pit, an emergency spill pond and emergency channel. The effluent is then pumped to a marine outfall. Current effluent generation is at 128 500 $m^3$/d (vs. historical 106 100 $m^3$/d) and a specific effluent volume of 64.6 $m^3$/adt (vs. historical 70.5 $m^3$/adt). Refer Figure 78 for the effluent generation trend.

Reductions in effluent generation are an indirect result of activities to reduce water abstraction as listed in par 5.3.10.

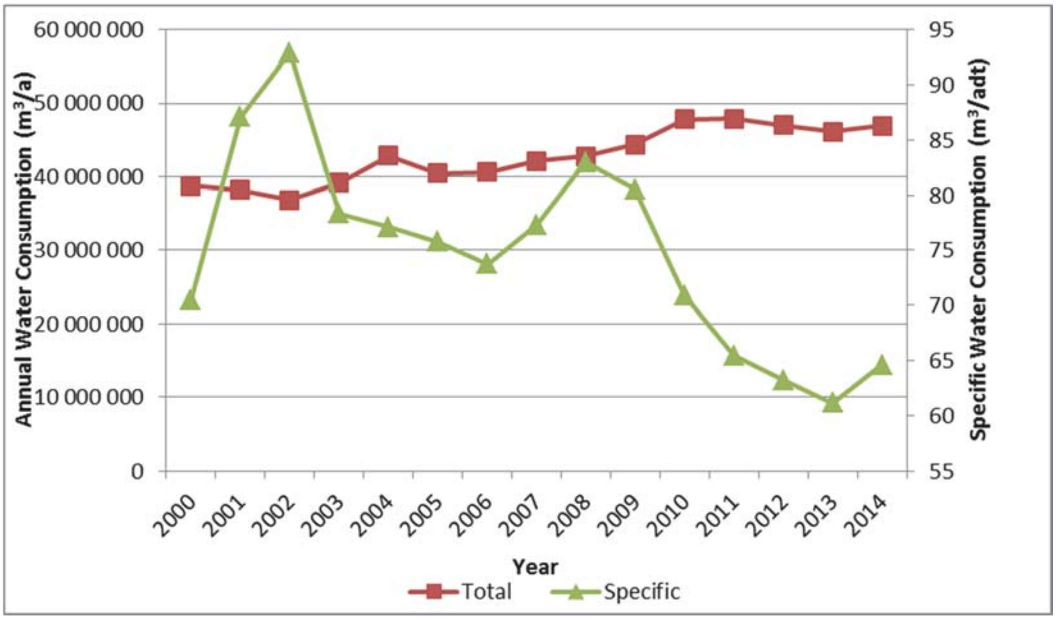



**Figure 78: Mill J Historical Specific Effluent Volumes**

### 6.2.11. Mill K

The daily effluent production for Mill K is approx. 53 900 $m^3$/d. The specific effluent volume is 26.2 $m^3$/adt. The historical effluent generation trend is reflected in Figure 79.

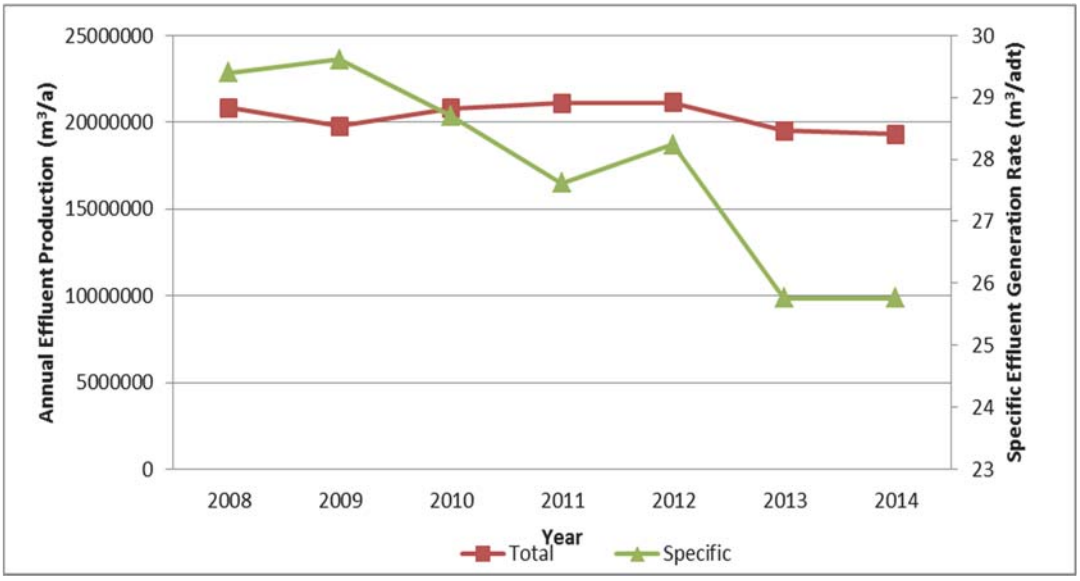



**Figure 79: Mill K Historical Effluent Volumes**

At times the acidity levels to the primary treatment are a problem, but the demineralisation plants are being upgraded to rectify this in 2015. The treated effluent is discharged into a marine outfall pipeline.

The underflow of the primary clarifiers is pumped to a sludge dewatering system that recovers the solids. The dried fibre is recycled if possible.

### 6.2.12. Mill L

Process effluent, demin waste and cooling tower blowdown (approx. 26,000 m$^3$/d) are combined and are treated on site by clarification.

The facility also treats sewage from the site and surrounding communities.

Current effluent generation is at 25 900 m$^3$/d (vs. historical 27 500 m$^3$/d) and a specific effluent volume of 18.9 m$^3$/adt (vs. historical 20.4 m$^3$/adt and higher). Refer Figure 80 for the effluent generation trend.

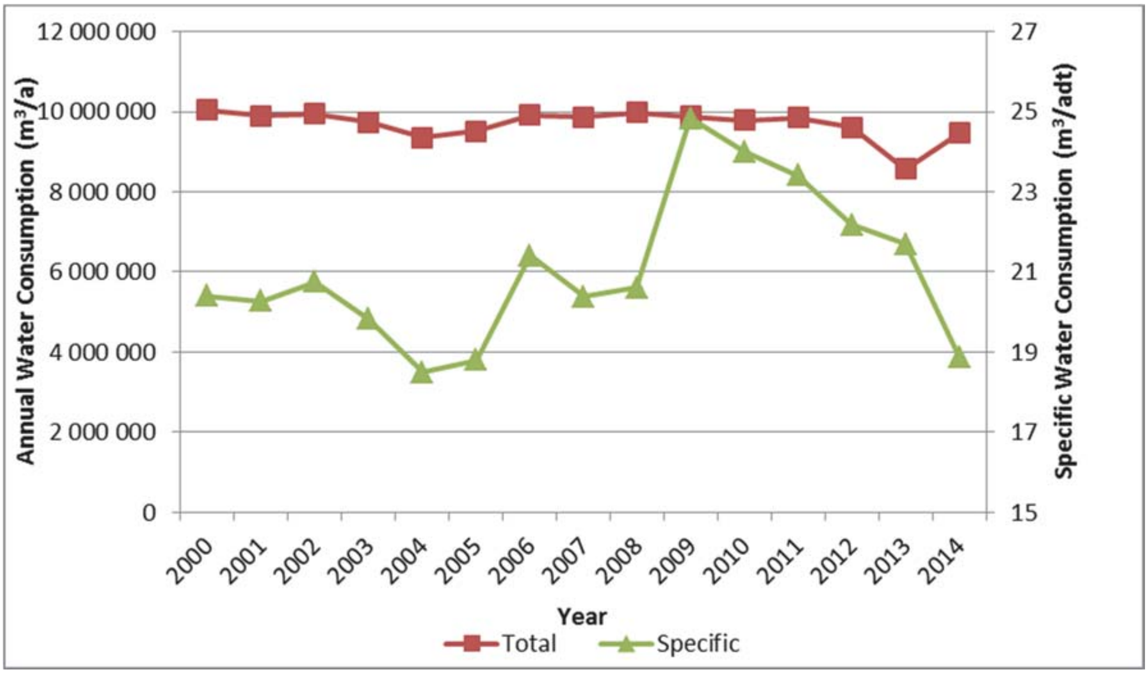



**Figure 80: Mill L Historical Specific Effluent Volumes**

Reductions in effluent generation are an indirect result of activities to reduce raw water usage as listed in par 5.3.12.

The Integrated Water and Waste Management Plan for the facility is currently being updated. The study will not only entail updating of the plan, but the consultant used must also provide guidance to the mill as water user on water and waste management.

### 6.2.13. Mill M

Recycled fibre stock preparation reject streams are the main effluent streams routed to the treatment plant (approx. 2 660 m$^3$/d). Here the water is treated to containing < 1 ppm ash and cellulose fibre.

The treated effluent is either re-used (approx. 1 650 m$^3$/d) at a typical specific rate of 24 m$^3$/adt or excess is released to the municipal sewer (approx. 970 m$^3$/d) at a specific effluent volume of 14 m$^3$/adt.

Water consumption reduction actions are expected to result in a corresponding reduction in effluent generation.

### 6.2.14. Mill N

Mill N produces approximately 5 600 m$^3$/d of effluent at a specific effluent volume of 12.0 m$^3$/t product. Historical effluent generation information is included in Figure 81. In 2011 the mill installed a clarifier at the effluent plant to improve wastewater quality and upgrade the sludge handling system.

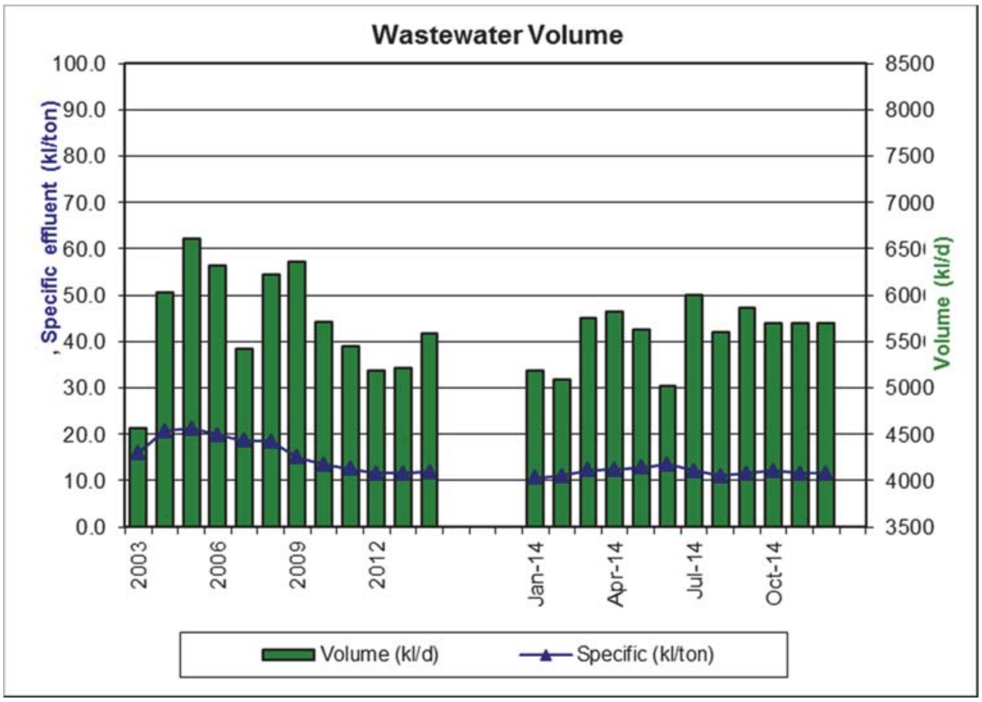



**Figure 81: Mill N Historical Effluent Production**

The excess treated effluent is released to a marine outfall pipeline. The outlet is sensitive to COD, pH, Colour and TSS, however over time these parameters have shown a continuous improvement.

The sludge produced from the treatment plant sludge is given to farmers who plough it into lands as a soil conditioner. The mill also gives about 750 dry ton per month to the informal block making industry.

The improvements are as a result of projects such as:

- Installation of belt washer and decommissioning of brown-stock washers had improved black liquor quality.
- Installation of Water and Fibre Recovery process to recover fibre loss to effluent.
- Optimisations of feedstock processing system to reduce reclamation overflow TSS.
- Installation of modern, efficient RCF pulping and screening equipment.
- Upgrade broke handling system to reduce fibre loses to effluent.
- Automation of Effluent treatment plant equipment and instrumentation.
- Regular cleaning of the emergency ponds.

Future projects planned to reduce the effluent quantities and improve quality include:

- Installation of additional sludge press to improve solid liquid separation.
- Optimization of the sludge press filtrate system.
- Optimize Clarifier efficiencies.
- The most significant impact will be achieved by elimination of virgin pulp production and this is expected to reduce TSS, COD and colour levels significantly.

### 6.2.15. Mill O

Effluent from the paper making processes is treated by DAF and clarification before being recycled for re-use with excess released to the municipal sewer system. Approx. 1 300 $m^3$/d is released at a specific effluent volume of 7.4 $m^3$/adt. Historical effluent volumes are reflected in Figure 82.

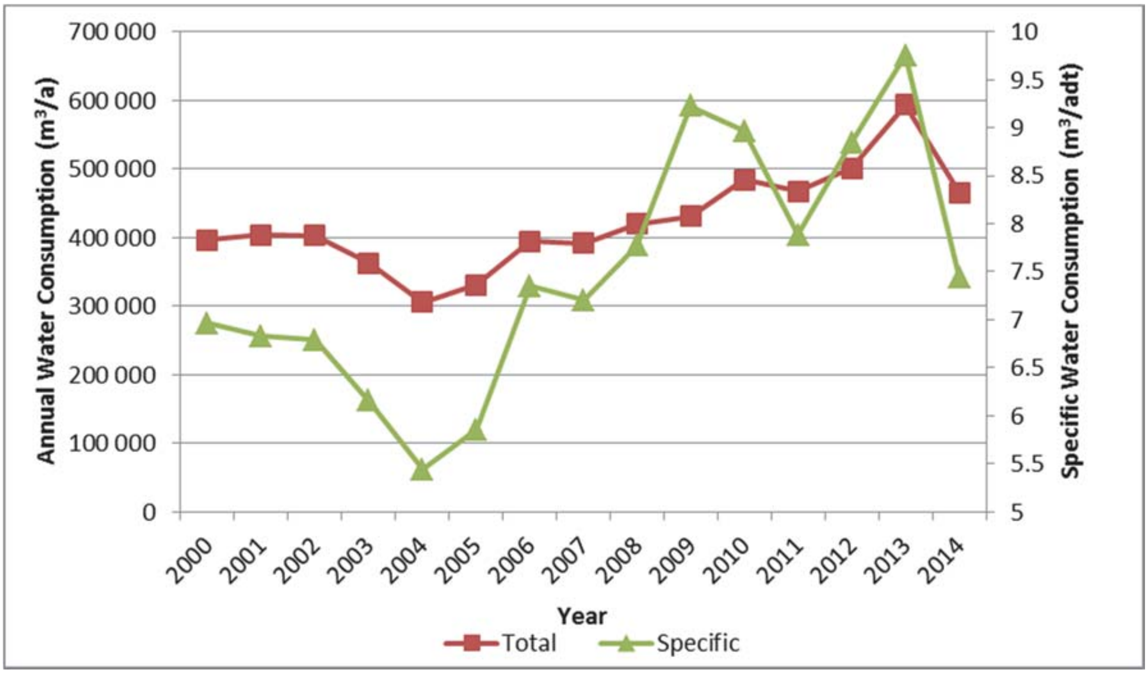



**Figure 82: Mill O Historical Specific Effluent Volumes**

Continuous improvement in effluent generation is targeted through further equipment upgrades, including improved control, replacing treated effluent with process water, improved water cleaning, possibly with a disk filter.

### 6.2.16. Mill P

Mill P currently generates approx. 11 m$^3$/t of effluent.

The mill is in the process of commissioning a newly installed effluent treatment unit that will result in water being recycled and re-used, thus resulting in a future specific effluent volume of approx. 5 m$^3$/t paper.

### 6.2.17. Mill Q

It was indicated that the effluent generated, is treated on site and treated effluent is at times used to substitute fresh water import, but no values were specified.

### 6.2.18. Mill R

Mill R did not specify any data related to effluent treatment, re-use and release.

### 6.2.19. Mill S

Mill S does perform effluent treatment and re-uses some of the effluent as processing allows. Approx. 240 m$^3$/d of effluent is generated at a specific effluent volume of 10.6 m$^3$/t paper.

### 6.2.20. Mill T

Mill T operates a closed loop system and thus produces only 0.08 m$^3$/t paper of product produced.

### 6.2.21. Mill U

Mill U does perform effluent treatment and re-uses some of the effluent in the processing steps. The mill produces approx. 1 025 m$^3$/d of effluent (9.9 m$^3$/t paper) of which 345 m$^3$/d (3.4 m$^3$/t paper) is re-used and the remaining 678 m$^3$/d (6.7 m$^3$/t paper) is released to the municipal sewer system.

Historical effluent treatment improvements include the installation of microfilters to recover fibres and upgrade the effluent to a quality suitable for re-use have resulted in a reduction of effluent by 345 m$^3$/d reducing the specific effluent volume from 9.9 m$^3$/t paper to the current levels of 6.7 m$^3$/t paper.

Future effluent treatment equipment installations are expected to reduce the specific effluent volume further by approx. 1.6 $m^3$/t paper.

### 6.2.22. Mill V

Mill V treats effluent on site and then recycles and re-uses a significant portion of this effluent to reduce fresh water intake. The mill produces approx. 7 200 $m^3$/d of effluent (30-32 $m^3$/t paper) of which 5 300 $m^3$/d (22-24 $m^3$/t paper) is re-used and the remaining 1 900 $m^3$/d (8-9 $m^3$/t paper) is released to the municipal sewer system.

Historical effluent treatment improvements have resulted in a reduction of effluent production from 2 500 $m^3$/d (11.4 $m^3$/t paper) to the current levels of 1 900 $m^3$/d (9 $m^3$/t paper).

The installation of a gravity strainer for further cleaning of process water is planned and this will result in more water being recycled and thus less fresh water imported. It is expected that 1 500 $m^3$/d (7-7.5 $m^3$/t paper) will be released after this modification.

# 7. ENERGY USE AND MANAGEMENT

Energy consumption in the Paper and Pulp sector as with almost all sectors in South Africa, has become a daily focus point as a result of the energy restrictions prevailing in South Africa.

## 7.1. Energy Intensity of Paper and Pulp Industry

According to the European Emissions Trading Scheme, the Paper and Pulp industry in Europe is classified as a high energy intensive industry (NACE 3-digit code 211)[26].

In South Africa, the Paper and Pulp sector accounts for approximately 12% of the total industrial sector energy consumption and the same fraction of coal consumption. It is a less significant consumer of electricity at approx. 7% of the sector total and the consumption of petroleum products is negligible. A significant portion (approx. 30%) of the Paper and Pulp Industry's energy demand is also provided from biomass waste, e.g. stripped bark and black liquor residue [(37)].

The use of recovered fibres can result in substantially less energy consumed when compared to virgin pulp (the BAT values for recovered fibre is 0.7-3 GJ/t compared to around 14.3 GJ/t for Kraft pulping)[27]. However, the availability of recovered paper is sometimes limited due to the levels of recycling already achieved in South Africa, causing the incremental cost for recovering recyclable paper to increase substantially[28]. The amount of energy used by paper machines is generally dependent on the pulp quality and paper grade, and it can show big variations. Integrated mills can achieve higher energy efficiency by eliminating intermediate pulp drying and using better processes[27]. World best practice energy consumption for standalone pulp mills, standalone paper mills and integrated Paper and Pulp mills is summarised in Table 40, Table 41 and Table 42 respectively.

**Table 40: World Best Practice Final and Primary Energy Intensity Values for Stand-Alone Pulp Mills[27]**

| Raw Material | Product | Process | Fuel Use for Steam (GJ/ADt) | Steam Exported (GJ/ADt) | Electricity Use (GJ/ADt) | | Electricity Produced (GJ/ADt) | | Total (GJ/ADt) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Final | Primary | Final | Primary | Final | Primary |
| Non-wood | Market Pulp | Pulping | 10.5 | -4.2 | 1.4 | 4.4 | | | 7.7 | 10.7 |
| Wood | Market Pulp | Kraft | 11.2 | | 2.3 | 7.0 | -2.4 | -7.1 | 11.1 | 11 |
| | | Sulphite | 16 | | 2.5 | 7.6 | | | 18.5 | 23.6 |
| | | Thermo-mechanical | | -1.3 | 7.9 | 23.9 | | | 6.6 | 22.6 |
| Paper | Recovered Pulp | | 0.3 | | 1.2 | 3.6 | | | 1.5 | 3.9 |

Note: Values in kWh/ADt converted to GJ/ADt for comparative purposes using 277.8 kWh = 1 GJ

**Table 41: World Best Practice Final and Primary Energy Intensity Values for Stand-Alone Paper Mills[27]**

| Raw Material | Product | Process | Fuel Use for Steam (GJ/ADt) | Electricity Use (GJ/ADt) | | Total (GJ/ADt) | |
|---|---|---|---|---|---|---|---|
| | | | | Final | Primary | Final | Primary |
| Pulp | Uncoated fine (wood free) | Paper machine | 6.7 | 2.3 | 7.0 | 9.0 | 13.7 |
| | Coated fine (wood free) | Paper machine | 7.5 | 2.9 | 8.8 | 10.4 | 16.3 |
| | Newsprint | Paper machine | 5.1 | 2.1 | 6.2 | 7.2 | 11.3 |
| | Board | Paper machine | 6.7 | 2.9 | 8.7 | 9.6 | 15.4 |
| | Kraftliner | Paper machine | 5.9 | 1.9 | 5.8 | 7.8 | 11.7 |
| | Tissue | Paper machine | 6.9 | 3.6 | 10.9 | 10.5 | 17.8 |

Note: Values in kWh/ADt converted to GJ/ADt for comparative purposes using 277.8 kWh = 1 GJ

**Table 42: World Best Practice Final and Primary Energy Intensity Values for Integrated Paper and Pulp Mills[27]**

| Raw Material | Product | Process | Fuel Use for Steam (GJ/ADt) | | Electricity Use (GJ/ADt) | | Total (GJ/ADt) | |
|---|---|---|---|---|---|---|---|---|
| | | | Final | Primary* | Final | Primary* | Final | Primary* |
| Wood | Bleached uncoated fine | Kraft | 14 | 14 | 4.3 | 13.1 | 18.3 | 27.1 |
| | Kraftliner (unbleached) and bag paper | Kraft | 14 | 14 | 3.6 | 10.9 | 17.6 | 24.9 |
| | Bleached coated fine | Sulphite | 17 | 14 | 5.4 | 10.9 | 22.4 | 24.9 |
| | Bleached uncoated fine | Sulphite | 18 | 17 | 4.3 | 16.4 | 22.3 | 33.4 |
| | Newsprint | TMP | -1.3 | 18 | 7.9 | 13.1 | 6.6 | 31.1 |
| | Magazine paper | TMP | -0.3 | -1.3 | 7.6 | 24 | 7.3 | 22.7 |
| | Board | 50% TMP | 3.5 | -0.3 | 8.3 | 22.9 | 11.8 | 22.6 |
| | Board (no de-inking) | | 8 | 3.5 | 3.2 | 25 | 11.2 | 28.6 |
| | Newsprint (de-inked) | | 4 | 8 | 3.6 | 9.8 | 7.6 | 17.8 |
| | Tissue (de-inked) | | 7 | 4 | 4.3 | 10.9 | 11.3 | 14.9 |

Note: Values in kWh/ADt converted to GJ/ADt for comparative purposes using 277.8 kWh = 1 GJ

The energy information received from the NATSURV surveys is summarised in Table 43. Most survey responses focussed on electricity consumption (either imported or generated on site) and did not include aspects such as energy for steam generation. Hence comparisons have to be made with the electricity use values reported in the tables above.

**Table 43: Specific Energy Consumption of South African Paper and Pulp Mills**

| Mill Code | Specific Energy Consumption (GJ/ADt) |
|---|---|
| 1 | IP |
| 2 | Generated Renewable: 1.6<br>Steam: 13 |
| 3 | Eskom Electricity: 2 |
| 4 | Eskom Electricity: 2.2 to 2.5 |
| 5 | Eskom Electricity: 3.7 |
| 6 | Eskom Electricity: 1.8<br>Coal to Steam: Not Specified<br>Total: 9 |
| 7 | Eskom Electricity: 5.6 |
| 8 | Eskom Electricity: 0.26<br>Renewable: 2.2 |
| 9 | Eskom Electricity: 2.2<br>Coal to Steam: Not Specified<br>Total: 11.3 |
| 10 | Eskom Electricity: 4.6 |
| 11 | Eskom Electricity: 1.7<br>Generated Renewable: 1.2<br>Total: 3.7 |
| 12 | Eskom Electricity: 3.4-5.4<br>Gas: 6.5<br>Total: 10.3 |
| 13 | Eskom Electricity: 4.9<br>Steam: 5.4<br>Gas: 1.7<br>Total: 12.0 |
| 14 | Electricity Line 1: 1.8<br>Electricity Line 2: 7.2<br>Steam: 4.2 |
| 15 | Eskom Electricity: 4.1<br>Steam: NA<br>Gas: NA<br>Total: 12.4 |
| 16 | Electricity 1.7 |
| 17 | Electricity 2.1 |
| 18 | Electricity 6.3 |

**Note: the order of sites as listed above are different to those in Table 37 and Table 38.**

As with water and effluent generation, taking a simplistic approach can result in inappropriate conclusions. From the data, the South African Paper and Pulp Industry is performing on par or better than international standards. Each site must however again be considered for its unique properties.

Most of the sites visited and interviewed highlighted that continuous improvement on energy consumption is a focus and energy consumption values are reported to management on a daily or weekly basis against target values.

Most of the companies also operate in the international market and already benchmark themselves in-house against international best practices. The use of renewable energy sources is one of the aspects considered either directly or indirectly by a number of the South African mills, if not already done.

From the nature of the Paper and Pulp Industry, the generation of renewable energy from waste products is a consideration. For sites using only or mainly recycled paper as feed this would not be an option, but where wood is pulped on site, a number of by-product streams could be considered for renewable energy generation. Economy of scale however also plays a role and thus such projects will only be viable at larger mills.

## 7.2. Effect of Load Shedding

Load shedding poses a complex problem for the Paper and Pulp Industry, not only directly due to unavailability of electricity, but also indirect impacts.

Most of the PAMSA member mills have a cooperative load shedding agreement with Eskom on a national basis in order to reduce the impact of load shedding on the overall operation. Certain high energy consuming equipment at selected mills will then be taken off-line in a planned shutdown activity when load shedding is required rather than randomly shutting down whole mills as part of load shedding. Some mills have also adjusted their operating philosophy and will operate equipment with high energy requirements only during the night when Eskom is running at off-peak capacities.

Unplanned load shedding results in secondary effects such as increased water consumption and effluent generation, as well as product and raw material wastage. This results from the fact that, if equipment goes into shutdown, it is required to first wash out the equipment to remove all residual product and then perform the start-up procedure until on-specification product is made. This can require significant quantities of water considering that paper machines (such as in Figure 83) are several meters wide and up to 100 m long per paper machine.

For the independent producers in both the tissue and packaging material sectors, load shedding results in production stoppages. Since they cannot negotiate load shedding effects based on a wider foot print such as is done by the large Paper and Pulp mills, they are far more susceptible to the effects of load shedding.

## 7.3. Energy Demand Management

Most South African Paper and Pulp mills utilise a combination of electricity, coal and heavy fuel oil as energy sources. Some of the larger mills also generate electricity on site from e.g. bark removed during the processing of logs to wood chips and recovered fibres.

**Figure 83: Following Unplanned Load Shedding Paper Machines need to be washed out before re-start**

### 7.3.1. Mill 1

The main energy supply is Eskom electricity. Coal fired boilers are used for the generation of process steam.

Electricity is used to run various equipment units and to meet lighting requirements. The mill typically consumes 6 253 MWh/month of electricity. Energy reduction programmes are being implemented and increased production contributes to lower specific consumption. Usage is managed through KPIs and the ISO 14001 system.

The total energy consumption of the mill is 59 750 GJ/month.

Energy reduction programme information is classified as intellectual property but on average the mill expects a 5% year on year reduction for as long as is possible.

### 7.3.2. Mill 2

Mill 2 is a nett energy producing facility. Energy sources used are biomass (bark), coal, Sasol gas, black liquor and some purchased energy.

All electricity requirements are produced on site and the balance of the produced energy is exported to the Eskom grid. Energy is generated by two units, namely:

- A steam turbine generating 27 MW;
- A 3rd coal fired boiler generating 48 MW.

A portion of the steam generated is extracted for process purposes and the balance is utilised for electricity generation for on-site consumption and export.

The facility has also performed a heat recovery study for the entire mill heat exchanger network and has received an ETA award in 2006 for this project.

### 7.3.3. Mill 3

Mill 3 uses mainly steam and Eskom electricity as well as small amounts of LPG & Diesel. Steam is bought in and is used for the drying of the paper in the paper machine dryer section. Electricity is used for pumps, pressure screens, cylinders and other rotating equipment. No energy is generated from waste.

Energy consumption has been improved by steam and electricity optimisation projects including implementing an improved cascade steam system.

Future potential energy saving projects include implementing a Maxiflo System, improved sizing of rotating equipment and improved maintenance of equipment.

### 7.3.4. Mill 4

Approximately 12 MW of electrical energy is imported daily.

In addition, coal is used to produce steam in 6 boilers. Some steam applications include the dry end of the paper machine, in the pulpers and for starch cooking.

There has been an observable decrease in the electricity usage (Figure 84). This is largely due to many mill improvements, projects and optimisation. Installation of new refiners in 2013/2014 has decreased the specific energy requirement. Another big contributor in 2013/2014 was the bypassing of the cleaning system on the underliner system, resulting in 1 MW of saving.


**Figure 84: Mill 4 Historical Electricity Consumption**

Future energy savings opportunities that are under investigation include consolidation of the stock preparation and the production of energy from waste. The impact of these projects has not yet been quantified.

### 7.3.5. Mill 5

The mill uses coal for steam production in boilers, and electricity from Eskom. No electricity is generated on site.

Waste to energy opportunities using on site waste are being investigated and could reduce electricity requirement.

### 7.3.6. Mill 6

The site uses imported Eskom electricity as well as fuels such as diesel, coal and heavy fuel oil. Energy is mainly consumed at the paper machine, pulp plant, RCF plant and Boiler House. Specific energy, electricity and coal consumption has decreased as a result of on-going optimisation activities as reflected in Figure 85.

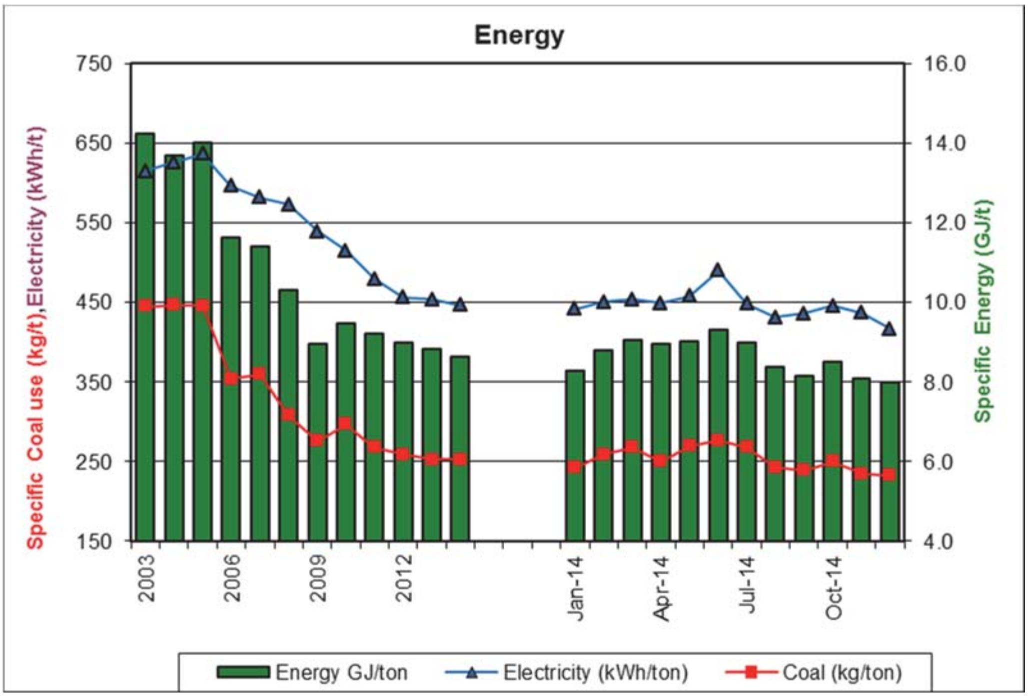



**Figure 85: Mill 6 Historical Specific Energy Consumption**

Actions already implemented include:

- Replace lighting with energy efficient lights,
- Replace electrical motors with energy efficient motors,
- Implement systems to reduce waste from air conditioners and geysers,
- Establish usage monitoring system. Install meters at strategic points,
- Air Compressors -Reduce energy loses /air leakages.

Future projects that will result in further energy optimisation results include:

- Site feedstock conversion,
- Replacement of liquid ring vacuum pumps with vacuum turbine blowers,

### 7.3.7. Mill 7

The mill currently uses electricity, coal, and heavy fuel oil and diesel in order to meets its energy requirement. Coal Fired Boilers are used to generate the required steam.

### 7.3.8. Mill 8

The mill currently uses coal to generate steam and generates electricity for its own use and export to the national grid. Bark and organic Strong Black Liquor are combusted for electricity generation. Heavy fuel oil and gas coal is also used to supplement main fuels. The mill also exports electricity to the grid.

### 7.3.9. Mill 9

Energy use is in the form of coal (for steam generation that is in turn used in the pulp digester, for drying on the paper machine and electricity generation) and in the form of electricity purchased from Eskom.

On-site electricity generation increased from 30 to 80 TJ/a while electricity purchased decreased from 330 to 290 TJ/a between 2006 and 2014 (Figure 86). In total energy consumption varied between 11.4 GJ/t and

14 GJ/t of production between 2006 and 2013 depending on electricity generation (Figure 87). In 2014 significant energy saving saw an increase in electricity generation yet with a decrease in overall energy to 11.3 GJ/ton.

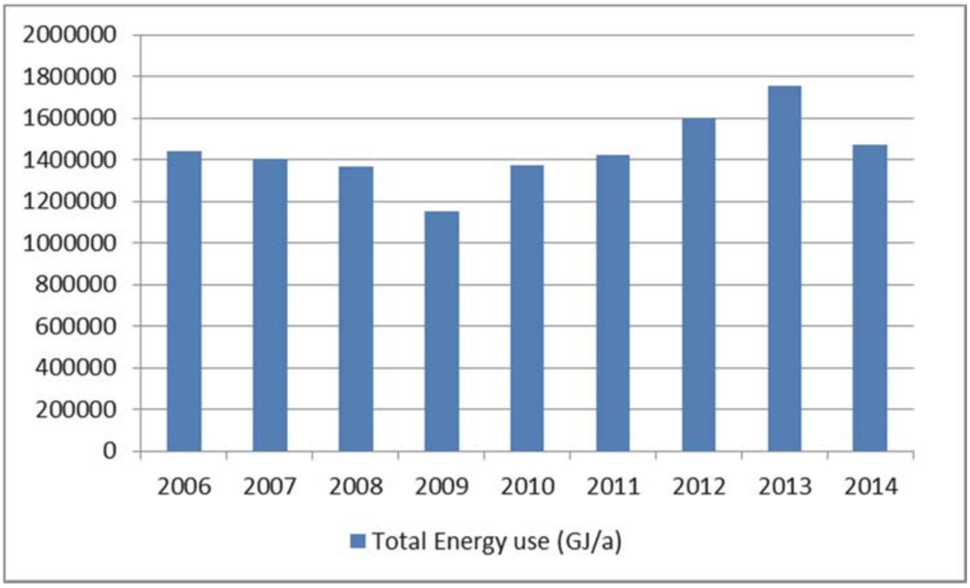



**Figure 86: Mill 9 Historical Total Energy Consumption**

Energy saving projects already implemented include:

- Installation of a second on site generator,
- Rebuild of paper machine to improve efficiency,
- Installation of variable speed drives where appropriate,
- Energy efficient lighting,
- New refiner technology installed.

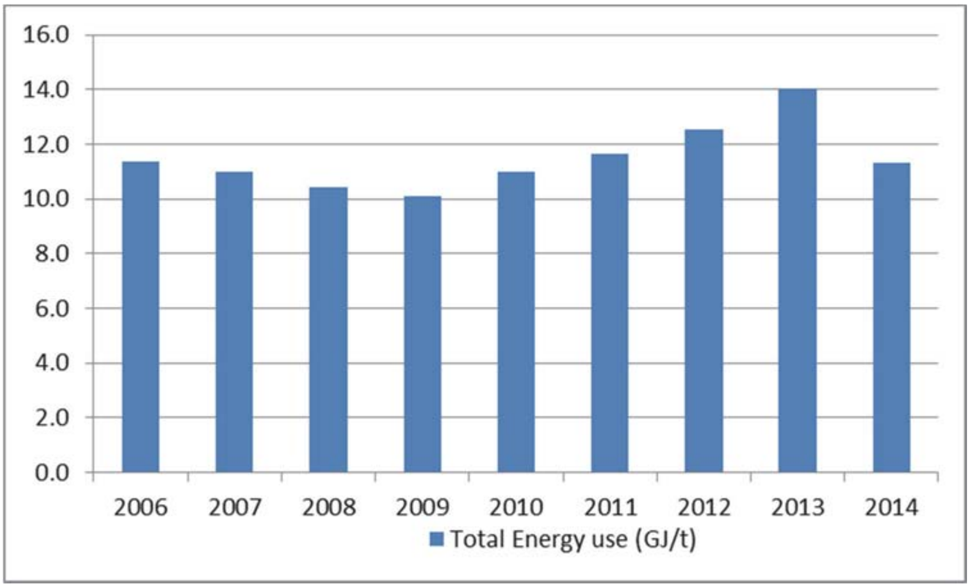



**Figure 87: Mill 9 Historical Specific Energy Consumption**

Further energy optimisation activities planned include:

- New boiler plant with turbine.
- Solar panels.
- Turbine vacuum pumps to replace liquid ring units

The intention is to reduce specific total energy consumption from the current 11.3 to 10 GJ/t.

### 7.3.10. Mill 10

The mill currently uses electricity, coal and diesel in order to meets its energy requirement. Coal Fired Boilers are used for steam generation.

### 7.3.11. Mill 11

The mill currently uses Eskom electricity, coal, heavy fuel oil, sulphur and own generated black liquor to meet its energy requirements. HFO is only used when black liquor volumes cannot sustain boiler operation for various reasons.

Black liquor is the spent cooking liquor from the pulping process which results when pulpwood is digested into pulp. The resulting black liquor is an aqueous solution of lignin residues, hemicellulose, and the inorganic chemicals used in the process. Black liquor contains more than half of the energy content of the wood fed into the digester. This black liquor is recovered and used as a fuel source in the process.

Since then focus was placed on increasing black liquor solids recovery which will resultantly reduce non-renewable energy consumption. Black liquor is used as a fuel in the recovery boilers to generate high pressure steam. The steam generated by the boilers is sent to turbines for the generation of electricity and is also used as a heating medium in the plant. The Mill is currently busy with a project that involves increasing black liquor solids recovery and processing in order to increase steaming rates on the recovery boilers which will result in a reduction in heavy fuel oil (HFO) and coal consumption as well as increased electrical power generation.

The mill is investigating the possibility to replace current Coal Fired Boilers with a Biomass or Multi-fuel boiler. In addition, the mill is investigating the feasibility of converting some of the existing Coal Fired Boilers to a combination of coal and biomass.

### 7.3.12. Mill 12

The site utilises two energy sources, namely electricity for motor drives and LPG for the boiler burner. The main energy consumers on site are the boiler, the hood burner, electrical motors.

Electricity consumption varies between 3.4 and 5.4 GJ/t for the site, while specific LPG energy represents 6.5 GJ/t for a typical total specific energy consumption of 10.3 GJ/t.

Between 2000 and 2015 a number of energy improvement projects were implemented. These include:

- Power factor panel improved from 0.92 to 0.98,
- Improved steam & boiler burner efficiency.

Thus, the total energy consumption reduced from 14.3 GJ/t to 10.3 GJ/t.

Future energy reduction plans include:

- 80% of lights are energy saver,
- 75% of pumps are variable speed drives.

### 7.3.13. Mill 13

The site utilises three energy sources, namely electricity for motor drives, steam from coal boilers to heat process water and paper machine drying cylinders and LPG to heat air for paper convection drying. Eskom electricity and steam are the main energy source at approximately 4.9 and 5.4 GJ/t respectively. Historical trends are reflected in Figure 88.

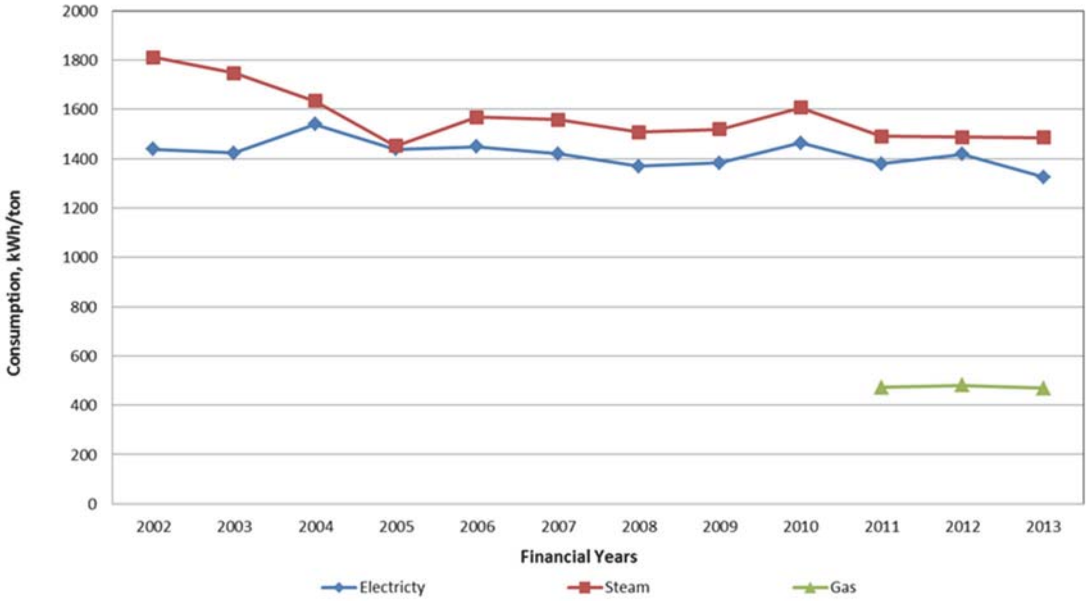



**Figure 88: Mill 13 Specific Energy Consumption**

Various optimization projects are planned, involving insulation as well as equipment and process upgrades.

### 7.3.14. Mill 14

Energy sources for Mill 14 are Eskom electricity as well as coal for steam generation and some gas. The biggest energy consumers are the paper machines, power plant and pulp mill.

Various initiatives are in place to reduce energy consumption on an on-going basis.

### 7.3.15. Mill 15

The site utilises three energy sources, namely electricity for motor drives, steam from coal boilers and LPG. The paper machine is the main energy consumer.

Approximately 4.1 GJ/t of Eskom electricity is consumed and the total specific energy consumption for the site is 12.4 GJ/t.

Energy savings have been achieved through a number of initiatives such as:

- Installed a steam box to pre-heat the sheet before drying,
- Replaced big electrical motors with energy efficient motors,
- Replaced jet aerators,
- Maximise condensate return to boilers,
- Recover heat from the gas fired hoods for re-heating incoming water,
- Recover heat from the steam system for re-heating incoming water.

Future energy consumption plans are classified as confidential.

### 7.3.16. Mill 16

Mill 16 uses a combination of electricity from Eskom and coal as energy sources. The biggest energy consumer is the Paper Machine. Eskom electricity is consumed at approximately 1.7 GJ/t.

### 7.3.17. Mill 17

Mill 17 uses a combination of electricity from Eskom and natural gas from Sasol as energy sources. The biggest energy consumers are the High Density Pulpers, Refiners and Paper Machines. Eskom electricity is consumed at approximately 2.1 GJ/t.

Various initiatives are in place to reduce energy consumption on an on-going basis.

Energy savings have been achieved through a number of initiatives such as:

- Halogen Lights in the factory has been replaced with Energy Efficient Lamps,
- Clear roof sheeting has been installed in section of the roof for natural lighting in order not to switch lights on in the factory during the day,
- Installation of efficient Siphon systems for steam and condensate on the dryers.

Future energy consumption reduction plans include:

- All electrical motors are currently being replaced with Energy Efficient Motors,
- Upgrade of the paper machine in order to run faster speed at the same energy input, thus reducing the KW/t output.

A reduction of 5% in energy consumption is targeted by these activities.

### 7.3.18. Mill 18

Energy sources for Mill 18 are Eskom electricity as well as gas. The biggest energy consumers are the drying ovens. Eskom electricity is consumed at approximately 6.1 GJ/t.

Projects have been done in the past and will be continued to increase the dewatering efficiencies as this has a positive impact on the energy requirements.

# 8. WATER USE AND EFFLUENT TREATMENT: BEST PRACTICE

## 8.1. Water Pinch Studies

All the mills visited have at some stage performed a water pinch study. Although some recommendations from these studies have been implemented, the sheer footprint of the facilities makes the required integration economically unjustifiable for many of the recommendations. In general, a process of continuous improvements has been followed as discussed in section 5 of the report.

## 8.2. Specifications and Standards

The Paper and Pulp mills comply with a number of standards and specifications that include some inherent properties driving their water use improvement. Certifications typically include:

- ISO 9001: Quality Management
- ISO 14001: Environmental Management
- OHSAS 18001: Occupational Health and Safety
- ISO 22000: Food Safety Management System (where applicable)
- Various Forest Stewardship Council (FSC) certificates ensuring that products come from well managed forests that provide environmental, social and economic benefits.

## 8.3. Storm water Management

The design of the storm water management systems as operated by the various mills is site specific based on local conditions and types of operations on site. The philosophy followed is updated with every EIA and is therefore in the public domain and with DWS. Changes to an existing storm water network is extremely complex and expensive and due to all aboveground infrastructure on an existing site very difficult to modify based on changing requirements.

A number of mills visited have dual systems which segregate the clean and the potentially polluted run-off water. Potentially polluted water is collected on site and then routed to a wastewater treatment plant. Rain water flows to an interceptor trap which operates on first flush principles where the initial run-off has a potential risk of containing contaminants and is retained and processed on site. Any run-off in excess of the first flush quantity is then clean and is released to the environment.

## 8.4. Irrigation of Effluent

A method of resource recovery that is utilised by some of the South African mills is the use of treated effluent for irrigation purposes. The soil then effectively serves as a biofilter to further purify the treated effluent prior to the water entering any water stream, unlike most sites where the water is treated microbiologically and then released to a stream or municipal sewer system.

This practise is however site- and situation specific. There is no 'one size fits all' approach. Proper research and strategy development is required. Various factors play a role in determining how irrigation can be performed at a site; these include, but are not limited to:

- Soil Properties e.g. Sodium Adsorption Ratio, pH, etc.,
- Soil Permeability,
- Water table,
- Mill processing methodology and types of contaminants in the treated effluent,
- Typical rainfall figures,
- Type of crop grown under irrigation, e.g. grass for grazing, plantations, etc.,
- Availability of sufficient area to irrigate.

Based on the interaction between the above factors a responsible irrigation strategy can be developed and irrigation can be used as a safe method to convert the effluent to a resource for further crop growth.

Once irrigation has commenced, monitoring of the soil, subsurface water and surrounding surface waters is required to verify that unacceptable levels of unabsorbed contaminants are not entering any water resource. These monitoring results are submitted to DWS on an annual basis.

## 8.5. Best Practice Application

The industry is aware that Best practices are continually evolving and that it is possible that yesterday's best practice is no longer considered as best practice today, but rather normal operating procedure. The following areas of best practice is generally applied in the industry:

**Better overall management**: refers to an integrated water management plan combined with continuous improvement initiatives (29). This seems to be the model of water use reduction management adopted by the South African Paper and Pulp Industry. Many examples have been listed in the discussions of improvements achieved and planned for the various South African mills.

**Design stage procedures**: refer to the consideration of water savings during the initial design phase of a mill or a modification at a mill. Due to the global decrease in demand for paper no new mills are being considered in South Africa and it is unlikely that a new mill will be developed in the near future. Thus, installation of new equipment as part of expansion and diversification drives is the more relevant consideration. Based on feedback received from mills regarding their expansion plans this already forms an important part of the technology selection criteria in South Africa.

**Low-cost improvements**: relates to the awareness of water savings during the execution of daily production activities. These types of activities were listed by almost all South African mills as part of the information supplied.

**Process modifications**: Relates to smaller optimisation modifications that can be performed such as more efficient shower nozzles being used, reconfiguring vacuum pump seal water systems, etc. Again, the mills in South Africa seem to be aware of these opportunities and implementing them where feasible.

**Process redesign**: refers to more capital intensive options that can show a financial return through improved fibre recovery, reduced water consumption and lower effluent treatment charges. Typical technologies proposed are filters, screens, DAF and gravity sedimentation. Most South African mills already utilise one or more of these technologies to treat their effluent and recycle it for re-use in the equipment.

**Total system closure**: As has been found by some mills, it is not viable to indefinitely close the system, since concentration of undesirable components result in off-specification product. Thus, this approach entails more advanced and costly treatment technologies such as biological treatment, membrane processes, mechanical vapour recompression, freeze crystallisation, etc. Although theoretical system closure could be achieved, the life cycle costing of implementation of these types of technologies may be prohibitive. Energy scarcity and cost will in the current South African energy scarcity scenario prohibit the use of most of these technologies. Furthermore, the final waste product from a fully closed system will be classified as a hazardous waste with disposal implications.

Biological treatment is the only technology currently utilised by some South African mills.

Based on the above the best practice for reducing the impact of the South African Paper and Pulp Industry on our water resource is by using the principles of continuous improvement to a techno-economical justifiable point as listed above. Since a single target value cannot reasonably be set for the whole industry, measurement against specific water intake reduction would be the best parameter to use. This has already been adopted and has been used by the local industry for decades and is driven by both the law as well as social responsibility pressure from shareholders. A typical example provided by one of the mills is that they set an internal sustainability goal to reduce fresh water usage by 10% by 2015 based on 2010 benchmarks. As water consumption targets are met, effluent generation rates will decrease, since there generally is a correlation between the two parameters in the Paper and Pulp Industry.

Target specific water intakes are already widely monitored and reported on a daily or weekly basis on forums at different levels on the companies' management.

**International BAT application:** SA-based mills are aware of international perspectives and techniques that can be considered in BAT application. Site specific conditions do not always render application of certain techniques feasible, whereas other BAT applications are already implemented in South Africa.

Setting the scene by European Commission in 2001[40], the Confederation of European Paper Industries has issued an implementation guide to give mill operators and environmental managers an understanding of the BAT principles [52]. The report summarises a total of 53 BATs for the different sectors of the Pulp in Paper sector, of which 18 are relevant to all sub-sectors in the industry [52]. The "Best Practice Guideline for Water and Wastewater Management in the Paper and Pulp Industry" (DWS, 2015) provides more information on the following BATs:

***General BATs for the Paper and Pulp Industry***

- BAT 1 – Environmental management system
- BAT 2 – Materials management and good housekeeping
- BAT 3 – Chelating agents from bleaching
- BAT 4 – Wood storage and preparation
- BAT 5 – Reduction of fresh water use
- BAT 6 – Energy consumption and efficiency
- BAT 7 – Emissions of odour from wastewater system
- BAT 8 – Monitoring key process parameters
- BAT 9 – Monitoring emissions to air
- BAT 10 – Monitoring emissions to water
- BAT 11 – Monitoring of diffuse total reduced sulphur emissions
- BAT 12 – Waste management
- BAT 13 – Reduce emission of nutrients (N and P)
- BAT 14 – Wastewater treatment
- BAT 15 – Tertiary wastewater treatment
- BAT 16 – Biological wastewater treatment
- BAT 17 – Emissions of noise
- BAT 18 – Decommissioning

***BATs for Kraft Pulping Process***

- BAT 19 – Wastewater and emissions to water
- BAT 20 – Reduction of emissions in strong and weak odorous gases
- BAT 21 – $SO_2$ and TRS emissions from recovery boilers
- BAT 22 – NOx-emissions from recovery boilers
- BAT 23 – Dust emissions from recovery boilers
- BAT 24 – $SO_2$ emissions from lime kilns
- BAT 25 – TRS emissions from lime kilns

- BAT 26 – $NO_X$ emissions from lime kilns:
- BAT 27 – Dust emissions from lime kilns:
- BAT 28 – Emissions from burners for strong odorous gases
- BAT 29 – Emissions of NOx from burners for strong odorous gases
- BAT 30 – Waste generation
- BAT 31 – Energy consumption
- BAT 32 – Energy efficiency

***BATs for the Sulphite Pulping Process***

- BAT 33 – Wastewater and emissions to water
- BAT 34 – Measures to reduce SO2 emissions
- BAT 35 – Measures to reduce diffuse S-emissions
- BAT 36 – Reduction of NOX emissions from recovery boilers
- BAT 37 – Reduction of dust and SO2 emissions from recovery boilers
- BAT 38 – Energy consumption
- BAT 39 – Energy efficiency

***BATs for Mechanical Pulping***

- BAT 40 – Wastewater and emissions to water
- BAT 41 – Energy consumption and efficiency

***BATs for Processing Paper for Recycling***

- BAT 42 – Materials management
- BAT 43 – Water use, wastewater flow, pollution load
- BAT 44 – Water circuit closure and increased recycling of process water
- BAT 45 – Pollution load of wastewater from the whole mill
- BAT 46 – Energy consumption and efficiency

***BATs for Papermaking***

- BAT 47 – Reduction of the generation of wastewater
- BAT 48 – Water use and emissions to water from specialty paper mills
- BAT 49 – Reduction of emission load colours and binder
- BAT 50 – Prevent and reduce the pollution load of wastewater
- BAT 51 – Emissions to air
- BAT 52 – Waste generation
- BAT 53 – Energy consumption.

## 8.6. WISA Workshop Outcomes

As part of the WISA Biennial Conference (Durban, 15-18 May 2016), a workshop entitled "Water and Effluent Management in the Iron & Steel, Paper & Pulp, Soft Drink, Metal Finishing and Dairy Industries" was held to discuss the outcomes of the various Natsurv documents updated as part of the current cycle.

This session focussed on the application of best practises as discussed above, but also on the wider South African water landscape. Consideration was also given to lessons learnt during the current drought cycle that has become much more intense than during the period of compilation of the document.

As per the best practise discussions in the previous sections, an important consideration remains the balance between water conservation and reuse vs the energy intensity of more advances effluent treatment and recovery processes.

Reference was made to both the work done by the UKZN on "Environmental Life Cycle Assessment"[55] as well as the WRC report on Cost Benefit Analysis with reference to Water Resource Development [56]. It was emphasised that, just as a pinch study for a specific site can result in improved water practices for the site, so a regional and intra-industry pinch study is also required e.g. for a catchment within which an industry is located. An example of the benefits of such a regional pinch may be that when looking at an industry in isolation, a technology for effluent recovery may be too energy intensive. However, the water resource in the specific catchment may be over allocated resulting in the need for sea water desalination to provide in drinking water requirements in the area. Thus, within the regional perspective, the effluent treatment solution may be the solution with the most beneficial Environmental Life Cycle Assessment. At the same time government, will have to support the process by providing suitable incentives for industry to act in a regionally beneficial way when selecting further effluent treatment options.

These types of regional studies could be conducted either by universities of as part of WRC sponsored studies.

The reuse of treated domestic sewage offers the closest available water resource in many residential and industrial areas. As discussed, this resource is already utilised at both the Mondi Merebank as well as the Sappi Enstra sites. The option of 'sewer mining' to recover treated sewage water at rates that do not result in a significant increase in pollutants remaining in the treated sewage released to the environment could also serve as a potential source of non-potable water for use by industry. This would further free up potable water, used by industry, for human consumption.

The severe drought in the last rainy season (summer 2015/16) has emphasised the need for good stewardship of this scarce resource and the provision of the necessary incentives to encourage such behaviour. This could then serve as a role model to mitigate the increasing risk to both water quality and water quantity, which can enable water security for a longer period.

# 9. CONCLUSIONS AND RECOMMENDATIONS

The 2nd edition of NATSURV 12 on water management in the South African Paper and Pulp Industry reflects an industry in which significant changes have occurred since the 1st edition was developed in 1990. A number of independent paper and packaging material manufacturers are now operating in the sector, contributing to a wider diversity in sites that could be included in the report. In general, the support of industry for the study was good with approximately 76% of mills providing inputs to the report. A 100% response rate was received by PAMSA members and independent packaging material mills, supported by comprehensive information to ensure the development of a document that gives an accurate reflection of the status of the industry.

The Specific Water Intake (SWI) for the 22 sites participating varied between 3.5 and 76.1 $m^3/t$. For the Paper and Pulp mills the SWI varied between 11.9 and 76.1 $m^3/t$ and for Paper mills between 3.5 and 38.8 $m^3/t$. This represented a marked decrease from the 1990 NATSURV Survey which was between 33 and 136 $m^3/t$ for Paper and Pulp Mills and between 1 and 49 $m^3/t$ for Paper mills.

The Specific Effluent Volume (SEV) generated varied between 0.08 and 84.5 $m^3/t$. For Paper and Pulp mills, SEV varied between 10.5 and 84.5 $m^3/t$ and for Paper mills between 0.08 and 38.2 $m^3/t$.

Compared to the results achieved during the compilation of the 1990 NATSURV 12: Water and Wastewater Management in the Paper and Pulp Industry report, the current SWI and SEV values reflect a marked improvement. The values are also comparing well with international reported water consumptions.

The participating companies listed a range of best practice improvements that have been implemented or are being implemented at their sites. These practices generally correspond to the recommendations made in international publications on best environmental practices in the Paper and Pulp industry. These practices are outlined in more detail in the "***Best Practice Guideline for Water and Wastewater Management in the Paper and Pulp Industry***" which has been developed in conjunction with the NATSURV 12 study. Typical recommended BAT principles include:

- Integrated water management and continuous improvement initiatives are widely used as model of water use reduction;
- Design stage procedures or modification at mills considers water savings as a criterion in its risk based technology selection
- Low-cost improvements and awareness forms part of the daily production activities
- Process modifications are seen as potential opportunities to reduce water demand and improve effluent quality where feasible.
- Process redesign refers to more capital intensive options and include for best possible technologies to treat effluent, recycle or re-use effluent in the production cycle
- Total system closure is theoretically possible, but due care is taken that it is not viable to indefinitely close the system and can result in off-specification product.

The BAT principles identified during the execution of the NATSURV study generally compare well with international recommended BAT practices for the Paper and Pulp industry. These principles are already reflected in a number of the reported improvements reported by industry.

It is recommended that continuous improvement focusing on improved SWI and SEV target continue to be used in this industry. This will require continued consideration of technologies and treatment processes to further enhance effluent reuse, reduction of water intake and the efficient use of water. This must include the principles of "Environmental Life Cycle Assessment" as well as Cost Benefit Analysis considering the catchment landscape within which a site operates.

The study concludes that the industry is extensively regulated through the application of national legislation (in particular water use authorisations), municipal trade-effluent bylaws, as well as national and international norms and standards such as ISO and SANS. The majority of case studies participating in the study have authorisations in place and reported good compliance against the requirements of their respective authorisations and agreements. Internal standards are also adopted to ensure best management practice and benchmarking with national and international peers.

Considerable use of recommended best practises for the sector has been identified during the execution of the study, but there is still room for further improvement. Continuous improvement until full uptake of best practises is recommended. Suitable incentives will however need to be provided to encourage technology selection that supports the regional interests in preventing water scarcity.

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