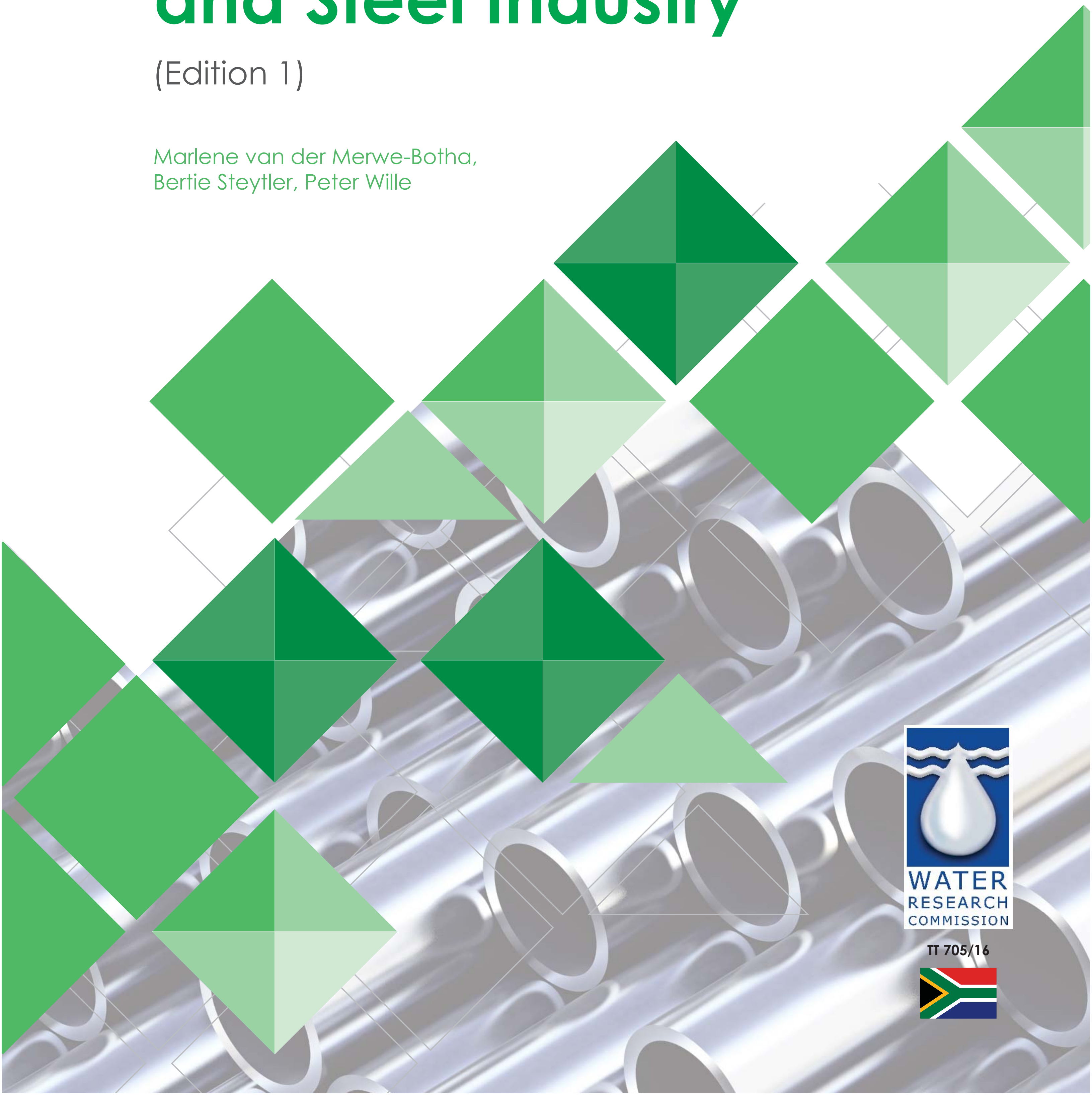
Natsurv 17:

Water and Wastewater Management in the Iron and Steel Industry

(Edition 1)

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



WATER RESEARCH COMMISSION

TT 705/16

NATSURV 17
Water and Wastewater Management in the Iron and Steel Industry
(Edition 1)

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

Report to the
Water Research Commission

by

Water Group Holdings (Pty) Ltd
Prodromos Technologies (Pty) Ltd

WRC Report No. TT 705/16
January 2017

Obtainable from

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The publication of this report emanates from a directed project entitled *Natsurv 17: Water and Wastewater Management in the Iron and Steel Industry (edition 1)* (WRC Project No. K5/2422)

ISBN 978-1-4312-0872-2
Printed in the Republic of South Africa

EXECUTIVE SUMMARY

The purpose of this NatSurv was to review the status of the South African Iron and Steel Industry with specific focus on national production capacity, specific water intake and effluent volumes, specific energy consumption rates and a best practices in the management of water and effluent. The study includes an evaluation of the most pertinent legislation that regulates the industry on national and local levels.

The research methodology included a literature survey, discussions with the regional environmental managers, site specific surveys and site visits, and processing of data and information. The findings are documented as a WRC Report and shared with industry, the regulator and the water sector as a whole. The NATSURV report can be read in conjunction with the '***Best Practice Guideline for Water and Effluent Management in the Iron and Steel Industry'***, issued by the Department of Water and Sanitation (2016).

The research confirms that there are five companies currently operating Iron and Steel mills in South Africa. One of these companies declined to participate, with the other four providing information to different levels of completeness. Due to the severe economic pressure in this sector, one of the four companies went into business rescue procedures and another entered a round of retrenchments with the result that these two companies could not provide all requested information due to limited resource availability. Thus only a limited amount of data is available for comparative purposes.

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 four sites for which data was received varied between 2.3 and 9.3 m^3/t. The Specific Effluent Volume (SEV) generated varied between 0.9 and 3.6 m^3/t.

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 floatation and evaporation. The treated effluent is discharged to the receiving environment or reused / recycled to the manufacturing process where technically feasible. The variation between water intake and effluent generation is a function of a range of factors such as age of facility, technology selection and product produced.

Since this is the first edition of the NATSURV series for Iron and Steel, there are no comparative results from previous editions.

Table i: Summary of Survey Results

	2015 Survey Results		
	N	Range	Average of N Companies
Specific Water Intake (m^3/t)	4	2.3 to 9.3	4.8
Specific effluent volume (m^3/t)	3	0.9 to 3.6	2.0
COD (mg/ℓ)	1	13	-
Cond (µS/cm)	3	81 to 3 493	1 728
Fe (mg/ℓ)	3	0.02 to 3.28	1.1
Cr (mg/ℓ)	3	0.01 to 0.14	0.06
Cl (mg/ℓ)	2	2.5 and 145	-
Na (mg/ℓ)	2	0.12 and 160	-
Mn (mg/ℓ)	2	0.03 and 1.72	-
pH	3	8.8 to 10.2	-

Note: N = Number of companies contributing data

Depending on the product range, the concentration of various heavy metals used on site are also monitored.

Comparison of Surveys:

- Of the six mills that participated, not all mills were willing to share all information requested, thus the typical sample size was three mills, with different mills supplying information for different parameters;

- Since there is no previous NATSURV survey for the Iron and Steel industry comparisons to past data could not be drawn. However at the time of compilation of the report two mills were in the process of installing and commissioning new effluent treatment facilities, and hence no treated effluent data was available for these mills;

- Mills constructed after 1990 have significantly lower SWI and SEV requirements due to the incorporation of evaporative processes to recover and re-use effluent;

- The SWI and SEV values for the two mills where new effluent treatment facilities are being commissioned will decrease from currently reported values; and

- At the older facilities significant projects are being executed to address water and effluent related restraints and to modernise the systems. Thus, further SWI and SEV improvements are expected as commissioning of the newly installed effluent treatment facilities take effect.

Energy awareness has grown in the industry, both as a result of increasing electricity costs as well as due to the detrimental effect of load shedding.

Based upon the conducted surveys, the following conclusions pertain to the South African steel industry in terms of best practice and proposed practice:

Imbed water management in good corporate governance structures: water use already forms a focus area of sustainability reporting in the South African Steel Industry.

Form a Water Management Team: various Steel Mills have teams responsible for water management and control, dictated by best practice to include a project manager, assessment task manager, engineers, maintenance staff, a financial manager and executive management representative. The committee focuses on tracking water savings, championing capital proposals, coordinate and promote inter-departmental water savings projects and staff involvement and education.

Undertake a water audit: One mill indicated that a formal water pinch study was performed. Most mills did however indicate that they either already have or are in the process of installing facilities to recover treated effluent for re-use which would indicate that some form of audit had to have been conducted to identify water streams to treat and to what quality to enable re-use. Primary effluent treatment is performed at source e.g. oil, TSS, ammonia, etc. removal. Secondary effluent treatment is mostly end-of-pipe treatment, rather than stream segregation. A water audit considers quantity and quality in order to assist in identifying applications where wastewater is directly used as water source for another process requiring a lower grade of water.

> These best practices are documented in "***Best Practice Guideline for Water and Wastewater Management in the Iron and Steel Industry***"
>
> [DWS, 2015]

Identify the major areas of water usage: The main usage is typically for cooling and process uses.

Analyse water saving options: A number of mills treat, re-use and recycle water on site, and two of the sites are also already, or in the process of, importing treated wastewater as an alternative to using potable water. The option of importing treated effluent from neighbouring industries could also provide some opportunities to reduce potable water imports. Since most South African mills are located inland, the use of sea water is not feasible, but some mills have incorporated desalination on effluent streams to enable re-use there-of. Options similar to the Durban Water Recovery facility supplying treated and disinfected sewage water to industrial areas around Durban could be evaluated by some of the steel mills. To make this financially sustainable, cooperation with neighbouring industry will probably be required.

Undertake cost benefit analyses: Effluent can in theory be recovered to a large extent at a significant cost. The international Steel Industry is in a low product value cycle, making the economy of expansion and improvement projects marginal at current prices. The availability of cheaper products from countries such as China is also putting further pressure on the local industry. Thus cost benefit analyses should be performed, but also revisited as the industry's drivers change continuously

Develop Key Performance Indicators: KPI's can be used as a tool to monitor water management performance. Total water consumption is not recommended as a measurement tool, since a larger mill may use more water but at a better efficiency. Typical parameters should rather include parameters such as specific fresh water intake per ton of steel, volume of wastewater discharged per ton of steel and % recycle achieved. It also is not practical to set a single target value for all steel mills since each mill is unique with unique factors dictating what can be achieved. A more realistic model would be to agree on continuous improvement targets set up, taking the site-specific factors into consideration.

Setting targets: Continuous improvement targets is a tool used widely in many industries to drive water consumption reduction. Targets can be both on divisional, as well as for site-wide, performance. Short- and long term targets should both be considered, where short term targets will typically focus more on day-to-day operation and maintenance improvements, whereas long term targets are project driven.

On-going monitoring, review and reporting: In order to quantify any successes achieved, sufficient monitoring is required. Targets should also be reviewed on an on-going basis. Today's best practice will eventually become tomorrow's norm with new best practices being developed. Monitoring without testing against targets is however of no value and thus setting of reasonable continuous improvement targets is recommended.

Partner with business water saving initiatives: Partnering with neighbouring industries, communities and municipalities could result in additional water re-use opportunities being realised.

The study found that the industry is extensively regulated through 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 regulator 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.

Acknowledgements

The research team would like to extend their thanks to the following people for their contributions in the compilation of the report:

- The Water Research Commission for funding the project.
- Dr Valerie Naidoo for initiation of the project, and Dr Jo Burgess for her able lead as Project Manager.
- The Project Reference Group for their guidance.
- The Department of Water and Sanitation for guidance and input in terms of the regulatory and legislative framework.
- The Water Institute of Southern Africa (WISA) for providing a platform to consult the water sector on this report and its findings.
- All Steel Industries who participated in the project and contributed through site visits, interviews and information sharing. In particular:
    - Mr K Bladwell — Evraz Highveld
    - Mr R de Valence — ArcelorMittal Newcastle
    - Ms Y Dell — SCAW Metals
    - Mr K Harilal — Evraz Highveld
    - Mr C Jordaan — Columbus Stainless
    - Ms T Oberholzer — Evraz Highveld
    - Ms M de O. Ramos Furlan — ArcelorMittal Corporate
    - Mr A Riekert — ArcelorMittal Saldanha Bay
    - Mr P Scurr — Columbus Stainless
    - Mr S Spanig — ArcelorMittal Corporate
    - Ms D van Rensburg — Cape Gate

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List of Abbreviations

AMSA	:	ArcelorMittal South Africa
ASU	:	Air Separation Unit
BFW	:	Boiler Feed Water
BOF	:	Basic Oxygen Furnace
BOS	:	Basic Oxygen Steelmaking
BP	:	Best Practice
CISCO	:	Cape Town Iron and Steel Works
COD	:	Chemical Oxygen Demand
CW	:	Cooling Water
DAF	:	Dissolved Air Flotation
DRI	:	Direct-Reduced Iron
DWS	:	Department of Water and Sanitation
EAF	:	Electric Arc Furnace
EU	:	European Union
HBI	:	Hot Briquetted Iron
IDC	:	Industrial Development Corporation
IWUL	:	Integrated Water Use License
LPG	:	Liquefied Petroleum Gas
NACE	:	Nomenclature statistique des Activités économiques dans la Communauté Européenne
RO	:	Reverse Osmosis
SA	:	South Africa
SAISI	:	South African Iron and Steel Institute
SEV	:	Specific Effluent Volume
SWI	:	Specific Water Intake
UF	:	Ultrafiltration
UK	:	United Kingdom
USA	:	United States of America
USCO	:	Union Steel Company
WRC	:	Water Research Commission
ZAR	:	South African Rand
ZED	:	Zero Effluent Discharge

1. INTRODUCTION

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

No such document has previously been prepared for the Iron and Steel Industry, and this report will form the 17th document in this NATSURV series. The document addresses the South African Iron and Steel industry and does not consider other metal processing industries such as vanadium, aluminium, manganese, zinc, etc.

1.1. Project Objectives

The aims of this project are to undertake an assessment of the South African Steel 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 Steel 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 Steel 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 by-laws 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 14 000 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 Steel Industry, the technologies, growth and changes before and after 1980, inclusive of a list of Steel 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 effluent, 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 process data processing, development 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. Effluent 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:

- Historical as available in literature
- Status quo 2015 (baseline)
- Planned – >2020 future horizon.

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

The draft report was firstly 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 20**

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

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

The draft BP-Guide is presented (in parallel to the NATSURV report) to the WRC Reference Group and DWS for input and guidance.

9. **Finalise NATSURV 20 and BPG**

The NATSURV and BP-Guide is updated towards a final draft, by incorporating any input and recommendations received from role players, and re-circulated for final perusal.

10. **Workshop at WISA 2016**

The NATSURV report is presented and distributed at the WISA Biannual Conference in May 2016.

11. **Finalise NATSURV 20 and the BPG**

Any additional recommendations from WISA, which guide this particular industry in terms of best practice, trends, growth, technology and meeting regulatory requirements by DWS, are incorporated before the report enters the final quality assurance and print process.

1.3. Site visits

The sites considered and level of visits proposed are summarised in Table 1.

Table 1: Site Visit Summary

Company	Site	Level of visit
ArcelorMittal	Vanderbijlpark	Introductory
ArcelorMittal	Newcastle	Site Visit
ArcelorMittal	Vanderbijlpark	Assessment Schedule only
ArcelorMittal	Pretoria	No longer steel mill activity at site
ArcelorMittal	Saldanha	Site Visit
ArcelorMittal	Vereeniging	Not surveyed
Columbus Stainless	Middelburg	Site Visit
Evraz Highveld	Emalahleni	Site Visit
Cape Gate	Vanderbijlpark	Intro + Assessment Schedule
Scaw Metals	Germiston	Declined to participate

1.4 Research Output

The study delivered two main outputs:

1. NATSURV 17: Water and Wastewater Management in the Iron and Steel Industry (1st Edition, 2016)

2. Best Practice Guideline for Water and Wastewater Management in the Iron and Steel Industry (2016)

2. INDUSTRY OVERVIEW

2.1. History of Steel

The history of the modern Steel Industry commenced in the late 1850's and since then steel has been fundamental to the world's industrial economy. Steelmaking was centred in Sheffield, Britain and supplied the European and the American markets. The bulk production of steel began after Henry Bessemer's development of the Bessemer converter in 1857. Prior to that steel was very expensive to produce and only used in small expensive items such as knives, swords and armour.

2.1.1. Pre 1970 Era [1]

By the 1850's, the speed, weight, and quantity of railway traffic were limited by the strength of the wrought iron rails in use. The solution was to convert to steel rails. Experience soon indicated that steel had greater strength and durability and could handle the heavier and faster engines and cars, resulting in increased demand for steel.

The growth of pig iron production in the latter half of the 19th century was dramatic in the UK (refer Table 2). The United States started from a lower base, but grew faster. Germany as well as the combined production of France, Belgium, Austria-Hungary and Russia, increased significantly just before the outbreak of World War I. During the war the demand for artillery shells and other supplies caused an increase in demand and hence production, and also a diversion to military uses.

Table 2: Production (in Mt/a) in Different Countries

Year	Great Britain	United States	Germany	France, Belgium, Austria-Hungary, Russia
1840	1.3	0.32		
1859			0.19	
1870	6.7	1.74		2.2
1871			1.56	
1913	10.4	31.5	19.3	14.1

The history of steel production in the main steel producing countries is discussed in more detail in the following sections.

Great Britain

Britain led the world's Industrial Revolution with its early commitment to coal mining, steam power, textile mills, machinery, railways, and shipbuilding. Britain's demand for iron and steel, combined with ample capital and energetic entrepreneurs, made it the world leader in steel production in the first half of the 19th century.

In 1875 Britain produced 47% of the world's pig iron and almost 40% of the steel. Almost half of the British production was exported to the United States, which was rapidly expanding its rail and industrial infrastructure. By 1896 the British share of world production had plunged to 29% for pig iron and 22.5% for steel, and little was sent to the United States.

Entrepreneurship was lacking in the 1940's and the government could not persuade the industry to upgrade its plants. A patchwork growth pattern had taken place and was inefficient compared to world competition. In 1946 the first steel development plan was put into practice by the British government to increase capacity. The "Iron and Steel Act of 1949" meant nationalization of the industry. The American Marshall Plan aid in 1948-50 reinforced these changes and provided funding for them. However, the reforms were dismantled by the Conservative governments in the 1950's. In 1967, under Labour Party control again, the industry was again nationalized. Twenty years of political manipulation had left companies such as British Steel with serious problems. By the 1970s the Labour government had its main goal to keep employment high in the declining industry. Since British Steel was a main employer in depressed regions, it had kept many mills and facilities that were operating at a loss. In the 1980's, Conservative Prime Minister Margaret Thatcher re-privatized BSC as British Steel. Under private control the company has dramatically cut its work force and undergone a radical reorganization and massive capital investment to again become competitive in the world marketplace [(3)].

Germany

Because of the availability of raw materials, coal, transport, a skilled labour force, nearby markets, and an entrepreneurial spirit, the Ruhr Valley became the centre of the German Iron and Steel Industry, often in close conjunction with coal mines. By 1850 the Ruhr had 50 ironworks with 2 813 full-time employees. The first modern furnace was built in 1849. The creation of the German Empire in 1870 gave further impetus to rapid growth, as Germany started to catch up with Britain.

The economic depression of the 1870's reduced the earnings in the German Iron and Steel Industry. The industry was forced to reorganise to adapt to conditions. As a result Germany became Europe's leading steel-producing nation in the late 19th century, thanks largely to the protection from American and British competition afforded by tariffs and cartels.

By 1913 American and German exports dominated the world steel market, with Britain in third place. German steel production peaked in 1918 during the World War I. Output plunged by 1933 when World War II broke out and under the Nazis, steel output peaked in 1940, then dipped in 1944 under Allied bombing.

West Germany rebuilt and modernized its mills after World War II. It produced 3 Mt of steel in 1947, 12 million in 1950, 34 million in 1960 and 46 million in 1970[(1)].

United States of America

From 1875 to 1920 American steel production grew from 380 000 tons to 60 Mt annually [(1)], making the United States the world leader at the time. This growth was based on solid technological foundations, but also tariff protection and the rapid expansion of urban infrastructure and other sectors, especially automobiles and household appliances that demanded steel. A key element was the easy availability of iron ore, coal, and manpower.

In 1869 iron was already a major industry, accounting for 6.6% of manufacturing employment and 7.8% of manufacturing output [(1)] with Pittsburgh as the centre of the industry. Focus was on scale of operations, and specifically in the cheap and efficient mass production of steel rails for railroad lines.

In the late 1880's, Carnegie Steel was the largest manufacturer of pig iron, steel rails, and coke in the world, with a capacity to produce approximately 2 000 tons of pig iron per day. The Carnegie Steel Company was officially launched in 1892 when all the assets of Carnegie and his associates were combined. Carnegie sold all his steel holdings in 1901 when they were merged into US Steel. In that year, it accounted for 66% of America's steel output, and almost 30% of the entire world.

The American Steel Industry grew slowly but other industries grew even faster, so that by 1967, as the downward spiral began, steel accounted for 4.4% of manufacturing employment and 4.9% of manufacturing output.

India

In 1907, Tata Iron and Steel Company was established by Dorabji Tata. By 1939 it operated the largest steel plant in the British Empire. [(1)]

Prime Minister Jawaharlal Nehru, a socialist, was of the opinion that the technological revolution in India needed maximisation of steel production. A government owned company, Hindustan Steel Limited (HSL), was formed and built three steel plants in the 1950's.

The Indian Steel Industry began expanding into Europe in the 21st century. In January 2007 India's Tata Steel made a successful $11.3 billion offer to buy European steel maker Corus Group. In 2006 Mittal Steel (based in London but with Indian management) acquired Arcelor for $34.3 billion to become the world's biggest steel maker, ArcelorMittal, with 10% of the world's production. (1)

Japan

The Steel Industry was central to the economic development of Japan. The nation's sudden transformation from feudal to modern society in the late nineteenth century, its heavy industrialisation and imperialist war ventures in 1900-1945, and the post-World War II high-economic growth, all depended on iron and steel. The other great Japanese industries, such as shipbuilding, automobiles, and industrial machinery are closely linked to steel. From 1850 to 1970, the industry increased its crude steel production from virtually nothing to 93.3 Mt. (1)

The government's activist Ministry of International Trade and Industry (MITI) played a major role in coordination. The transfer of technology from the West and the establishment of competitive firms involved far more than buying foreign hardware. MITI located steel mills and organised a domestic market; it sponsored Yawata Steel Company.

China

Communist party dictator Mao Zedong disdained the cities and put his faith in the Chinese peasantry for a Great Leap Forward. Mao saw steel production as the key to overnight economic modernisation, promising that within 15 years China's steel production would surpass that of Britain. In 1958 he decided that steel production would double within the year, using backyard steel furnaces run by inexperienced peasants. The plan was a fiasco, as the small amounts of steel produced were of very poor quality, and the diversion of resources out of agriculture produced a massive famine in 1959-61 that killed millions.

With economic reforms brought in by Deng Xiaoping, who led China from 1978 to 1992, China began to develop a modern Steel Industry by building new steel plants and recycling scrap metal from the United States and Europe. This drive eventually led to China becoming the largest country producer of steel in the world.

Steel Making Technology

The introduction of low-cost steel to the world was mainly due to the development of the Bessemer and Open-Hearth processes.

Henry Bessemer demonstrated the Bessemer process in 1856 and developed it into a commercial operation by 1864. Molten pig iron is converted to steel by blowing air through it, after it was removed from the blast furnace. The air oxidises the carbon and silicon out of the pig iron, releases heat and increases the temperature of the molten metal. By 1870, this steel was widely used for the manufacture of ship plate.

After 1890 the Bessemer process was being replaced by open-hearth steelmaking. The open-hearth process was developed in Germany and France around 1860. The typical open-hearth process became known as the Siemens-Martin process and used pig iron, ore, and scrap. It allowed better control of the steel composition and allowed a substantial quantity of scrap to be included in the charge. This process remained important for making high quality alloy steel into the 20th century (3). By 1900 the electric arc furnace was adapted to steelmaking and by the 1920's, the falling cost of electricity allowed it to largely supplant the crucible process for specialty steels.

The Basic Oxygen Steelmaking (BOS) process was developed in 1948 by Robert Durrer and commercialised in 1952-1953 by Austrian VOEST and ÖAMG. The blowing of air was replaced by the blowing of oxygen. Due to the absence of inert nitrogen (79% of air) the capital cost of the plants reduced since smaller equipment was required. Smelting time reduced and labour productivity was improved. Presently, the vast majority of steel manufactured in the world is produced using the basic oxygen furnace (BOF). In 2000, it accounted for 60% of global steel output. [(2)]

2.1.2. The Post 1970 Era

Global steel production grew enormously in the 20th century from a mere 28 million tonnes (Mt) at the beginning of the century to 781 Mt at the end. During the 20th century, the consumption of steel increased at an average annual rate of 3.3%. In 1900, the United States was producing 37% of the world's steel. With post war industrial development in Asia, that region now (at the start of the 21st century) accounts for almost 40%, with Europe (including the former Soviet Union) producing 36% and North America 14.5%. [(4)]

Generally, steel consumption increases when economies are growing, as governments invest in infrastructure and transport, and as new factories and houses are built. Economic recession typically meets with a dip in steel production as demand weakens.

The third quarter of the 20th century witnessed massive growth of the global Steel Industry. Annual production rose more than three times in 15 years from 1960. In the last quarter of the century, production reached a plateau, rising only by around 100 Mt. Increase in production gave way to increases in productivity.

After being in the focus in the developed world for more than a century, where steel is now a sunset industry, attention has shifted to the developing regions such as China, Brazil and India, as well as newly developed South Korea.

Towards the end of the 20th century, steel production was growing in the developing countries. Steel production and consumption grew steadily in China in the initial years but later it picked up momentum and the closing years of the century saw it racing ahead of the rest of the world. China produced 220.1 Mt in 2003, 272.2 Mt in 2004 and 349.36 Mt in 2005. That was much above the production in 2005 of Japan at 112.5 Mt, the USA at 93.9 Mt and Russia at 66.2 Mt.

Amongst the other new steel-producing countries, South Korea has stabilised at around 46-48 Mt, and Brazil at around 30 plus Mt.

Considering a steel consumption of 300 kg per person per year to be a fair level of economic development, India will have to come up to somewhere around 300 Mt, if it is to fulfil its ambitions of being a developed country. India was producing only around a Mt of steel at the time of its independence in 1947. By 2012, it was around 78 Mt. Steel Production in India is expected to reach 275 Mt by 2020 which could make it the second largest steel maker. [(4)]

In the developed countries, the trend is on consolidation of industry. Cross-border mergers have been taking place for several years. The focus is on technological improvements and new products.

Globally, the Steel Industry became a billion tonne industry in 2004. How much more it will grow will depend primarily on how much more steel is consumed in the developing countries.

The world Steel Industry peaked in 2007. That year, ThyssenKrupp spent $12 billion to build the two most modern mills in the world, in Alabama and Brazil. The worldwide great recession starting in 2008, however sharply lowered demand and prices fell 40%.[(4)]

During the period 1974 to 1999, the Steel Industry had drastically reduced employment all around the world by more than 1 500 000.

Table 3: Employment in the Steel Industry

Country	1974 Employment	1999 Employment
USA	521 000	153 000
Japan	459 000	208 000
Germany	232 000	78 000
UK	197 000	31 000
Brazil	118 000	59 000
South Africa	100 000	54 000

2.1.3. South Africa

A discussion about steel in South Africa would be incomplete without reference to iron ore mining and reserves.

In 2005, the South African iron ore resources were estimated at 5 370 million metric tons, the 9th largest in the world. If one includes the lower grade potential resources of the Bushveld Complex, the resource base increases to 31 770 million metric tons, which would then make the South African resources the 6th largest in the world. [5]

In South Africa, iron presents itself mostly in the form of hematite and magnetite. [5] These minerals are converted to pig iron in blast furnaces, an intermediate product for the production of steel.

Hematite, also spelled as haematite, is the mineral form of iron(III) oxide (Fe_2O_3), one of several iron oxides. Hematite crystallizes in the rhombohedral lattice system, and it has the same crystal structure as ilmenite and corundum. Hematite and ilmenite form a complete solid solution at temperatures above 950 °C. Hematite is harder than pure iron, but much more brittle. [6]

Magnetite is a mineral, one of the common naturally occurring iron oxides (chemical formula Fe_3O_4), and a member of the spinel group. Magnetite is the most magnetic of all the naturally occurring minerals on Earth. Naturally magnetized pieces of magnetite, called lodestone, will attract small pieces of iron, and this was how ancient people first noticed the property of magnetism. [7]

Small grains of magnetite occur in almost all igneous and metamorphic rocks. Magnetite is black or brownish-black with a metallic luster, has a Mohs hardness of 5-6 and a black streak. [7]

The principal deposits of iron ore of South Africa are the formations of the Transvaal Supergroup in the Northern Cape Province, which can be traced as a prominent, arcuate range of hills for some 400 km from Pomfret in the north to Prieska in the south. The most significant deposits occur in the vicinity of Postmasburg and Sishen, where high-grade hematite concentrations have been preserved in the Asbestos Hills Subgroup (~2 670 Mt at Beeshoek Mine, Sishen Mine and Welgevonden deposit – Astrup *et al.*, 1998). [5]

An additional 100 Mt is estimated to occur as hematite concentrations within the Penge Formation of the Chuniespoort Group (Transvaal Supergroup), which crop out along the northern rim of the Bushveld Complex near Thabazimbi in the Limpopo Province. [5]

The Bushveld Igneous Complex also contains approximately 26 400 Mt of iron ore resources in the form of titaniferous magnetite, titanium dioxide and vanadium pentoxide [5]

Other significant magnetite deposits are estimated to contain in the region of 2 600 Mt iron ore resources (Astrup *et al.,* 1998). These include the high-grade Palabora and Mapochs Mines (300 Mt) as well as the low-grade Zandrivierspoort, Moonlight, Cascade, Delft, De Loskop, Kraaipan Station, Kromdraai and Crocodile River deposits (2 300 Mt). [(5)]

On 1 September 1913, South Africa's first ingot of steel was tapped from the furnace of the Union Steel Company (USCO), at Vereeniging, on the Vaal River. [(8)] The USCO was founded in 1911 with the aim to produce steel from scrap iron salvaged from the railways. They built a 10 t open hearth furnace and their first order was to supply 100 t of fencing posts. [(8)]

This was the start of the SA Steel Industry, but industry and commerce were still dependent on steel imports from Europe and America. As the demand for steel grew, especially due to the gold mining sector, the need grew for South Africa to smelt its own abundant iron ore deposits. Thus other steelmakers were also formed: Dunswart Iron & Steel Works Ltd., Pretoria Iron Works Ltd., Newcastle Iron & Steel Works Co. Ltd and Transvaal Blast Furnace Co. Ltd. [(8)]

Puddled and merchant iron was first produced in 1912 in Boksburg and the company name changed to Dunswart Iron and Steel Works in 1914. [(9)]

Larger scale efforts to develop South Africa's own steel feedstock began in 1916, with the launch of the country's first ferrous ore mine in Pretoria West. The mine fed a newly constructed blast furnace, which produced approximately 4 000 tonnes of pig iron between 1918 and 1921. The believe that an Iron and Steel Industry could succeed only if it had a sufficiently large capacity resulted in the formation of the SA Iron and Steel Corporation in 1919. Meanwhile the Transvaal Blast Furnace Company was formed in 1917 to build an experimental blast furnace in Vereeniging. Shareholders included the Industrial Development Company and the chairman of Dunswart Iron and Steel. [(9)]

Newcastle became the next site of the South African Steel Industry's development, with the construction of a large-scale blast furnace starting in 1919. A new company was formed to operate the furnace, called Newcastle Iron and Steel Works. Production starts in 1926. [(9)]

After the discovery of iron ore at Thabazimbi, the African Metals Corporation (Amcor) was established near Vereeniging in 1937. They took over the Newcastle Iron and Steel Works, which was renamed Amcor Iron Works and later acquired by Iscor. [(10)]

In 1924 SCAW Metals starts operations in Johannesburg as a steel ceilings and aluminium window frames manufacturer. SCAW moves to Germiston in 1939. The sale of Scaw South Africa (Pty) Ltd. and related companies by Anglo American plc was completed on 23 November 2012. [(9)]

During the 1920's, the Union Parliament debated the need for a statutory parastatal organisation to provide not only inexpensive steel (by reducing imports) but also to create job opportunities. [(8)] Legislation was tabled in 1927 that effectively led to the founding of the South African Iron and Steel Industrial Corporation – Iscor, which was founded as a statutory parastatal the following year. [(9)] Iscor's brief in 1927 was to establish a fully integrated steelworks, west of Pretoria, which became a reality on the 4th April 1934, when the first steel was tapped from the open hearth furnace. [(8)]

In 1929, Cape Gate Fence & Wire Works (Pty) Limited was founded in Parow, Western Province as a wire netting manufacturer. [(9)] Cape Gate (Pty) Limited was established in 1962 by the purchase of a wire netting plant on 15 hectares in Vanderbijlpark, Gauteng Province. [(9)] The Sharon Wire Mill division was established in 1967 to produce uncoated and galvanized wire, welded mesh, diamond mesh, barbed wire, field fence and other products. In 1975, the Davsteel division of Cape Gate was established, and rolling mills for the production of wire rod, re-bar and rounds were commissioned in Vanderbijlpark. An EAF melt shop consisting of a 45 tonne electric arc furnace, casting machine and associated plant for steel manufacturing was commissioned in 1980. [9] The Oren Wire division, to produce specialist wire products, was established the year thereafter. [9]

Back to the late 1930's, wartime needs for steel and the local manufacture of numerous necessities brought about a sharp increase in demand. Iscor had to expand, and the Pretoria works had reached their limit of growth. [10] For the immediate war needs it was decided in 1941 to begin building a plate rolling mill near Vereeniging, planned in such a way that it could later form part of a large integrated steelworks. Iscor commissioned a heavy plate mill at Vanderbijlpark in 1943. [10]

Directly after World War II, it was decided to build a fully integrated steel works at Vanderbijlpark, and a start was made on this early in 1947. Iscor established the green field integrated steel works and flat products mill in Vanderbijlpark completing the first phase in 1953. Major expansions followed during 1964 to 1969 and during 1973 to 1977. [10]

In 1957, Minerals Engineering of Colorado opened a plant in Witbank designed to produce vanadium pentoxide. In November 1959 Anglo American Corporation of South Africa acquired a two-third share in Minerals Engineering and in August 1960 the company's name was changed to Transvaal Vanadium Company (Pty) Ltd. The Highveld Development Company Limited was established on 19 May 1960 to investigate the viability of processing titaniferous magnetite ore for the production of liquid pig iron and vanadium-bearing slag. [9]

In November 1964 the Highveld Development Company embarked on a programme to build an integrated iron and steel works near Witbank. The name of the Highveld Development Company Limited was changed to Highveld Steel and Vanadium Corporation Limited on 11 June 1965. Following the acquisition of the remaining shareholding of Transvaal Vanadium Company (Pty) Ltd, this company, in August 1966, became a division of Highveld, the largest vanadium producer in the world. [9]

Highveld Steel acquired 65 % of Transalloys (Pty) Ltd in 1976, and the remaining interest in 1985 and Transalloys operated as a division of Highveld, producing manganese alloys. In 1978, Highveld Steel acquired the total issued share capital of Rand Carbide Limited, which was founded in 1918 in Germiston. The plant moved to Witbank in 1926 and Rand Carbide operated as a division of Highveld, producing ferrosilicon and various carbonaceous products. In 1985, the group acquired Rheem South Africa (Pty) Ltd, a company involved in the manufacture of drums, pails and crown closures. It operated as a division of Highveld until the various parts were sold by early 2003. [9]

In 1991, Highveld Steel expanded its activities into stainless steel with the acquisition of the stainless steel operation of Middelburg Steel & Alloys (Pty) Ltd in partnership with Samancor Limited resulting in the formation of the Columbus Joint Venture. [9] Between 2005 and 2010 the shareholding in Highveld Steel changed a number of times and became Evraz Highveld Steel and Vanadium Limited.

In 1993, Highveld and Samancor each sold a one-sixth share of the Columbus Joint Venture to the Industrial Development Corporation. [9] Acerinox of Spain acquired a 64% stake in Columbus Stainless with effect from 1 January 2002 from the three founding partners of Columbus, i.e. Highveld Steel, Samancor and the IDC. In 2005, Highveld Steel disposed of all its shareholding in Columbus and Acerinox. [9]

Iscor went through a relatively quiet period until the major expansion of its Vanderbijlpark works from 1964 to 1969, when a second development phase started at Vanderbijlpark Works. Large extensions were added; older plants modernised to supply higher quality and value-added products such as electrolytic tinplate for the canning and beverage industries. [10]

On 17 May 1969 the South African Government decided that Iscor's third fully integrated steelworks be erected at Newcastle. The main factor leading to this selection was to decentralise industry away from the Witwatersrand complex and to promote industrial development in Natal, the best watered province of South Africa. Iscor starts erecting an integrated steel works and long products mill at Newcastle in 1971, and the blast furnace produces first iron in 1976. As part of this initiative, Iscor took ownership of the Amcor Works in Newcastle, to be referred to as the South Works. (10)

In 1973, Iscor took ownership of Cape Town Iron and Steel Works (CISCO). The Cape Town Iron and Steel Works (Pty) Ltd was established in 1965. In 1995, CISCO formed a JV with Reinforcing Steel Contractors, known as RSH. Murray & Roberts Limited acquired full ownership of CISCO in 1999. Murray & Roberts disposed of CISCO in September 2012 to DHT Holding, a Turkish investment group. CISCO had been placed on care and maintenance in 2010. (9)

The world Steel Industry entered a crisis period during the end of the 1970's and early 1980's with the global recession which occurred at that time. South Africa did not escape this recession and the local demand for steel fell as a result. A world oversupply situation occurred in the steel market with export prices falling to uneconomic levels. (10)

During 1982 Iscor was forced into the early closure of the two oldest blast furnaces at Pretoria Works, as well as the closure of the South Works at Newcastle which had been taken over from Amcor. (10)

In 1988, the first commercial Corex unit in the world was commissioned at Iscor Pretoria. In the following year, Iscor privatised and listed on the Johannesburg Securities Exchange on 8 November 1989. (10)

Iscor Pretoria works is upgraded to produce stainless steel in 1994, only to be decommissioned in 1998. (10)

Construction of the Saldanha Steel plant, a joint venture between Iscor and the IDC, commenced. The plant was commissioned in 1999. (9) Iscor acquired the IDC's 50% shareholding in Saldanha Steel and fully integrated Saldanha Steel into Iscor's flat steel products division from April 2002. (10)

Iscor transferred its mining companies and businesses to Kumba Resources Limited, except for a portion of the mineral rights at Sishen mine entitling it to delivery of 6.25 Mtpa of iron ore. (9)

LNM acquired more than 51% of Iscor Ltd and the LNM subsidiary's name was changed to Ispat Iscor Limited from September 2004. On 14 March 2005, Ispat Iscor Limited was officially renamed Mittal Steel South Africa Limited. This development followed the December 2004 merger of Ispat International and LNM Holdings, the parent company, to form Mittal Steel Company N.V. Following the merger between Arcelor and Mittal Steel to form the world's largest steel company in 2007, formerly Mittal Steel South Africa Limited is known as ArcelorMittal South Africa Limited. (9)

2.2. Steel Production around the world

All figures quoted in this and the following section are based on the World Steel Association report "World Steel in Figures 2013" (12) and also it's "Steel Statistical Yearbook 2014" (13), unless otherwise indicated.

Figure 1 shows the growth in crude steel production worldwide, from just below 200 Mt in 1950, up to 1 547 million in 2012.

In 2002, the world steel production was 905 Mt. Crude steel production thus increased by 642 Mt per annum. The growth in China alone over this period was 723 Mt. This means the steep growth on the right hand side of the curve is due to growth in China. The balance of the world actually showed an aggregate reduction in steel production.

It is also interesting to note how this production is shared amongst the steel producing companies as listed in Table 4. Both ArcelorMittal (ranked 1) and Evraz Group (ranked 19) have operations in South Africa.

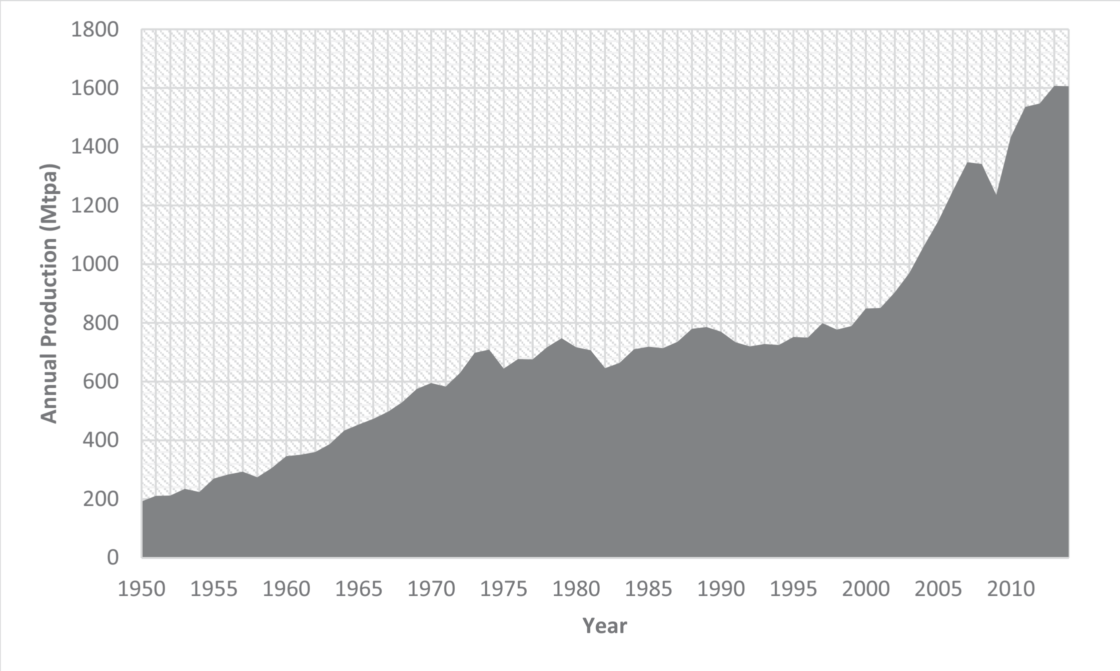


Figure 1: World Steel Production 1950-2014 (13)

Table 4: Steel Production per Organisation (14)

Rank	Company	Tonnage (millions)	Rank	Company	Tonnage (millions)
1	ArcelorMittal	93.6	26	IMIDRO	13.6
2	Nippon Steel & Sumitomo Metal Corporation	47.9	27	SAIL	13.5
3	Hebei Group	42.8	28	Rizhao	13.2
4	Baosteel Group	42.7	29	MMK	13.0
5	POSCO	39.9	30	China Steel Corp.	12.7
6	Wuhan Group	36.4	31	Metinvest	12.5
7	Shagang Group	32.3	32	Baotou	10.2
8	Shougang Group	31.4	33	Taiyuan	10.1
9	JFE	30. 4	33	Jiuquan	10.1
10	Ansteel Group	30.2	35	Pingxiang	9.1
11	Shandong Group	23.0	35	Zongheng	9.1
11	Tata Steel	23.0	35	Jinxi	9.1
13	U. S. Steel	21.4	38	Techint Group	8.7
14	Nucor	20.1	38	Xinyu	8.7
15	Gerdau	19.8	40	ISD	8.5
16	Maanshan	17.3	40	JSW Steel	8.5
17	Hyundai Steel	17.1	42	Guofeng	8.0
18	RIVA Group	16.0	43	Ereğli Demirve Çelik Fabrikalari TAS	7.9
19	Evraz Group	15.9	44	Anyang	7.7
20	Severstal	15.1	45	CELSA Group	7.6
20	ThyssenKrupp	15.1	45	Zenith	7.6
20	Benxi Steel	15.1	47	Voestalpine	7.5

23	NLMK	14.9	48	Jingye	7.3
24	Valin Group	14.1	49	Nanjing	7.2
25	Jianlong Group	13.8	49	Usiminas	7.2

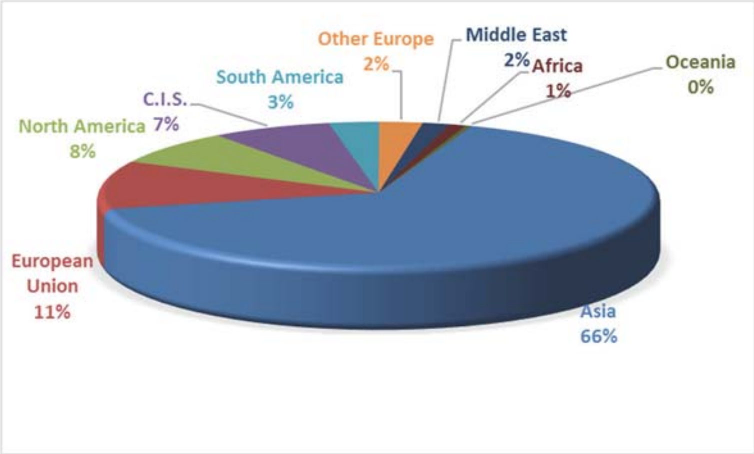


Figure 2: Steel Production per Region

From the above regional breakdown of world production (Figure 2), it can be seen that production in Africa is only 1% of the world steel production.

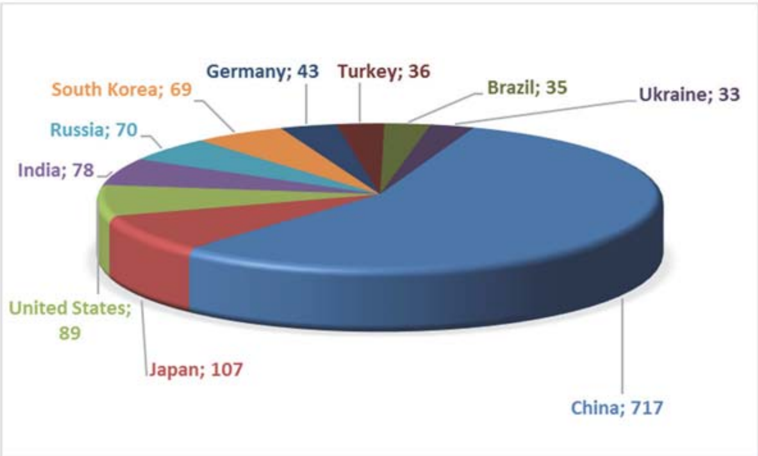


Figure 3: Top Ten Steel Producing Countries

Figure 3 shows the distribution of the ten top producing countries in the world. China dominates the production scene. However, if we limit our evaluation to Africa (Figure 4), it can be seen that African production is dominated largely by South Africa and Egypt. South Africa, with a total production of 6.9 Mt in 2012 was ranked 22nd in the world, down from 7.5 Mt in 2011 and a ranking of 21st.

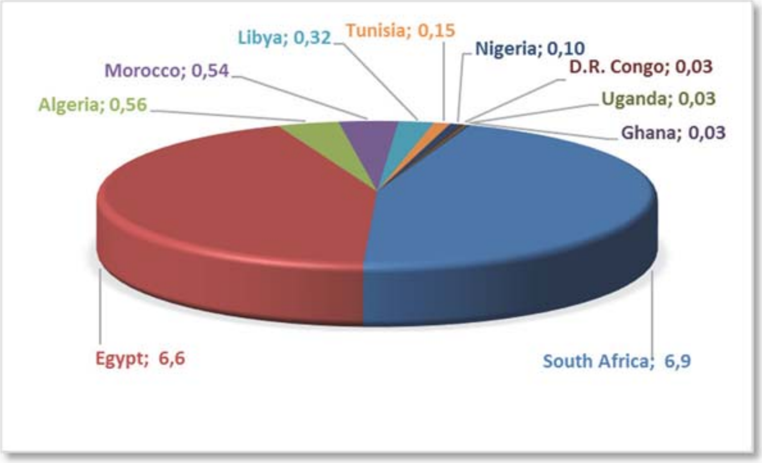


Figure 4: Top African Steel Producing Countries

2.3. Current Steel Production in South Africa

Current South African steel production figures are summarised in Table 5.

Table 5: Capacity of Steel Producing Organisations in RSA

Entity	Capacity (Mt/a)	Percentage
ArcelorMittal Vanderbijlpark	3.2	66.7
ArcelorMittal Vereeniging	0.4	
ArcelorMittal Saldanha	1.3	
ArcelorMittal Newcastle	1.9	
Evraz Highveld	1.0	9.8
SCAW	0.5	4.9
Columbus Stainless	1.0	9.8
Cape Gate	0.5	4.9
CISCO	0.4	3.9
TOTAL	10.2	100.0

* Data from company websites and Cisco from Engineering News Mar 20, 2013

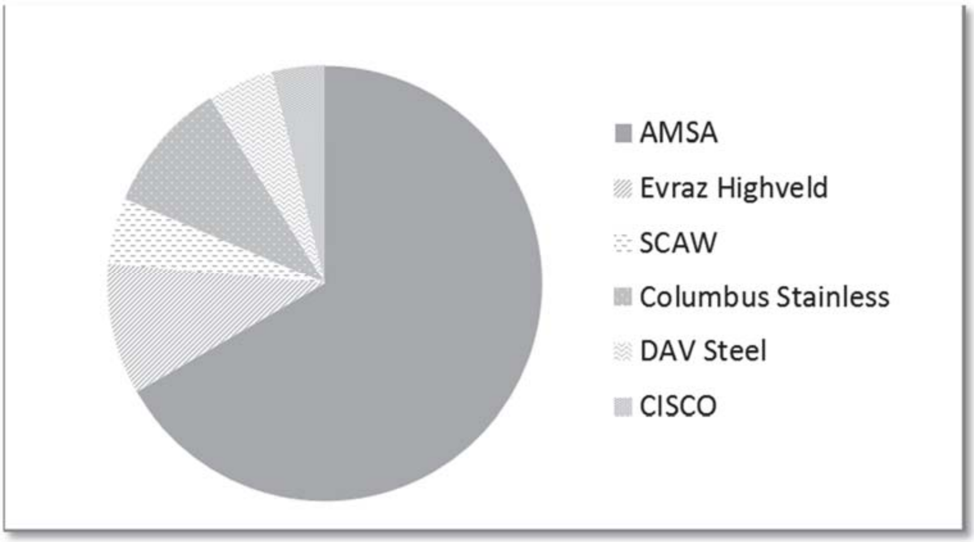


Figure 5: Contribution to Potential National Steel Production Capacity

ArcelorMittal has two thirds of the country's crude steel production capacity. No other company has more than 10% of the overall capacity, showing ArcelorMittal's dominance of the industry in South Africa.

Although Cisco is not currently operational, the potential production capacity from this site is included in the data.

As can be seen from Figure 6, South African production has been significantly under capacity from 2007 onwards.

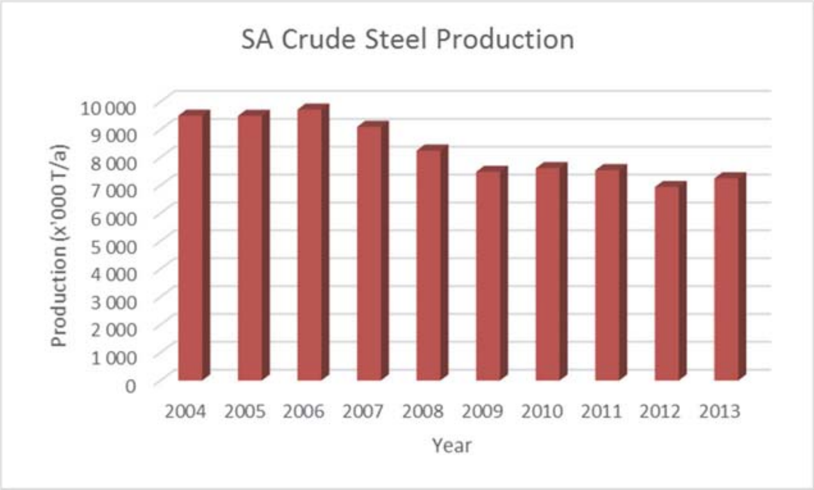


Figure 6: South African Steel Production

The South African Steel Industry made significant contributions to the economy in 2008, contributing R12.7 bn in GDP (0.6%) and R4.0 bn to the fiscus. However, the Steel Industry lost approximately 5000 jobs between 2002 and 2008, having directly employed approximately 12 800 people in 2008, down from 18 400 people in 2002. [14]

2.4. Water Consumption in the Industry

Most of the water used in the Iron and Steel Industry is used for cooling (CW), to protect equipment and to improve the working conditions of the employees. A smaller, but still considerable, amount of water is used as process water to cleanse coke-oven gases, quench coke and slag, and descale steel (in this report, water used to descale steel is classed as cooling water). A small amount of water is used for boiler feed water (BFW) and for sanitary and service water.

Walling *et al*.[15] reported on a survey performed on 29 steel plants in the USA in 1957 and 1958. These plants withdrew from various sources about 5.3 billion m^3 of water annually and produced 40.8 Mt of steel. This is equivalent to 130 m^3/t of steel. About 40% of this was required for the blast furnace.

About 97% of the water used in the steel plants came from surface sources, 2.2% was reclaimed sewage, and 1.2% was ground water. Steel plants supplied about 96% of their own water requirements.[15]

Gross water use varied significantly. In integrated steel plants (plants that begin with iron ore and produce a rolled or cast product) it ranged from 42 to 416 m^3 per ton of steel, and in steel processing plants (plants that begin with pig iron or scrap and produce a rolled or cast product) it ranged from 16 to 101 m^3 per ton.[15]

Consumption by a typical integrated steel plant was 2.6 m^3 per ton of steel, about 1% of the gross water use. Consumption by a typical steel processing plant was 2.4 m^3 per ton, about 3.2% of the gross water use. The balance of the water typically reported as effluent.[15]

Water reuse also varied widely. Availability of water seemed to be the principal factor in determining the rate of reuse.[15]

A world survey of steel mills showed that the spread of figures ranged from 1 to over 148 m^3/t crude steel for water input and from <<1 to 145 m^3/t for water discharge. Different steel mills use hugely different quantities of water, depending on access to water, mostly determined by geography, and by local regulations.(16)

Table 6: Typical Water Use per Product (17)

Commodity	Water Use (litre)
1 beverage can	3
1 kg of PVC	550
1 kg dyed yarn	2 500
1 cotton jeans	8 000
1 ton of steel	20 000
1 PC	30 000
1 t petrol	70 000
1 t of pulp	550 000
1 ton of paper	500 000 to 1 500 000
1 car avg	380 000

From the above, it appears that 20 m^3/t steel is regarded as a norm in industry.

Data published by Salzgitter AG indicated that their intake water consumption varied between 3.5 and 4.9 m^3/t crude steel production in the years 2007 to 2011.(18)

In 2008, ArcelorMittal Vanderbijlpark produced 3.227 Mt steel and abstracted 8 928 000 m^3 of water, giving a water use of 2.77 m^3/t steel. At the same time, the use in Saldanha was 1.95 m^3/t, the use in Newcastle was 4.64 m^3/t and in Vereeniging 2.48 m^3/t.(19)

While steelmakers require approximately 284 m^3 of water to produce one ton of steel, that number includes water that has been recycled, and process and cooling water that has been reused. Typically, more than 95% of the water used in steelmaking is recycled. Due mainly to evaporation losses, steelmakers require 49-87 m^3 of additional water per ton of product through all stages of production.(20)

2.5. Effluent production

No relevant published data could be found in terms of effluent production.

2.6. Iron Making Processes

At steel plants, iron ore is reduced to iron and processed into useful steel products, and scrap steel is reprocessed into new products. Integrated steel plants consist of blast furnaces, one or more units for making steel from iron (open- hearth furnace, electric arc furnace, or basic oxygen furnace), and a rolling mill or casting unit. An integrated plant may include coke ovens, wire- drawing machines, rod mills, and other iron working units.

This section focuses on the iron making processes. The steel making processes are dealt with in the next section.

The majority of pig iron production in South Africa is via the Blast Furnace process (Figure 7). This process requires coke. Coking plants are described first, followed by a description of the blast furnace process, after which the other processes are dealt with.

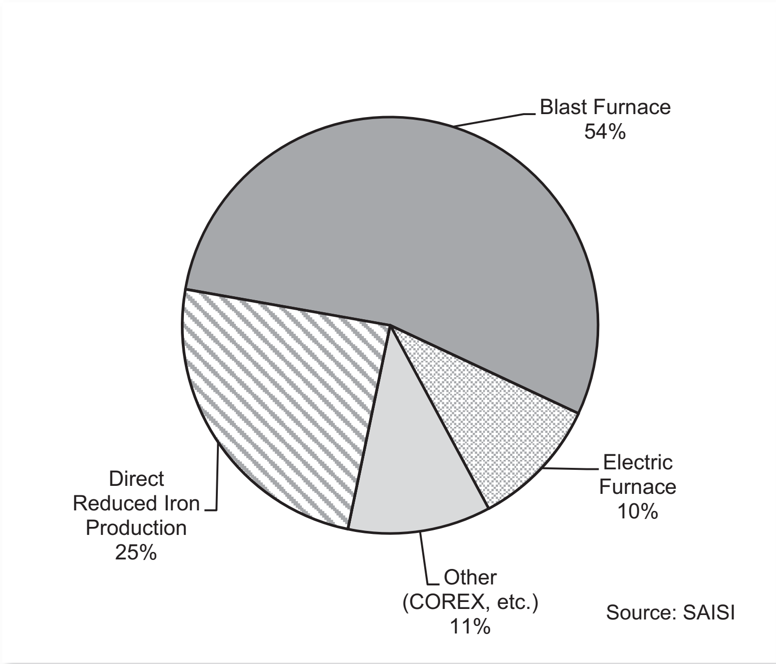


Figure 7: SA Iron Production per Process – 2012 (21)

2.6.1. Coking Plants

The cokemaking process involves carbonization of coal to high temperatures (1100°C) in an oxygen deficient atmosphere in order to concentrate the carbon(37). This process leaves only carbon and ash in the coke (coke from the ovens contains 1-3% volatile matter).

The blended coal is charged into a number of slot type ovens wherein each oven shares a common heating flue with the adjacent oven. Coal is carbonized in a reducing atmosphere and the off-gas is collected and sent to the by-product plant where various by-products are recovered. Hence, this process is called by-product cokemaking(37). The gas evolved from the coke ovens contains several useful chemicals such as ammonia and benzene and a low percentage of fuel gases. Processing of coke-oven gas consists of cooling to condense water vapour and tars, absorption of ammonia in an acid solution, and scrubbing the gas to remove light oils (benzol, solvent naphtha, and other products).

After the volatiles have been expelled, the coke is pushed into a car and as quickly as possible is moved to a quenching tower to be cooled by a spray. Quenching reduces the temperature to less than the combustion temperature, but enough heat is left in the coke to assure a low moisture content. Water for coke quenching, often including excess ammonia liquor from the gas coolers, commonly is circulated through the quenching tower until completely evaporated.(15)

Figure 8:Coke Oven Discharge before Quenching (22)

2.6.2. Blast Furnace

In the reduction of iron ore to iron, iron ore, coke, and a fluxing agent (limestone or dolomite) are charged into the top of the blast furnace while hot air is blown in through tuyeres near the bottom.

Coke provides both the fuel for heating the reactants to reaction temperature and the reducing agent for the reduction of iron oxide to iron. [15]

Molten iron, being heavier than the other products, collects in the hearth from which it is periodically withdrawn; it is transferred to the steel plant (open-hearth, electric or basic oxygen furnace) or is cast into pigs. The fluxing agent fuses and forms a slag on top of the iron and dissolves many impurities that would otherwise contaminate the iron. The slag is periodically withdrawn and is sometimes quenched with water.

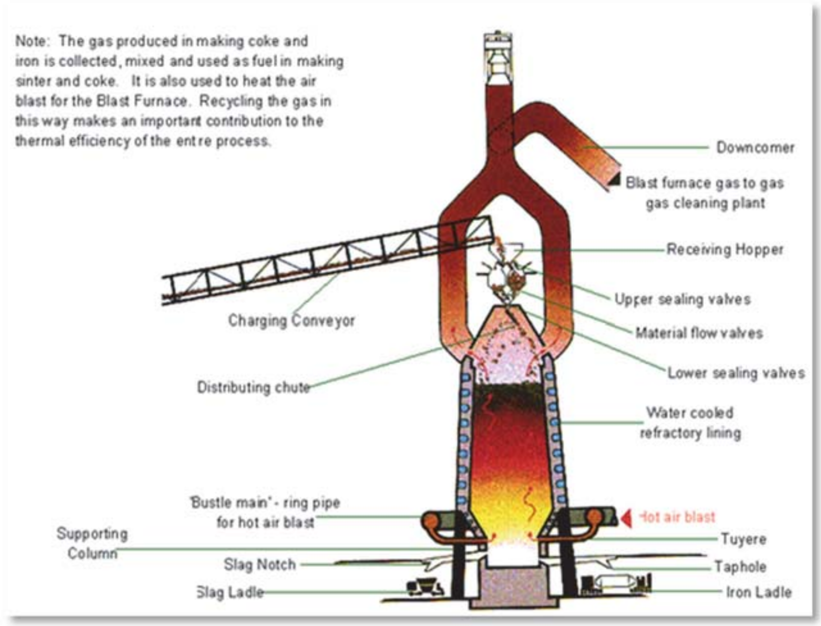


Figure 9: Typical Blast Furnace [22]

A blast furnace is normally in continuous operation for several years during which only minor repairs can be made. Refractory linings are in contact with materials and gases at a temperature that ranges from about 1650°C in the hearth to 1370°C around the mantle and 175°C at the top. At the higher temperatures, refractories become relatively soft and subject to erosion and corrosion, and without cooling their service life would be short. This necessary cooling is effected by circulating large quantities of water through pipes embedded in the furnace walls. Blast furnace hearths are usually cooled by water flowing through staves inside the hearth jacket, but some hearths may be cooled by water sprayed on the jacket. A water spray may also be used for emergency cooling. All water sprayed on the outside of a blast furnace is probably evaporated.

Large volumes of air are compressed for the blast furnace (usually by steam-driven turbo blowers), heated to 530°C to 810°C, and blown into the furnace near the bottom. The steam turbines require a considerable amount of cooling water for condensers. Tuyeres through which the air is blown into the furnace are cooled by water circulating through an annular space around the tip and a conical copper cooler in the wall around the tuyere. Copper coolers also surround the slag notch.

Gases from blast furnaces have a low heating value and are cleaned and cooled before being used for heating requirements in the plant. In most plants, the gases flow through dry dust collectors, spray towers, and finally through wet electrostatic precipitators. Most of the dust is removed in the dry dust collector by gravitational and centrifugal forces. From the dust collector, the gases enter the spray tower at the bottom and rise through water sprays. The towers commonly contain trays, baffies, rotating cones, and other devices to assure intimate contact between the dust and water. Final cleaning is usually done with an electrostatic precipitator in which gas and dust pass between two electrically charged surfaces. A thin film of water flows over the collecting surface and carries the dust to a waste disposal system. Wastewater from the spray tower and electrostatic precipitator is usually treated to remove the suspended solids. [15]

2.6.3. Direct Reduction

Direct reduction, has been developed to overcome some of the difficulties of conventional blast furnaces. Direct-reduced iron (DRI), also called sponge iron, is produced by direct reduction of iron ore by a reducing gas produced from natural gas or coal, at temperatures below the melting point of iron (1536°C). The iron oxide is reduced at 800-1050°C by interaction with reductants mainly hydrogen (H_2) and carbon monoxide (CO) which act as reducing agents. This process of reducing the iron ore in solid form by reducing gases is called direct reduction. (23)

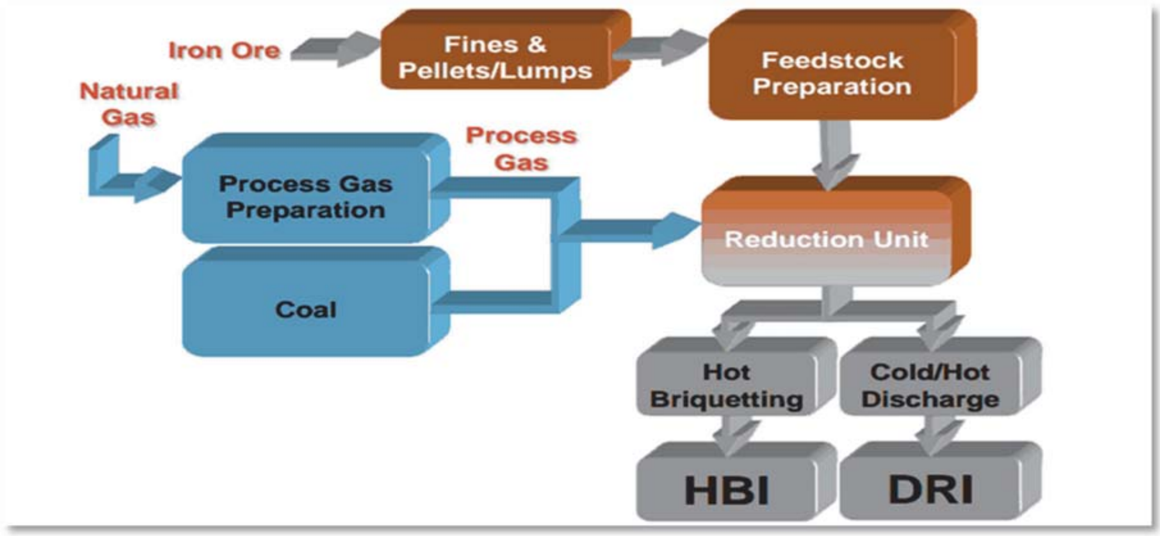


Figure 10: Direct Reduction Process for Iron Making (24)

DRI lump, pellets, and cold-moulded briquettes have an apparent density of less than 5.0 g/cm^3. Cold-moulded briquettes are formed at a temperature less than 650°C. Hot Briquetted Iron (HBI) is a compacted form of DRI with enhanced physical characteristics, which make it ideal for handling, shipping, and storing as a merchant product.

The specific investment and operating costs of direct reduction plants are low compared to integrated steel plants and are more suitable for many developing countries where supplies of coking coal are limited. (24)

2.6.4. Corex

Corex is a smelting-reduction process, which was considered cost-efficient at the time of development and environmentally friendly method of production of hot metal from iron ore and coal. The process differs from the conventional blast furnace route in that non-coking coal can be directly used for ore reduction and melting work, eliminating the need for coking plants.

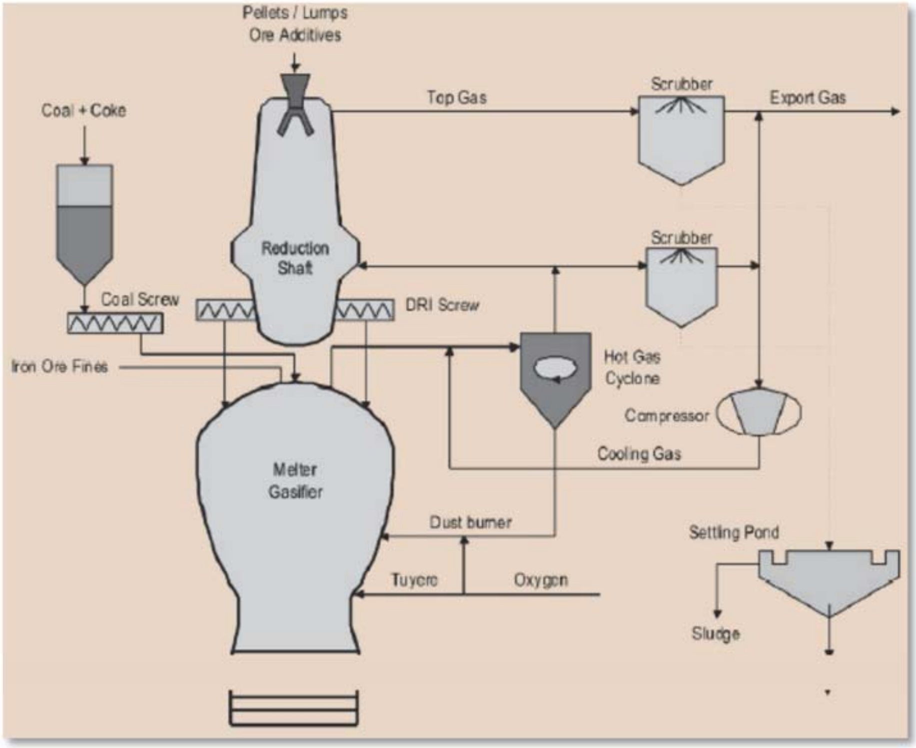


Figure 11: Corex Process for Iron Making [25]

All metallurgical work is carried out in two separate process reactors – the reduction shaft and the melter gasifier. Lump ore, pellets and fluxes are fed into a reduction shaft and reduced to direct-reduced iron (DRI) by a reduction gas. Discharge screws convey the DRI from the reduction shaft into the melter-gasifier where final reduction and melting takes place in addition to all other metallurgical and slag reactions. The gas from the melter-gasifier contains about 75% CO and 25% H_2 and is used as reduction gas in the shaft. The off-take gases from the shaft and the residual gas has high calorific value suitable for wide range of industrial application like power generation, etc.

2.6.5. Electric Furnace

This is not a conventional method for iron making, but is employed at Evraz Highveld Steel because of the high titanium containing ore it uses. Pre-reduction of the ore is done in a rotary kiln using coal as reductant. Final reduction happens in an electric arc furnace, similar to what is used in steel-making. The main difference is that reducing conditions are maintained.

2.7. Steel Making Processes

As previously indicated, iron is converted to steel through primarily three major processes, namely open hearth, electric or basic oxygen furnaces. In South Africa, the open-hearth process is not used any longer (Figure 12). Each one is described separately in the following section.

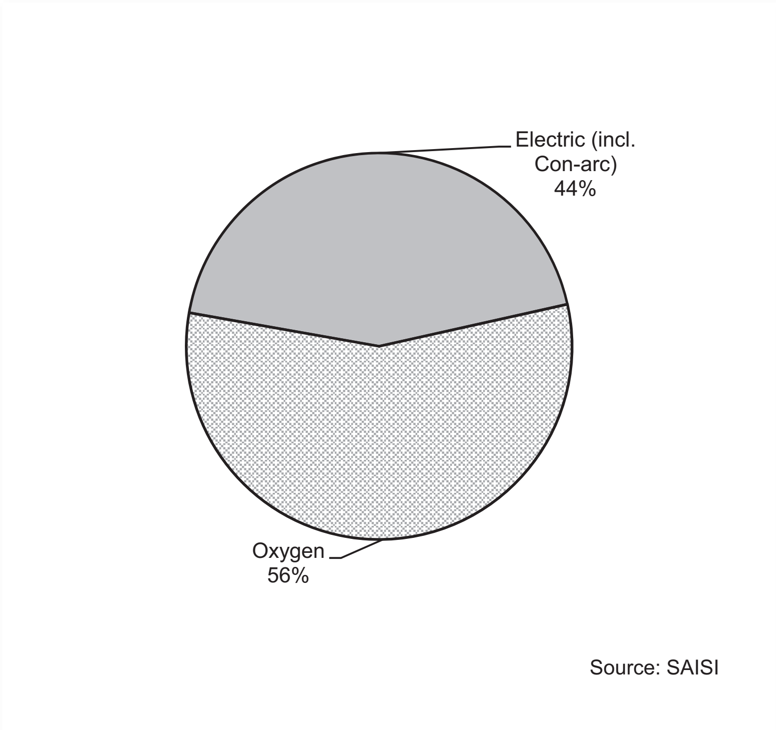


Figure 12: SA Steel Production per Process [21]

2.7.1. Electric Arc Furnace

Steel production in electric furnaces showed steady growth since 1910. Electric furnaces are more easily controlled than open-hearth furnaces, and they are therefore more adaptable to the production of high-quality steel.

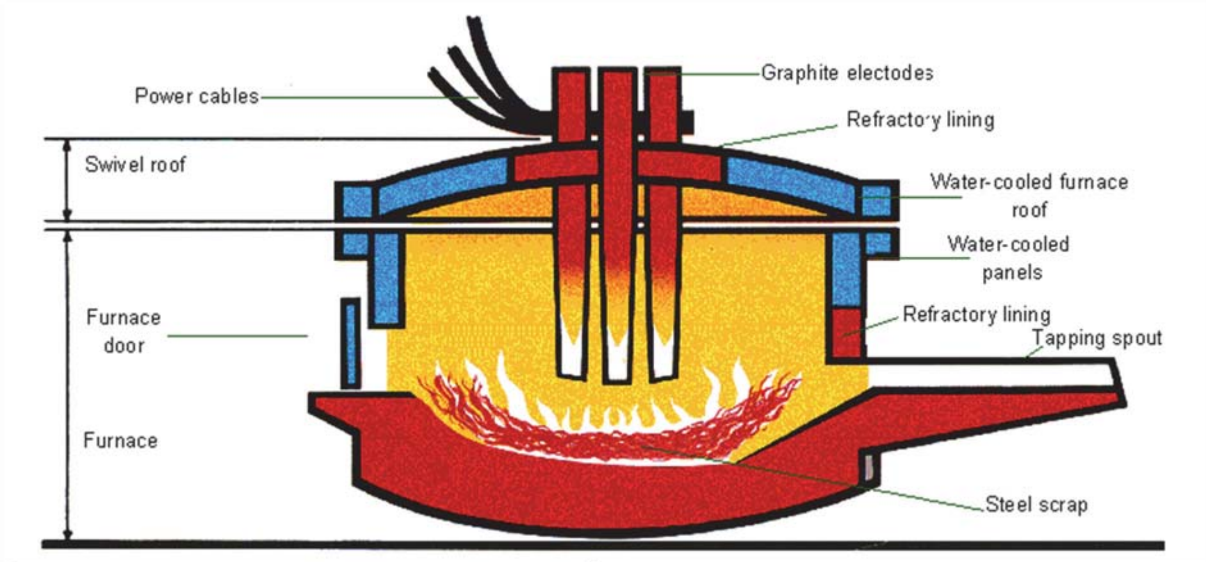


Figure 13: Typical Electric Arc Furnace (EAF) [27]

The EAF operates as a batch melting process producing batches of molten steel known as "heats". The operating cycle is called the tap-to-tap cycle and is made up of the following operations: [26]

- Furnace charging
- Melting
- Refining
- De-slagging

- Tapping
- Furnace turn around

Modern operations aim for a tap-to-tap time of less than 60 minutes. Some twin shell furnace operations are achieving tap-to-tap times of 35 to 40 minutes.

The first step in any tap-to-tap cycle is "charging" into the scrap. The roof and electrodes are raised and are swung to the side of the furnace to allow the scrap charging crane to move a full bucket of scrap into place over the furnace. The bucket bottom opens up and the scrap falls into the furnace. The scrap crane removes the scrap bucket. The roof and electrodes swing back into place over the furnace. The roof and then the electrodes are lowered to strike an arc on the scrap. This commences the melting portion of the cycle.

Melting is accomplished by supplying energy to the furnace interior. This energy can be electrical or chemical. The EAF has evolved into a highly efficient melting apparatus and modern designs are focused on maximizing the melting capacity of the EAF.

Electrical energy is supplied via graphite electrodes and is usually the largest contributor in melting operations.

Chemical energy is supplied via several sources including oxy-fuel burners and oxygen lances. Oxy-fuel burners burn natural gas using oxygen or a blend of oxygen and air.

Once enough scrap has been melted to accommodate the second charge, the charging process is repeated. Once the final scrap charge is melted, the furnace sidewalls are exposed to intense radiation from the arc.

Once the final scrap charge is fully melted, a bath temperature and sample will be taken. The analysis of the bath chemistry will allow the melter to determine the amount of oxygen to be blown during refining. At this point, the melter can also start to arrange for the bulk tap alloy additions to be made. These quantities are finalized after the refining period.

Refining operations in the electric arc furnace have traditionally involved the removal of phosphorus, sulphur, aluminium, silicon, manganese and carbon from the steel. In recent times, dissolved gases, especially hydrogen and nitrogen, have been recognized as a concern. Oxygen was lanced at the end of meltdown to lower the bath carbon content to the desired level for tapping. Most of the compounds which are to be removed during refining have a higher affinity for oxygen than the carbon. Thus the oxygen will preferentially react with these elements to form oxides which float out of the steel and into the slag.

In modern EAF operations, oxygen may be blown into the bath throughout most of the heat. As a result, some of the melting and refining operations occur simultaneously.

The reaction of carbon with oxygen in the bath to produce CO is important as it supplies a less expensive form of energy (between 30 and 40% of the net heat input to the furnace) to the bath, and performs several important refining reactions.

De-slagging operations are carried out to remove impurities from the furnace. During melting and refining operations, some of the undesirable materials within the bath are oxidized and enter the slag phase. It is advantageous to remove as much phosphorus into the slag as early in the heat as possible. The furnace is tilted backwards and slag is poured out of the furnace through the slag door. Removal of the slag eliminates the possibility of phosphorus reversion.

Once the desired steel composition and temperature are achieved in the furnace, the tap-hole is opened, the furnace is tilted, and the steel pours into a ladle for transfer to the next batch operation. During the tapping process bulk alloy additions are made based on the bath analysis and the desired steel grade.

Furnace turn-around is the period following completion of tapping until the furnace is recharged for the next heat.

Water cooling is used to prevent warping of metal parts and to maintain a seal at the top of the furnace and around the door. A water jacket in the rim of the lid or in the furnace rim in which the lid rests provides cooling for the top. Doors and door jambs are usually of double-wall construction and have water circulating through them. In electric-arc furnaces, water-cooled rings protect the electrodes. In induction furnaces, transformer-type coils are cooled by oil which in turn is cooled by water in a heat exchanger, whereas the copper-tube coils are cooled by water circulating through the tubing.

2.7.2. Basic Oxygen Furnace

The Basic Oxygen Steelmaking process differs from the EAF in that it is self-sufficient in energy. The primary raw materials for the Basic Oxygen Furnace (BOF) are 70-80% liquid hot metal from the blast furnace and the balance is steel scrap. [28] These are charged into the BOF vessel. Oxygen (>99.5% pure) is "blown" into the BOF at supersonic velocities. If the oxygen is lower in purity, nitrogen levels at tap become unacceptable. It oxidizes the carbon and silicon contained in the hot metal liberating great quantities of heat which melts the scrap. There are lesser energy contributions from the oxidation of iron, manganese, and phosphorus. The post combustion of carbon monoxide as it exits the vessel also transmits heat back to the bath.

The product of the BOS is molten steel at 1600°C, with a specified chemical analysis. From here it may undergo further refining in a secondary refining process or be sent directly to the continuous caster where it is solidified into semi-finished shapes: blooms, billets, or slabs.

Basic refers to the magnesia (MgO) refractory lining which wears through contact with hot, basic slags. These slags are required to remove phosphorus and sulphur from the molten charge.

Since the BOS process increases productivity by almost an order of magnitude, generally only two BOFs were required to replace a dozen open hearth furnaces.

The process operates in a batch mode. A "heat" begins when the BOF vessel is tilted about 45° towards the charging aisle and scrap charge (about 25 to 30% of the heat weight) is dumped from a charging box into the mouth of the BOF. The hot metal is immediately poured directly onto the scrap from a transfer ladle. Fumes and graphite flakes from the carbon saturated hot metal are emitted from the vessel's mouth and collected by the pollution control system. Then the vessel is rotated back to the vertical position and lime/dolomite fluxes are dropped onto the charge from overhead bins while the lance is lowered to a few feet above the bottom of the vessel. The lance is water-cooled with a multi-hole copper tip. Through this lance, oxygen is blown into the mix.

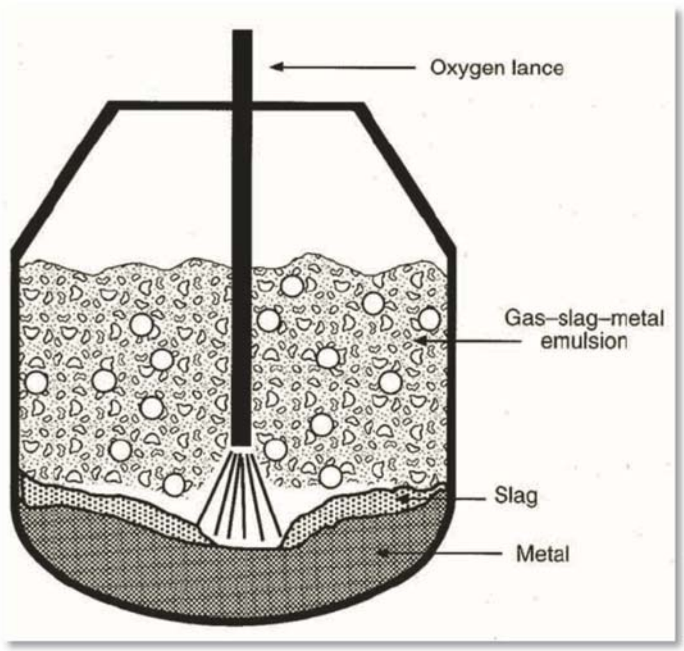


Figure 14: Section through BOF during blowing [28]

The gas is primarily carbon monoxide (CO) from the carbon in the hot metal. Blowing typically continues 15 to 20 minutes based on the metallic charge chemistry and the melt specification.

Once the heat is ready for tapping the vessel is tilted towards the tapping aisle, and steel emerges from the tap hole in the upper "cone" section of the vessel.

Near the end of a campaign, gunning with refractory materials in high wear areas may also be necessary. Once vessel maintenance is complete the vessel is ready to receive the next charge.

Environmental challenges at BOS shops include:

- the capture and removal of contaminants in the hot and dirty primary off-gas from the converter;
- secondary emissions associated with charging and tapping the furnaces;
- control of emissions from ancillary operations such as hot metal transfer, desulfurization, or ladle metallurgy operations;
- the recycling and/or disposal of collected oxide dusts or sludges; and
- the disposition of slag.

2.8. Casting

Before molten steel can be rolled or formed into finished products, it has to solidify and be formed into standard, semi-finished casting products which are available in basic shapes called billets, blooms or slabs. Until the development of the continuous casting process, these shapes were always produced by pouring the molten steel into ingot moulds. The ingots are placed in soaking pits (ingot re-heating furnaces) to bring them up to a uniform temperature before being passed to the primary mills, which then begin to roll them into the required shapes. However, most modern steels are now continuously cast.

Different design principles are used for casting strands of different cross sections. Billet casters solidify 80 to 175 mm squares or rounds, bloom casters solidify sections of 300 by 400 mm, and beam blank casters produce large, dog-bone-like sections that are directly fed into an I-beam or H-beam rolling mill. Huge slab casters solidify sections up to 250 mm thick and 2600 mm wide at production.

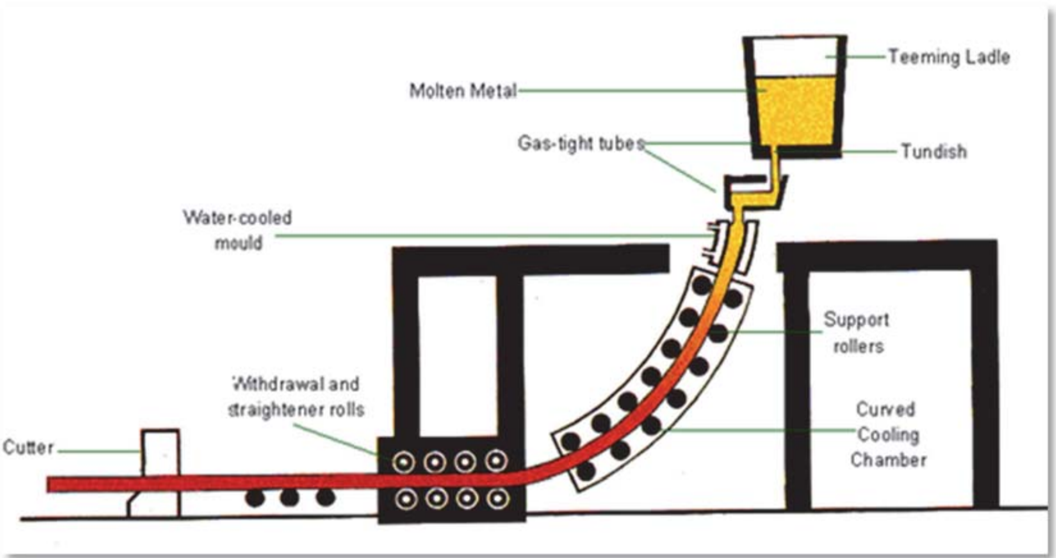


Figure 15: Continuous Casting Machine [29]

In the process, a ladle of steel is brought to the continuous casting plant by overhead crane and after pre-treatment, which may involve stirring by the injection of an inert gas (argon) the open mouth of the ladle is covered by an insulating lid to reduce heat loss. The whole unit is lifted by crane onto a rotating turret. This makes sequence casting possible – the casting of a number of ladles of the same grade steel without stopping the machine. Before the casting operation, a gas-tight refractory tube is fitted to the outside of the ladle nozzle. This device prevents the liquid steel from taking up excessive oxygen and nitrogen from the atmosphere. The ladle nozzle is then opened, allowing the steel to flow out of the ladle into the tundish, a reservoir supplying the water-cooled copper mould of the casting machine, through another gas-tight tube at a controlled rate. With only its outer shell solidified, the steel is then drawn downwards from the bottom of the mould through a curved arrangement of support rolls and water sprays until it emerges horizontally as a solid steel slab from the discharge end of the machine, where it is automatically cut to the lengths required.

It is now ready for shaping into finished products.

2.9. Growth Projections

The yearly production growth in the South African Steel Industry is expected to average about 1% from 2013 to 2017, owing to a deteriorating business environment in South Africa. (30)

This is slower than the predicted GDP growth for the same period. This deterioration is caused by an increased trade deficit, which, in turn, is caused by weak demand for manufactured goods in Europe, declining levels of production and investment in the mining sector, a lack of large infrastructure development, and the slow pace of project implementation.

Other factors that will negatively affect the Steel Industry include reduced capital expenditure in the mining industry, owing to labour unrest, and the deterioration of the rand. In addition, the domestic economy is further confronted by electricity supply concerns and tariff increases, which will adversely affect the competitiveness of South Africa's domestic Steel Industry. (30)

Furthermore, the global economy remains weak and has not reached the levels of growth needed to induce a strong recovery in steel demand. Judging by recent standards, global steel prices are expected to remain weak, owing to global overcapacity. (30)

2.10. Generic Water Flow Schemes

As was discussed in previous sections, different Iron and Steel mills utilising different technologies, e.g. iron furnace technology and producing different grades of iron and steel products 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. Coke Oven Plant

The data reported in this section is historical data from 2010 and is based on EU Mills' operating performance. Variations may occur when compared to South African Mills.

The main wastewater contaminant and properties to consider in the Coke Oven process are(38):

- COD,
- BOD_5,
- Total Nitrogen Bound (TNb),
- NH_4,
- Phenol index,
- CN^-,
- S_2^-,
- BTX,
- PAH,
- Fish toxicity,
- Temperature,

Water sources are typically:

- Condensates,
- Washing water,
- Water from direct cooling,
- Water from wet dedusting,
- Water from quenching,
- Runoff water from coal storage and blending.

A typical water flow scheme for a Coke Oven Plant is shown in Figure 16.

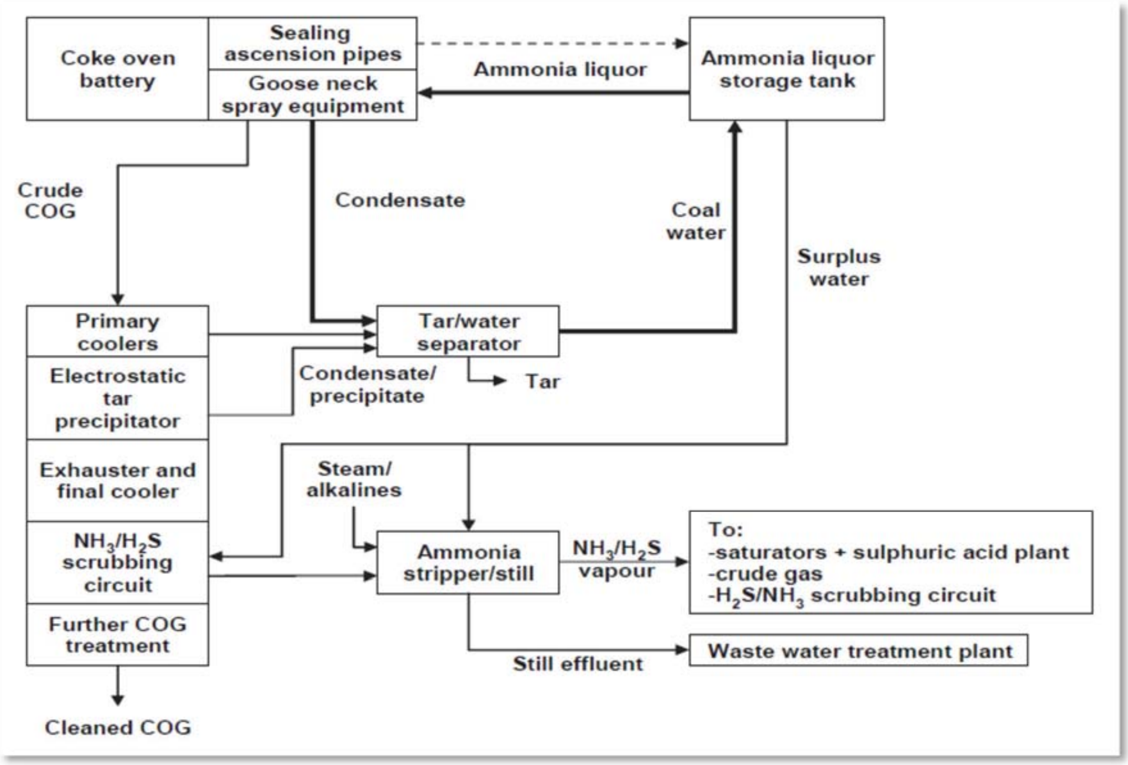


Figure 16: Typical Water Flow Scheme for a Coke Oven Plant[38]

The wastewater from a coke oven plant contains a mixture of hydrocarbons, cyanide compounds and nitrogen compounds in relatively high concentrations. Several methods are available to treat this wastewater. In all cases, the wastewater goes through an ammonia stripper before further treatment[38].

The wastewater can be treated biologically and chemically. When biological treatment is applied, tar is often removed by a physico-chemical process and the wastewater is often diluted in order to avoid the influents having toxic effects on the microorganisms, especially the inhibition of nitrifying bacteria.

The most commonly applied biological technique for the treatment of coke oven wastewater is the aerobic, biological system with activated sludge. In some cases, special attention has been paid to nitrification and (anoxic) denitrification. In other cases, a biological system based on a fluidised bed is used to treat the wastewater.

Table 7: Typical Influent and effluent concentrations of a pre-denitrification-nitrification effluent treatment system for Coke Oven effluent[(38)]

Aspect/component		Unit	Data
Specific effluent flow (specific wastewater amount)		m^3/t coke	0.31-0.69
Untreated Effluent	pH	–	8.5-9.5
	Suspended solids	mg/ℓ	30-40
	COD (x±s)	mg/ℓ	200-6500
	TOC (x±s)	mg/ℓ	835-1215
	BOD_5	mg/ℓ	800-3000
	Phenol	mg/ℓ	500-1500
	SCN	mg/ℓ	150-380
	Kjeldahl-N	mg/ℓ	300
	Ammonia (x±s)	mg/ℓ	50-200
	Nitrite	mg/ℓ	NA
	Nitrate	mg/ℓ	NA
	Oil and tar	mg/ℓ	40
	PAH (6 Borneff)	µg/ℓ	200
Treated Effluent	pH	–	7.6-8.0
	Suspended solids	mg/ℓ	42-75
	COD (x±s)	mg/ℓ	45-800
	TOC (x±s)	mg/ℓ	30-60
	BOD_5 (x±s)	mg/ℓ	<20
	Phenol	mg/ℓ	0.1-<2
	SCN^-	mg/ℓ	<4.0
	Kjeldahl-N	mg/ℓ	3-10
	TNb	mg/ℓ	3-30
	Ammonia (x±s)	mg/ℓ	0.6-80
	Nitrite	mg/ℓ	<1.3
	Nitrate	mg/ℓ	0 (*)-27
	Oil and tar	mg/ℓ	5-15
	PAH (6 Borneff)	µg/ℓ	0.2-<50

(*) From the coking plant at Lorfonte Serémange this value is reported, although in theory it is impossible; but high residual ammonia content and a negligible nitrate concentration indicate nitrification inhibition.

NB:— Ranges reflect the maximum and minimum of daily averages over two years (2004-2005) except for BOD, BTX and PAH that refer to fewer samples.

— TNb = Total nitrogen bound.

— NA = Not available.

Source: [65, InfoMil 1997] [88, Löhr *et al.,* 1996] [89, Löhr *et al.,* 1997] [260, Germany 2007] [272, Germany 2007] [320, Eurofer 2007] [341, Eurofer 2007] [372, Czech TWG member 2008].

2.10.2. Blast Furnaces

The data reported in this section is historical data from 2010 and is based on EU Mills' operating performance. Variations may occur when compared to South African Mills.

Wastewater from a blast furnace typically originates from[38]:

- Overflow water from Blast Furnace gas scrubbing,
- Wastewater from slag granulation,
- Blowdown from cooling water circuits.

Water from Blast Furnace gas scrubbing is normally treated, cooled and recycled to the scrubber (see Figure 17). Treatment usually takes place in circular settling tanks. Overflow of water from slag granulation primarily depends on water availability and is in the range of 0.125-10 m^3/t hot metal produced. Information on pollutant concentrations and emission factors for wastewater from blast furnace slag granulation with fresh water is available in Table 9. The emission factors are based on a specific fresh water demand of 3.57 m^3/t hot metal.

The overflow of the circuit is normally 0.1- 3.5 m^3/t hot metal depending on raw material quality/specification and wastewater availability which influences the measures taken to optimise water recycling. Especially raw materials with a high salt content can require significantly higher volumes of wash water[38].

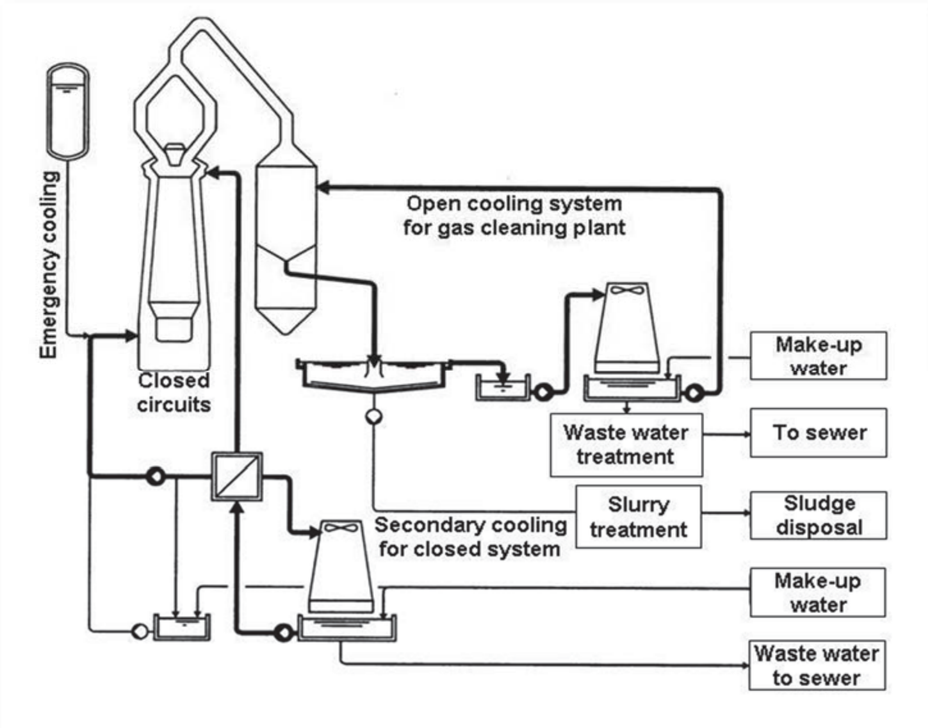


Figure 17: Typical water management flow scheme at a blast furnace[38]

Table 8: Composition of wastewater from BF gas scrubbing before treatment[38]

Parameter	Concentration (mg/ℓ)
CN^-	0.1-50
Cl	73.6 (1)
F	1.74 (1)
SO_4^{2-}	42 (1)
NH_4^+	2.0-200
S	0-5
Fe	6.77 (1)
Mn	0.48 (1)
Zn	0.1-29.36
Pb	0.01-5
Na	19.19 (1)
Phenols	0.1-5

(1) Average value.

NB: Data from a study carried out in 1990 and 1992. Six blast furnaces (volume: 837-1680 m^3) producing between 280-400 kg slag/t hot metal. Average basicity: CaO/SiO2 0.9-1.1. Alkali input: 1.4-4.8 kg/t hot metal.

Source: [232, Brouhon *et al.* 1990] [233, Poos *et al.*, 1993].

Table 9 provides a typical analysis of the wastewater from Blast Furnace gas scrubbing before treatment.

Table 9: Pollutant concentrations and emission factors for wastewater from blast furnace slag granulation[38]

Parameter	Unit	Average	Median	Range (min-max)	SD	Emission factor	Unit
Water demand						3.57	m^3/t HM
Pb	µg/ℓ	2.52	2.00	<2.00-6.40	1.10	7.13	mg/t HM
Cr	µg/ℓ	2.41	2.00	<2.00-6.90	1.08	7.13	mg/t HM
Cu	µg/ℓ	4.06	3.80	<2.00-9.50	2.05	13.55	mg/t HM
Zn	µg/ℓ	20.92	20.00	<20.00-38.00	3.62	71.31	mg/t HM
Cd	µg/ℓ	0.20	0.20	<0.20-0.23	0.01	0.71	mg/t HM
Ni	µg/ℓ	3.74	3.15	<2.00-10.00	1.98	11.23	mg/t HM
Fe	mg/ℓ	0.44	0.18	0.03-2.60	0.61	0.64	g/t HM
Cl	mg/ℓ	262.96	264.00	140-402	57.60	941.26	g/t HM
AOX	µg/ℓ	21.63	16.50	<10.0-66.0	13.18	58.83	g/t HM
Suspended solids	mg/ℓ	27.11	5.90	0.6-145.0	42.68	21.04	g/t HM
DOC	mg/ℓ	4.70	4.00	3.10-8.70	1.46	14.26	g/t HM
TOC	mg/ℓ	5.51	5.00	3.10-11.3	2.06	17.83	g/t HM
COD	mg/ℓ	22.17	22.50	14.00-27.00	4.22	80.22	g/t HM
HC	mg/ℓ	0.15	0.10	<0.10-0.25	0.05	0.36	g/t HM

NB: — SS: Suspended solids.
- HC: Mineral oil hydrocarbons.
- SD: Standard deviation.
- The data are based on the median of 24 measurements (for COD on six measurements).
- Data from Stahlwerke, Bremen Germany, random sample measurements for the composition of wastewater from slag granulation from March 2000 to November 2006.
- Figures in *italics* indicate that measurement values below the detection limit have been computed as the detection limit.

Source: [357, Germany 2007].

2.10.3. Basic Oxygen Steelmaking and Casting

The data reported in this section is historical data from 2010 and is based on EU Mills' operating performance. Variations may occur when compared to South African Mills.

Wastewater from a basic oxygen furnace typically originates from[38]:

- Scrubbing water from BOF gas treatment,
- Scrubbing water from the wet dedusting of desulphurisation,
- Water from vacuum generation,
- Water from direct cooling from continuous or ingot casting.

The BOF gas can be treated by either wet or dry processing. In the case of wet cleaning, a wastewater stream is produced which is normally recycled after treatment. Treatment is typically performed in two steps: separation of coarse particles (>200 µm grain size) followed by sedimentation in circular settling tanks. Flocculating agents are added to improve sedimentation[38]. The water from the scrubbers mainly contains suspended solids; zinc and lead being the main heavy metals present.

For the vacuum treatment step, the specific process water flow from vacuum generation is 5-8 m^3/t liquid steel that is vacuum treated. This water is almost fully recycled. However not all of the liquid steel has to be vacuum treated. Therefore, the weighted specific overall wastewater output from vacuum treatment is 1.3 m^3/t liquid steel. Usually this wastewater is treated together with other streams from the rolling mill(s) where they are located in the direct vicinity[38].

Emissions to water from continuous casting machines are generated by the direct cooling system. This is used for the direct cooling of slabs, blooms, billets and the machines. The wastewater contains mill scale (1-3 g/ℓ) and oil/grease. This water is very often treated together with wastewater from rolling mills where they are located in the direct vicinity. The amount of wastewater strongly depends on local conditions and water management. The specific water demand for continuous casting is usually between 5 and 35 m^3/t liquid steel. The amount of wastewater which can arise from continuous casting is up to 2 m^3/t liquid steel. Typical concentration of pollutants in treated wastewater from continuous casting at a basic oxygen furnace are summarised in Table 10.

Table 10: Concentration of pollutants in treated wastewater from continuous casting at a BOF(38)

Parameter	No. of measurements	Mean value	Median	Max	Min	Std dev.
Pb (µg/ℓ)	33	3.03	2.00	16.00	<2.00	3.11
Cr (µg/ℓ)	33	2.99	2.00	13.00	<2.00	2.17
Cu (µg/ℓ)	33	6.03	5.70	15.00	0.50	2.74
Zn (µg/ℓ)	33	87.12	62.00	340.00	<20.00	73.89
Cd (µg/ℓ)	33	0.20	0.20	0.27	<0.20	0.01
Fe (mg/ℓ)	33	0.59	0.14	8.50	0.05	1.63
Ni (µg/ℓ)	33	21.88	22.00	37.00	11.00	6.15
$N_{mineral}$ (mg/ℓ)	31	5.09	5.07	7.16	3.29	1.21
AOX (µg/ℓ)	33	41.06	40.00	66.00	21.00	11.00
Suspended solids (mg/ℓ)	33	2.77	1.00	19.00	0.80	4.37
DOC (mg/ℓ)	33	5.31	5.00	10.00	4.30	1.11
TOC (mg/ℓ)	33	5.68	5.40	10.70	4.60	1.22
Mineral oil hydrocarbons (mg/ℓ)	31	0.16	0.18	0.40	<0.10	0.07
Fish egg toxicity	8	1.25	1.00	2.00	1.00	0.43

NB: Random sample measurement data from Feb. 2000 to Nov. 2006. Figures in italics indicate that measurement values below the detection limit have been computed as the detection limit.
Source: [260, Germany 2007] [362, Germany 2007].

2.10.4. Electric Arc Furnace Steelmaking and Casting

The data reported in this section is historical data from 2010 and is based on EU Mills' operating performance. Variations may occur when compared to South African Mills.

In an EAF mill water is typically used for(38):

- Cooling of the EAF,
- Rapid quenching of the hot off-gases,
- Scrubbing water if wet dedusting is applied,
- Vacuum generation,
- Direct cooling in continuous or ingot casting.

Water is used in the EAF unit for cooling the wall panels and the roof and for spraying the electrodes. The water used for the cooling of the EAF is about 5-12 $m^3/(m^2h)$. For an EAF of a production capacity of 70 t/h the cooling water demand is 1000 m^3/h. Since the water is used in a closed cooling cycle, no wastewater occurs(38).

Continuous casting in the EAF process is similar to the basic oxygen furnace process. Usually this wastewater is treated together with other streams from the rolling mill(s). The main pollutants are suspended solids and oil. The main measures to reduce discharges to water are a high rate of recirculation along with sedimentation and/or filtration of the bleed. Skimming tanks can be used to remove oil.

For vacuum treatment, the usual specific process water flow from vacuum generation ranges from 5-8 m^3/t liquid steel vacuum treated. This water is nearly fully recycled. It should be mentioned that not all of the liquid steel should be vacuum treated(38).

Water is used for rapid quenching. From one plant it is reported that 25 m^3/h is used to quench approximately 870 000 m^3/h. No wastewater occurs since the used water is mostly evaporated and leaves the process with the exhaust airflow. A minor part leaves the process with the residual moisture of the dust[38].

The main raw material of EAF, the different kinds of scrap are often stored on unpaved scrapyards. Drainage water can be contaminated, especially in the case of scrap which contains oil/emulsions like turnings. Drainage water is usually at least treated in an oil separator prior to being discharged[38].

Table 11: Composition of wastewater from direct cooling after wastewater treatment[38]

Parameter	Units	Continuous casting after sand filtration (^{1})	Hot rolling mill after sand filtration (^{1})
Flow	m^3/h	421	802
Temperature	°C	39	30
Suspended solids	mg/ℓ	30.8	4.8
TOC	mg/ℓ	1.33	1.85
AOX	mg/ℓ	<0.01	<0.01
Fe	mg/ℓ	0.053	<0.1
Zinc	mg/ℓ	<0.05	<0.05
Ni	mg/ℓ	<0.02	<0.02
Copper	mg/ℓ	<0.02	<0.02
Mineral oil hydrocarbons (mg/ℓ)	mg/ℓ	<0.1	<0.1
(^{1}) 24-hour random sample. *Source:* [178, N.N. 2008].			

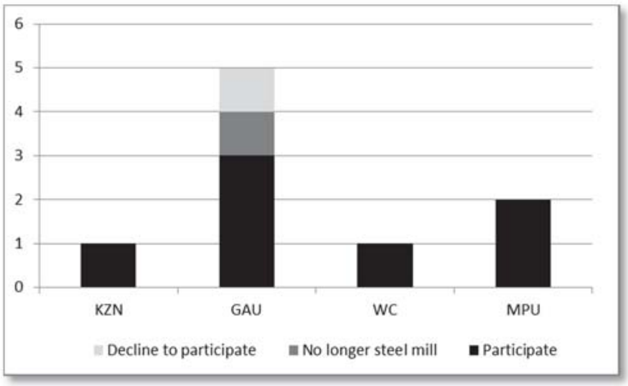
3. PROCESS OVERVIEW AND PARTICIPATION

The Steel Industry in South Africa consists of a number of works, each operating in a specific sector of the industry. Different feedstocks, processing 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.

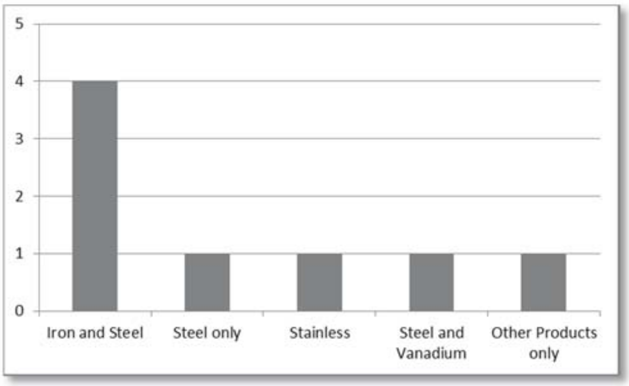
The large steel manufacturers in South Africa are members of the South African Iron and Steel Institute (SAISI). The members and their works are listed in alphabetical order in Table 12. Not all works were visited, but assessment schedules were sent to all participating works.

Table 12: Works operated by SAISI members

Company	Location	Level of Involvement		Region	Municipality
		Survey	Site Visit		
ArcelorMittal	Newcastle		X	KZN	Newcastle
	Pretoria	No longer steel works		GAU	City of Tshwane
	Saldanha Bay		X	WC	Saldanha Bay
	Vanderbijlpark	X		GAU	Emfuleni
	Vereeniging	Not surveyed		GAU	Emfuleni
Cape Gate	Vanderbijlpark	X		GAU	Emfuleni
Columbus Stainless	Middelburg		X	MPU	Steve Tshwete
Evraz Highveld	Witbank		X	MPU	Emalahleni
Scaw Metals	Germiston	Declined to participate		GAU	Ekurhuleni



(a) Location and level of Participation



(b) Type of Mill

Figure 18: Profile of Companies Participating (a) Location and Level of Participation and (b) Type of Mill

As can be seen from the graphs the bulk of the South African Iron and Steel sector is located in the Gauteng province, with only one mill, ArcelorMittal Saldanha Bay being located at a sea port. One site that used to be a steel mills, namely ArcelorMittal Pretoria no longer operated the Iron and Steel Mill sections and only processes steel to final products and therefore their data was not included in the study.

The respective steel works are discussed in more detail in the following sections. **Where data for mills are reflected in the following chapters, the mills will be numbered and listed in a different order as that used in Table 12** and with the combined ArcelorMittal figures also included as a separate mill number.

A related sector, namely the metal finishing industry is covered in the NATSURV 2 report and therefore is not considered in this document.

3.1. ArcelorMittal South Africa

ArcelorMittal is the largest steel producer in South Africa with the following production capacity:

- Flat Steel Products
  - Vanderbijlpark Works – 3.2 Mtpa
  - Saldanha Works – 1.25 Mtpa
- Long Steel Products
  - Newcastle Works – 1.9 Mtpa
  - Vereeniging Works – 0.4 Mtpa
- Coke & Chemicals
  - Coke – 597 000 tpa
  - Tar – 133 000 tpa

3.1.1. ArcelorMittal Newcastle

ArcelorMittal's site in Newcastle (refer Figure 19), in Northern KwaZulu-Natal, produces 1.9 Mtpa of long steel products for sub-Saharan Africa and exports to international markets. The plant's major markets are the mining, engineering, automotive, building, construction and agricultural industries.

Figure 19: ArcelorMittal Newcastle Site

This highly efficient and low cost operation, rated among the lowest billet cash-cost producer's in the world, bears testimony to the success of the intensive re-engineering programmes undertaken at ArcelorMittal. The plant employs 1 850 staff.

A process flow scheme for the mill is included in Figure 20. The main processing steps are:

- Coke Ovens: the ovens are designed for 2 200 t/d and current production is 945 000 t/a,
- Sinter Making with an average production rate of 7 150 t/d,
- Blast Furnace producing on average 5 000 t/d at a 96% availability,
- Steel making where additives are added to the iron to produce the different grades of steel,
- Basic Oxygen Furnace is a 2 out of 3 system producing 1.9 million t/a of steel,
- Ladle Furnace where alloying elements are added,
- Vacuum Degasser to produce low hydrogen and ultra-low carbon steels at about 15 000 t liquid steel per month,
- Continuous Casting consists of two machines each capable of producing 175 t/h,
- Rolling Operations,
  - Billet Mill is the primary mill and has two 150 t/h pusher furnaces for reheating the steel,
  - Medium Mill between 30 000 and 50 000 t/month of nearly 500 different products are produced in this mill,

- o Bar Mill producing final products such as angles, flat bars, squares, round bars and special sections and
- o Rod Mill producing rod from 5.5 to 14 mm at rolling speeds up to 100 m/s.

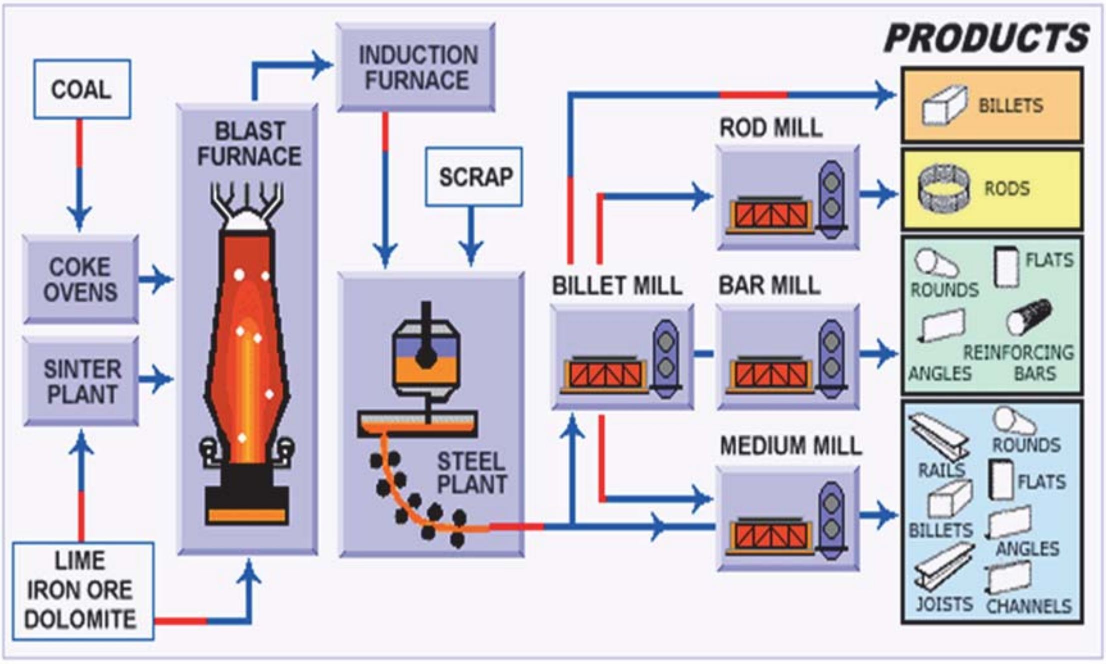


Figure 20: ArcelorMittal Newcastle Process Flow Scheme

A simplified water flow scheme for ArcelorMittal Newcastle is included in Figure 21.

Water treatment at ArcelorMittal Newcastle consists of two sections, namely the clarification of abstracted raw water at the Main Water plant and the treatment of effluent at the new effluent treatment unit.

An aerial photograph of the main water treatment plant is included in Figure 22. The plant treats water from the Ngagane River with plans to also install a pipeline from the Buffels River. The incoming TDS is in the region of 150 ppm, but excursions up to 600 ppm have been experienced. Due to the varying flows in the river, linked to rainfall, the turbidity is extremely variable, usually between 30-40 NTU, but excursions to > 1 000 NTU have been measured. The industrial water is treated by clarification only.

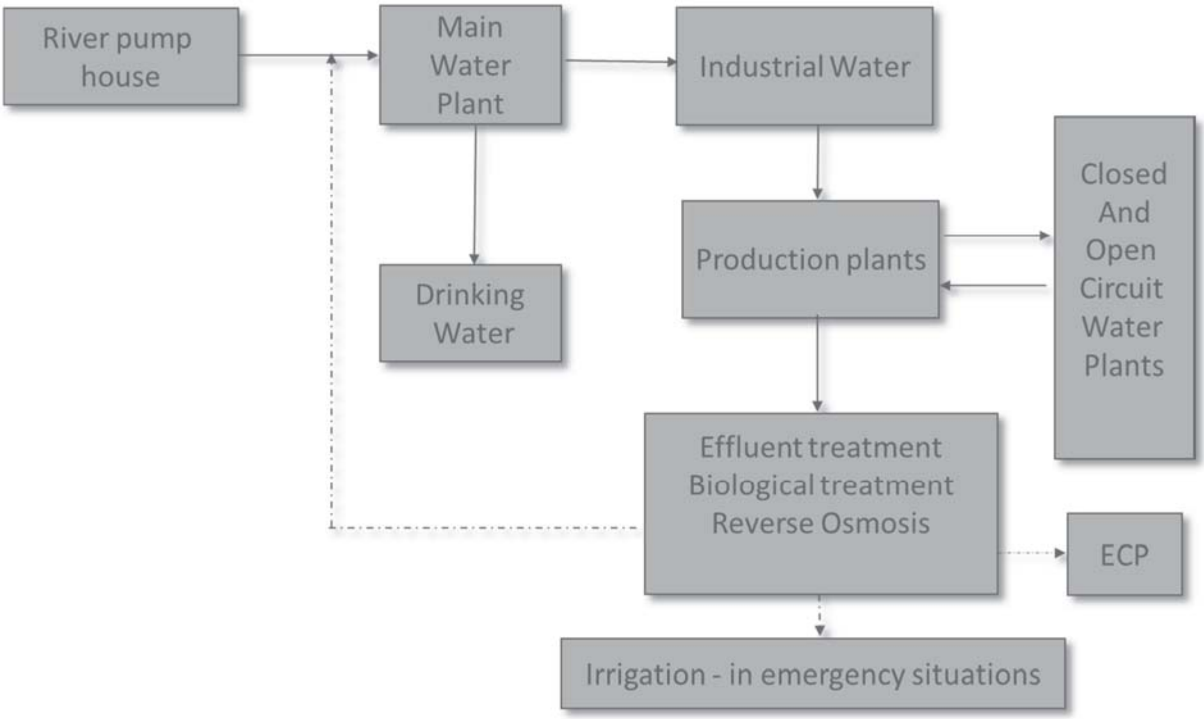


Figure 21: ArcelorMittal Newcastle Simplified Water Flow Scheme

A portion of the clarified water is upgraded to drinking water by two trains of clarification, multimedia filtration and granular activated carbon filters. Primary chlorination is done in the feed to the drinking water plant and secondary chlorination of the drinking water prior to distribution.

Figure 22: ArcelorMittal Newcastle Main Water Plant

The effluent generated on site was irrigated, but all effluent is now treated in a new effluent treatment plant (refer Figure 23) with the objective to treat and re-use all process effluent ensuring its quality is according to specification. A secondary benefit of installing the facility is a reduction of fresh water abstraction by 40 %.

Figure 23: ArcelorMittal Newcastle New Effluent Treatment Plant

The effluent treatment consists of two sections, a biological treatment unit, with separate nitrification and de-nitrification stages, purifying coke oven effluent followed by a reverse osmosis (RO) unit for removing salts from saline effluent. All effluent streams are combined upstream of the unit and treated in both processes. The brine from the RO plant will be dewatered by the existing recently installed evaporator/crystallizer plant which has sufficient capacity. The project also included the construction of a buffer dam to buffer the system during upset plant conditions.

The biological treatment plant consists of the following treatment steps:

- Dissolved Air Flotation
- Equalisation
- Pre-clarification
- De-nitrification
- COD removal
- Degassing 1
- Intermediate clarification
- Nitrification
- Degassing 2
- Flocculation
- Final Clarification
- Sludge handling, dewatering and treatment system

After the biological plant, pre-treatment for the salt removal section is done by the precipitation of manganese, calcium, fluoride and silica. Additional filter systems are included to improve the reliability by protecting the Ultrafiltration (UF) and RO membranes by sand filters and cartridge filters. Cross-flow configuration UF membranes are used for significantly improved cleaning and reduced risk of blockage. The RO plant consists of two stage reverse osmosis design to reduce the salt load on the membranes. Standby RO trains are included to allow cleaning during operation.

3.1.2. ArcelorMittal Pretoria

The ArcelorMittal South Africa site in Pretoria was an integrated steel works that started production in the early 1930's and ceased production in 1997. The main objectives of Pretoria Works are to manage the Environmental legacy of the site and to provide services and infrastructure for other business units and lessee's.

3.1.3. ArcelorMittal Saldanha

ArcelorMittal's site in Saldanha Bay (refer Figure 24), in the Western Cape, is an integrated Iron and Steel Mill and produces 1 250 000 tonnes of steel products per year. It is located at the deep sea port of Saldanha Bay and focusses mostly on the export market.

Figure 24: ArcelorMittal Saldanha Works

The plant is the most recently built steel works in South Africa and therefore utilises more modern technologies to produce ultra-thin hot rolled coil. It is the only steel mill in the world to have combined the Corex/Midrex process (refer Figure 25) in a continuous chain, replacing the need for coke ovens and blast furnaces, thus making it a leader in emission control and environmental management. The mill was specifically designed to produce 'clean steel' with virtually no impurities such as tin and copper.

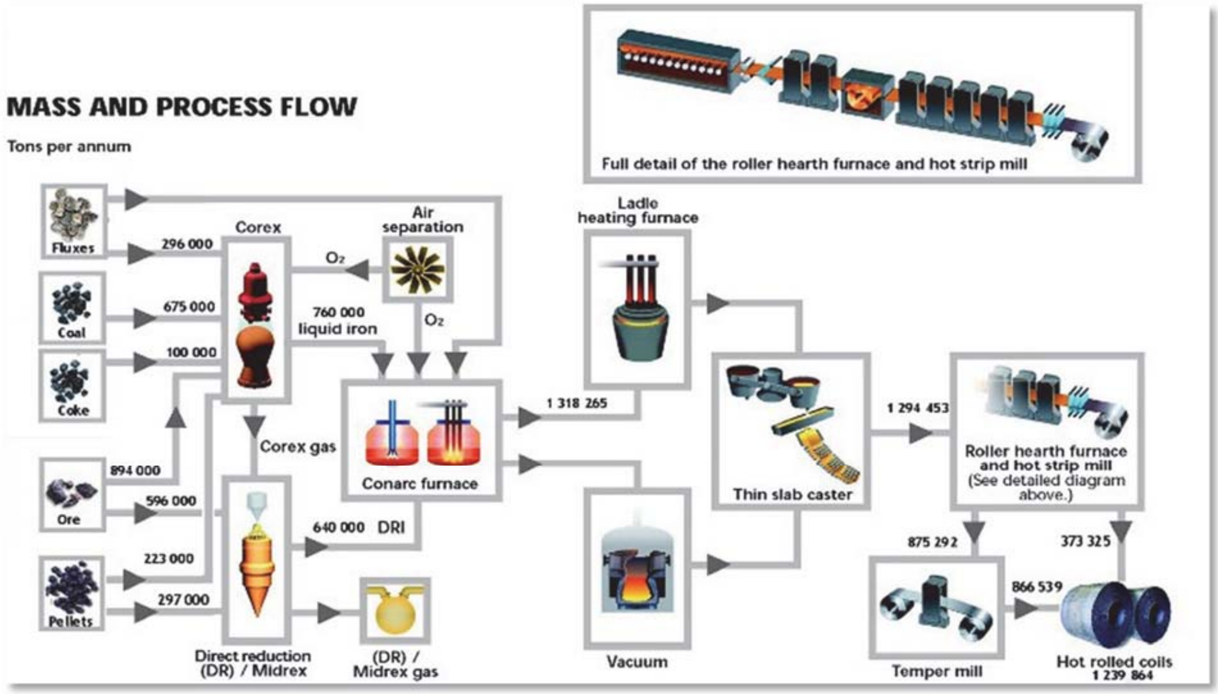


Figure 25: ArcelorMittal Saldanha Process Flow Diagram

The iron production takes place in a combined Corex/Midrex process with heated Corex gas being used as energy source for the Midrex process. Oxygen for the Corex unit is generated at an Air Separation Unit (ASU) on-site. Both the liquid iron from Corex and the direct reduction iron from Midrex are fed to the Conarc furnaces at the steel section of the plant where they are mixed.

The steel section consists of two steel electric arc furnaces but with facilities to also inject oxygen. This is followed by a ladle furnace and then a caster to pour the steel in slabs. The next processing step is the Roller Hearth Furnace which is approx. 100 m long and uses Midrex gas together with LPG as heat source. The hearth furnace serves as a holding space to equalise production differences between the caster and the hot strip mill, thus enabling continuous operation of upstream processing even when product grades need to be changed. If there is no liquid iron entering the steel section, it can also accept scrap metal as feed. Off-gases are extracted by fans and cleaned in bag filters prior to release. The continuous operation process results in more energy efficient operation.

Since the facility was developed in an arid region and in close proximity to a National Park, with average precipitation of 270 mm and evaporation of 2000 mm per annum, it was designed to be a zero effluent discharge facility from the beginning. Sewage is the only exception and that is discharged to the municipal wastewater works. All other process effluent, as well as storm water run-off is treated on site and re-used.

There are no fresh water sources in Saldanha Bay area and water is sourced from the Berg River approx. 100 km away.

The water management flow scheme for the facility is indicated in Figure 26. The main process use of water is for cooling purposes. Thus the bulk of effluent is cooling tower blowdown from the cooling towers that are typically operating at 4-5 cycles of concentration. All effluent streams from the ASU as well as different sections of the iron and steel plant are routed to a central water treatment plant.

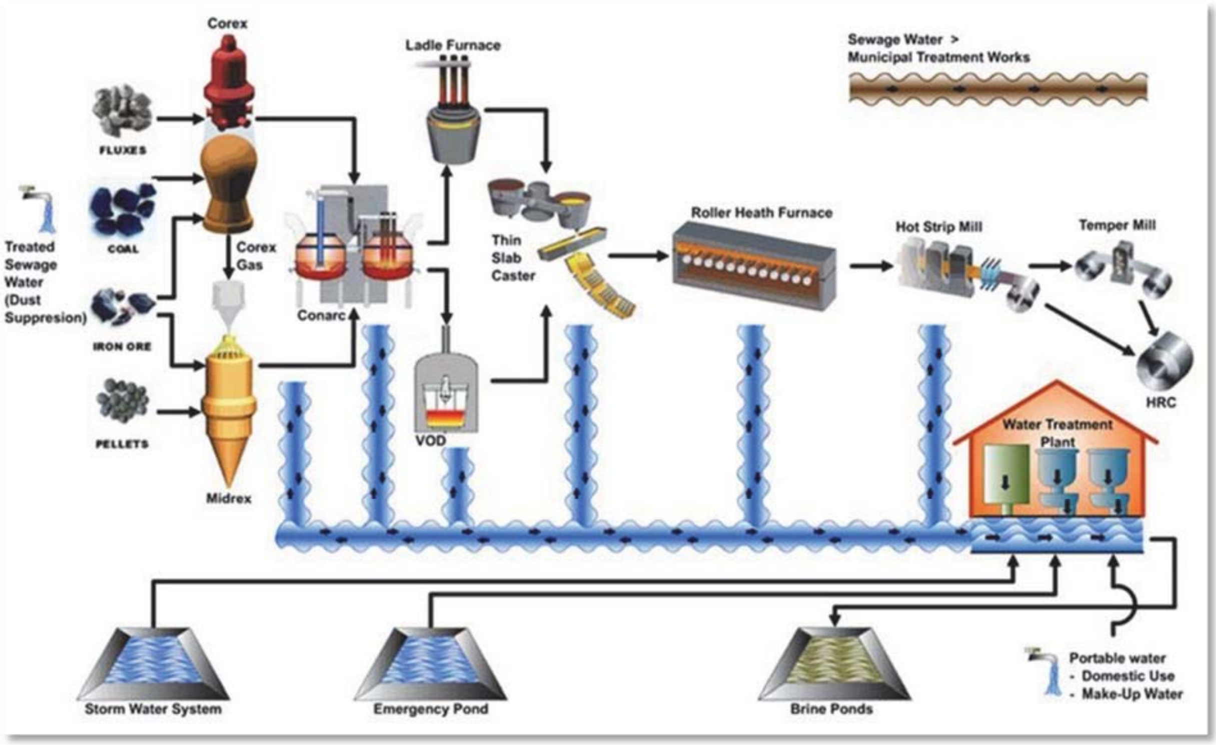


Figure 26: ArcelorMittal Saldanha Bay Water Management Flow Scheme

The water treatment plant flow diagram is included in Figure 27.

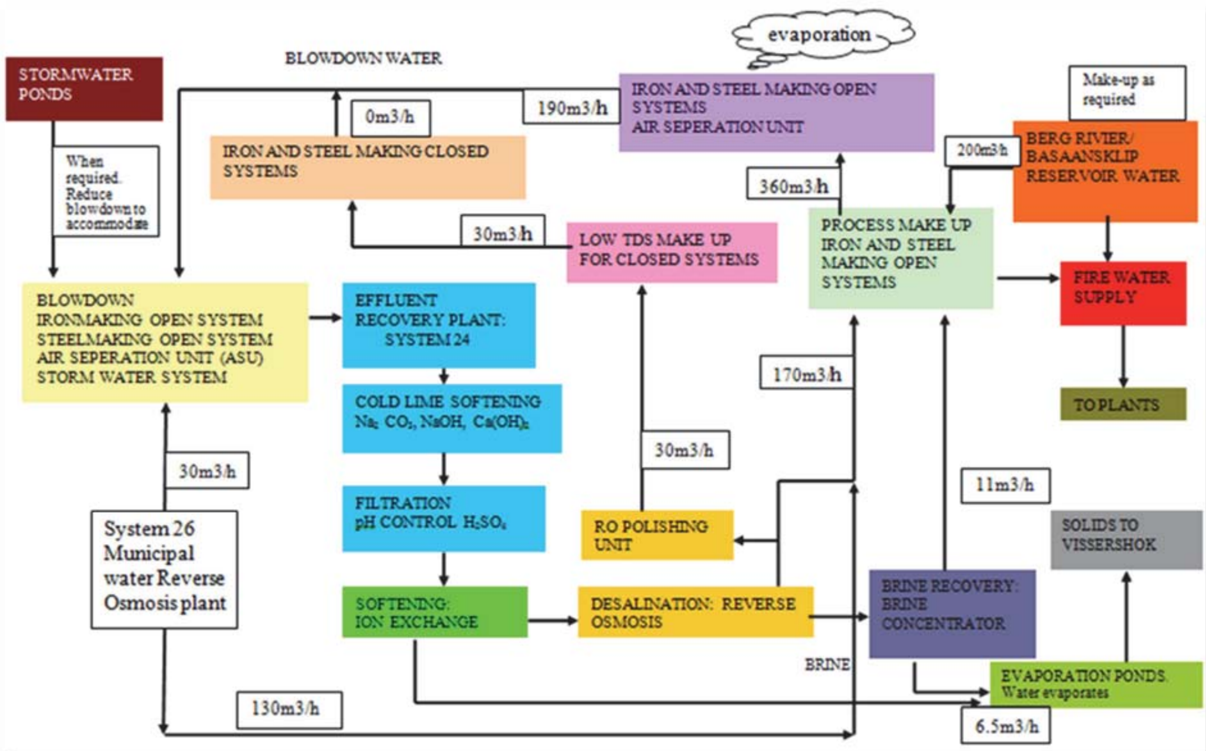


Figure 27: ArcelorMittal Saldanha Bay Water Treatment Plant Flow Diagram

Due to the Saldanha Bay location imported water quality can deteriorate significantly due to run-off from the Malmesbury shale formation in the Swartland which tend to be saline, especially with regard to chloride concentration of up to 300 ppm. Thus an RO plant has been installed to purify approx. a third of the incoming municipal water prior to use in the plant and then blending it with the balance of the incoming water to ensure a chloride concentration of < 100 ppm. Efforts are also made by the municipality to provide lower chloride concentration water.

The effluent treatment section of the water treatment plant processes the effluent of which approx. 65% is returned to the production facility for re-use. Primary treatment of water takes place at source such as at the iron making, caster and mills sections. Blowdown from the various cooling and other water systems is collected in a central collection tank for equalization prior to the water treatment plant. Blowdown is controlled based on chloride and total dissolved solids in the water. Water from the blowdown tank is pumped to the mixing tank upstream of the DAF tanks to assist in the homogenous mixing of the coagulant in the water before it enters the DAF tanks. The water then enters the DAF system where oils from the steel making process as well as suspended solids are removed from the water. Sludge and flotate from the DAF is sent to the sludge treatment unit.

The water from the DAF then flows to a cold lime softening unit where lime and caustic soda is dosed to increase the pH of the inlet water from 7.5 to approx. 10.5 to aid in carbonate and bicarbonate hardness removal associated with calcium and magnesium. Soda Ash is added for reduction of non-carbonate hardness. Flocculant is dosed to aid in the precipitation/settling process. The clarifier contains lamella plates enhance clarification. The sludge is partially recirculated and used as a seed material for flocculation. The excess sludge is sent to the sludge treatment unit. Clarified water is collected on side channels and overflows to a final compartment. Sulphuric acid addition is done to lower the pH to prevent scaling and lump formation in sand filters. pH range after correction is 8.0 to 8.3.

The clarified water pumped to dual media filters to remove residual solids and COD. Filtered softened water from sand filters is then collected in a tank from where it is pumped through ion exchangers. Chlorine gas is also dosed in this section to inhibit bacterial growth. The water is pumped through the Sodium cycle ion exchange resin bed vessels to remove most of the calcium, magnesium and other bivalent cations to a total Hardness of < 15 ppm before being routed to the RO feed water tank.

The demineralised water is then pumped through 10 and 1 µm cartridge filters from where it is fed through the RO plant to produce permeate with a conductivity of < 300 µS/cm and chloride concentration of < 80 ppm. Brine from the RO plant is sent via settlers to a clarified water tank. The brine is then pumped through sand filters and cartridge filters before it is fed to an RO train with sea water membranes to further recover water from the brine.

The final brine is then sent to a brine concentrator which utilizes vacuum evaporation technology, evaporating or boiling off the water from the brine at pressures very much lower than atmospheric pressure lowering the boiling point of water to about 55°C. The condensate stream is routed to the process water tank and the brine is pumped directly to the pre-evaporation ponds. Inflow to the evaporation ponds is at a concentration of approx. 50 000 mg/ℓ. As natural evaporation occurs the concentration slowly increases to 250 000 mg/ℓ. Salts typically crystallise at these concentrations. The salt is landfilled at this stage, but recovery of gypsum is considered.

At the time of construction water scarcity was the main focus since electricity was cheap and regularly available. The main focus on maximising water recovery has thus resulted in an energy intensive water treatment plant, which poses concerns in the current load shedding environment. To further reduce water consumption most systems (about 60%) on the steel manufacturing section utilise closed water loops with air cooling which again is energy intensive, but minimises water use. The option of generating electricity from biogas from waste from adjacent industries is being investigated to reduce Eskom power consumption.

3.1.4. ArcelorMittal Vanderbijlpark

Vanderbijlpark Works (refer Figure 28) located in Gauteng is one of the world's largest inland steel mills and the largest supplier of flat steel products in sub-Saharan Africa. The plant has two blast furnaces and three basic oxygen furnaces.

Figure 28: ArcelorMittal Vanderbijlpark Site

The plant's steel products are manufactured in an integrated process. Raw materials such as iron ore, coke and dolomite are charged to blast furnaces where they are converted to liquid iron. The liquid iron is refined in basic oxygen furnaces to produce liquid steel. The liquid steel is cast into slabs, which are hot rolled into heavy plate in a plate mill, or into coils in a hot strip mill. The coils are either sold or processed further into cold rolled and coated products, such as hot dip galvanized, electro galvanised and pre-painted sheet, and tinplate. Only Vanderbijlpark Works in ARCELORMITTAL has secondary processing such as coating, cold rolling, etc.

In 2012 the EAF at Vanderbijlpark Works was mothballed due to environmental and other reasons, resulting in a capacity loss of 1 Mtpa.

The process flow scheme for the Vanderbijlpark mill is included in Figure 29. The main processing steps are:

- Iron Making including two blast furnaces with a capacity of 240 000 t of liquid steel monthly,
- Direct Reduction is coal based producing 900 000 t of direct reduction iron per annum,
- Coke Making using coal to produce 1.4 Mt of coke per annum,
- Steel making since the EAF's have been decommissioned, only the BOF's operate, producing approx. 3.2 Mt of liquid steel of various grades,
- Rolling where slabs are rolled into heavy plates or coils,
- Hot Strip Mill producing hot rolled coils,
- Plate mill route where slabs are rolled into plates of 5 to 100 mm,
- Cold rolling where pickling is done prior to galvanising,
- Tinning line where tin coating is done for the food and beverage industries,

- Galvanising line where zinc coating is done in a hot dip process,
- Colour coating line where galvanised coils are painted.

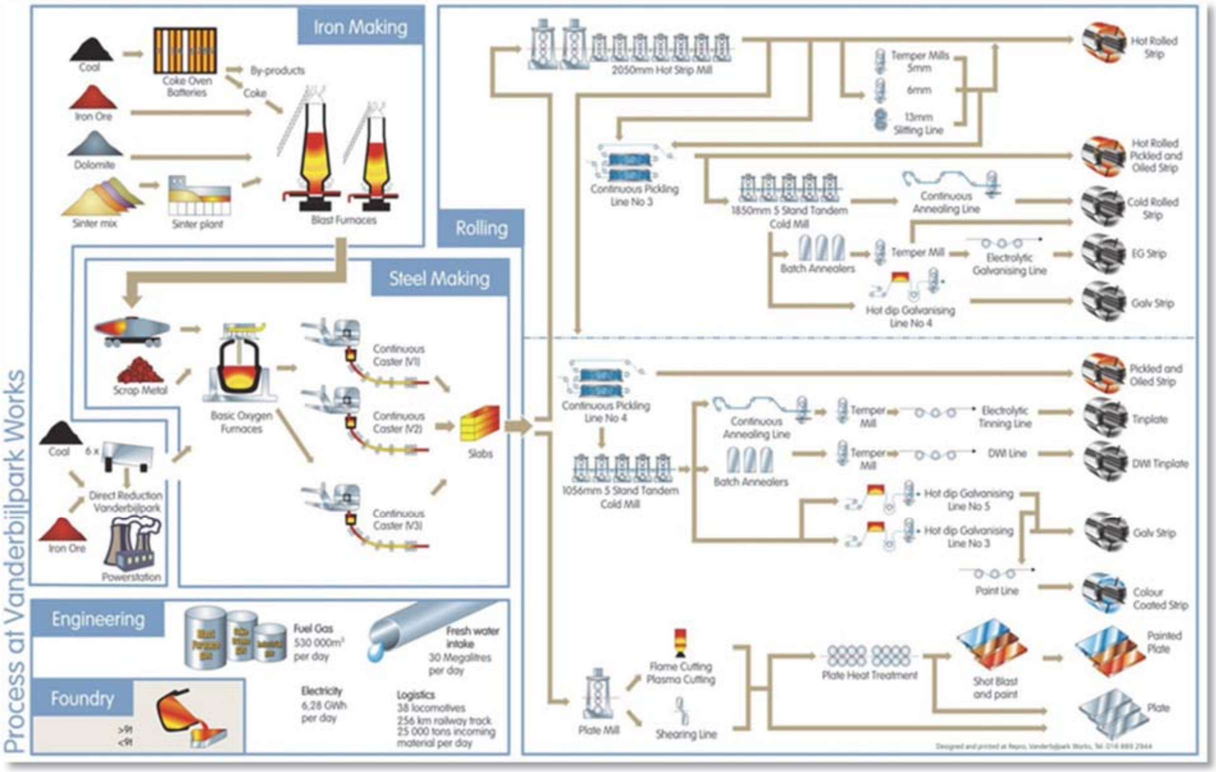


Figure 29: ArcelorMittal Vanderbijlpark Process Flow Scheme

Water abstraction and storm water management takes place as authorized in the water permit. Vanderbijlpark Works abstracts water from the Vaal Dam, Vaal River and Emfuleni Local municipality. Water is used mainly for cooling purposes throughout the iron and steel making processes starting from the iron making plant (coke making plant, Blast Furnaces, etc.) until the downstream plants at the mills.

Wastewater facilities are also in place to treat effluent and enable the plants to reuse treated and desalinated water. Vanderbijlpark Works has two wastewater treatment facilities being the Main Treatment Plant and the Central Effluent Treatment Plant which together have made possible a reduction of 50% of fresh water intake. Treatment technologies such as softening, salt removal, Reverse Osmosis, etc. form part of the operational system to generate high quality reusable water.

3.1.5. ArcelorMittal Vereeniging

Vereeniging Works has a capacity to produce in the region of 400 000 t of Liquid Steel per annum and about 100 000 t/a is supplied to the Tubular Mill. The remainder is rolled into various profiles at this facility and is an important supplier of speciality steels for the mining and automotive sector. ArcelorMittal Vereeniging Tubular Products offers a range of seamless products for the energy market. Located close to Johannesburg, products are distributed throughout South Africa and, through two seaports, to Europe, North America, the Middle East, and Asia. The pipe and tube plant has an annual capacity of 100.000 tonnes.

Vereeniging Works is the country's major supplier of speciality steel products, seamless tube and forge products. The ISO 14001 certified plant produces 400.000 tonnes of Liquid Steel a year, of which around 32% is exported.

3.2. EVRAZ Highveld Steel

EVRAZ Highveld Steel and Vanadium is an integrated iron and steel mill located at eMalahleni (Witbank) in Mpumalanga.

Iron making: Raw materials such as iron ore, coal and fluxes are blended to the correct proportions and fed into one of 13 pre-reduction kilns. Burners located at the end of the kilns are fired using pulverized coal and Polyfuel. Air is injected into the kilns by means of air fans to burn the coal volatiles. Waste gases emitted from the kilns are cooled by water sprays in a conditioning tower and cleaned in electrostatic precipitators.

The hot pre-reduced charge is routed into either one of the five open slag bath smelting furnaces or one of the two submerged arc smelting furnaces. Cleaned gas is collected in a gas-holder and used as fuel for heating purposes at the Steel plant and rolling mills. Wet gas scrubbers installed on the furnaces, clean the gasses generated during the smelting process.

The hot metal generated in the electric arc furnace is transported via rail to the Steel plant. Slag is tapped into a slag pot and discarded to the slag storage facility. The average iron production is 2 200 t/d.

Steel making: Hot metal arrives from Iron making and is charged into a Shaking ladle. Processing at the Shaking ladle involves top blowing the hot metal with oxygen, with the main purpose to oxidise vanadium in the metal to vanadium oxide and transfer it to the slag. Blown metal is transported to one of the three Basic oxygen furnaces (BOF) and Vanadium slag is decanted into slag pots.

The typical mass of a cast is 67 t. Hot metal, fluxes, scrap and Ferro-silicon are added and are blown with pure oxygen via a water-cooled copper tipped lance. This process reduces the carbon content of the metal and thus hot iron is converted to steel. Each BOF has a hood fitted with a tubular water-cooling system immediately above the furnace, to collect waste gases for delivery to a dry-plate electrostatic precipitator where pollutants are removed.

During tapping of the steel into a ladle, alloy and deoxidizing agent are added. The majority of steel produced is treated via one of the 2 ladle furnaces, where the temperature, analysis and slag composition are optimized. Steel is transported to the continuous casters. An average of 2 350 tons of steel is cast per day.

Structural Mill: Blooms that are received from the Steel plant are transferred to the Blockyard, where they undergo de-hydrogenisation and then heated to approximately 1 200°C for rolling to take place.

The basic shaped bloom is transferred to the 32” mill where sections such as rails, channels, rounds and certain beams are produced. Formed sections are transferred to the Finishing mill.

Flat products: Plates: Slabs are received via rail from the Steel plant slab caster and then cut into sub slabs on the cutting beds. Slabs intended for rolling are re-heated to approximately 1 260°C. After rolling and cutting the plate is then dispatched.

Flat products: Coils: In like manner slabs intended for coil products are also re-heated and then rolled through a reversing mill to a thickness of approximately 32 mm and sent through a vertical edging mill. Further processing includes de-scaling and coiling.

The coil is allowed to cool down for a few days before dispatch. The average volume of coils and plates is 1 200 t/d.

Water used is mainly raw water received from Witbank Dam and also re-used process water. At the main raw water plant, the raw water is split into three circuits:

1. Raw water pumped directly to the plants,

2. Process water – Raw water that is clarified and chemical treated before being pumped to the plants,
3. Domestic water – Raw water treated to comply with SANS241 standards.

All forms of water as mentioned above are metered to account for the consumption by the various plants on site. The main points of water consumption are the spray circuits, hot wells, cooling ponds, cooling towers, swirl pits and for emergency purposes.

There is no purposeful effluent release from the site. Water is contained in dams and re-used in processes. Effluent is generated from the Sewage system, slimes dam and thickener underflows. Effluent management is to collect the effluent in the various dams. Limited treatment is provided to these effluents. Sewage effluent is also treated on site before released back into the dams. Major effluent treatment processes are:

- Plant thickeners,
- Scrubbers / abatement equipment,
- Clarifiers,
- Sewage Plant and
- Blow downs

Sewage is treated in an activated sludge reactor, followed by chlorination. Treated sewage effluent is sent back to the scrubber dam and re-used in the system.

All effluent streams are combined in the dams. Water quality is assessed and the call made to combine with raw water from Witbank dam or not.

3.3. Columbus Stainless

Columbus Stainless (Pty) Ltd is located outside Middelburg in the Mpumalanga Province of South Africa (refer Figure 30). The site is an integrated steel mill producing various grades of stainless steel.

Figure 30: Columbus Stainless Aerial Photograph

The Columbus steel making process is divided into 7 categories (Figure 31) namely:

- Steel plant,
- Hot Mill,
- Plate,
- Hot Band,
- Cold Band,
- Finishing,
- Finished Goods.

Raw materials are melted and cast in slabs. From there materials are hot rolled in the Hot Mill. Materials are then routed to either Plate or Hot Band units. From the Hot Band units it is routed to either Cold Band or Finishing units from where it is moved to finished goods. Material may be moved into finished goods from any of the above mentioned units.

The mill produces a range of stainless steel products as listed in Table 13.

Table 13: Columbus Stainless Steel Product Range

CLASSIFICATION		INTERNAL TYPES			EXTERNAL TYPES		
		Unity	ACX	Columbus	Common or AISI	UNS	EN
Ferritic	Utility	U-3CR12	C211	41211	3CR12	S41003 S40977	1.4003
		U-3CR12Ti	C313	41313	3CR12Ti		
		U-3CR12L	C220	41220	3CR12L		
		U-3CR12LT	C311	41311	3CR12LT		
		U-410S	C420	41011	410S	S41008	-
	Standard	U-40910	C800	40962	409	S40910	1.4512
		U-40920	C801	40963	409	S40920	1.4512
		U-430	C500	43012	430	S43000	1.4016
		U-430DDQ	C530	43311	430DDQ		
		U-439Nb	C515	43911	439Nb	S43932	1.4510
		U-441	C845	44101	441	S43940	1.4509
	Moly	U-434	C535	43411	434	S43400	1.4113
		U-436	C550	43611	436	S43600	1.4526
		U-444	C555	44411	444	S44400	1.4521
Duplex	Lean	U-2001	C920	22112	2001	S32001	1.4482
		U-2304	C940	23041	2304	S32304	1.4362
	Standard	U2205	C900	22051	2205	S32205 S31803	1.4462
Austenitic	Cr-Mn-Ni	U-202	C335	20211	CS202	-	-
	Cr-Ni	U-301LN	C111	30111	301LN 301L	S30153 S30103	1.4318
		U-304/U304H	C120	30431	304/304H	S30400	1.4301
		U-304DQ	C160	30423	304DQ		
		U-304DDQ	C181	30428	304DDQ		
		U-304L-ASTM	C150	30411	304L 304	S30403 S30400	1.4307 1.4301
		U-304L-ASME	C151	30412			
		U-304LS	C152	30427	304LS		
		U-304LDDQ	C200	30442	304LDDQ	S30403 S30400	1.4306 1.4307 1.4301
		U-304LN	C130	30453	304LN 304N	S30453 S30451	1.4311
		U-321	C315	32113	321	S32100	1.4541
	Cr-Ni-Mo	U-316L-1.4404	C240	31613	316L 316	S31603 S31600	1.4404 1.4401
		U-316L-1.4435	C300	31628	$316L_{2.5Mo}$ $316_{2.5Mo}$		1.4432 1.4435 1.4436
		U-316LN	C320	31619	316LN 316N	S31653 S31651	1.4406
		U-316Ti	C280	31663	316Ti	S31635	1.4571
	Heat Resisting	U-309S-1.4833	C340	30911	309S 309 309H	S30908 S30900 S30909	1.4833
		U-309S Si-1.4828	C309	30921	-	-	1.4828
		U-310S-1.4845	C350	31085	310S 310 310H	S31008 S31000 S31009	1.4845

Quantity produced per product may not be disclosed. However the initial manufacturing schedule was to process 70% Austenitic material and 30 % Ferritic. Currently the order book has shifted to a 50-50 ratio. It is therefore very difficult to put a ratio to future product throughput due to the volatile market conditions.

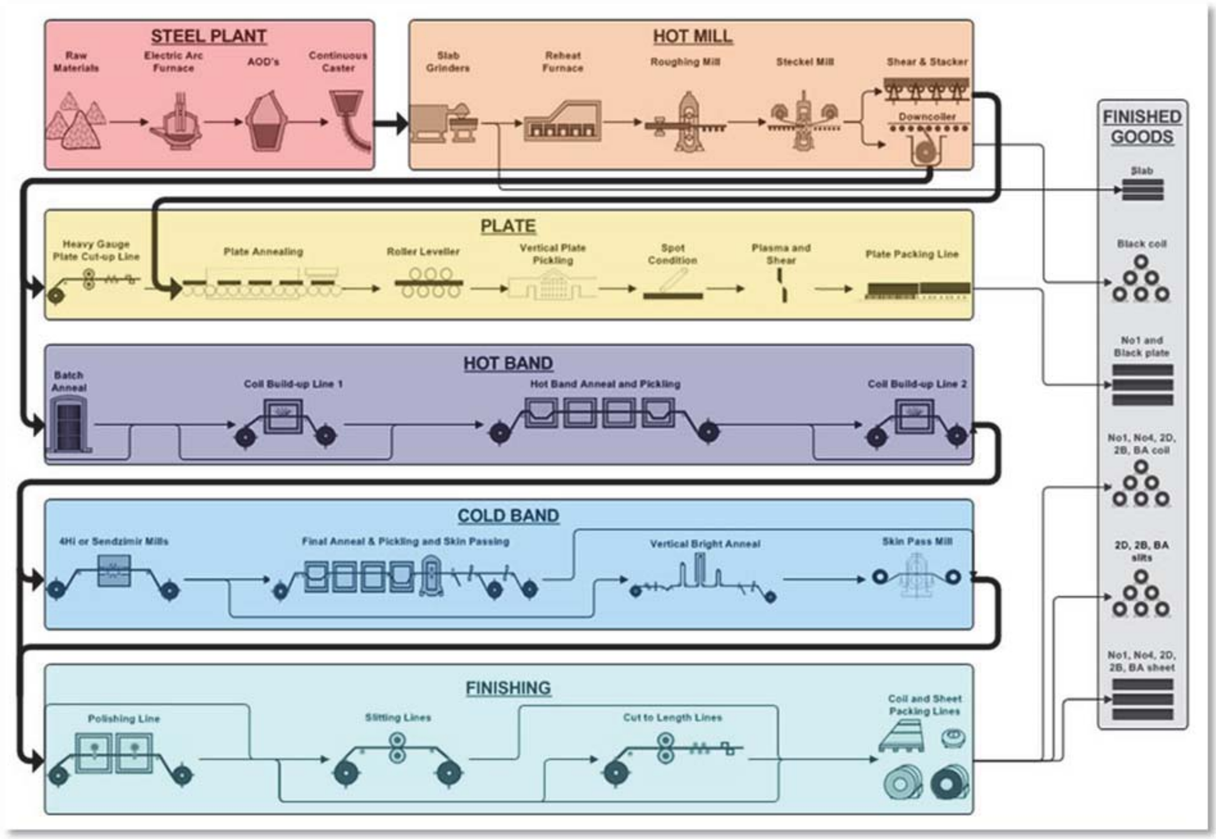


Figure 31: Columbus Stainless Steel Making Process

Stainless steel manufacture entails the following main process steps:

Melting, Slab Casting and Grinding: To make ferritic stainless steels, requires iron and chromium, and to make austenitic stainless steels, nickel is added to the mixture. This raw material mixture is melted in an electric arc furnace. The molten metal is refined and decarburised in an Argon-Oxygen Decarburiser (AOD) vessel by blowing oxygen, argon and nitrogen into the molten steel. The refined stainless steel is processed through a continuous casting machine to produce stainless steel slabs. The slabs can go through a surface grinding process to remove any possible surface defects. This is our first saleable product.

The slabs are typically between 900 mm and 1 600 mm wide, 200 mm thick, and can be cut to lengths of between 4 and 12 m.

Hot Rolling: The hot rolling process begins at the reheat furnace where the slabs are heated to between 1 100 and 1 300°C, depending on the stainless steel grade. The slabs are then rolled on a reversing four high mill to gauges between 65 and 25 mm. Thinner gauges are rolled down further on the Steckel mill. Once the predetermined gauge is reached, the material can either be coiled or cut into plate. This is the second range of saleable products. Coil mass is between 20 and 30 tons and the thickness is generally between 3 mm and 8 mm. Plate thickness can range between 3 mm and 65 mm.

Annealing and Pickling: The hot rolled products are softened (annealed) and descaled (pickled with acids) to produce a No. 1 finish product. This product has a light grey matt surface finish. No. 1 coil and plate are also saleable products.

Cold Rolling and Finishing: Cold rolling of the No. 1 coils takes place on one of four Sendzimer mills, which produce smooth, shiny finished, cold rolled stainless steel. The thickness range of the cold rolled product is between 0.2 mm and 6 mm. The material is then annealed (softened) and pickled (and passivated), before it is processed through the skinpass mill, to ensure a smooth surface. Alternatively, the cold rolled material can be processed to a bright annealed finish. This is achieved by annealing in a vertical furnace with an inert atmosphere, to retain the bright surface imparted by the cold rolling process. These cold rolled stainless steel coils can then be cut into smaller coils or sheets, or slit to narrower widths before being packed and shipped to our customers.

Polishing: Following the cold rolling, annealing and skin passing processes, a material can be given a uniform scratch finish by polishing with abrasive belts.

When Columbus Stainless was established in 1995 (Table 13) they adopted the TA Luft standard for air pollution control and also adopt the European Standard for a zero effluent plant. Columbus treats and recycles all effluent (refer process flow in Figure 32). Lined dams are used to accumulate rain water during the rainy seasons and this water is then used during the winter months. Should water release be required, it is done under strict regulation as set out by the Department of Water and Sanitation by means of Reverse Osmosis plants.

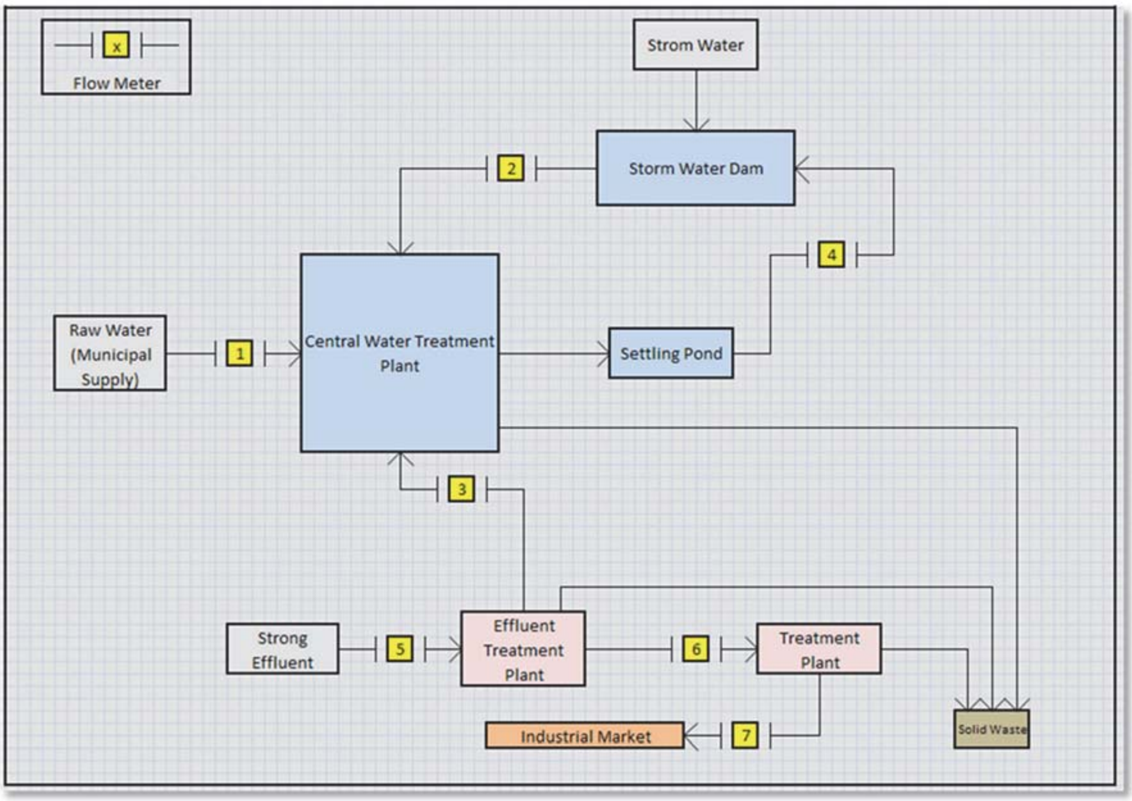


Figure 32: Columbus Stainless Water Process Flow Diagram

The main source of water is Municipal Raw water (Middelburg Dam) supplemented by recycled and re-use water on site. Water is used as quench medium, cleaning medium and cooling medium. Because of the facility to store rain water, seasonal fluctuation in water use occur.

Effluent produced consists mainly of Acidic water generated from the annealing and pickling lines, as well as regeneration effluent from the demineralisation units. Effluent is treated in an evaporator unit as shown in Figure 33.

Boiler blowdown is controlled on quality and is routed back to the raw water system for re-use. Treated sewage water is also used for irrigation of gardens on site.

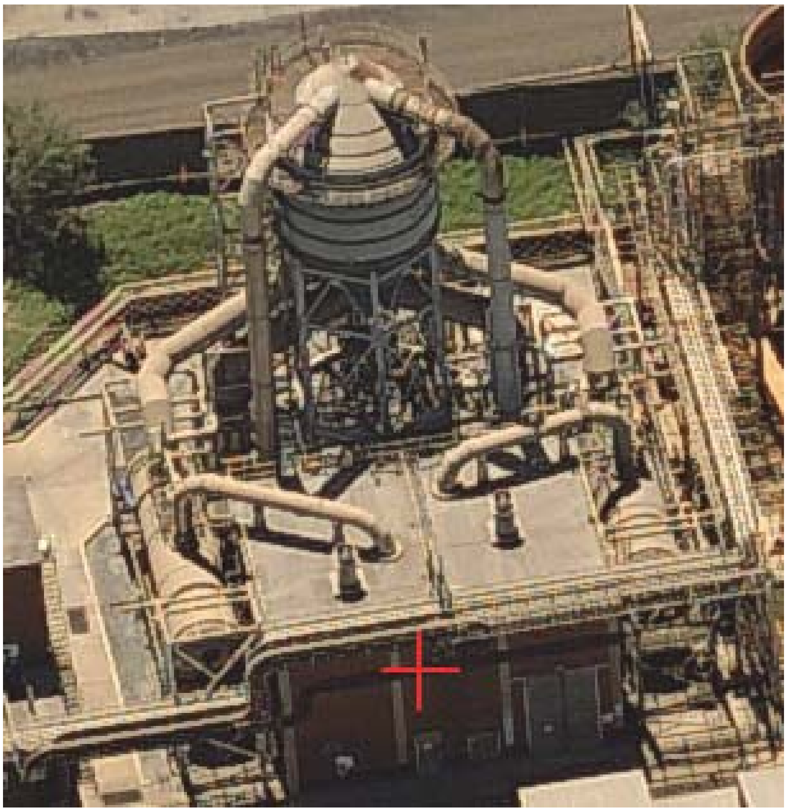


Figure 33: Columbus Stainless Evaporator Unit

3.4. Cape Gate

Cape Gate is based in Vanderbijlpark in Gauteng, South Africa (refer Figure 34). It is a steel mill producing steel products from scrap metal.

Figure 34: Cape Gate Aerial Photograph

The feed material to the plant is mostly scrap metal based (approx. 90%) with the balance being DRI (approx. 10%) from the reduction unit in Cullinan. An electric arc furnace is used in steel production at the site (refer Figure 35).

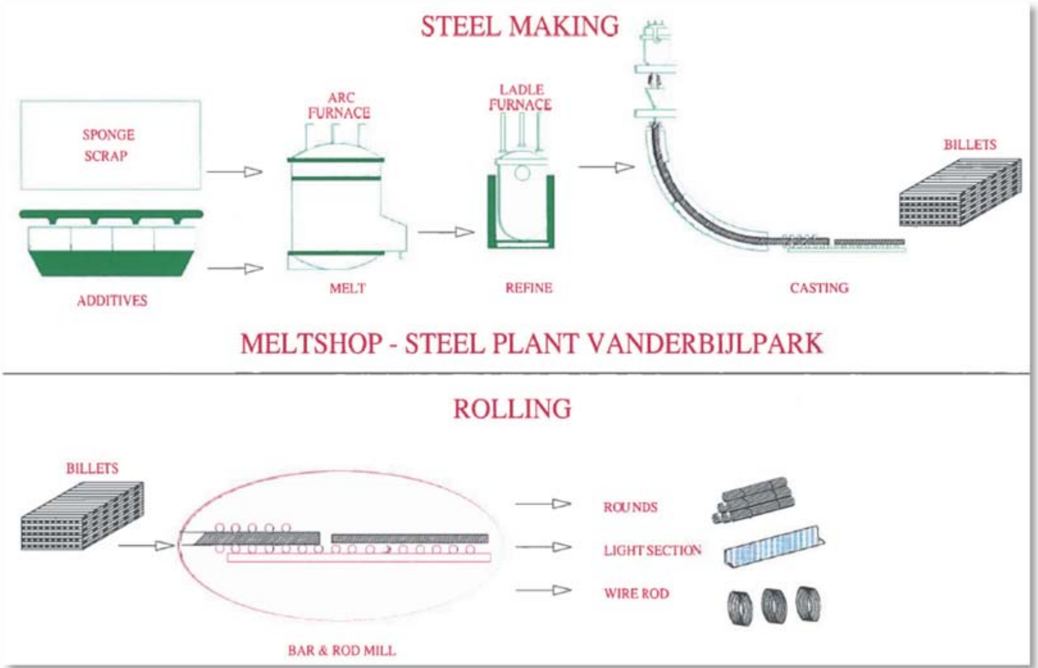


Figure 35: Cape Gate Steel Making and Rolling Flow Diagram

The steel is then rolled into various different products for the construction industry (refer Figure 36). The steel is also drawn into wire for the manufacturing of wire products for various industries including mining and agriculture. Cape Gate produces approx. 500 000 t/a of steel and wire products. Products produced include galvanised wire, black wire, fencing products, stranded products, hot rolled round bar in coils and in lengths, wire rod and light sections.

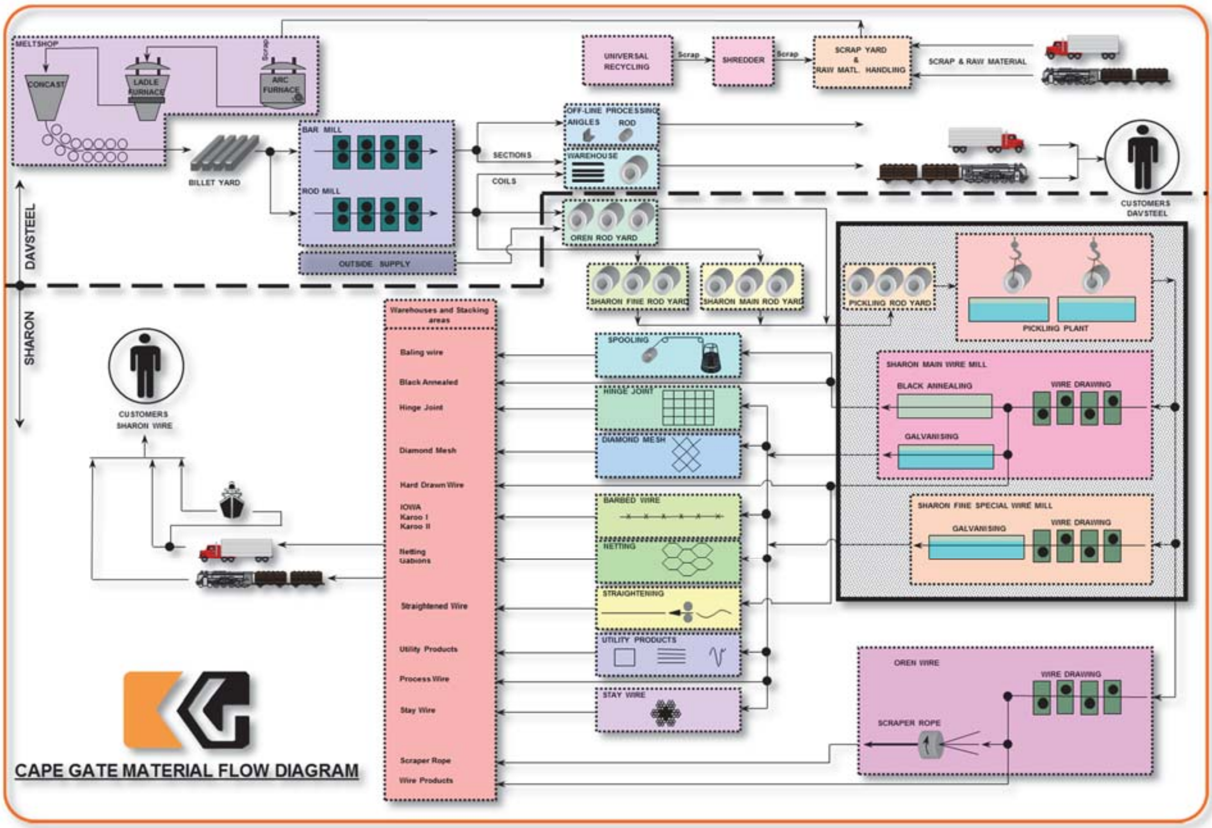


Figure 36: Cape Gate Process Flow Diagram

Cape Gate mainly uses municipal water as fresh feed, both for cooling and process consumption. Groundwater is also pumped out from under the Bar and Rod Mill section due to seepage water and in order to continue working in the area. Seepage water is also pumped out under the raw materials silos. Main water uses are as follows:

- Cooling at Mills, Davsteel, Galvanising, (Poor quality)
- Process water
- Galvanising and Picking plant
- Cooling of slag – Poor quality water (Recycled water)
- Water coming from the Millscale Plant (Bad quality water)

The only effluent generated on site is from the pickling and galvanising plant, which with the permission of Emfuleni Local Municipality is sent to sewer. However Cape Gate is currently in the process of commissioning a Reverse Osmosis Plant at the effluent plant in order to recover this water for re-use on site and also to eliminate releasing this wastewater to sewer. This will thus result in a reduction of both fresh water intake as well as effluent released. All other process water such as cooling water is stored, treated and re-used in the process. Effluent analyses reflect that the heavy metal and related components are well within specification, although excursions in TDS are experienced at times.

Cape Gate also operates a number of lined landfill compartments. Seepage from these compartments is recovered and used to cool slag from the EAF thus disposing of the water by evaporation.

Rainwater and stormwater is released in stormwater drains. It is not collected and used on site.

From an environmentally responsible viewpoint, Cape Gate was totally willing to participate in the study and to share the requested information. However in view of the current extremely tough global business environment in the Iron and Steel Industry, the technical personnel who need to complete sections of the Assessment Schedule are currently more than fully occupied with retrenchment activities, whilst still having to maintain production activities in parallel. Hence they unfortunately could not complete certain sections of the assessment schedule.

3.5. SCAW Metals

SCAW Metals is based in Germiston in Gauteng, South Africa. The Industrial Development Corporation (IDC) is the majority shareholder (74%) in the SCAW Metals Group. Main Street 510 (Pty) Ltd, consisting of a Black Economic Empowerment consortium holds 21% and an employee share ownership plan trust holds 5%(35).

The SCAW Metals management decided not to participate in the study and thus no further information on their process, water use and effluent generation was received.

4. REGULATORY ENVIRONMENT

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 iron and steel industry in South Africa. The section concludes with the key findings from the case study sites that participated in the NATSURV study.

4.1. Industry Standards and Specifications

A number of standards and specifications, that include inherent properties which drives water use improvement, are used in the iron and steel industry. Typically standards used in the iron and steel industries include:

- ISO 9001: Quality Management
- ISO 14001: Environmental Management
- OHSAS 18001: Occupational Health and Safety
- ISO 31000: Risk Management

- ISO 55000: Asset Management
- ISO 22301 Business Continuity Management System
- SANS 10330:2007: Hazard Analysis and Critical Control Point System (HACCP System).
- SABS 17025 (water sampling).

4.2. National Legislation

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

Table 14: A summary of the most pertinent water legislation relevant to the Iron and Steel Industry

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: • 21. Identification of activities which will probably have detrimental effect on the environment; • 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: • prevent pollution and ecological degradation; • 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; • 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; • "Polluter pays" principle, whereby the 'Waste Discharge Charge System' applies; • Pollution prevention is everybody's responsibility and environmental pollution or degradation, in so far as it is authorized by law or cannot reasonably

Responsible Government Department	**Regulation**	**Sector covered and Applicable area to Industry**	**Main aspects**	**Of note to Industry**
				be avoided or stopped, must be minimized and rectified; • 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; • Outlines the requirements for waste management plans; • Outlines waste management measures such as reduction, reuse, recycling and recovery; • Storage collection and transportation; • Treatment, processing and disposal; • Licensing requirements; Remediation of contaminated land and registration on the waste information system.
	- 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; • Establishes a mechanism and procedure for the listing of waste management activities that do not require a Waste Management Licence; • Prescribes the requirements for the disposal of waste to landfill; • Prescribes the requirements and timeframes for the management of certain wastes; and • Prescribes the general duties of waste generators, transporters and managers.	• Requirement to classify waste ito SANS 10234 and period of re-classification; • Management of waste and recording of hazardous waste, e.g. safety data sheet, labelling, etc.; • Conditions of mixing and treating waste is linked to the potential for re-use, recycling and waste recovery; • Assessment and disposal of waste in accordance with the *Standard for Assessment of Waste for Landfill Disposal;* • Motivation for- and consideration of listing Waste Management Activities that do not require a Waste Management Licence; • Requirements regarding record keeping and waste manifest system; • Prescribes the general duties of waste generators, transporters and managers.
	National Environmental Management: Waste Amendment Act,	All industries: Production process, waste & wastewater minimisation, resource	To amend the National Environmental Management: Waste Act, 2008, so as to: • to establish a pricing strategy for waste management charges and to provide for the content	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

Responsible Government Department	**Regulation**	**Sector covered and Applicable area to Industry**	**Main aspects**	**Of note to Industry**
	2014 (Act No. 26 of 2014)	recovery, waste & wastewater discharge	and application of the pricing strategy; • 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.	definition of 'waste' itself, as well as that of 'recovery'. 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; • Identifies priority areas and the management thereof; • Listing of activities resulting in atmospheric emissions; • Pollution prevention plans; • Measures in respect of dust, noise and offensive odours; • 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: • the establishment of the National Air Quality Advisory Committee; • to provide for the consequences of unlawful	Of specific note to industry is the following: • 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;

Responsible Government Department	Regulation	Sector covered and Applicable area to Industry	Main aspects	Of note to Industry
			commencement of a listed activity; • to provide for monitoring, evaluation and reporting on the implementation of an approved pollution prevention plan; • to clarify that applications must be brought to the attention of interested and affected parties soon after the submission to the licensing authority; • to provide for a validity period of provisional atmospheric emission licence; • to create an offence for non-compliance with controlled fuels standards; • to provide for the development of regulations on climate change matters and the procedure and criteria for administrative fines.	• 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; • Time period placed on the validity of a provisional atmospheric emission licence.
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.
			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.
			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
				Of specific interest to Industry are:
				• Chapter 1 Interpretation and fundamental principles;
				• The section dealing with how water will be protected, used, developed, conserved, managed and controlled;
				  o Chapter 2 Water management strategies
				  o Chapter 3 Protection of water resources
				  o Chapter 4 Use of water
				  o Chapter 5 Financial provisions
				• Chapter 14 Monitoring, assessment and information;
				• The section dealing with Mechanisms to address appeals, offences and remedies;
				  o Chapter 15 Appeals and dispute resolution

Responsible Government Department	Regulation	Sector covered and Applicable area to Industry	Main aspects	Of note to Industry
			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: • Resource directed measures aim to protect and manage the receiving environment; • Source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms. 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.	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: • Section 7 - Industrial use of water; • Section 9 - Standards; • 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 - No.1191 General And Special Authorisation - Discharge limits and conditions set	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. Also identifies the test method to be used, and Areas where the special standards must be applied are provided. Defines the General And Special Authorisation - Discharge limits and conditions	

Responsible Government Department	Regulation	Sector covered and Applicable area to Industry	Main aspects	Of note to Industry
	out in the National Water Act, Government Gazette No. 20526, 8 October 1999			

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

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:

- ***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.

4.3. Municipal Bylaws

The Section 21 of the Water Services Act require all municipalities (water services authorities) to publish and 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.

4.3.1. 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).

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 360 mg/ℓ and SS greater than 9 ml/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:

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

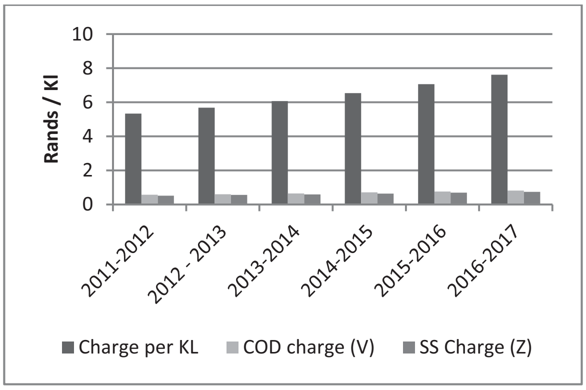
Where:	
COD	: Chemical Oxygen Demand in mg/ℓ
SS	: Settleable Solids in l/ℓ
V	: rate for the treatment in the treatment works of standard domestic effluent having a prescribed COD value
Z	: rate for the treatment in the treatment works of standard domestic effluent having a prescribed settleable solids 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 15.

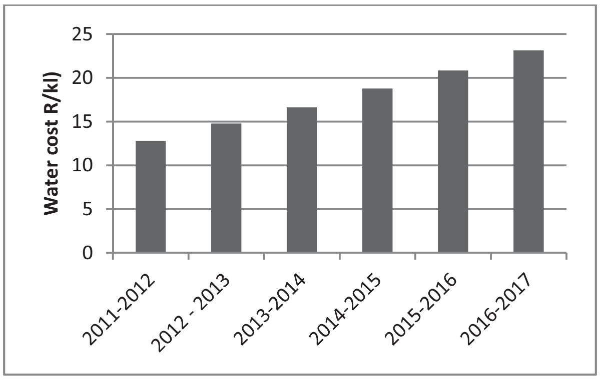
Table 15: Basic unit costs for water and effluent in eThekwini Municipality (EWS, 2014)

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 in 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

4.3.2. 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						

4.3.3. 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
N_d = 25 mg/ℓ

3. **Non-compliance with By-Law 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 by-law
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 16: 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
0-1 0 000 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**

4.3.4. 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-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.

4.3.5. Amajuba District Municipality: (seat in Newcastle)

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 by-laws***)** 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 by-laws*) 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 promotes 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 17: Amajuba Schedule for limits and maximum concentration of substances that may be contained in discharged effluent

Parameter	Allowed Specification
Electrical conductivity not greater than	500 mS/m at 20 degrees Celsius
Substances not in solution including fat, oil, grease, waxes and like substances – (a) of mineral origin (b) of vegetable origin	(a) < 50 mg/ℓ (b) (b) < 200 mg/ℓ
Chlorides (expressed as Cl)	1 000 mg/ℓ
Anionic surface active agents	250 mg/ℓ
Sulphates (expressed as SO_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

4.3.6. 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:

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

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

4.3.7. uMhlathuze Local Municipality (seat in 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 specify 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:

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

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 18: 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 19: 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

General Quality	Limits Large Works > 25 Mℓ/d	Small Works < 25 Mℓ/d	Units
9. Flouride (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
Heavy Metal Limits			
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 20: Conditions for discharge into the sea outfall:

Sea Outfall Quality Limited		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

4.4. Industry Conformance to Standards and Specifications

4.4.1. Compliance with Industry Standards

The iron and steel 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 include the following Certification:

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

In general companies have indicated that they are not accredited for:

- ISO 31000 – Risk Management
- ISO 55000 – Asset Management

Other approaches and standards used to inform best practice management and site expansion include:

- Water footprinting;
- Risk assessment and management;
- HIRA (Hazard Identification and Risk Assessment), which entail the identification and assessment of hazards and associated risks, and to validate and finally to implement control measures to eliminate or mitigate the risks to an acceptable level
    - Cost allocation for all capital projects is based the HIRA process.
    - Environmental related projects are prioritized as part of the drive to care for the environment.

Below is also an extract from the ArcelorMittal Environmental Policy as a typical example:

"Environmental excellence, incorporated into all processing activities, is to be promoted by the following principles:

1) Implementation of **environmental management systems** including ISO 14001 certification for all production facilities;
2) **Compliance** with all relevant environmental laws and regulations, and other company commitments;
3) **Continuous improvement** in environmental performance, taking advantage of systematic monitoring and aiming at pollution prevention;
4) Development, improvement and application of low impact, **environmental production methods** taking benefit of locally available raw materials;
5) Development and manufacture of **environmentally friendly products** focusing on their use and subsequent recycling;
6) Efficient use of **natural resources, energy and land**;
7) Management and reduction where technically and economically feasible of the **CO2 footprint** of steel production;
8) **Employee commitment** and **Employee commitment** and responsibility in environmental performance;
9) **Supplier and contractor awareness** and respect of ArcelorMittal's environmental policy;
10) **Open communication** and dialogue with all stakeholders affected by ArcelorMittal's operations."

4.4.2. Raw Water Specifications

One of the sites participating in the study purifies drinking water on site for all its employees and contractors and has adopted the South African National Drinking Water Standard (SANS) 241 as a guideline. As such the raw water must not contain any elements that may be harmful to humans. One of the concerning elements for drinking water is aluminium as the raw water aluminium concentrations often exceeds the standard.

Secondly, a site that recycles a large volume of effluent for treatment and re-use raised a concern regarding incoming TDS as a result of upstream activities not complying with water use licences. Due to the nature of the water processes, the recycling of effluent is TDS dependant. When the TDS in the incoming raw water becomes high, then recycling of effluent is not possible due to process TDS constraints. This normally occurs when mines upstream discharge mine water during the rainy season.

4.4.3. Effluent Release Specifications

Generally the effluent release quality and quantity specifications are based on municipal bylaws or the applicable Water Use Licence.

4.4.4. Contaminants of Emerging Concern

No specific monitoring was reported by any of the sites participating in the study.

4.5. Industry Conformance with South African National Legislation

4.5.1. Water Use Licences

The steel mills participating in this study all 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.

Although these documents have been made available by industry for the study purposes, it is too extensive to include as support documentation in the report

> Refer to the "Best Practice Guidelines for Water and Wastewater Management in the Iron and Steel Industry" for guidance on the application for water use authorisations.
>
> [DWS, 2016]

4.5.2. Compliance with Water Use Licences

The feedback from industry is as follows:

- ✓ Due to the worldwide economic recession, the Steel Industry is under severe pressure with some sites on the verge of closing down;
- ✓ Some of the licences focus on converting sites to ZED facilities and both technical and financial difficulties are experienced in achieving this at some of the mills;
- ✓ Stormwater management on old sites covering massive footprints is extremely difficult and expensive to rectify and would in some cases require total demolition of sites which is not viable. Compliance in this regard is a focus area, but full compliance is not achieved; and
- ✓ Varying levels of compliance have been reported by different mills and are in general between 90 and 100% depending on which aspect of the licence is considered.

4.6. Industry Perspective

4.6.1. Challenges Experienced

In general, good relations exist between DWS and industry. The most significant frustration experienced by most iron and steel mills are:

1. The lack of feedback and extensive time taken by DWS with regards to the permit application/transfer/renewal process;
2. Certain mills also believe that unreasonable conditions are enforced and some limits that are set do not make sense. Industry perceives these to be due to a lack of understanding of the industry and water chemistry by government;
3. It appears as if limits set are based on averaging the values of analyses submitted during the IWLA process, which is not considered to be a practical approach;
4. Some case sites reported that limits set were based on internal "stretch targets" set by management for investigation by their engineers; and
5. Further concerns raised include high staff turnover and thus lack of continuity at DWS, language barriers and communication gaps between officials.

4.6.2. Use of Targets

Apart from the licensed standards and limits, no other targets are set for the industry by the DWS. The Iron and Steel Industry expressed the following perspectives regarding the use of targets:

- Setting of targets is already done voluntarily at some of the steel mills;
- No single target value can be set for the whole industry due to the extreme variability between different sites;
- Concerns were expressed if targets are set arbitrarily without a full understanding of the specific industry and what is achievable, e.g. a stainless steel producer will require completely different targets to a carbon steel or vanadium producer; and
- A more realistic target methodology will be to focus on specific water intake and effluent generation rates and continuous improvement on these values.

4.6.3. Use of Incentive Based Regulation

Industry is aware of the Department of Water and Sanitation approach to incentive based regulation, and is generally supportive of the philosophy. Industry holds the opinion that this form of regulation should be considered, and will help to maintain focus on good water conservation practices. A possible methodology with regards to the incentive based regulation of water consumption should be to perhaps reduce the cost of water (paying a better rate at lower abstraction volumes).

5. WATER USE AND MANAGEMENT

5.1. Factors Affecting Water Use

Water use in the Steel 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 would be. Due to the physical size of these facilities it is also often not economical to retrofit more water-wise processes in these facilities.
2. Processing technology used – Different technologies are utilised in the industry worldwide and impacts directly on the water requirement of the site.
3. Feed source used – Different feed sources require different processing steps, impacting directly on water requirements. The footprint of using recycled steel is also much smaller than for using iron ore.
4. Type of product produced – Again a range of different products such as carbon steel, stainless steel, vanadium, etc. are produced in SA that will impact on the water consumption.

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.

5.2. Water Consumption at South African Steel Mills

Based on 2014 results for the different mills in SA, the specific fresh water intake is summarised in Table 21. Due to a requirement by a number of sites for anonymity, site names are not included.

Table 21: Specific Fresh Water Intake for Different Steel Mills

Site	Specific Abstracted Water Intake (m^3/t product)
Site A	0.82
Site B	2.34
Site C	3.8
Site D	9.32
Site E	4.1
Site F	DNS
Site G	DNS

DNS – Did not supply

From the table it can be seen that specific fresh water intake per ton of product can vary significantly between different sites. This is as a result of the factors listed in paragraph 5.1. 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. Where available, this is evaluated in more detail on a per mill basis in the following sections.

Since the bulk of water is used for cooling in the Steel Industry, the consumption is directly proportional to the quantity of steel produced. Further, based on the laws of conservation of energy the quantity of water required to cool a certain quantity of steel from a fixed high temperature to a low temperature cannot be reduced. Hence the only way to significantly reduce water consumption in this industry is to treat effluent to a purity level where it can be re-used and thus replace a portion of the fresh water used for cooling.

Smaller uses such as wash-down, seal water and chemical make-up could provide smaller opportunities for water saving.

Most sites also incorporate effluent treatment and re-use. The specific treated effluent consumption per ton of product is summarised in Table 22. A high specific effluent consumption rate relative to fresh water indicates a larger proportion of effluent that is treated and re-used and thus a reduced fresh water footprint for a site.

Table 22: Specific Treated Effluent Consumption for Different Steel Mills

Site	Specific Treated Effluent Consumption (m^3/t product)
Site A	3.6
Site B	1.4
Site C	Not Specified
Site D	0.9
Site E	Not Specified
Site F	DNS
Site G	DNS

DNS – Did not supply

5.3. Typical Water Sources Used

All the sites listed in Table 22 typically utilise a combination of two water sources, namely raw water and re-use of purified effluent in differing ratios depending on the level of treatment done per site.

The fresh water is either river water abstracted under a Water Use Licence or municipal potable water supply under a supply agreement with the relevant municipality.

All the sites listed do some form of effluent treatment from fairly rudimentary to maximising re-use of effluent water. At a number of the sites new treatment facilities have been installed within the last 12 months or are in the process of being installed. As the new units come on-line and start achieving improved treatment results, the ratio of re-used water to fresh water will improve. At some sites as much as a 40% reduction in fresh water intake has been reported since commissioning the effluent treatment facility.

5.4. Trends in Specific Water Intake

A number of the sites provided information on their historical specific fresh water intake which often reflects the impact of treated effluent re-use on fresh water intake as new effluent treatment units come on-line. Specific fresh water intake for sites A, B, C and E are respectively presented in Figure 37, Figure 38, Figure 39 and Figure 40.

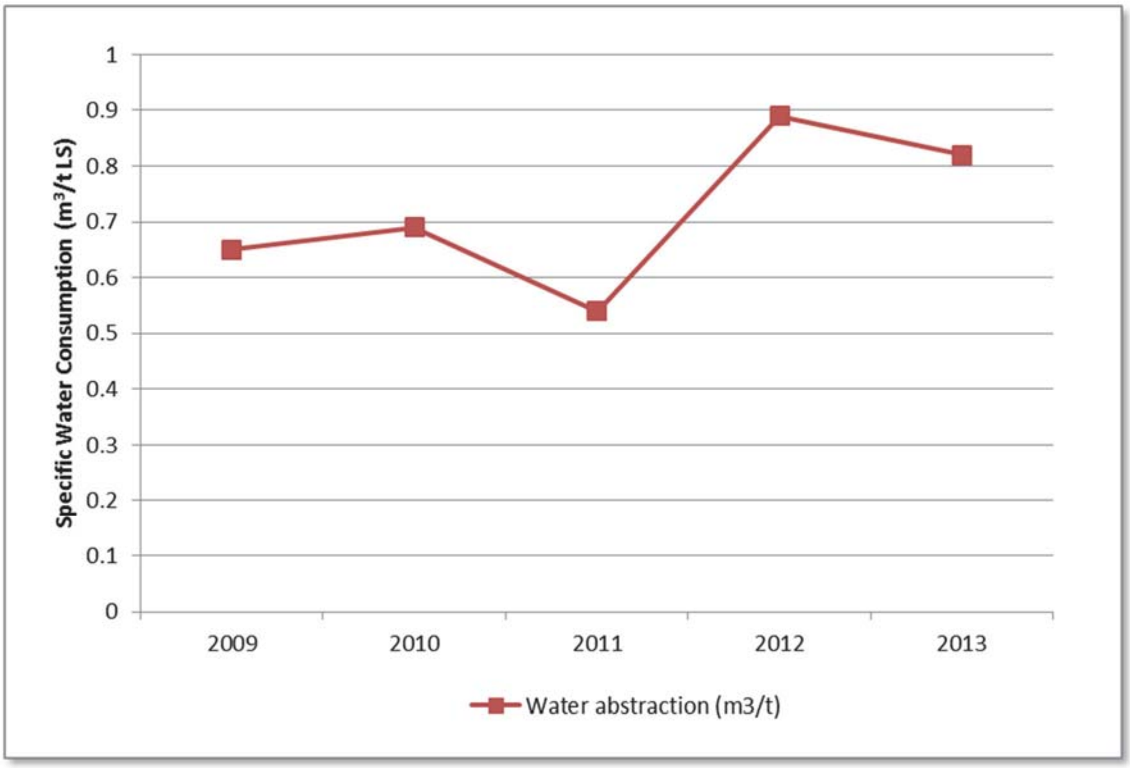


Figure 37: Site A Specific water Intake between 2009 and 2013

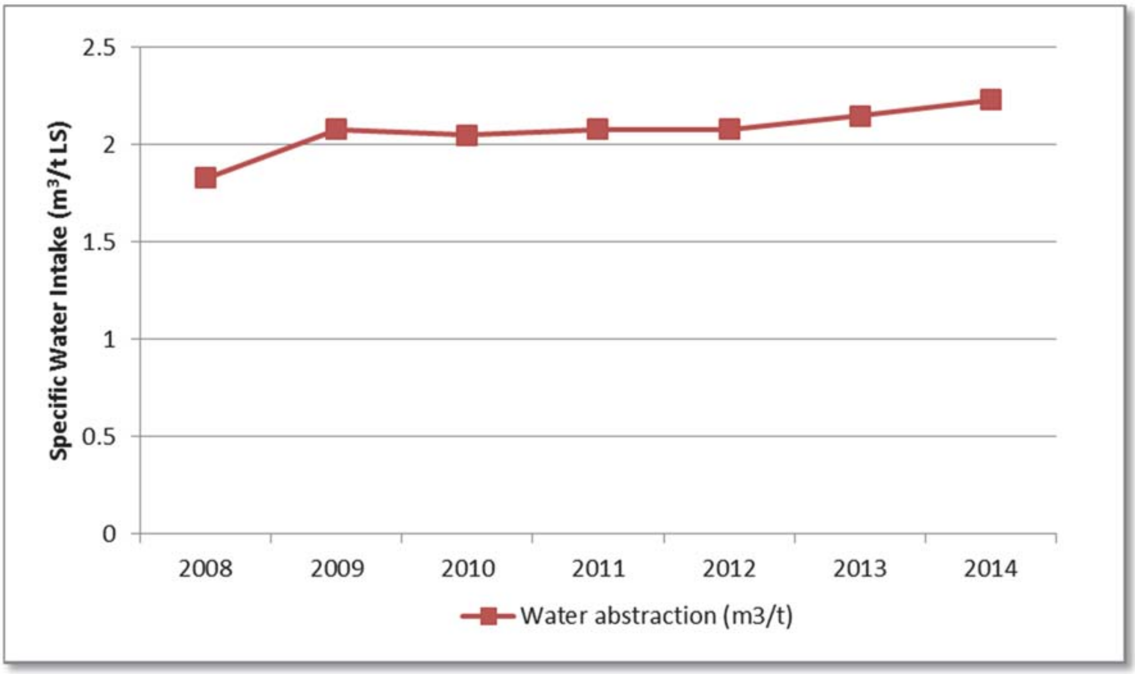


Figure 38: Site B Specific water Intake between 2008 and 2014

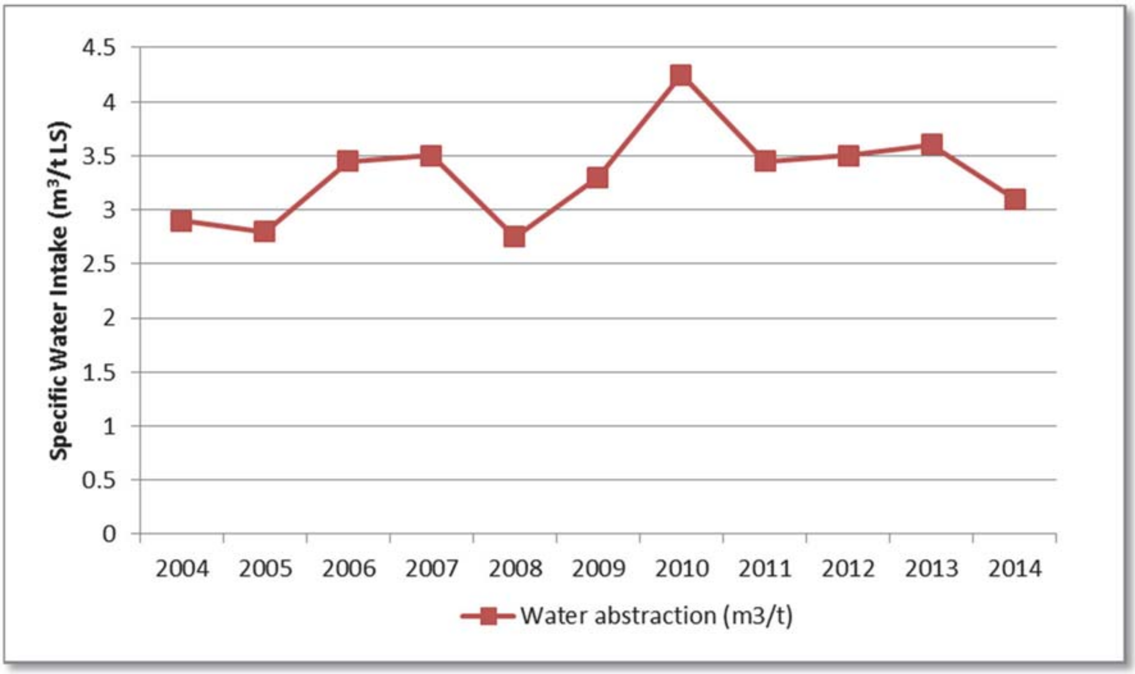


Figure 39: Site C Specific water Intake between 2004 and 2014

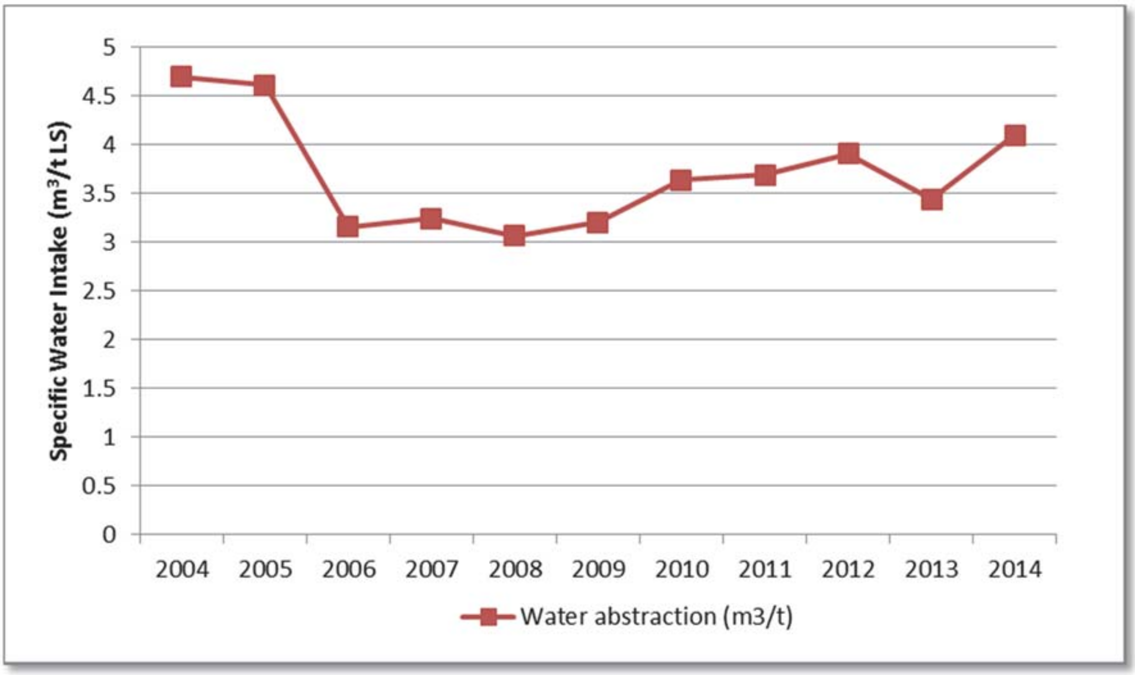


Figure 40: Site E Specific water Intake between 2004 and 2014

5.5. Actions Taken by Industry to Reduce Water Intake

As discussed in the previous sections, the most viable method for the Steel Industry to reduce water intake is to treat effluent to a re-usable quality. Most of the sites involved in the study have or are in the process of implementing some form of effluent treatment to a quality suitable for re-use.

At sites like Saldanha Bay and Columbus incorporation of the ZED design principle formed part of the original design philosophy and apart from continuous fine-tuning of the process no significant further reductions in raw water consumption are possible.

At older sites water conservation was typically not as important a focus point at the time of design and construction of these sites as it is today. In general in any industry the retrofitting of an effluent treatment plant in an already operating facility is a complex and expensive exercise. However all the companies involved in this study have indicated that improved water management practices are being considered. Some examples of projects recently implemented at various sites were shared with the NATSURV team and are discussed below.

ArcelorMittal Newcastle:

The effluent generated on site was traditionally irrigated, but is now treated in a new effluent treatment plant with the objective to treat and re-use all process effluent. The plant was commissioned in 2014. A secondary benefit of installing the facility is a reduction of fresh water abstraction by 300 m^3/h (40 %).

The effluent treatment consists of two sections, a biological treatment unit followed by a desalination section. All effluent streams are combined upstream of the unit and treated in both processes. The brine from the RO plant will be dewatered by the existing evaporator crystallizer plant which has sufficient capacity. Some start-up changes are being implemented that is expected to further improve the operation of the facility.

ArcelorMittal Vanderbijlpark:

For the AMSA Vanderbijlpark site, a flagship effluent treatment project at cost of R 220 million has recently been completed. DWS rewarded ArcelorMittal South Africa with a Sector Award to celebrate this achievement.

The project included the construction of a new wastewater treatment plant (the Main Treatment Plant) and the upgrade of the Central Effluent Treatment Plant wastewater treatment plant.

The site has also targeted to be a ZED facility from 1 January 2006. Unfortunately, Vanderbijlpark currently faces some technical challenges to maintain the ZED status and a project is currently under way to improve the situation.

These projects have resulted in a reduction of more than 50% in raw water abstraction. From 2004/2005 Vanderbijlpark reduced its annual fresh water intake from approximately 23 billion litres to ~9.3 billion litres in 2014.

Cape Gate:

Cape Gate is in the process of commissioning a new RO plant on the galvanised wire effluent plant. Product water from this unit will be re-used on site and will thus result in a reduction of both fresh water intake as well as effluent released, however the site will still not be a zero effluent site.

Evraz Highveld:

In the period between 2000 and 2003 the return water dams were repaired and dam walls lifted as well as ump station installed, resulting in improved water recycling.

A water balance study was conducted in 2006/2007 and ongoing maintenance is performed on the water circuit to minimise water losses.

Continuous improvement plans include:

- An acid mine drainage project that is being investigated,
- Bio-growth technology to be looked at and

- Implementation of a better control system to supply water only on need. This will be dependent on production factors.

The intent is to improve on water consumption depending on technology development.

6. EFFLUENT GENERATION AND MANAGEMENT

6.1. Factors Impacting on Effluent Generation

As has been discussed, the bulk of water use in the Steel Industry is for cooling purposes and thus evaporative water losses account for most of the fresh water utilised on these sites. Water that has not evaporated is typically routed to effluent treatment facilities at most sites. Thus from most sites no effluent leaves the facility battery limits and therefore the specific effluent volume for most sites is zero. Thus no specific effluent volume can be reported as part of this study.

6.2. Actions Taken by Industry to Reduce Effluent Release

As mentioned in paragraph 5.5 effluent treatment and re-use constitutes the best way to reduce raw water intake. Hence the discussion on raw water intake reduction has already largely discussed actions taken by industry on effluent treatment. Some additional site specific best practises as shared by industry are included in the following sections.

ArcelorMittal Newcastle:

The facility is becoming a ZED facility. As the operation of the new effluent treatment plant has improved, irrigation of effluent will be phased out. The intention is to treat and re-use all process effluent, thus reducing raw water intake (already 40% reduction).

A design team is also currently working on conceptual stormwater management infrastructure designs.

ArcelorMittal Saldanha Bay

Based on the complexity of the effluent processing to achieve the maximum water recovery, it has been found that operator skills levels are critical and matric as a minimum is required to be able to operate such a complex plant. This facility was designed from the onset to be a ZED facility and was able to maintain such status to date.

ArcelorMittal Vanderbijlpark

At Vanderbijlpark, the company has invested ZAR 39 M in the first phase of a coal water project, to improve the treatment of organically polluted water at the steelworks. The second phase will be to build a biological water treatment plant to effect further improvements. These projects will help the works maintain its ZED status over the longer term and improve on its water management practices in general.

The company has also phased out the effluent storage ponds that were used in Vanderbijlpark in the past. AMSA Vanderbijlpark is in the process of remediating the sediments that are still in the ponds, using ground-breaking biological methods to break down the organics.

The site's maturation ponds (pictured in Figure 41 during the rehabilitation phase), which were mainly used for the storage of coke making effluent, and Dam 10 (the main effluent storage facility in the past) were taken out of operation in 2006. In addition, another set of ponds, used for the storage of leachate was phased out in December 2010.

Figure 41: AMSA Vanderbijlpark Storage Pond Remediation

Columbus

This site is the only site to have made use of water pinch technology to optimise the water systems.

Effluent quality as per the feed to the evaporators is included in Table 23.

Table 23: Columbus Stainless Evaporator Feed Quality

METHODS	UNITS	METHOD NO	SAMPLE INFORMATION				
					SCE 10		
SampNo:					6025656		
Al	mg/l	WLB-TEST-016*			33.2		
Ca	mg/l	WLB-TEST-016*			1251		
Chrome six	mg/l	WLB-TEST-341			< 0.01		
Cl-	mg/l	WLB-TEST-334			78.4		
Co	mg/l	WLB-TEST-016*			2.15		
Conductivity at 25 °C (m	mS/m	WLB-TEST-311			8006		
Cr	mg/l	WLB-TEST-016			511.7		
Cu	mg/l	WLB-TEST-016*			10.3		
F-	mg/l	WLB-TEST-312			6186		
Fe	mg/l	WLB-TEST-016*			3920		
K	mg/l	WLB-TEST-016*			257		
Mg	mg/l	WLB-TEST-016			16.1		
Mn	mg/l	WLB-TEST-016			30.2		
Na	mg/l	WLB-TEST-016			791		
Ni	mg/l	WLB-TEST-016*			85.8		
Nitrate	mg/l as N	WLB-TEST-336			15345		
pH	-	WLB-TEST-313			1.8		
Si	mg/l	WLB-TEST-016*			1625		
SO4	mg/l	WLB-TEST-335			1634		
TDS	mg/l	Calculation*			52300		
temperature	°C	WLB-TEST-313			20.4		
TALK	mg/l CaCO3	WLB-TEST-309*			<20.0		
V	mg/l	WLB-TEST-016*			1.95		
Zn	mg/l	WLB-TEST-016*			2.52		

The evaporator then produces a condensate quality water as per Table 24.

Table 24: Columbus Stainless Evaporator Condensate as Re-used on Site

METHODS	UNITS	METHOD NO	Evaporator condensate
SampNo:			6155984
Ca-Hard	mg/l CaCO3	WLB-TEST-017*	<2.5
Chrome six	mg/l	WLB-TEST-341	< 0.01
Cl-	mg/l	WLB-TEST-334	< 2.5
Conductivity at 25 °C (m	mS/m	WLB-TEST-311	8.08
Conductivity at 25 °C (u	uS/cm	WLB-TEST-311	
Cr	mg/l	WLB-TEST-017*	<0.02
F-	mg/l	WLB-TEST-312	<0.5
Fe	mg/l	WLB-TEST-017*	0.0441
K	mg/l	WLB-TEST-017*	0.0637
Mg-Hard	mg/l CaCO3	WLB-TEST-017*	<2.5
Mn	mg/l	WLB-TEST-017*	
Na	mg/l	WLB-TEST-017*	0.121
P	mg/l	WLB-TEST-017*	
pH	-	WLB-TEST-313	10.21
Si	mg/l	WLB-TEST-017*	
SiO2	mg/l	WLB-TEST-017*	
SO4	mg/l	WLB-TEST-335	
TDS	mg/l	Calculation*	
temperature	°C	WLB-TEST-313	23.7
T-Hard	mg/l CaCO3	WLB-TEST-017*	<5.0
TALK	mg/l CaCO3	WLB-TEST-309*	192

Evraz Highveld:

Effluent generation at Evraz Highveld has been reduced by discontinuing the practice of coke production, thus eliminating the generation of coke effluent. This happened approx. in 2003/2004

A wastewater plant project is underway which could result in the possible revamp of the existing wastewater plant to convert it to a bioremediation plant depending on the success of the trial.

7. ENERGY USE AND MANAGEMENT

Energy consumption in the Steel Industry 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. Often water consumption and energy consumption impact on each other.

7.1. Energy Intensity of the Steel Industry

According to the European Emissions Trading Scheme, the basic Iron and Steel Industry and ferro-alloys industry in Europe are classified as high energy intensive industries (NACE 3-digit code 271). The energy input corresponds to about 15% of the production value and electricity to 4%. The EU Steel Industry has cut its energy consumption by 47% per ton of finished steel between 1975 and 2000 [31].

The typical EU based electricity consumption was 0.25-0.65 MWh/t (0.7-2.3 GJ/t) depending on the type of furnace in 2004 with electricity being the 3rd most important energy source for the industry. Coal, mainly as coke, remains the main energy source [31].

The decreasing trend in specific energy consumption is confirmed by the Worldsteel Association (refer Figure 42). The energy efficiency is also dependant on the production route, the type of iron ore and coal used, the steel product mix, operational control technology and material efficiency [32].

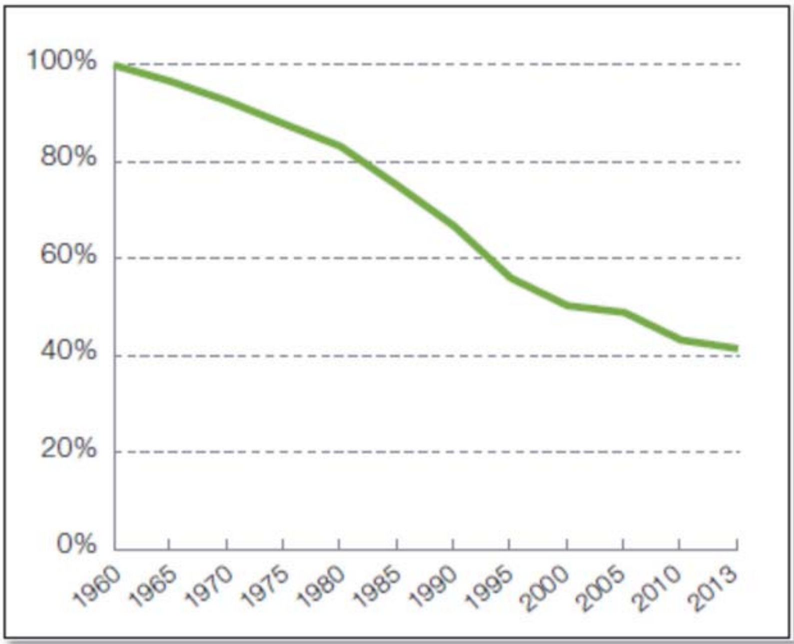


Figure 42: Decrease in Global Energy Consumption per tonne of Crude Steel Production [32]

By-product gasses from coke ovens, blast furnaces and basic oxygen furnaces can be re-used to save on fossil fuel consumption [32]. From the investigation this is standard practice in South African Steel Mills.

Predicted specific energy consumption by different steel processing technologies is summarised in Figure 43 [33].

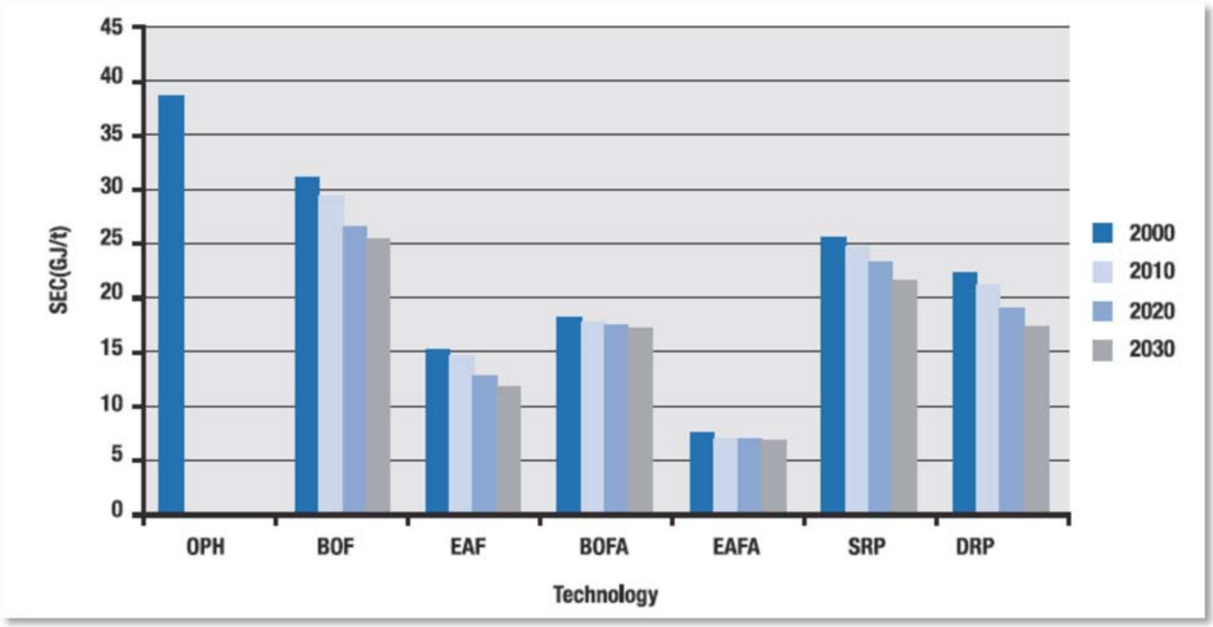


Figure 43: Predicted Specific Energy Consumption [33]

Most South African steel manufactures were unwilling to share energy consumption information, due to the fact that it is seen as sensitive intellectual property. Information received is summarised in Table 25 below.

Table 25: Specific Energy Consumption for Different Steel Mills

Site	Specific Energy Consumption (GJ/t product)
Site α	Electricity: 4.64
Site β	DNS
Site γ	Electricity: 9.4 Total: 10.6
Site δ	Not disclosed
Site ε	Not disclosed
Site η	Not disclosed
Site θ	Not disclosed

DNS – Dis not supply

NB: Note that the order of sites as listed here are different to those in Table 21 and Table 22.

7.2. South African Steel Industry Energy Consumption

The South African industry has confirmed that energy together with labour costs constitutes the two main operating costs.

Typical energy sources used are electricity from Eskom, Methane-rich gas from various suppliers, coal, diesel/petrol and gas produced and re-used on site and other smaller energy sources.

Main energy consumers are the various furnaces used at the different facilities, the mills as well as auxiliary electrical machinery, wire drawn machinery, etc.

Energy saving measures that have been implemented includes conversion to variable speed drives on larger electrical motors, lighting, heat recovery and a reduction in fuel rates in the furnaces.

7.3. Potential Energy Improvement Opportunities

Industry members have listed some energy improvement studies they are busy conducting, namely:

- Recovery of Waste heat,
- Optimisation of CO gas used to heat ladles and furnaces,
- Process / operational control and kiln operation improvements,
- Using tyre waste material as an alternative fuel source in the process,
- Oxygen enriched burning in kilns,
- Ore sizing projects,
- Furnace roof improvements,
- Studying alternative reduction methods.

8. WATER USE AND EFFLUENT TREATMENT: BEST PRACTICE

8.1. Water Pinch Studies

Water pinch studies have not found widespread interest in the South African Steel Industry, with only one mill indicating that such a study was conducted and some of the recommendations having been implemented. Oil removal and TSS removal takes place at source prior to further centralised treatment. In general further effluent treatment facilities are end-of-pipe treatment facilities with all effluents combined prior to treatment.

8.2. Specifications and Standards

All the companies that participated in the NATSURV survey of the South African Steel Industry are both ISO 9001 and ISO 14001 certified. They also have a number of product specific quality certifications.

8.3. Stormwater Management

The design of the stormwater 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 DW&S. Changes to an existing stormwater network is extremely complex and expensive and due to all aboveground infrastructure on an existing site very difficult to modify based on changing requirements.

Typically stormwater is routed to central collection facilities on site. From here it is either routed to evaporation ponds or integrated with effluent treatment feed water. The water is the processed and re-used on site.

8.4. Irrigation of Effluent

A method of resource recovery that has historically been 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.

This practise is however extremely 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.

The trend at a number of sites visited is however to move away from irrigation and also from storage of effluent in evaporation ponds.

At a site where irrigation is currently practiced, but is being phased out as an effluent treatment facility is being commissioned to replace irrigation, the principles according to which irrigation was practised were:

- Ploughing and plant of the three irrigation circles on an annual, basis. Teff is planted during summer months and Oats during the winter months,
- Daily inspections are performed to prevent pooling and water logging,

- Boreholes and surface water is sampled and monitored to manage pollution of surface and underground water and
- Runoff due to rain and excessive irrigation is managed by collection, testing and release (or recycle).

8.5. World Steel Association Water Position Paper

The steel industry recognises the important role that water plays in its manufacturing operations and also its value to society. The World Steel Association has issued a position paper on behalf of the steel industry on water use in the steel industry. The main points from the paper [36] are discussed in the "***Best Practice Guideline***".

8.6. Best Practices

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.

Water is considered by the Steel Industry in general as an important consideration and forms part of their sustainability considerations and reporting. Typical international water best practices for the Steel Industry have been developed by the Australian National University for the Australian Government [34] and are discussed in more detail in the "***Best Practice Guideline***", which may be studied in conjunction with the NATSURV 20 report.

The following areas of best practice is generally applied in the industry:

Imbed water management in good corporate governance structures: Water use already forms a focus area of sustainability reporting in the South African Steel Industry.

Form a Water Management Team: a number of Steel Mills have indicated that they have teams responsible for water management and control. Best practices recommend that the team includes a project manager, an assessment task manager, engineers, maintenance staff, a financial manager and executive management representative. The committee should focus on tracking water savings, championing capital proposals, coordinate and promote interdepartmental water savings projects and staff involvement and education.

Undertake a water audit: Only one mill indicated that they have performed a formal water pinch study. Most mills did however indicate that they either already have or are in the process of installing facilities to recover treated effluent for re-use which would indicate that some form of audit had to have been conducted to identify water streams to treat and to what quality to enable re-use. Primary effluent treatment is performed at source, e.g.: oil, TSS, ammonia, etc. removal. Secondary effluent treatment is mostly end-of-pipe treatment, rather than stream segregation. A water audit not only considers quantity, but also quality in order to be able to assist in identifying applications where wastewater may be directly used as water source for another process requiring a lower grade of water.

Identify the major areas of water usage: In the Steel Industry this is typically for cooling and process uses.

Analyse water saving options: A number of the South African steel mills already treat, re-use and recycle water on site as per the proposed best practice approaches. At least two of the sites are also already or in the process of importing treated wastewater as an alternative to using potable water. The option of importing treated effluent from neighbouring industries could also provide some opportunities to reduce potable water imports. Since most South African mills are located inland, the use of sea water is not feasible, but some mills have incorporated desalination on effluent streams to enable re-use there-of. Options similar to the Durban Water Recovery facility supplying treated and disinfected sewage water to industrial areas around Durban could be evaluated by some of the steel mills. To make this financially sustainable, cooperation with neighbouring industry will probably be required.

Undertake cost benefit analyses: Although effluent can in theory be recovered to a large extent it comes at a cost. The international Steel Industry is in a low product value cycle, making the economy of expansion and improvement projects marginal at current prices. The availability of cheaper products from countries such as China is also putting further pressure on the local industry. Thus cost benefit analyses should be performed, but also revisited as the industry drivers change, since projects that are not viable under the current world economy may again become viable at a later stage.

Develop Key Performance Indicators: KPI's can be used as a tool to monitor water management performance. Total water consumption is not recommended as a measurement tool, since a larger mill may use more water but at a better efficiency. Typical parameters should rather include parameters such as specific fresh water intake per ton of steel, volume of wastewater discharged per ton of steel and % recycle achieved. It also is not practical to set a single target value for all steel mills since each mill is unique with unique factors dictating what can be achieved. A more realistic model would be to agree on continuous improvement targets set up taking the site specific factors into consideration.

Setting targets: Continuous improvement targets are a tool used widely in many industries to drive water consumption reduction. Targets can be both on divisional, as well as for site-wide, performance. Short and long term targets should both be considered, where short term targets will typically focus more on day-to-day operation and maintenance improvements, where-as long term targets are project driven.

On-going monitoring, review and reporting: In order to quantify any successes achieved, sufficient monitoring is required. Targets should also be reviewed on an on-going basis. Today's best practice will eventually become tomorrow's norm with new best practices being developed. Monitoring without testing against targets is however of no value and thus setting of reasonable continuous improvement targets is recommended.

Partner with business water saving initiatives: Partnering with neighbouring industries, communities and municipalities could result in additional water re-use opportunities being realised.

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. Best practices studies that was in the EU in 2010 highlighted the potential water and wastewater BAT practices for following:

- Coke Oven Plants(38)
- Blast Furnaces(38):
- Basic Oxygen Steelmaking and Casting(38)
- Electric Arc Furnace Steelmaking and Casting(38).

Refer to the "***Best Practice Guideline for Water and Wastewater Management in the Iron and Steel Industry***".

8.7. Techniques Considered in BAT application in the EU

Although this section provides an international perspective on some techniques that can be considered in BAT application, site specific conditions may make the application of techniques impractical. Not all proposals may be relevant and in many of the South African mills these BAT applications are already implemented. Life-cycle costing taking the full environmental footprint of a modification into consideration must form a central part of BAT application.

What may be considered as BAT for a certain aspect of the production process may not be the best option when considering the full environmental footprint of a modification, e.g. targeting zero liquid effluent discharge may seem the best solution to protect water resources, but such techniques become extremely energy intensive and could result in increased air emissions and water consumption as a result of power generation resulting in an overall detrimental environmental impact.

8.7.1. Coke Oven Plants

A best practices study for the Iron and Steel industry that was performed in the EU in 2010 highlighted the potential water and wastewater BAT practices for Coke Oven Plants[38]:

- BAT is to minimise and reuse quenching water as much as possible,
- BAT is to avoid the reuse of process water with a significant organic load (like raw coke oven wastewater, wastewater with a high content of hydrocarbons, etc.) as quenching water,
- BAT is to pretreat wastewater from the coking process and coke oven gas (COG) cleaning prior to discharge to a wastewater treatment plant by using one or a combination of the following techniques:
  - using efficient tar and polycyclic aromatic hydrocarbons (PAH) removal by using flocculation and subsequent flotation, sedimentation and filtration individually or in combination
  - using efficient ammonia stripping by using alkaline and steam.
- BAT for pretreated wastewater from the coking process and coke oven gas (COG) cleaning is to use biological wastewater treatment with integrated denitrification/nitrification stages.

The BAT-associated emission levels, based on a qualified random sample or a 24-hour composite sample and referring only to single coke oven water treatment plants, are:

- chemical oxygen demand (COD([1])) — <220 mg/ℓ
- biological oxygen demand for 5 days (BOD_5) — <20 mg/ℓ
- sulphides, easily released ([2]) — <0.1 mg/ℓ
- thiocyanate (SCN^-) — <4 mg/ℓ
- cyanide (CN^-), easily released ([3]) — <0.1 mg/ℓ
- polycyclic aromatic hydrocarbons (PAH) — <0.05 mg/ℓ
  (sum of Fluoranthene, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene, Indeno[1,2,3-cd]pyrene and Benzo[g,h,i]perylene)
- phenols — <0.5 mg/ℓ
- sum of ammonia-nitrogen (NH_4-N)
  nitrate-nitrogen (NO_3-N) and nitrite-nitrogen (NO_3-N) — <15-50 mg/ℓ.

Regarding the sum of ammonia-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N) and nitrite-nitrogen (NO_2-N), values of <35 mg/ℓ are usually associated with the application of advanced biological wastewater treatment plants with predenitrification/nitrification and post-denitrification.

(1) In some cases, TOC is measured instead of COD (in order to avoid $HgCl_2$ used in the analysis for COD). The correlation between COD and TOC should be elaborated for each coke oven plant case by case. The COD/TOC ratio may vary approximately between two and four.

(2) This level is based on the use of the DIN 38405 D 27 or any other national or international standard that ensures the provision of data of an equivalent scientific quality.

(3) This level is based on the use of the DIN 38405 D 13-2 or any other national or international standard that ensures the provision of data of an equivalent scientific quality.

8.7.2. Blast Furnaces

A best practices study for the Iron and Steel industry that was performed in the EU in 2010 highlighted the potential water and wastewater BAT practices for Blast Furnaces[38]:

- BAT for water consumption and discharge from blast furnace gas treatment is to minimise and to reuse scrubbing water as much as possible, e.g. for slag granulation, if necessary after treatment with a gravel-bed filter.
- BAT for treating wastewater from blast furnace gas treatment is to use flocculation (coagulation) and sedimentation and the reduction of easily released cyanide, if necessary.

  The BAT-associated emission levels, based on a qualified random sample or a 24-hour composite sample, are:

  - suspended solids <30 mg/ℓ
  - iron <5 mg/ℓ
  - lead <0.5 mg/ℓ
  - zinc <2 mg/ℓ
  - cyanide (CN^-), easily released ([1]) <0.4 mg/ℓ.

  ([1]) This level is based on the use of the DIN 38405 D 13-2 or any other national or international standard that ensures the provision of data of an equivalent scientific quality.

8.7.3. Basic Oxygen Steelmaking and Casting

A best practices study for the Iron and Steel industry that was performed in the EU in 2010 highlighted the potential water and wastewater BAT practices for Basic Oxygen Steelmaking and Casting[38]:

- BAT is to prevent or reduce water use and wastewater emissions from primary dedusting of basic oxygen furnace (BOF) gas by using one of the following techniques:
  - dry dedusting of basic oxygen furnace (BOF) gas;
  - minimising scrubbing water and reusing it as much as possible (e.g. for slag granulation) in case wet dedusting is applied.
- BAT is to minimise the wastewater discharge from continuous casting by using the following techniques in combination:
  - the removal of solids by flocculation, sedimentation and/or filtration,
  - the removal of oil in skimming tanks or any other effective device,
  - the recirculation of cooling water and water from vacuum generation as much as possible.

  The BAT-associated emission levels, based on a qualified random sample or a 24-hour composite sample, for wastewater from continuous casting machines are:

  - suspended solids <20 mg/ℓ
  - iron <5 mg/ℓ
  - zinc <2 mg/ℓ
  - nickel <0.5 mg/ℓ
  - total chromium <0.5 mg/ℓ
  - total hydrocarbons <5 mg/ℓ.

8.7.4. Electric Arc Furnace Steelmaking and Casting

A best practices study for the Iron and Steel industry that was performed in the EU in 2010 highlighted the potential water and wastewater BAT practices for Electric Arc Furnace Steelmaking and Casting[38]:

- BAT is to minimise the water consumption from the EAF process by the use of closed loop water cooling systems for the cooling of furnace devices as much as possible unless once-through cooling systems are used.
- BAT is to minimise the wastewater discharge from continuous casting by using the following techniques in combination:
  - the removal of solids by flocculation, sedimentation and/or filtration,
  - the removal of oil in skimming tanks or in any other effective device,
  - the recirculation of cooling water and water from vacuum generation as much as possible.

  The BAT-associated emission levels, for wastewater from continuous casting machines, based on a qualified random sample or a 24-hour composite sample, are**:**

  - suspended solids <20 mg/ℓ
  - iron <5 mg/ℓ
  - zinc <2 mg/ℓ
  - nickel <0.5 mg/ℓ
  - total chromium <0.5 mg/ℓ
  - total hydrocarbons <5 mg/ℓ

8.8. 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”[46] as well as the WRC report on Cost Benefit Analysis with reference to Water Resource Development [47]. 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 type 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 1st edition of NATSURV 20 on water use in the South African Iron and Steel industry reflects an industry that is under severe pressure due to the global decline in steel prices. Despite this, a number of upgrades were being implemented and commissioned at a number of sites during the time that the survey was conducted. In general the support of industry for the study was good with only one mill declining to participate. Two other mills could only provide partial information due to a lack of resource availability due to restructuring resulting and retrenchment activities occurring. However where available, information was freely shared in order 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 4 sites participating varied between 2.34 and 9.32 m^3/t. The Specific Effluent Volume (SEV) generated varied between 0.9 and 3.6 m^3/t.

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 Iron and Steel industry. These practices are outlined in more detail in the "***Best Practice Guideline for Water and Wastewater Management in the Iron and Steel Industry***" which has been developed in conjunction with the NATSURV 12 study. Typical recommended BAT principles include:

- **Imbed water management in good corporate governance structures:** Water use already forms a focus area of sustainability reporting in the South African Steel Industry.
- **Form a Water Management Team**: a number of Steel Mills have indicated that they have teams responsible for water management and control.
- **Undertake a water audit**: Only one mill indicated that they have performed a formal water pinch study. Most mills did however indicate that they either already have or are in the process of installing facilities to recover treated effluent for re-use which would indicate that some form of audit had to have been conducted to identify water streams to treat and to what quality to enable re-use. Primary effluent treatment is performed at source, e.g.: oil, TSS, ammonia, etc. removal. Secondary effluent treatment is mostly end-of-pipe treatment, rather than stream segregation.
- **Identify the major areas of water usage**: In the Steel Industry this is typically for cooling and process uses.
- **Analyse water saving options**: A number of the South African steel mills already treat, re-use and recycle water on site as per the proposed best practice approaches. At least two of the sites are also already or in the process of importing treated wastewater as an alternative to using potable water. The option of importing treated effluent from neighbouring industries could also provide some opportunities to reduce potable water imports. Since most South African mills are located inland, the use of sea water is not feasible, but some mills have incorporated desalination on effluent streams to enable re-use there-of.
- **Undertake cost benefit analyses**: Although effluent can in theory be recovered to a large extent it comes at a cost. The international Steel Industry is in a low product value cycle, making the economy of expansion and improvement projects marginal at current prices. Thus cost benefit analyses should also be revisited as the industry's drivers change, since projects that are not viable under the current world economy may again become viable at a later stage.
- **Develop Key Performance Indicators**: KPI's can be used as a tool to monitor water management performance. It is not practical to set a single target value for all steel mills since each mill is unique with unique factors dictating what can be achieved. A more realistic model would be to agree on continuous improvement targets set up taking the site specific factors into consideration.

- **Setting targets**: Continuous improvement targets are a tool used widely in many industries to drive water consumption reduction. Targets can be both on divisional, as well as for site-wide, performance. Short and long term targets should both be considered, where short term targets will typically focus more on day-to-day operation and maintenance improvements, where-as long term targets are project driven.
- **On-going monitoring, review and reporting**: In order to quantify any successes achieved, sufficient monitoring is required. Targets should also be reviewed on an on-going basis. Today's best practice will eventually become tomorrow's norm with new best practices being developed. Monitoring without testing against targets is however of no value and thus setting of reasonable continuous improvement targets is recommended.
- **Partner with business water saving initiatives**: Partnering with neighbouring industries, communities and municipalities could result in additional water re-use opportunities being realised.

The reported SWI and SEV values are also comparing well with international reported water consumptions.

The BAT principles identified during the execution of the NATSURV study generally compare well with international recommended BAT practices for the Iron and Steel industry. These principles are already reflected in a number of the improvements reported by industry as well as in the design of the more recently constructed mills.

It is recommended that future BATs focus on continuous improvement in SWI and SEV targets; and that research continues to explore the energy and resource recovery potential associated with the 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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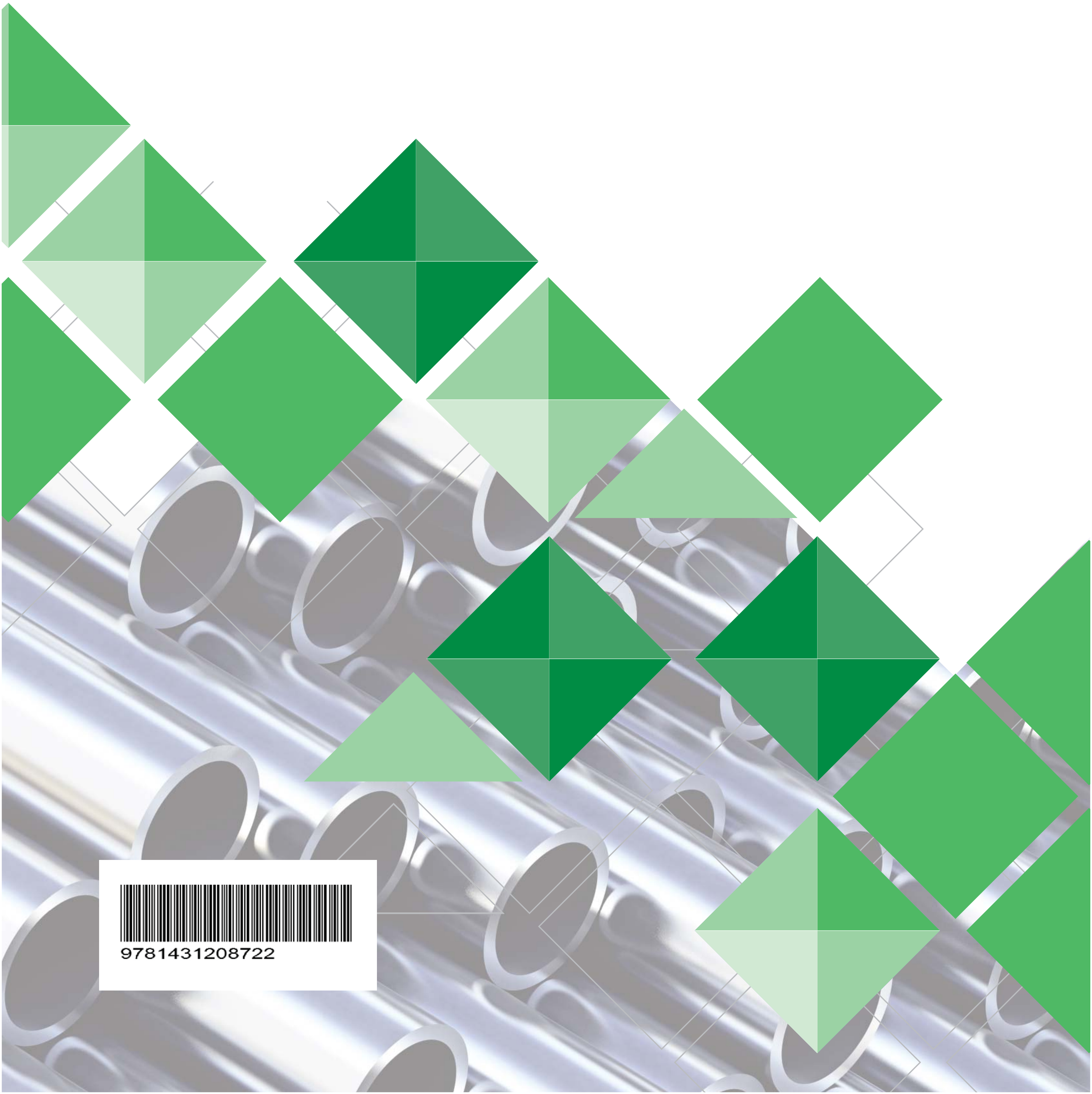

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