Natsurv 1:

Water and Wastewater Management in the Malt Brewing Industry

(Edition 2)

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WATER RESEARCH COMMISSION

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NATSURV 1: WATER AND WASTEWATER MANAGEMENT IN THE MALT BREWING INDUSTRY (EDITION 2)

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Executive Summary

South Africa is a semi-arid country, where water is a key strategic resource in the development of all sectors of the economy. Efficient management of these limited water resources is therefore an essential element in the malt brewing industry. This segment of the Natsurv series provides insights into specific aspects of production in the malt brewing industry that would have direct or indirect impacts on water resources. An earlier Natsurv edition of water and wastewater management in the malt beer brewing industries in South Africa was conducted in 1986 by Binnie and Partners Consulting Engineers for the Water Research Commission. Since this time, the industry has undergone a number of significant changes such as: form/type of raw material used, operational changes, and the introduction of improved technologies for wastewater and waste treatment. It is therefore considered an opportune time to review the water and wastewater management practices of this industrial sector and update the earlier Natsurv document.

Owing to sustained increases in the costs of fuel oil, raw materials (including freshwater), the discharge of waste and effluent treatment, the brewing industry has been compelled to reduce production costs by intensifying and optimising their production processes. In addition to these economic challenges, the regulatory framework governing production industries has also become more stringent. In South Africa, the industry is expected to comply with an increasing number of national laws as well as provincial ordinances and local by-laws. It is in this context that the conservation and efficient use of energy and water; and pollution control has become important in the modern brewing industry.

Beer production for large breweries amounts to over 6,000,000 barrels (704,087 m^3) per annum, medium is between 15,000 to 6,000,000 barrels and small is less than 15,000 barrels (17,602 m^3) per annum (Brewers Association, 2013). Since the publication of Natsurv 1 – Water and Wastewater Management in the Malt Brewing Industry in December 1986, the number of breweries in South Africa has increased from seven breweries to more than 150 (including craft or microbreweries), as have production volumes. Previously, most breweries were locally-owned; however, current ownership is both national and multi-national for the large breweries, whilst the medium-, small and craft/micro-breweries tend to be locally owned. Published literature estimates water consumption to range from 4 to 8 litres/litre of beer produced (World Bank, 2007), but may be even higher in the case of small breweries, generally owing to inefficient water management processes and systems.

In the brewing industry water is used for beer production and also for cleaning, sanitation, heating and cooling processes. The malt brewing industry is classified under the food and beverage category and generates three forms of waste streams, namely: solid waste (from raw material inputs and packaging), liquid waste (wastewater from various processes) and gaseous waste. The two dominant waste streams that impact on wastewater generation management are solids and liquids.

The study methodology included a review of the current literature, an assessment of industry reports and a questionnaire survey undertaken among the small local breweries. Responses were obtained from 15 of the 44 small breweries surveyed. Water used by the local breweries is variously obtained from four main sources: borehole, municipal, rainwater and freshwater springs. The majority of breweries in South Africa use municipal water and the municipal sourced water quality show little variation at the different breweries. There are a few breweries that use borehole (well) water and rainwater.

The pH of the wastewater samples (combined wastewater streams) from small malt breweries has an average of 5.9 which is within the preferred range for brewing, while the nitrate loads were much lower at 0.1mg/l, rather than the 1.5mg/l described by EC (2006). Parameters such as COD, SS, TDS, and TOC, total nitrogen, total phosphorous and soluble orthophosphate fall outside of the given ranges or exceed the EC recommended maximum values; requiring local wastewater pre-treatment.

A common challenge experienced in other similar studies is the unavailability of data and information from breweries for several reasons including: “the information is simply not easily accessible on their systems”, “the system fails to capture accurate waste information” (Fakoya and Van der Poll, 2013:139), or “The accounting division do not have express access to production waste data through the system” (Fakoya and Van der Poll, 2013:140). Poor local data and information provision was a consequence of concerns expressed by local breweries regarding the use and publication of their data. Despite these challenges, an analysis of available data and information obtained from the local survey showed similar comparative trends to those adopted by breweries internationally.

The study has also shown that, for a number of different industrial sectors, there are common technologies available and applicable to reduce resources use and impacts (such as energy and water consumption) and wastewater generation. Many of these technologies would be applicable to breweries in general.

Abbreviations

CIP	Clean In Process
COD	Chemical Oxygen Demand
DEA	Department of Environmental Affairs
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	European Commission
EWS	eThekwini Water and Sanitation
FCDA	Foodstuffs, Cosmetics, and Disinfectants Act
GWh	Gigawatt hours
kWh	kilowatt-hour
IWRM	Integrated Water Resource Management
LED	Light Emitting Diode
NWA	National Water Act
OHSA	Occupational Health and Safety Act
SAB	South African Breweries
SANS	South African National Standards
SS	Suspended Solids
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
UNEP	United Nations Environment Programme
USA	United States of America
WSA	Water Services Authority
WSP	Water Services Provider
WWTP	Wastewater Treatment Plant

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1 Introduction

1.1 Malt Brewing Industry Overview

South Africa is a semi-arid country with limited water resources, making this a key strategic resource necessary for the country's sustained economic development. There is fierce competition for water in several parts of the country, particularly where there is a high level of water intensive economic activity but low water availability. Ideally, water intensive industries would be located in areas of high water security to offset potential water supply risks. The malt brewing industry has a high water input requirement in its production value-chain; hence, industry location and operational efficiencies are paramount considerations in minimising potential economic viability and environmental impact risks, particularly in South Africa. In terms of water usage in beer production, the ratio of water to beer is 5.5 hl water to 1 hl. South Africa accounts for 34% of Africa's beer market with a beer consumption estimated at 60 litres per capita in 2012 (Research and Market, 2012).

An earlier Natsurv edition that examined water and wastewater management in the malt beer brewing industries in South Africa was prepared by Binnie and Partners Consulting Engineers for the Water Research Commission in 1986. Since this time, the industry has undergone a number of significant changes such as: form/type of raw material used, operational changes, and the introduction of improved technologies for wastewater and waste treatment. The number of breweries in the country has increased from 7 large breweries to over 150 as a conservative estimate. It must further be noted that this study included the craft/micro-breweries, which generally operate at a household or local micro enterprise scale and there is anecdotal evidence indicating that this sector has grown substantially over the last decade, with the numbers estimated to be doubling annually since 2013. Most micro-breweries operate as commercial local-level micro-enterprises, with household operations being hobbies having an estimated combined market share just under one percent of the local market. Production ranges between 25 hl/year to several thousand litres a batch of beer produced.

South African Breweries (SAB) controls majority South Africa beer market at 98% followed by Brandhouse (merger of Heineken & Diageo) established in 2009 in Sedibeng, South of Johannesburg, Gauteng Province. The SAB operates 7 breweries across the country (SAB report, 2012) as shown in Fig 1. The micro-breweries have entered into the South African market, where the first one was introduced in 1983. In terms of geographical distribution of breweries, mostly they are concentrated in Western Cape and Gauteng provinces. In terms of beer production, the microbreweries accounts for less than 17,600 hectolitres of beer annually and generally serves mainly the local communities. The micro-breweries geographical spread in South Africa is as follows regionally: 44 in Western Cape, 1 Mpumalanga, 25 Durban, 38 Gauteng, 5 Free State, 15 Eastern Cape, and 10 Northwest provinces (Beer garden SA).

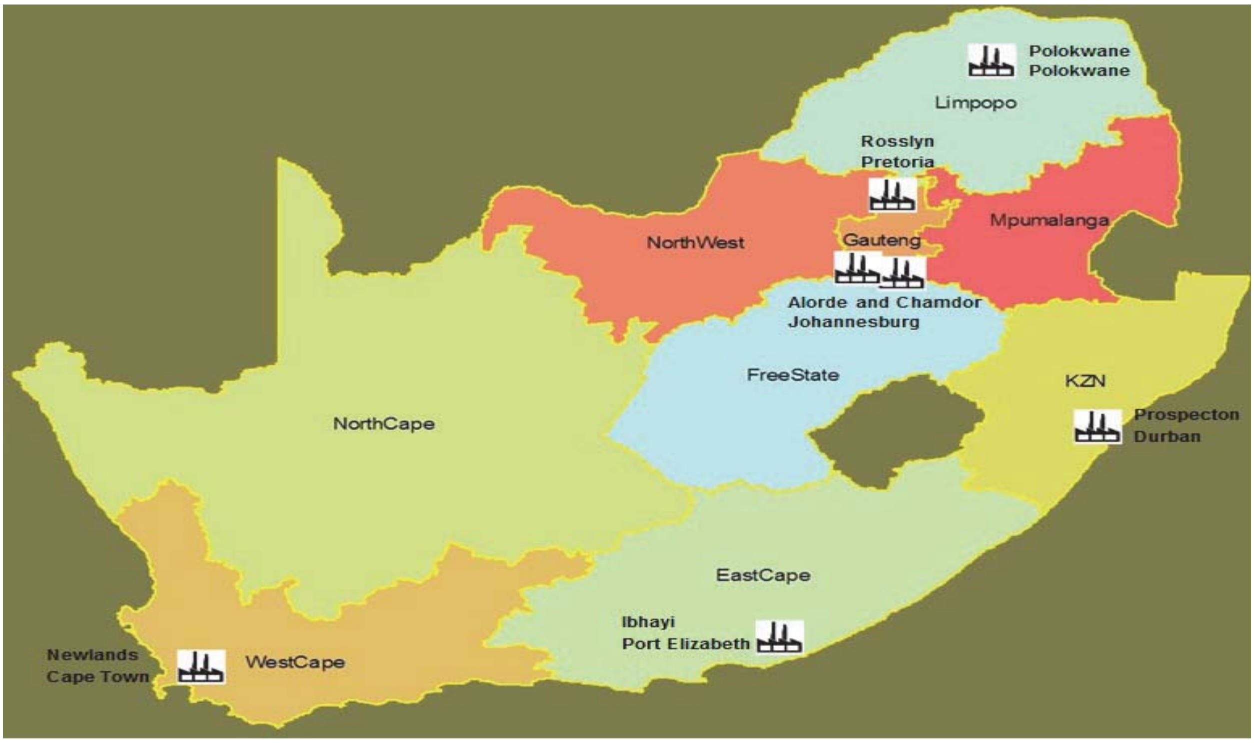

Figure 1 Geographical mapping of the SAB breweries in South Africa

As shown in Table 1, SAB, the largest brewer, owns and operates seven breweries with a total annual brewing capacity of 3.1 billion litres (SAB report, 2014). The individual breweries vary in size, where the smallest brewery is 150 million litres a year and the largest is 830 million litres a year. Brandhouse has one brewery with a production capacity of 400 million litres (Brandhouse Report, 2014). Although Brandhouse has grown market its share since it took over production and marketing of the Amstel brand, it still makes up less than 10% of the malt beer market. The beer market share for SAB and Brand house is approximately 99%. There has been a significant increase in the number of microbrewers in South Africa; however, together with the medium- and small-breweries, they still account for a very small share of the market amounting to less than 1% in South Africa (Beer Garden SA).

Table 1 Beer production capacity in South Africa per annum

	Capacity (million litres)	**Share of Total Beer Market (%)**
SAB Miller	3100	88.20
Brandhouse	400	11.40
Medium-, Small and Craft/Micro-breweries	15*	0.40
Total	3515	100

Source: SAB, Brandhouse and Craft Brewery (2014)
*estimated from average craft brewery numbers supplied by Craft Beer South Africa

SABMiller produces all the top-selling beer brands in South Africa. These are, in the order of market share: Carling Black Label, Castle, Hansa, Castle Milk Stout and Castle Lite. The

Brandhouse brands are Heineken, Amstel, Windhoek, Guinness, Kilkenny and Tafel Lager. There is great diversity among the medium-, small- and craft/micro-breweries in South Africa, ranging in size from a few thousand litres a year (targeting production for beer festivals); to those that produce for the draught and bottled/canned product markets which tend to have a larger capacity. The bigger breweries include the Cape Brewing Company (3 million l/a), Mitchell's (2.5 million l/a), Darling Brew, Jack Black, Boston (1.6 million l/a) and Soweto Gold (2 million l/a).

Most changes in the malt brewing sector have taken place as a result of sustained increases in the production input and waste management costs: fuel oil, raw materials (including water) and the treatment and discharge of waste and effluent. Accordingly, the brewing industry has been compelled to reduce costs and environmental impacts by increasing process efficiencies through intensifying and optimising their production and waste management practices. In addition to economic challenges, the regulatory framework governing production industries has also become more stringent, particularly regarding waste management. In South Africa the industry is expected to comply with a number of national laws as well as provincial ordinances and local by-laws. It is in this context that the conservation and efficient use of energy and water; and waste and pollution management and control has become important for the modern brewing industry.

The regulatory framework affecting the brewing industry extends beyond the beer preparation phase to all aspects of the production value chain including: distribution, labelling, packaging, advertising, trade and pricing practices and alcohol content (Goldammer, 2008). There is realization of the extensive water impacts and intensive energy requirements associated with beer production processes. As a result, national environmental legislation now compels industry, including the malt brewing sector, to optimise and reduce water usage and energy requirements. Although these legislative changes are intended to encourage industrial efficiency in general (optimisation and productive use of raw materials, energy and water), it sets industry on a more environmentally responsible and sustainable pathway (Goldammer, 2008).

In view of these changes in the operating environment of the malt brewing industry in South Africa, the timing is appropriate to review current water and wastewater management practices in the industry and identify what changes have taken place since the 1986 survey, and assess the impact of these changes and its relevance to current practices and requirements.

1.2 Project Objectives

The purpose of the project was to:

- Establish current generic industry processes;
- Determine water consumption and specific water intake volumes;
- Determine the wastewater generation and typical pollutant loads;
- Examine the legislative frameworks within which these industries operate; and,
- Critically evaluate the water (inclusive of wastewater) management processes adopted for process optimisation with the view to water, wastewater and waste minimisation.

1.3 Methodology

The methodology adopted to achieve the project objectives included:

- A literature survey;

- An assessment of industry reports, particularly to compare local and international practices and benchmarks; and,
- Evaluation of local brewing processes by means of a questionnaire survey. No site inspections and meetings or field visits were undertaken to verify the information provided in the questionnaires.

The literature survey was conducted to ascertain whether and what general and specific processes and operations were taking place within the malt brewing industry with respect to production, process inputs, technology evolution and standards among other factors. A comparative assessment could then be undertaken between local and international processes and operations relating to benchmarks and best practice. It was also necessary to ascertain the numbers and location of malt brewing industries operating within South Africa and to classify these according to their production capacity. The malt brewing industries were classified into three size categories. Beer production for large breweries amounts to over 6,000,000 barrels (704,087 m^3) per annum, medium is between 15,000 to 6,000,000 barrels and small is less than 15,000 barrels (17,602 m^3) per annum (Brewers Association, 2013).

Once identified, breweries were contacted to determine their willingness to participate in a survey by means of a questionnaire. The survey considered information from literature and companies that participated by completing the questionnaire. Data obtained from the questionnaire provided an inventory of breweries, as well as insights into production processes and the likelihood and potential impacts of brewery operations at their various localities nationally.

1.3.1 Questionnaire Administration

Questionnaires were formulated based on information from the literature survey. The questionnaire covered the following aspects:

- manufacturing processes – which included seven structured questions;
- water consumption – ten questions;
- energy consumption – nine questions;
- waste and wastewater treatment – three questions; and,
- best practices – three questions.

Breweries were contacted telephonically, depending on their willingness to participate in the survey, followed by an email with an introduction letter and the questionnaires. Breweries were given three weeks to return the completed questionnaires.

2 Malt Brewing Industry Process Overview

Malt brewing processes have remained unchanged and the only change has been the introduction of new technology that is faster and efficient in electricity usage. The malt brewing process is summarised in Figure 2, the major steps of beer production includes: malting, brewing, fermentation and storage (bottling or barrelling). Though breweries have adopted changes, most of the breweries that participated in this survey they operate seasonally and use manual washing processes. An overview of areas that inform the development of best practices particularly with respect to water, wastewater, waste, and energy management during different phases of malt brewing processes is essential.

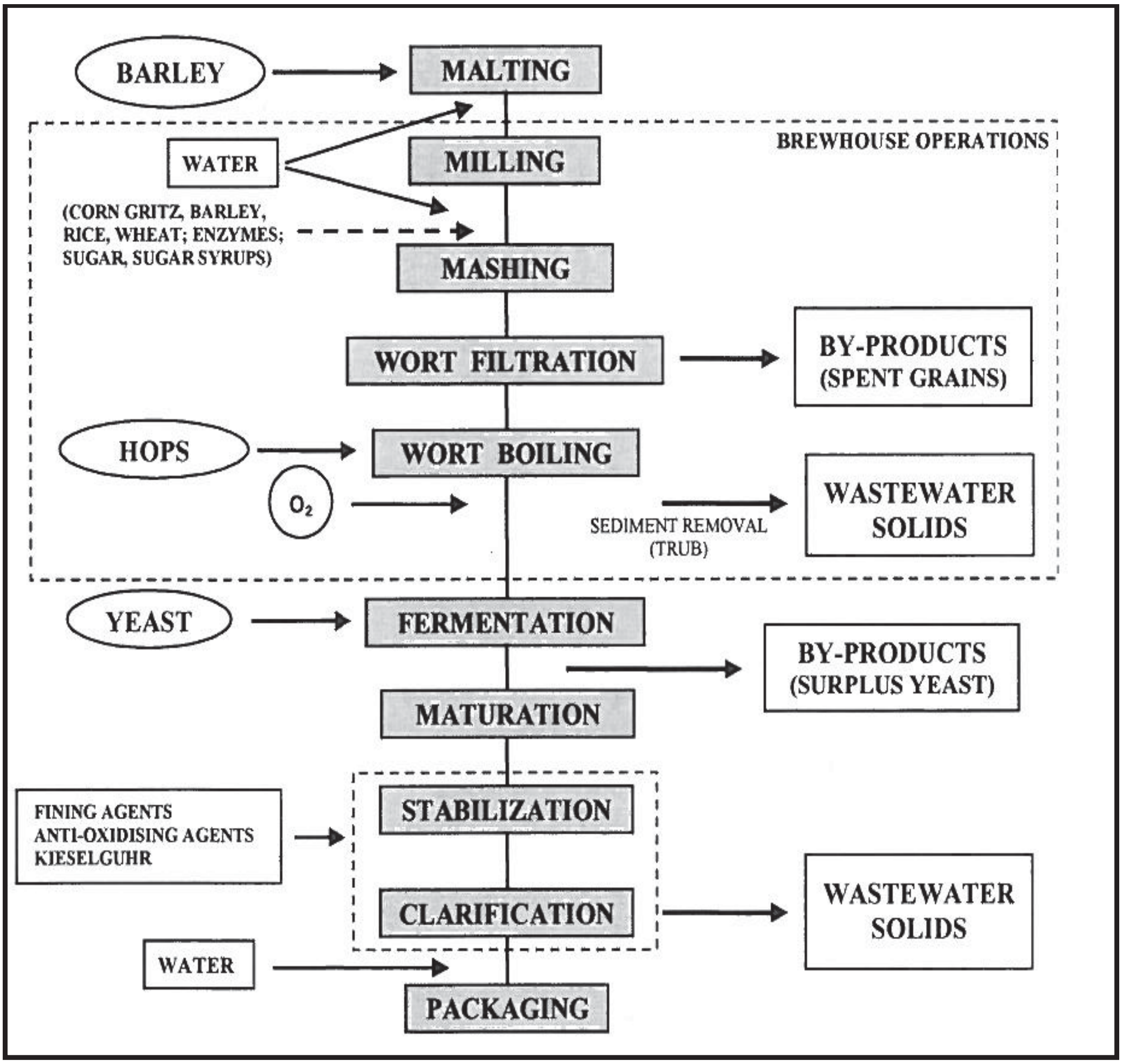

Figure 2 The generic brewing processes for beer production
Source: Varman and Sutherland (1994); Unicer, SA (2005)

2.1 Beer Production Processes

The overall beer production method is similar for most breweries and has not fundamentally changed over the years. Where changes and differences are noted, depends on factors such as: type of beer brewed, and the size of the brewery. For example, smaller breweries typically only produce beer from malted barley to give it a stronger taste; mass market beer, on the other hand, is produced from a combination of malt and maize to make the beer lighter and the flavour less intense. The brewing process requires ingredients such as Maize, rice, wheat, sugar, water, barley, hops, and yeast. The first step in the process is malting which is usually done outside the brewhouse at a dedicated facility, although some breweries may have an in-house malting plant. In this process the grain is soaked in water to increase its moisture content to promote germination. The germinated grain is then dried in a kiln before it is transferred into the brewhouse.

The brewing process involves milling, mashing, separation, boiling, cooling, fermentation with yeast, maturation and pasteurization, and packaging.

- The malted grain is milled either under dry or wet condition to increase the surface area to achieve higher yield extraction. Then the grist is transferred to the mashing tank.
- During mashing process, hot water is added to the grist in order to convert starches to fermentable sugar. The mash is constantly stirred and also heated to a specific temperature before it is later transferred to the lautertun where the liquid phase called wort is separated from spent grain and send to the wort kettle.
- The wort at the kettle is boiled, and the hops are added. Wort is boiled for several reasons, namely to: extract and isomerise hop components, coagulate proteins, sterilize and inactivate enzymes, form reducing and aromatic compounds, form colouring substances, remove undesired substances, acidify the wort, and evaporate water. An alternative approach is the use of high gravity brewing procedure where it employs wort at higher concentration, and consequently, requires dilution with water at a later stage.

- Wort is then cooled to allow the initiation of the fermentation process. When the right wort temperature is reached it is transferred to the fermentation tank where yeast and oxygen are added. At this stage sugar is converted to alcohol and carbon dioxide. Fermentation takes several days before the maturation process begins. Depending on the type of beer being produced, maturation or aging process of beer can take up to four months or more. Maturing of beer is aimed to achieve carbonation and also enhance its stability to ensure it remains bright. The bright beer is then sent for packaging either into bottles, cans or kegs. Most breweries conduct all the processes in the same plant for efficiencies; however there are breweries that may procure malt from another player and others that outsource packaging. Packaging is an important aspect to the production process as it is not only a source of economies of scale but also determines how the product can be distributed. Between 70 and 80% of the beer consumption in South Africa is of canned/bottled beer.

- For the beer to have long shelf life, pasteurization is required though not all types of beer are pasteurized. To pasteurize beer is achieved by two ways. One way is by bottling and passing it through a tunnel where it is sprayed with hot water for about 10 minutes to kill bacteria – and the process is called tunnel pasteurization. Alternatively beer can be pasteurized using flash pasteurization process. In this process, beer is run through two heat exchangers where one has hot running water to heat up the beer, and then it is transmitted to another exchanger where cooled is done quickly before bottling.

Environmental issues associated with operations and processes of breweries include energy and water consumption, emissions to the air as well as generation of wastewater, solid waste, and by-products. Energy in brewery process is consumed mainly by boilers and the refrigeration system. Other processes which account for substantial consumption of electricity are the bottling and wastewater treatment plant. Notably water consumption is affected by cleaning of process equipment, pasteurization, general washing (e.g. bottles, floors, etc.) as well in by-products leaving the brewery.

Modern brewing requires application of technology that meets environmental requirements. One way of achieving this is through the improvement of actual brewing processes using technology advancement, for example, in the recover energy and on-line process control. Other changes include replacing of pumps, filters, etc., efficient water usage (reuse), and better effluent disposal. Through these changes the brewing process has improved, for example, through freshwater and energy use reduction as well as minimization of wastewater production. Many of these technologies are broadly implemented by large breweries industries (due to economy of scale) where the focus is to improve efficiency to optimise resource utilization. However these technologies are cost prohibitive to smaller breweries. In the context of this study, the focus will be to examine in detail technologies (and/or technological modifications), operational practices, substitution of input materials, and possible product/waste recovery mechanisms applicable to specific process or generally to different processes.

2.1.1 Mashing and Separation

Separation of wort and grain takes place in a lautertun where the grains settle at the bottom and acts as a sieve. After separation the water is sprayed to extract maximum amount of wort (Sturm *et al.,* 2013). Modern form of mash filters have been introduced, and consists of series of blades that squeezes the wort out of the grains but concurrently sparging. Thus, this has been reported to reduce the amount of water required for wort extraction.

2.1.2 Wort Boiling

It is during this process that most energy/heat is lost. Wort boiling system is the most energy intensive stage in the brewing process accounting for around 25 to 35 percent of total thermal consumption. Therefore considerable attention has been given to improve its efficiency. The advanced systems use internal heating system or external wort boiler and manage off heat from the boiler and deal with energy conservation by vapour condensation and wort stripping. The internal heating system use a simmering boil, with submerged wort flow and stripping phase to reduce undesired volatiles.

Other new breweries uses external boiling unit (e.g. thermo syphon wort boiler), where liquid flows into the bottom of the tubes then exit on top together with the steam. This system has large surface area that allows slow bur effective heat transfer. These systems are designed to reduce the thermal stress during wort boiling and recuperate energy. The heat is recovered using vapour condenser and extracting heat to hot water storage tank. The recovered heat is used as process energy in a transfer process of the wort to the wort kettle and for boiling the wort, whereas the hot water collected could be used for mashing stage or other cleaning processes (Scheller *et al.,* 2008)

2.1.3 Cooling, Fermentation and Maturation

Continuous fermentation for beer production was attempted years ago but the process was abandoned as no one managed to develop a widely applied industrial concept. However the use of immobilised cells for continuous primary and secondary fermentation of beer is currently generating interest. Though it is still in developmental stage for primary fermentation, the process is being used in maturation stage of beer. Continuous bioreactors with immobilized yeast have been successfully used in accelerating maturation stage where unwanted compounds are removed within a short space of time. Some fermenting tanks can handle both fermentation and maturation in the same tank (Linko *et al.,* 1998).

Wort cooling is one of the most significant ways of saving energy in brewery. During cooling of wort, cold water that is passed through heat exchanger exit hot and this water is collected and used for other processes like cleaning. Refrigeration of beer is another energy intensive step in the industry that has been improved by pre-cooling of liquids that need to be cooled down. The use of more efficient refrigerants like ammonia is also used to reduce energy consumption (The Carbon Trust, 2011).

2.1.4 Pasteurization

Beer has to be free of bacteria to increase its shelf life. To achieve this, the beer needs to be pasteurized and immediately cooled to the right temperature. Then finally the beer is packed in the kegs or single trip bottles in which they will leave the brewery. Pasteurization is potentially an energy intensive process as it involves heating followed by quick cooling and can use significant amount of water. Improvements have been made where some breweries moves from tunnel pasteurization to flash pasteurization which uses less amount of water.

Other breweries uses improved tunnel pasteurizer that has external water tank to recover and reuse energy and water that could be wasted and a closed cooling system which provides for cooling system of pasteurizer water. Many of breweries that produce light coloured beer use sterile filtration as an alternative to pasteurization. In this method beer is passed through a tight filter which strips out all yeast and bacteria. Though this method reduces water usage, it is understood to be energy intensive as pasteurizers. In 2011 SAB Alrode brewery installed the latest pasteurization technology and reduced its water and energy consumption.

2.1.5 Cleaning and Packaging

A large amount of water is used for cleaning operations in the brewery. In the packaging area significant amount of water is used to wash returned bottle. In view of this re-use of water has become a key opportunity. Brewing companies have automated their cleaning process improving their efficiency. Today most breweries have invested in new energy and water efficient bottle washer while others are using single strip nonreturnable bottle as it require less water usage though more energy is used in manufacturing.

Water conservation has been a priority for SAB especially in view of drought or water shortage situation in South Africa. At Alrode brewery (SAB) in Gauteng, their cleaning cycles has been reviewed to minimise their water use hence number of innovations have been introduced. Cascading of water from one process to the next is one of example of changes that has taken place. Bottle washer final rinse water and vacuum pump cooling water is cascaded into a dissolved air filtration plant on site where the water is cleaned and filtered to an acceptable standard to be re-used for floor and crate washing. Also, the final rinse water in CIP is recovered and use as a pre-flush in the same process (Harris, 2011).

3 Regulations, Policies, By-laws and Tariffs

South Africa has a three-tier system of government: national, provincial and local government. National legislations are becoming increasingly stringent with the requirement that all factors with the potential to affect the environment should be controlled or addressed. Thus, this can only be achievable through the implementation of effective environmental management systems. In terms of legislative framework, since the 1980s a number of legislations aimed to protect the environment have been promulgated in South Africa. For instance, at the time Natsurv 1 was published, the applicable legislative framework in South Africa was only at national level, but this has changed considerably after 1996 due to the adoption of new constitution. For example, the introduction of three tier government in South Africa has also introduced the issue of by-laws within which these industries currently function in, and must comply at provincial and local government settings.
The malt brewing industry in South Africa is regulated by the following legislations:

3.1 National Policies

The Bill of Rights in the Constitution of the Republic of South Africa (Act 108 of 1996) enshrines the concept of sustainability, particularly section 25 which affords all South African citizens the right to an environment, water, access to information, and just administrative action are specified in the act. These rights and other requirements are further legislated through the National Water Act (NWA) (Act 36 of 1998). The latter provides the legal basis for water management in South Africa by ensuring ecological integrity, economic growth, and social equity when managing water use.

The NWA introduced the concept of Integrated Water Resource Management (IWRM), which provides for resource and source directed measures to manage the aquatic environment. Resource directed measures aim to protect and manage the environment that receives water, while source directed measures aim to control the impact on the receiving environment by preventing pollution, reusing water, and treating wastewater. The integration of resource and source directed measures forms the basis of the hierarchy of decision-taking aimed at mitigating the effect of waste generation. This hierarchy is based on a precautionary approach and the order of priority for water and waste management decisions and/or actions are shown in Figure 3.

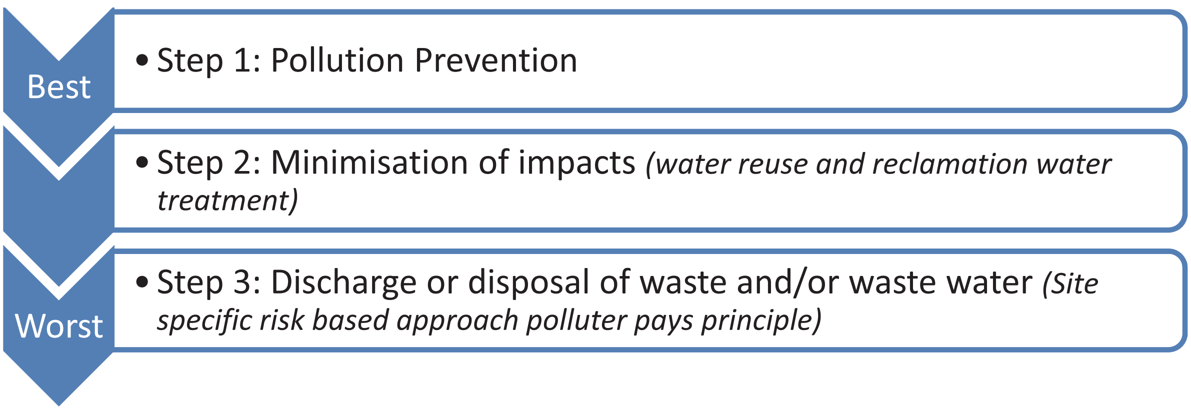

Figure 3 Resource protection and waste management hierarchy

3.1.1 Water

The Department of Water and Sanitation (DWS, 2014 – formerly the Department of Water Affairs (DWA) and the Department of Water Affairs and Forestry (DWAF)) is the water and sanitation sector leader in South Africa. DWS is the custodian of South Africa's water resources and of the National Water Act (NWA) (Act 36 of 1998) and the Water Services Act (WSA) (Act 108 of 1997). DWS is also the national regulator of the water services sector.

The NWA provides the legal framework for the effective and sustainable management of water resources within South Africa. The NWA aims to protect, use, develop, conserve, manage and control water resources as a whole, promoting the integrated management of water resources with the participation of all stakeholders.

The WSA deals the rights of access to basic water supply and basic sanitation – with water conservation as the key objective. It provides municipalities with powers to enforce water conservation and demand management – which in turn impacts on water users, including households, commercial and industrial entities. It contains rules about how municipalities should provide water supply and sanitation services. Within each municipal area, bylaws are developed which outline the water supply and effluent discharge regulations and tariffs for that area.

3.1.2 Wastewater

Under the NWA, norms and standards for the treatment of wastewater or effluent prior to discharge have been set. These consist of general and special standards and set limits for aspects such as pH, temperature, chemical oxygen demand (COD), suspended solids, metals etc. The test method that is to be used to determine these levels are also specified. Any industries, or municipal or private wastewater treatment works discharging to river or sea must comply with these limits. In turn, the entity operating a wastewater treatment works must set limits for industries discharging to the works such that the DWS final discharge limits can be met.

3.1.3 Health and Safety

The National Department of Health regulates issues on food safety to ensure fitness for human consumption. In this sense, malt beer industry should meet threshold standard for human consumption, and therefore, should comply with the Foodstuffs, Cosmetics, and Disinfectants Act (FCDA) of 1972 (Act No. 54 of 1972; Amendment Act, No. 39 of 2007). The Department of Labour promulgated the Occupational Health and Safety Act (OHSA) of 1993 (No. 85 of 1993; Amendment Act, No. 181 of 1993) to safeguard the safety of workers and other persons. The OHSA aims to provide for the health and safety of persons at work as well as those who use plant and machinery.

3.1.4 Trade and Licencing

The liquor industry in South Africa is governed by the Department of Trade and Industry's Liquor Act of 2003 (No. 59 of 2003). The main aims are to reduce socio-economic and other costs of alcohol abuse by means of setting essential national norms and standards in the liquor industry. These regulate the manufacture and wholesale distribution of liquor; including the regulation of retail sales and micro-manufacture of liquor. It also provides for public participation in the consideration of applications for registration and promotes the development of a responsible and sustainable liquor industry in a manner that facilitates entry of new participants into the industry. This includes the diversification of ownership and an ethos of social responsibility in the industry.

3.1.5 Environmental

The Constitution of South Africa states that everyone has the right to an environment that is not harmful to his or her health or well-being and the right to have the environment protected, for the benefit of present and future generations through 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. Regulation that addresses these rights falls under the responsibility of the Department of Environmental Affairs (DEA).

Policies that are the most relevant to the malt industry are the National Environmental Management Act, 1998 (Act 107 of 1998), the National Environmental Management: Waste Act (Act 59 of 2008), and the National Environmental Management: Air Quality Act (Act no. 39 of 2004). Broadly speaking, these Acts outline the requirements for the storage and handling of waste onsite, licensing requirements, the establishment of waste management plans, the setting of limits for air emissions, and the setting of penalties for offences.

3.2 Municipal By-laws

The malt beer industry as industrial user of water and sanitation services provided by the municipalities is governed by bylaws and tariffs which are municipality specific. The Water Service Authority sets out the regulatory framework for institutions tasked with the supply of water services. The act makes provision for different water service institutions to be established as follows: The WSA – i.e. the responsible municipality and the Water Services Provider (WSP) – the entity whose role is to physically provide the water supply and sanitation services to consumers. The calculation of industrial effluent tariffs varies significantly from one municipality to the next depending on the cost recovery systems of the municipalities, types of industries discharging to the municipal sewer and the wastewater treatment that will have to treat the effluent. Herein, bylaws and tariffs policies on water and sanitation services where the malt breweries operates are presented for the eThekwini, City of Cape Town and Tshwane municipalities by-laws and tariffs as illustrative examples.

3.2.1 eThekwini Metropolitan Municipality

Policies and practices developed by eThekwini Water and Sanitation Unit (EWS, 2013) outline the policy related to provision of Water Services Development Plan, Sewage Disposal Bylaws and, water and sanitation services (EWS, 2011). Any industry wishing to discharge to a wastewater treatment works must apply for a trade effluent permit. Industries permitted to discharge trade effluent with a pollution load exceeding that of typical domestic sewage, are charged for disposal according to Equation 1. 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 (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.

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

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 (COD < 360 mg/L)
Z = rate for the treatment in the treatment works of standard domestic effluent (SS < 9ml/L)

The volume of trade effluent discharged is determined by an effluent meter. If no meter is in place, the volume is determined from a water balance questionnaire which is filled in by the company. The effluent volume is calculated by deducting the volume of domestic effluent, process water, and evaporative losses from the incoming water volume.

3.2.2 City of Cape Town Metropolitan Municipality

The discharge of industrial effluent has been promulgated in the City of Cape Town Industrial Wastewater and Effluent By-law of 2006, which was amended in 2014. The volume of industrial wastewater discharged is calculated by the municipality after deducting "fair" amounts for atmospheric losses, water used for irrigation, and water present in product. The charge for industrial wastewater discharge to sewer is calculated according to Equation 2 and 3. 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).

$$Vw(SVC) + \frac{VieT(COD-1000)}{1500} + VieT(SF) \quad (2)$$

Where:
Vw = Total volume of water discharged
SVC = Sewage volumetric charge
VieT = Total industrial effluent discharged
SF = surcharge factor calculated according to equation 3

$$SF = (X - L)/L \quad (3)$$

Where:
X = concentration of one or more parameters from schedule
L = limit applicable to particular parameter

3.2.3 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):

3.2.3.1 Normal Conveyance and Treatment Costs

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%.

3.2.3.2 Extraordinary Treatment Costs

Applies in a case where the pollution loading of wastewater discharged into the Sewerage system exceeds the pollution loading of normal wastewater exceeds and the cost is calculated as given in Equation 4:

$$Tc = Qc.t[0.6\ \frac{(CODc-CODd)}{CODd} + 0.25\frac{(Pc-Pd)}{Pd} + 0.15\frac{(Nc-Nd)}{Nd}] \quad (4)$$

Where:
Tc = extraordinary cost to the consumer, Qc = wastewater volume (kL), t = unit treatment cost of wastewater (94c/kL in 2014), CODc = total measured COD (mg/L), CODd = COD of domestic wastewater (710 mg/L), Pc = measured orthophosphate (mgP/L), Pd = orthophosphate concentration of domestic wastewater (10 mgP/L), Nc = measured ammonia concentration (mgN/L), Nd = ammonia concentration of domestic wastewater (25 mgN/L)

3.2.3.3 Non-Compliance with By-laws Limits

In case where the stipulated limits are exceeded, the tariff is calculated according to Equation 5:

$$Tc = Q / D * N[C_{AIP} - B_{LL} / W_{PL}]t_{NC} \quad (5)$$

Where:
Tc = charge for non-compliance, Q = monthly volume in kL, D = working days in the month,
N = number of days exceeding by-law, CAIP = ave. concentration of parameter exceeding by-law, BLL= by-law limit, WPL= Water Affairs standard limitation on parameter exceeding by-law, tNC = tariff (65c/kL)

4 Water Use and Management

Though there are more than 150 breweries in South Africa, contacts were obtained for 44 of which 37 were willing to participate in the survey. Of these 37, only 15 breweries returned completed questionnaires. The study managed to survey 1 medium brewery in Gauteng and 9 small and 5 medium breweries in Western Cape.

Water used in the breweries is variously obtained from four main sources: borehole, municipal, rain water and fresh water spring. Table 2 shows that majority of the breweries in South Africa sources water from the municipality and the water quality do not differ for each brewing process. There are a few breweries that use borehole water (well) and rainwater.

Table 2 Water Source used by malt brewing industry

Brewery	Water Source
A	Municipality
B	Rainwater
C	Municipality
D	Rainwater
E	Municipality
F	Freshwater spring
G	Municipality
H	Borehole
I	Municipality
J	Borehole
K	Municipality
L	Borehole
M	Municipality
N	Municipality
O	Municipality

4.1 Water Consumption

Table 3 shows data for water consumption for breweries in South Africa[1]. Data was gathered from the questionnaire. Small breweries in South Africa have a specific water intake of between 1.5 and 9 hl. This figure varies depending on how the beer is packaged and pasteurised. UNEP and World Bank Publications give best practice specific water use in breweries as 5.5 hl of water per 1 hl of beer, some European and Japanese breweries use as little as 4 hl/hl. Based on the figures provided in Table 3, majority of breweries are currently performing to this level even when compared to an investigation by Binnie and Partners (1986) in Table 4.

[1] This data was from 15 small breweries.

Table 3 Water consumption for malt "Small" breweries in South Africa

Brewery	Average Beer Production (Litre)/ Year	Specific Water Intake	Average Water Intake of beer (litre)/ Year
A	30000		
B	1500	4.2	
C	100000		420000
D	180000		
E	96000		
F	2500-3000		
G	1000	1.7	1700
H	12000	30	360000
I	144000		
J	480 000-600 000	5	2 400 000-3 000 000
K	600 000-720 000	5	3 000 000-3 600 000
L	24000		41600
M	30000	1.67	50000
N	2000	3.5	
O	4000	9	36000

Table 4 Water consumption per beer produced for different breweries in South Africa

Brewery	Average Beer production per month in m^3	Specific water intake in m^3/m^3	Average water intake per month in m^3
A	17 100	6, 0	102 500
B	9 000	8,8	79 100
C	18 200	7,1	129 000
D	14 000	5,5	77 000
E	2 000	6,8	13 700
F	16 000	6,3	100 800
G	8 300	7,4	61 700
H	5 200	6,7	34 700

Source: Bennie and Partners (1986).

The brewing processes which consume most water are: floor cleaning, milling, mashing, separation, flushing of filter, vacuum pump for filter, keg washing, boiling, cooling, fermentation with yeast, maturation and pasteurisation, and cleaning of packaging materials (bottle washing). The main brewing intensive water use stages are: Milling, Filtration, Pasteurisation, Packaging and Cleaning.

Figure 4 shows that the water efficiency in beer production at SABMiller improved between 2008 and 2013, from 4.6 hl water/hl beer in 2008 to 3.7 hl water/hl beer in 2013. From 2014 to 2016 the breweries managed to reduce water consumption from 3.5 hl water/hl beer to 3.2 hl water/hl beer.

This figures where achieved because breweries employ new processes and they changed their behaviour to reduce water consumption whilst achieving the same high quality of product.

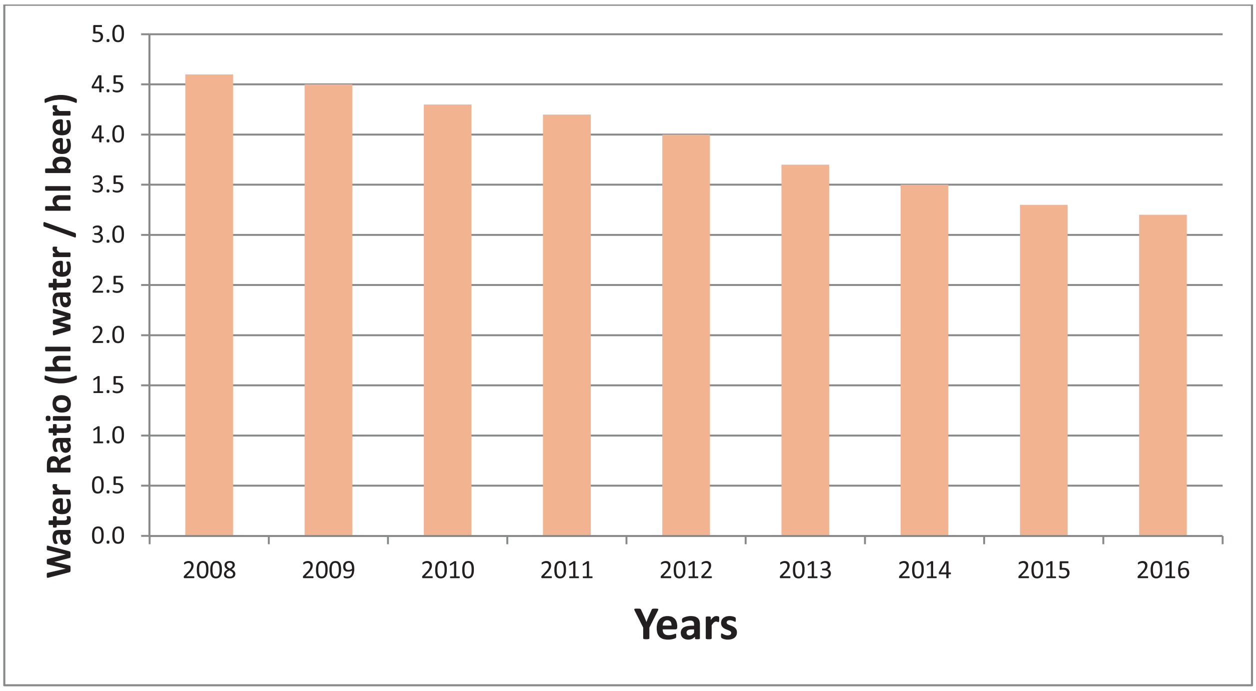

Figure 4 Water consumption for "Medium and Large" breweries in South Africa
Source: SABMiller (2008-2016).

5 Waste Generation and Management

Beside water used for beer product and that lost in by product, there is wastewater which is one of most significant waste products of brewery operations. This effluent is composed of organic material from process activity. Breweries have installed in-house wastewater treatment plant treating their own waste before discharging or re-using. Some breweries produce biogas through anaerobic wastewater treatment process and use the energy for their processes.

In order to reduce cost associated with wastewater treatment disposal and dependence on coal for steam generation, SAB installed an anaerobic digester to treat waste leaving its Alrode brewery in Gauteng to reduce the COD of the wastewater before leaving the site. In this process the 90% of the 25 tons a day of organic materials produced 9,000m3 of biogas containing 85% of methane. The recovered biogas is used in their brewing process to produce steam. This reduced the consumption of about 10.4 tons per day of coal (SAB report, 2012).

Brewery produces organic residues comprising of spent grains, spent hops, yeast, trub, and kieselguhr sludge. The solid waste has commercial value and is sold as by-products for cattle feed. Brewery process also produces liquid waste such as weak wort and residual beer that can enter the effluent stream. The main source of residual beer include process tanks, kieselguhr filters, pipes, beer rejected in packaging area, returned bottles and broken bottles in the packaging area. This residue is collected and returned to the process. Packaging is an important part of brewing process however it can end up impacting the environment with waste. The use of recyclable packaging reduced a burden that could be placed on the environment due to volume of waste generated. The required volumes of waste generated in beer production will be discussed in section 5 of this report.

5.1 Quantities of Waste Generated

The waste that is generated from the brewing process may be divided into two types: solid waste and liquid waste.

5.1.1 Solid Waste

The solid waste consists of raw materials used during the brewing procedure, filtering aids and containers used for packaging the beer. Solid waste management and typical solid wastes from breweries include: spent grains, trub, spent yeast, diatomaceous earth slurry from filtration, and packing materials. Most of the breweries feed sheep farms with their spent grains. The amount of waste generated can be broken down into two groups: Micro scale and Medium scale. Tables 5 and 6 list the typical breakdown of solid wastes for micro and medium scale breweries respectively:

Table 5 Typical breakdown of solid waste for micro scale breweries

Solid Waste	Range	Measurement unit
Spent grains	12-60	kg per brew
Surplus yeast	0.8-6	Litre per brew
Kieselguhr (Diatomaceous earth)	N/A*	kg per brew

* The microbreweries that were evaluated during the course of this study did not filter the beer that they produced thus no kieselguhr was used.
** A single brew ranges between 250 litres to 400 litres.

Table 6 Typical breakdown of solid waste for medium scale breweries

Solid Waste	Range	Measurement unit
Spent grains	440-1080	kg per brew
Surplus yeast	96-288	kg per brew
Kieselguhr (Diatomaceous earth)	3.2-72	kg per brew

* A single brew ranges between 2000 litres to 3000 litres.

5.1.2 Liquid Waste

Majority of South African breweries treated water at the source not as part of the brewery process. In some breweries effluent flows to an underground balancing tank with an average retention time of one week and the effluent is ph. balanced before being released to a French drain. Most of the breweries with the plan to construct WWTP have a sump that the wastewater goes into. The liquid waste is considered to be the effluent that leaves the brewery which enters the municipal water system. It should be noted that this effluent includes water used for cleaning and packaging. Table 7 listed and mentioned the operation of some of the main areas of wastewater generation during the production of beer.

Table 7 Main areas of wastewater generation in beer production

Source	Operation
Mash Tun	Rinsing
Lauter Tun	Rinsing
Spent Grain	Last running and washing
Boil Kettle	Dewatering
Whirlpool	Rinsing spent hops and hot trub
Fermenters	Rinsing
Storage tanks	Rinsing
Filtration	Cleaning, start up, end of filtration, leaks during filtration
Beer spills	Waste, flushing, etc.
Bottle washer	Discharges from bottle washer operation
Keg washer	Discharges from keg washing operations
Miscellaneous	Discharged cleaning and sanitation materials, etc.

Breweries have different wastewater concentrations; however, there are typical values and ranges of key components that have been associated with untreated brewery effluent. As in the case of the solid waste, the liquid waste is broken down into the micro scale and medium scale breweries and is presented in tables 8:

Table 8 Typical range of liquid waste for micro and medium scale breweries

Scale	Range	Measurement unit
Micro	70-220	Litres/brew
Medium	7200-16 200	Litres/brew

5.2 Typical Pollutant Loads

Should the parameter in question fall outside of the given range or exceed the maximum value stated, the pollutant needs to be pre-treated. In the event of the pollutant(s) not being pre-treated to the acceptable limits, the municipality will fine the brewery in question. The table 9 indicates the limits given for pollutants:

Table 9 Acceptable range for pollutants

Parameter	Required standard	Measurement unit
pH	5.5-7.5	
Dissolved Oxygen	75% Saturated	
Chemical Oxygen Demand	30	mg / l
Suspended Solids	10	mg / l
Nitrates	1.5	mg / l
Soluble orthophosphate	1	mg / l
Permanganate value	5	mg / l

Table 10, presents the pollutant, the load of the pollutant in the effluent and the measurement unit used for the pollutant being evaluated. The pH of the samples from malt breweries has an average of 5.9 which is within the given range while Nitrates had 0.1mg/l instead of 1.5mg/l as stipulated by EC (2006). As indicated in Table 10 parameters such as COD, SS, TDS, TOC, Total nitrogen, Total phosphorous and soluble orthophosphate fall outside of the given range or exceed the maximum value stated, the pollutant needs to be pre-treated.

Table 10 Typical pollutant loads of Small breweries

Pollutant	Load	Measurement unit
pH	5.9	N/A
COD	8049	mg/l
SS	554	mg/l
TDS	255	mg/l
Total Nitrogen	48	mg/l
Total Phosphorous	30	mg/l
TOC	1295	mg/l
Soluble orthophosphate	15	mg/l
Nitrates	0.1	mg/l

5.3 Macro-Pollutants

The macro pollutants that require management before entering the municipal system will be listed as soon as the pollutant load data becomes available.

5.4 Micro-Pollutants

The micro pollutants that require management before entering the municipal system will be listed as soon as the pollutant load data becomes available.

5.5 Pollutants of Environmental Concern

The kieselguhr or diatomaceous earth used as a filtration media needs to be disposed of in a specific manner due to it not being fit for cattle consumption. Various brewers have raised concerns of methods for disposing of this filtration media due to no prescribed method being stipulated. Currently this is disposed of at municipal landfill sites which raise environmental concerns regarding its biological degradation.

6 Energy Use and Management

The electricity consumption range is stated for micro scale and medium scale breweries in table 11 below:

Table 11 Electricity consumption

Scale	Range (kWh / month)
Micro	125-8250
Medium	12 000-38 400

The brewing industry could be considered to be a small user of electricity within South Africa when compared to the mining industry. The mining industry consumes 15% of the total amount of electricity generated in South Africa (Eskom Mining Efficiency, 2010). Eskom sold 217 903 GWh of electricity between March 2013 and March 2014 (Eskom, 2014). Thus the mining industry consumes approximately 32 685 GWh of electricity per annum. This indicates that the brewing industries electricity use is not intensive.

6.1 Energy Consumption

Using less water requires less energy to pump, heat and treat it. The brewing industry utilizes energy in different processes, and uses considered include: heating, cooling, packaging, and transportation of materials and products in the plants. Sources of energy are electricity from the grid, coal, liquid petroleum gas and diesel. Diesel is used for transport within the plant (forklifts) and standby generators whereas liquid petroleum gas is used for packaging beer in different containers. Electricity from the grid and coal (through steam generation used to produce electricity) are used in a number of processes such as brewing cleaning and sanitation, wort cooling procedure.

Figure 5 shows that the energy used since 2008 decreased till in 2010, from 26PJ to 23PJ, while there was an increase in 2011. Since 2013 there was a decrease in energy consumption till 2016.

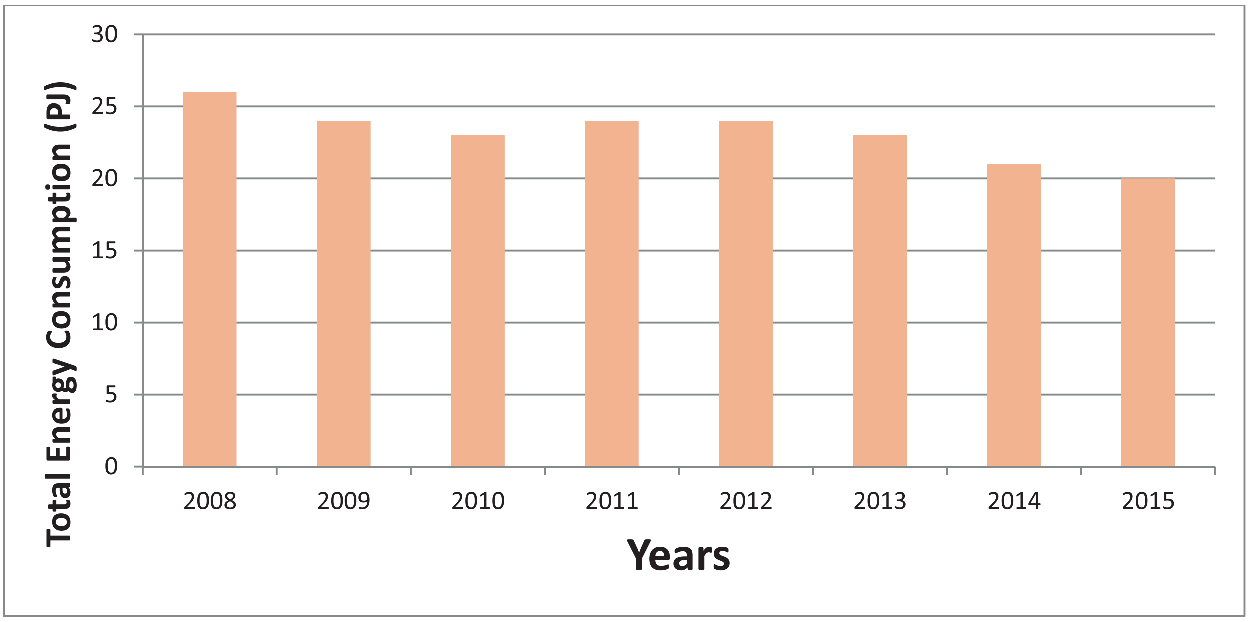

Figure 5 Total energy consumption for "Medium and Large" breweries in South Africa
Source: SABMiller (2008-2016).

The major consumers of energy are the wort boiling, cooling, pasteurisation, packaging and cleaning. Brewery processes are relatively intensive users of both electrical and thermal energy. The refrigeration system consumes high electrical energy, while the brewhouse, bottling hall, and wastewater treatment plant can account for substantial electricity demand. The thermal energy raises the steam in boilers and largely used for wort boiling and water heating in the brewhouse, and in the bottling hall. The specific energy consumption of a brewery is influenced by process design and utility system; however, site-specific variations can arise from differences in product recipe and packaging type, the incoming temperature to the brewery of the brewing water and climatic variations.

Table 12 presents the heat consumption for different brewery processes in a German brewery. From the literature it was found that the brewhouse used electricity of between 23.33 and 31.39 kWh/hl beer while the results from the German survey showed that brewhouses used 13.89 to 22.22 kWh/hl beer (World Bank, 2007).

During the kegging process, the literature showed that not much electricity was used when compared to the bottling process.

Table 12 Heat consumption for different breweries process

Process	**Figure (kWh/hl beer)**			**Range (kWh/hl beer)**	
	Minimum	Mean	Maximum	**Literature**[2]	Measured[3]
Brewhouse	24.17	25.56	33.61	23.33-31.39	13.89-22.22
Bottling	16.11	23.89	26.11	9.94-12.78	10.56-16.11
Kegging	2.22	3.06	3.61	2.22-3.61	-

Source: World Bank (2007)

[2] 20000 to 500000 hl beer per year

[3] 30000 to 50000 hl beer per year

7 Best Practices

7.1 Water Use

Management of South Africa's water resources involves catchment management, river systems, water storage, water abstraction and return-flow management. Integrated management techniques are required to ensure that water is both protected and utilized to its full potential. There is an improvement of water management in South African breweries compared to the 1980s. Majority of the breweries adopted water saving technologies that promote prevention, control, minimisation and recycling to the extent possible without compromising the hygienic standards. These technologies have water meters installed & maintained weekly, for example in:

Pasteurization, majority of breweries uses flash pasteurization instead of tunnel pasteurization to reduce water requirement of flash pasteurization.

Cleaning, some of the breweries uses automated bottle washing fixed spray injectors to reduce water usage (CIP with caustic and acid flush used for cleaning Fermenters and storage tanks). Cascaded Water Management: Water is recycled from one process to the next, for example, in cooling, pasteurization, cleaning and bottle washing processes.

Pollution prevention and control are best practiced through effective management, maintenance, and housekeeping in a process that incorporates water conservation and recycling, energy conservation, and disposal of solid wastes as by-products. Wherever water is used there is often an opportunity for conservation. Some options that may be considered include:

- Clean-in-place (CIP) methods for decontaminating equipment
- High-pressure, low-volume hoses for equipment cleaning
- Recirculating systems on cooling water circuits

7.1.1 Water Pinch Analysis

Water pinch analysis tool offer insights on how water is used in different processes with a goal to reduce the environmental impacts of water. Water Pinch Analysis, a systematic technique for analysing water networks and reducing water costs for processes has helped companies to systematically minimize freshwater and wastewater volumes. It uses advanced algorithms to identify and optimize the best water reuse, regeneration and effluent treatment opportunities. It has also helped to reduce losses of both feedstock and valuable products in effluent streams (Dakwala *et al.,* 2011).

7.1.2 Water Footprinting

If water footprinting is applied well it can be very useful from a business perspective, helping identify the scale of water use in water-scarce areas and the potential business risks that arise. The key test of a water footprint is whether it helps a business to take better operational decisions concerning how it manages its plants, how it works with suppliers and how it engages with governments, to reduce business risk and improve environmental sustainability. Water footprinting is primarily focused on quantitative water supply issues. In terms of actual quantitative footprint, the South African footprint is at 155 litres of water per litre of beer (l/l) (SAB report, 2009).

7.2 Wastewater Management

Water recycling is the reuse of water for the same application for which it was originally used. Recycled water might require treatment before it can be reused. Cooling water and wash water recycling are the most widely used water recycling practices. Identification of water re-uses opportunities and Cooling Water should be used when considering water reuse and recycling in breweries. Recycling water within a cooling system can greatly reduce water consumption by using the same water to perform several cooling operations. There are three cooling water conservation approaches used to reduce water consumption, e.g. evaporative cooling, ozonation and heat exchange.

Some options that may be considered water conservation and recycling include:

- Use of grit, weed seed, and discarded grain as chicken feed
- Use of spent grain as animal feed, either 80% wet, or dry after evaporation Disposal of wet hops by adding them to the spent grain Disposal of spent hop liquor by mixing with spent grain
- Use for livestock feed of spent yeast that is not reused
- Disposal of trub by adding it to spent grain
- Recovery of spilled beer, adding it to spent grain that is being dried through evaporation
- Filtration of bottom sediments from final fermentation tanks for use as animal feed
- Reduction of energy consumption through reuse of wort-cooling water as the process water for the next mash
- Collection of broken glass, bottles that cannot be used and waste cardboard for recycling.

Cleaner production is an approach to improving industrial process efficiency. Cleaner production in breweries focuses on minimisation of resource consumption, process efficiency, and, to a smaller degree, product substitution. Adoption of cleaner production principles reduces waste and this in turn results in lower environmental impact and occupational risks. Cleaner production reduces the cost of wastewater disposal by reducing the volume and strength of effluents that need to be treated (UNEP, 2003).

7.3 Energy

Energy Pinch technology aids to facilitate recycling of heat (energy) between processes. Heat exchangers allow numerous process streams to come in contact with one another to facilitate heating of cold streams and the cooling of hot streams. The practice is utilised in wort boiling, cooling, pasteurization and bottle cleaning processes. Lists of some of the technologies that may incorporate to reduce the electricity usage within the brewery are presented in table 13:

Table 13 Energy reducing technologies

Technology	Effect
Insulation (Tanks, valves, pipes, flanges)	Reduces heat loss and temperature fluctuations
Automated switch off cycles for equipment that are not in use.	Reduces electricity consumption of process equipment that are idle / on standby.
Variable speed drives in pumps, compressors, etc.	Reduces electricity consumption, reduces wear on equipment and motors, reduces voltage draw down on power lines during equipment start up.
Heat recovery (Heat exchangers)	Reduces electricity consumption with respect to heating and cooling of liquid streams. Streams are used to heat/ cool one another which in turn reduce the total heating and cooling duties.
Steam jackets on process vessels	Steam jackets used to heat water within the process vessels. Once steam flow is stopped, latent heat in pipes, flanges, etc are used to heat additional incoming water.
Solar panels	Reduces electricity consumption from the national power grid resulting in lower electricity bills. Electricity generated may be used to directly pre-heat boiler inlet streams or cleaning water streams.
High efficiency lighting (LED light bulbs)	Reduces electricity consumption
Boiler sequencing controls	Reduces electricity consumption by reducing the boiler idle time during start up and efficiently controls the boiler pressure to minimize fluctuations.
Energy Star brewing equipment	Reduces electricity consumption
Energy tracking/management system*	Allows close control of the brewery's energy usage per process or the brewing cycle as a whole. Energy intensive process can be closely measured to ensure operation falls in the acceptable range of operation.
Programmable controllers that allow set back temperature settings during non-production hours	Reduces electricity consumption that would occur as a result of heating / cooling processes not being regulated after production has ceased.
Tinted windows, window shades	Reduces energy burden on cooling processes due to better regulation of brew house ambient temperature
Regular maintenance on all equipment	Regular maintenance on air filters, water lines, compressed air lines, insulation and brewing equipment reduces additional consumption of electricity.
Boiler blow-down heat recovery	The boiler blow-down contains heat that may be recovered by means of a heat exchanger or flash tank. This heat may be used to pre-heat the boiler inlet stream or other process streams that result in reduced electricity usage for heating of streams.
Boiler condensate recovery	Reduces the amount of electricity required to generate steam due to the recovered condensate pre-heating the boiler inlet water.

Examples of good practices with respect to energy usage that are adopted internationally are listed below:

- Breweries in the USA and Europe make use of solar panels to generate their own electricity. The aim is to promote the use of renewable energy and to reduce the burden on the national power grid. Breweries currently using solar panels to generate electricity include New Belgium Brewing Company, Sierra Nevada Brewing Company and Anheuser-Busch.

- Asahi brewery in Japan has demonstrated that boiling wort and hops separately reduces electricity consumption. This is due to wort and hops having different optimum boiling times. The hops are boiled in hot water in a boiler that is approximately 1/50 of the size of the wort boiling kettle. This reduces the energy required per wort boiling cycle. The energy reduction is due to lower thermal loads and evaporation per boiling cycle (Worldwide Brewing Alliance, 2011).

- Miller Coors in the USA has installed ammonia refrigeration systems and compressors that conserve energy through automated controlling of pressure and temperature. Ammonia is a preferred refrigerant in modern breweries due it not being a greenhouse gas (Ammonia has a Global Warming Potential rating of zero) and it's high efficiency (Worldwide Brewing Alliance, 2011)

7.3.1 Alternative Electricity Generation Technologies

- Currently solar panels are used at various breweries to reduce the total electricity burden and/or generate additional electricity.

- Wind power is becoming increasingly popular among American and European brewers. Many American and European breweries make use of wind power to reduce the load drawn from the national power grids. Examples of American and European breweries that are making extensive use of wind power are: Brooklyn Brewery in the USA that sources all of their electricity from wind power and Diageo's packaging plant in Belfast, Europe that is run solely on wind power with no additional electricity being drawn from other sources (Worldwide Brewing Alliance, 2011).

- Electricity can be generated from biogas that is captured through wastewater treatment. This is however only reserved for very large breweries that can afford to have a wastewater treatment plant (WWTP) at the brewery itself.

8 Recommendations

- Breweries should treat their effluent before discharging to the municipal sewage system.
- Competition for clean water will only intensify further, however, awareness is still limited among brewing industry, government and public.
- Cleaner production has the potential to make a major contribution to reducing water consumption in African breweries.
- There is a shortage of adequate data to allow for more detailed decision-making at all levels, plant to national.
- A major effort still needs to be made in all stakeholder groups to raise awareness on the importance of improved water management and on the means to achieve it.
- Better information on water allocation, water use and discharge would allow for more effective application of government policy.
- Cleaner production should be promoted as a process efficiency enhancement tool and its use should explicitly include environmental cost accounting.
- Breweries should recycle water, wastewater and energy.
- Governments should make better use of financial instruments, such as water abstraction and discharge fees in order to encourage water saving goals.
- Water management targets should be more explicitly included into environmental management tools, and in public outreach and communication.

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