Natsurv 4

Water and Wastewater Management in the Dairy Industry
(Edition 2)

E. Visser, A. Kotsiopoulos, T. Mocumi,
J.E. Burgess

WATER RESEARCH COMMISSION

TT 928/23

NATSURV 4
Water and Wastewater Management in the Dairy Industry
(Edition 2)

Report to the
Water Research Commission

by

E. Visser[1], A. Kotsiopoulos[1], T. Mocumi[2], J.E. Burgess[1,2]

[1] University of Cape Town
[2] Isle Utilities

WRC Report No. TT 928/23
ISBN 978-0-6392-0571-7

December 2023

WATER
RESEARCH
COMMISSION

Obtainable from

Water Research Commission
Bloukrans Building, Lynnwood Bridge Office Park
4 Daventry Street
Lynnwood Manor
Pretoria
0084
South Africa

orders@wrc.org.za or download from www.wrc.org.za

The publication of this report emanates from a directed project entitled *Revision of NATSURV 4: Water and Wastewater Management in the Dairy Industry* (WRC Project No. C2022/2023-00760). The first edition was published in 1989 as WRC Report TT 38/89.

EXECUTIVE SUMMARY

Background

In the 1980s the South African Water Research Commission (WRC) and the Department of Water and Sanitation (DWS) launched a series of national surveys (NATSURVs) to establish standards for water utilization, wastewater disposal, and effective management of these resources across diverse industrial sectors. The resulting NATSURV reports have been a useful resource ever since they were developed. Over the years, South Africa and its industrial sectors have either grown or, in some cases, shrunk considerably.

Similarly, the dairy industry's landscape has experienced significant changes following the publication of the first edition NATSURV 4 in 1989 (authored by project staff from Steffen, Robertson, and Kirsten Inc. consulting engineers). For example, certain companies have embraced new technologies and systems, accompanied by heightened awareness of water consumption and wastewater management. As a result, certain aspects of the original NATSURV 4 are now considered obsolete, thereby presenting an opportunity to review the dairy sector's water and wastewater management practices and make firm recommendations. Following the methodology shown in Figure 1, this report revises, updates, and expands on the content of the first edition.

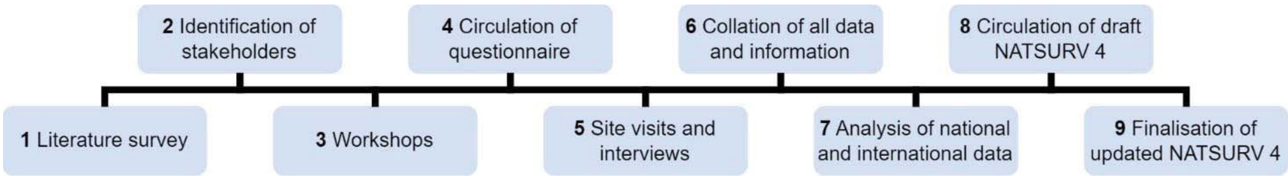


Figure 1: Approach followed for the methodology.

Industry overview

Over the last 13 years there has been a significant decrease – of 24% – in the number of milk processors, from 169 in January 2009 to 136 by January 2022 (Milk SA, 2022). This reduction can be attributed to a combination of factors, including drought conditions, liquidations, production sizes being too small for new technology to be cost-effective, and the tendency toward the consolidation of small independent processors into larger processors. Despite the decrease in processors, the annual unprocessed milk purchased increased from 2,624,000 tons in 2008 to 3,403,000 tons in 2021 (Milk SA, 2022). This annual unprocessed milk volume is more than threefold the amount recorded in 1989, which stood at 1,041,612 tons (Steffen Robertson and Kirsten Inc, 1989). South Africa contributes approximately 0.4% of the global milk production. Furthermore, similar to South Africa, countries such as India, the United States, and Germany saw an increase in milk production between 2014 and 2020.

Water consumption

Dairy processors evaluate their overall water consumption by monitoring a parameter known as specific water intake (SWI). This metric quantifies the volume of external water used to produce one litre of milk or other dairy products. The amount of water used varies depending on the type of products manufactured as well as other socio-economic and environmental factors that promote the adoption of more efficient water usage practices.

Table 1 shows that production volumes doubled between 1989 and 2022. Notably, the average SWI has decreased from 7 litres water per litre product to a more efficient 2.4 litres, with a smaller range within the same time period. This could possibly be attributed to technological advancements and process optimisation. Furthermore, the SWI values of selected dairy products such as yoghurt, cheese, and sterilised or UHT milk (from ultra-high temperature processing, or ultra-heat treatment) have improved since 1989. In the case of milk and butter, it differs; although some companies have progressed to SWI ratios lower than those recorded in 1989, others are now generating higher SWI ratios. The SWI target in the original NATSURV was 1.5 L/L milk, and two of the participating milk processors in this study had an average SWI lower than the 1989 benchmark.

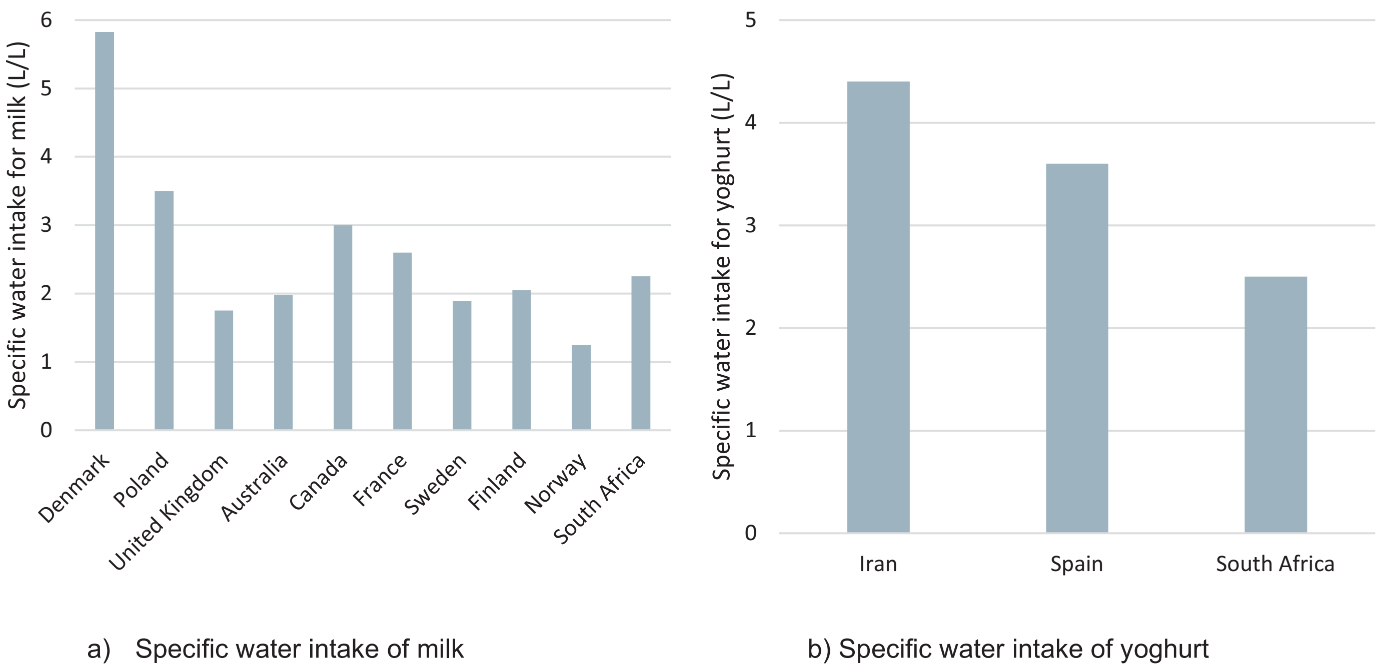
Table 1: Comparison of water usage in 1989 and 2022 based on survey results.

Parameter	Units	2022 Survey results			1989 Survey results		
		N*	Range	Average	N*	Range	Average
Water use	kL/y	10	2,000 - 2,400,000	452,139	19	-	-
Production	kL/y	16	700 - 150,000	49,484	19	1,000 - 48,000	27,500
Specific water intake	L/L	18	1 - 5	2.4	19	1.3 - 29	7

*N = Number of companies contributing data

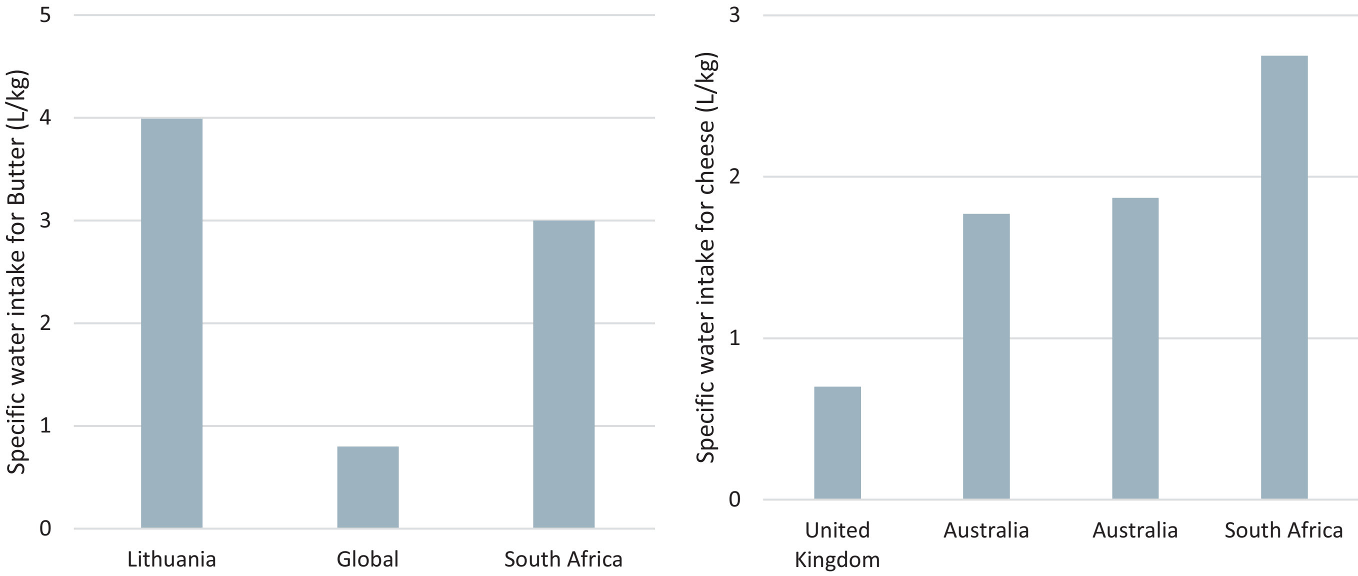
The National Water Act (NWA) was promulgated in 1998 (Act 36 of 1998), ten years after the publication of the first edition of NATSURV 4. The NWA's enforcement and municipal water and effluent tariffs may have contributed to the decrease in average SWI. South Africa is frequently praised internationally for the high standard of legislation governing water consumption and its emphasis on sustainability. However, a major concern is the lack of implementation, monitoring, enforcement, and general good governance of these laws. This could explain why some dairy processors have higher SWI ratios for specific products in 2022 than in 1989, because governance and implementation of water consumption sustainability may be better in some areas than in others.

Figure 2 summarises global SWI ratios derived from public literature, allowing global benchmarking of South African industry. South African dairies align with international trends and are consistent with worldwide dairy processor norms in terms of SWI ratios for milk and yoghurt. However, the potential for improving SWI ratios in cheese and butter remains.



a) Specific water intake of milk   b) Specific water intake of yoghurt

Figure 2: Summary of SWI of (a) milk and (b) yoghurt nationally and internationally



c) Specific water intake of butter

d) Specific water intake of cheese

Figure 2 cont'd: Summary of SWI of (c) butter and (d) cheese nationally and internationally

Wastewater generation

Table 2 shows that the average effluent volume generated has increased around sevenfold since 1989, as would be expected given the increase in milk demand and consequent water use. Moreover, the effluent volume range is much larger than previously reported. The dairy processors were surveyed on the characteristics of their wastewater streams and asked which is the most prominent; 50% of participating dairy processors responded that chemical oxygen demand (COD) was the most problematic. In most cases, the wastewater streams from the dairy processing plants were combined and discharged as one effluent stream.

Given the diverse array of processes within the dairy industry, making generalized statements about dairy wastewater streams proves challenging. The effluent characteristics of participants in 1989 and 2022 survey respectively are summarised in Table 2. Typically, the pH of the effluent was alkaline, ranging from 7-11. The 2022 survey found COD concentrations ranging from 100 to 8,000 mg/L, total dissolved solids (TDS) ranging from 50 to 2,000 mg/L, and total suspended solids (TSS) ranging from 10 to 400 mg/L. The 1989 NATSURV reported an average COD of 2,757 mg/L and TDS of 1,885 mg/L. The average COD of dairy effluent has increased, however, dairies with higher production volumes have managed to reduce their effluents' COD and TDS concentrations.

Table 2: Comparison of effluent characteristics in 1989 and 2022 based on survey results.

Parameter	Units	2022 Survey results			1989 Survey results		
		N	Range	Average	N	Range	Average
Total effluent volume	kL/y	8	1,000 - 2,000,000	388, 065	5	9,600 - 144,000	49,680
pH		6	7 - 11	9			
COD	mg/L	5	100 - 8,000	3,500	5	1,489 - 4,000	2,757
TDS	mg/L	2	50 - 2,000	875	5	1,106 - 3,000	1,885
TSS	mg/L	3	10 - 400	167			

Energy management

The participating dairies utilise a variety of energy sources, including electricity from the grid, solar, diesel, coal, steam, liquified petroleum gas (LPG), and heavy fuel oil (HFO). All three of the participating dairy facilities use electricity from the grid and incorporate solar power to supplement municipal supply. These dairies exhibit an annual energy consumption ranging from 144,000 to 275,500,000 kWh/year. Furthermore, they have demonstrated progress in energy saving initiatives by implementing energy efficiency solutions such as utilising low-grade energy, installing energy efficient equipment, and specifically upgrading infrastructure to reduce emissions and save energy.

Best practices

According to an analysis of best practice options implemented by the companies surveyed, the majority are aware of the need to optimize water use through internal reuse. The majority of the participating dairy processors are transitioning to cleaner production methods to reduce water consumption and wastewater costs. Aside from the potential commercial drivers, the dairy industry has recognized that demonstrating the principles of sustainability and corporate social responsibility (CSR) is critical to maintaining a social licence to operate and is increasingly influencing consumer behaviour.

Recommendations

To ensure that water use is optimised, and raw materials and products are not wasted, more emphasis should be placed on preventative management practices such as measuring, monitoring, and raising staff awareness. More data on the characteristics and pollution concentrations of dairy wastewater are required to determine national trends and draw sound conclusions. The survey would add further value to research and development in the dairy industry if the compliance from the dairy processors were better.

Conclusions

Since 1989, the dairy industry has experienced significant growth and a reduction in SWI across a variety of products, demonstrating the progress in water efficiency. The South African dairy sector aligns with international water consumption trends however, there is room for improvement as the consistent adoption of best practices are uneven across the sector. This necessitates ongoing efforts to raise awareness and assist companies in achieving water reduction targets, involving regular revisitation of best practices to assess their suitability for implementation at each unique dairy processing site.

ACKNOWLEDGEMENTS

The team wishes to anonymously thank the participating dairy companies without whom the project would not have been possible, as well as the following people for their contributions to the project.

Reference Group	**Affiliation**
John Ngoni Zvimba	Water Research Commission (WRC) – chairman
Alex McNamara	National Business Initiative (NBI)
Busisiwe Tshabalala	Department of Water and Sanitation, DWS
Colin Wellbeloved	Milk Producers' Organisation (MPO)
Kevin Cilliers	National Cleaner Production Centre (NCPC)
Ricki Govender	Clover SA
Thivhafuni Nemataheni	Department of Water and Sanitation, DWS
Zinzi Mboweni	Department of Water and Sanitation, DWS
Others	
Alwyn Kraamwinkel	South African Milk Processors' Organisation (SAMPRO)
Bertus Van Heerden	MPO
Colin Ohlhoff	Milk SA
Darrin McComb	Resource Innovations Africa
Heinz Meissner	Milk SA
Jompie Burger	Dairy Standard Agency (DSA)
Lindani Ncwane	NCPC
Ndumiso Mazibuko	SAMPRO
Raymond Greig	International Finance Corporation (IFC)

This page was intentionally left blank

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS & ABBREVIATIONS

CIP	Cleaning-in-place
CNG	Compressed natural gas
COD	Chemical oxygen demand
CSR	Corporate Social Responsibility
DEA	Department of Environmental Affairs (now DFFE)
DFFE	Department of Forestry, Fisheries, and the Environment (formerly DEA)
DM	Dry Matter
DSA	Dairy Standard Agency
DWA	Department of Water Affairs (now DWS)
DWAF	Department of Water Affairs and Forestry (now DWS)
DWS	Department of Water and Sanitation (formerly DWA and DWAF)
ESL	Extended shelf life
GDP	Gross Domestic Product
GMP	Good manufacturing practice
HACCP	Hazard Analysis and Critical Control Point
HFO	Heavy fuel oil
ISO	International Organization for Standardization
IWRM	Integrated Water Resource Management
L	Litre
LED	Light emitting diode
LPG	Liquefied petroleum gas
MPO	Milk Producers' Organisation
NATSURV	National Survey
NWA	National Water Act
PLC	Programmable logic controller
RO	Reverse osmosis
SAMPRO	South African Milk Processors' Organisation
SANAS	South African National Accreditation System
SANS	South African National Standards
SCM	Solid-corrected milk
SWI	Specific water intake
TBtu	Trillion British thermal units
TDS	Total dissolved solids
TSS	Total suspended solids
UHT	Ultra-high Temperature
USA	United States of America
WRC	South African Water Research Commission

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Water is used extensively in the processing of food, drinks, and dairy products. In the dairy industry, product contact surfaces are cleaned with potable water to maintain the required standard of hygiene. This includes cleaning and disinfection to prevent product contamination thereby ensuring that food safety is not compromised by pathogenic microorganisms. Consequently, a large volume of wastewater is generated along with the commercial products. This has forced dairy processors to put targets in place for water consumption and wastewater generation. The drivers for implementing sustainable water and wastewater management practices are physical water scarcity, increasingly stringent environmental legislative requirements, increasing production costs, increasing costs of waste disposal, and increasing environmental awareness in the general public, affecting consumers' purchasing choices and driving consumers to choose putatively "green" products.

In the 1980s, the South African Water Research Commission (WRC) and the Department of Water and Sanitation (DWS) embarked on a series of national surveys (NATSURVs) to establish norms for water utilisation, wastewater disposal, and effective management thereof across various industrial sectors. The NATSURV reports are a valuable resource for water management within different industries; however, South Africa and its industrial sectors have either grown or, in some cases, shrunk considerably since the 1980s. Similarly, the dairy industry landscape has changed since 1989 when the first edition of NATSURV 4 was published (Steffen Robertson and Kirsten Inc, 1989). These changes include the adoption of new technologies and systems and increased awareness about water usage and wastewater management. With these advancements, the reported survey in the 1989 edition of NATSURV 4 is now considered outdated, thereby presenting an opportunity to review the sector's water and wastewater management practices and make firm recommendations. This second edition revised, updated, and expanded the contents of NATSURV 4.

1.2 PROJECT OBJECTIVES

The overarching aim of this study was to obtain an updated overview of the dairy industry's operations, water management, and best practice implementation and to define factors that influence water consumption, effluent generation, and energy use.

The objectives of this study are:

1. To provide an overview of the dairy sector's current typical industry processes.
2. To review the legislative frameworks within which the dairy industry functions.
3. To provide water utilisation and specific water intake volumes.
4. To determine wastewater generation and typical pollutant loads.
5. To assess the progress the dairy industry has made towards process optimisation, with a focus on water and wastewater minimisation.
6. To recommend best practices for water use and wastewater management for the dairy industry.

1.3 METHODOLOGY

The approach used to identify the key challenge and address the intended objectives is summarised in Figure 1.1. A literature survey was undertaken to gain insight into the specific water requirements of dairy production processes and thereby identify which unit operations were the most water intensive. Armed with this knowledge, industry related information with respect to water and wastewater management practices was determined through engagement activities such as questionnaires, site visits, and interviews. This direct interaction enabled the identification of critical details, such as water consumption during dairy processing, patterns of wastewater generation, potential water reduction or recycling opportunities, existing treatment facilities, and currently implemented water management and minimisation efforts. With a comprehensive collection of data and insights in hand, this information was analysed and compared with international trends to create a benchmarking guide. The final benchmark document serves as a compass to navigate toward improved water and wastewater management in the dairy industry. A summary of each methodology step is provided in the sections that follow.

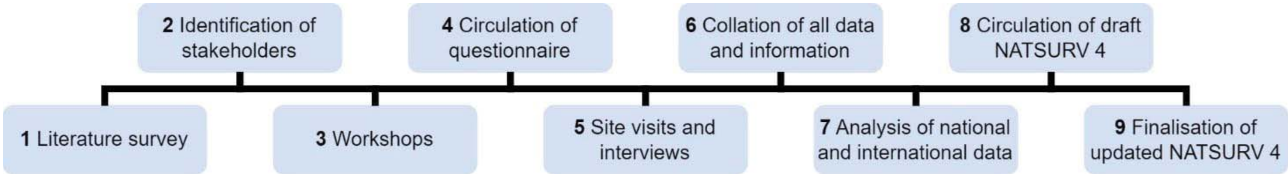


Figure 1.1: Approach followed for the methodology.

1.3.1 Literature survey and review

A comprehensive literature survey was initially undertaken to identify current water and wastewater management and best practices in the dairy industry both nationally and internationally. An extensive review of the literature provided insight into the dairy industry production processes in South Africa and identified which processes are the most water-intensive. The desktop research revealed information regarding industrial water stewardship activities, current investments, and global best practices in the dairy industry.

1.3.2 Identification of main dairy processors

In-depth desktop assessments of the industry were followed by engagement with a representative sample of companies to acquire current data relating to water use and wastewater management. Dairy processing companies were identified through internet searches and referrals from organisations within the dairy supply chain. In total, 130 different organisations were identified, of which 31 were suitable for invitation (e.g. manufacture products within the scope of this project) and were approached telephonically and/or by email. Out of the 31 organisations contacted, 13 were responsive and agreed to join the workshop.

1.3.3 Workshops

Workshops were held to generate interest in the survey and gain input from dairy processors regarding the information that should be included in the updated NATSURV 4. The first workshop was held in July 2022 and was attended by two relevant dairy processors. The workshops were presented several times during July 2022 to accommodate the availability of dairy processor representatives. Six dairy processor representatives attended the various workshops before the end of July and consented to participate in the survey.

The nature and purpose of the report was communicated in the workshops. The dairy processors were assured that their companies would not be identifiable from the research outputs. They were also offered the opportunity to preview the draft NATSURV and request factual corrections. The dairy processors had the opportunity to ask questions and state whether they were open to participating in the survey.

1.3.4 Questionnaire

Before the questionnaire was sent out, the nature and the types of questions that would be used in the survey were defined to ensure that accurate and relevant information would be captured. The questions were reviewed by the WRC and Reference Group to ensure they were well constructed, relevant, and clear. An example of the questionnaire is shown in Appendix A. Using the questionnaires, water usage, specific water consumption, and volumes of wastewater generated from each of the responding industries were mapped and quantified. The responses were monitored and validated to identify gaps and to clarify any incomplete or ambiguous responses.

The questionnaire was divided into six sections, including general information, an overview of production, water consumption and wastewater generation, wastewater composition, water and wastewater management, and further involvement. Each section contained pertinent questions to provide insight into water usage, specific water consumption and wastewater generated, seasonal variations, water sources, wastewater composition, the adoption of water stewardship practices, and progress the industry has made towards cleaner production.

Only a small fraction of the local industries completed the questionnaire. Out of the potential 130 milk processors, a total of only 10 participated in this survey. This translated to an overall participation rate of approximately 7.7%, compared to 12.67% in 1989 (Steffen Robertson and Kirsten Inc, 1989). It is therefore important to note, and emphasise, that the results reflect a partial cohort of the overall dairy industry. This acknowledgement is essential to emphasise that the findings do not necessarily represent the full spectrum of the dairy industry in South Africa.

1.3.5 Site visits and interviews

Some dairy processors indicated on the questionnaire that they were willing to host a site visit. The aim was to include a range of processor sizes since it was expected that larger processors would use more modern technologies than those with smaller capacities and have different approaches to water and wastewater management. Only three dairy processors out of the 10 respondents were willing and able to host site visits.

Visits included a site walk-through, the completion of the questionnaire, and acquiring further insights into the sites' water use, effluent quality, and treatment and water conservation practices. Information obtained from site visits together with the online questionnaires was used to compile the figures and data presented in this report.

Interviews were conducted to address gaps in the information accessible via desktop research. The type of information sought was tailored to each stakeholder. Through interviews with dairy processors, we identified the main barriers to the uptake of advanced wastewater treatment technologies and water management practices.

1.3.6 Data collation

The comprehensive dataset gathered through the questionnaire, site visits, and interviews was collated in a spreadsheet and used for a comparative analysis on water use, wastewater generation, wastewater quality, water management, water targets, and technologies applied.

1.3.7 Analysis of national and international data

Conducting a comprehensive analysis of both national and international data allowed for the benchmarking of national data against its international counterpart. This process provided valuable insights, facilitating the identification of opportunities for improvement and key industrial best practices.

1.3.8 Circulate draft report

The draft NATSURV 4 report was distributed to the WRC, the Reference Group, and the participating companies to gather their input, guidance, and suggestions for further refinement and ensure factual correctness while reporting companies' data.

1.3.9 Finalise NATSURV 4 report

This final NATSURV 4 report integrated inputs from both the Reference Group and the industry. Following the integration of all information accumulated during the online and in-person surveys, quality assurance was undertaken before the report's publication. This involved soliciting feedback and corrections from all contributing writers involved in this report. The final version was then made available via the WRC knowledge distribution networks.

1.4 INDUSTRY OVERVIEW

There are over 130 milk processors in South Africa producing a wide range of products, such as fresh milk, cream, butter, cheese, yoghurt, milk powder, ice cream, condensed milk, and various milk-based desserts and drinks (Milk SA, 2022). These products can be divided into two categories: liquid products such as pasteurised milk, ultra-high temperature (UHT) milk and cream, and concentrated products such as cheese, butter, and condensed milk (Bryden, 2021). A schematic overview of liquid products and concentrated products is given in Figure 1.2.

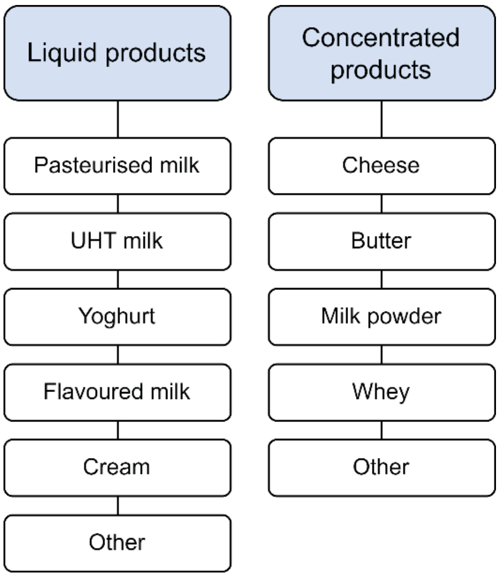


Figure 1.2: Schematic overview of two categories

The majority (62%) of dairy products consumed in South Africa are liquid products, while 38% are concentrated products (Bryden, 2021). The estimated market shares of different products from both the liquid and concentrated categories are given in Figure 1.3 and Figure 1.4.

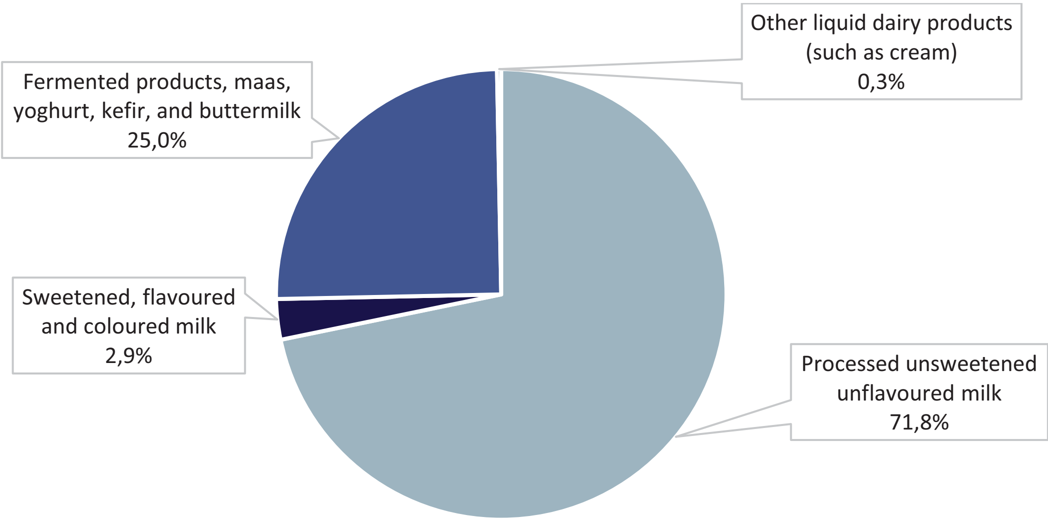


Figure 1.3: The composition of the South African liquid products market on a volume basis, 2021 (Milk SA, 2022)

Pasteurised milk and UHT processed milk were the major liquid products and took up approximately 71.8% of the market share. Table 1.1 shows the average composition of cow milk; however, it should be noted that the composition is often influenced by several factors such as breed, feeding, and climate (Bylund, 2015). In general, milk consists of approximately 87.2% water and 12.8% total solids (Bylund, 2015). The total solids consist of disaccharide sugar lactose, fat, proteins, which are mainly divided into casein and whey; and minerals/salts, which are described as ash.

Table 1.1: Cow Milk composition (Bylund, 2015)

Constituent	Approximate percentage (%)
Water	87.2
Lactose	4.9
Fat	3.9
Casein	2.7
Ash	0.7
Whey	0.6

The major product in the concentrated category was cheese, taking up 57.7% of the market share (Milk SA, 2022). Figure 1.4 shows that butter and milk powder take up 10.9% and 12.1% of market share, respectively (Milk SA, 2022). The liquid and concentrated categories consist over hundred products, with several new varieties becoming available with innovation. As a result, this study only focused on two liquid products, namely milk and yoghurt, and one concentrated product, butter. Consequently, to limit the complexity associated with flavoured products, the scope of this NATSURV report was limited to plain dairy products.

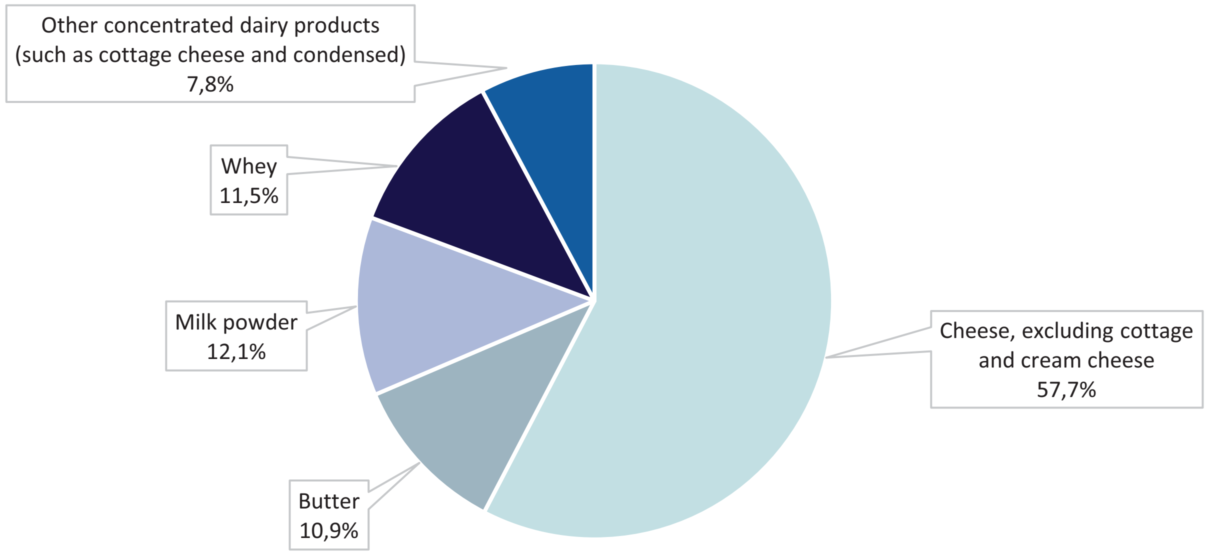


Figure 1.4: Composition of the South African concentrated product market on a mass basis, 2021 (Milk SA, 2022)

In addition to traditional liquid and concentrated dairy products, dairy alternatives have gained interest over the past decade (2012-2022). The non-dairy milk alternatives include soy milk, almond milk, oat milk, coconut milk, rice milk, and others. The key factors driving the increasing consumer preference for dairy alternatives are allergies and intolerances, environmental concerns, plant-based diets, taste, and perceived health benefits (Soutter, 2020).

The United States of America (USA) experienced an 18% decline in milk consumption per capita between 2010 and 2018 (Wolf *et al.*, 2020). However, during the same period, per capita consumption of cheese and butter increased by 20.6% and 18%, respectively (Wolf *et al.*, 2020). As a result, even though liquid milk consumption declined, more dairy products are being consumed overall (Wolf *et al.*, 2020). The recent decline in milk consumption in the USA is mainly a result of more consumption of plant-based milk alternatives (Wolf *et al.*, 2020). Plant-based milk alternatives continue to replace the dairy fluid milk sector; however, further innovation is required before alternatives can replace dairy commodities (cheese, butter, yoghurt, etc.) and the nutritional density of dairy products (Soutter, 2020). The Asia-Pacific region consumes the most dairy alternatives worldwide (Soutter, 2020). In 2021, it held over 50% of the global alternatives market where the market grew by 11.83% from USD10.13 billion in 2020 to USD11.49 billion in 2021 (Soutter, 2020; Fortune business insights, 2021).

The steady decline in fluid milk consumption is mainly experienced in developed economies such as Western Europe and North America (Fortune business insights, 2021). South Africa experienced an increase in fluid milk consumption per capita of approximately 6% between 2010 and 2017 (Shahbandeh, 2020). Dairy and non-dairy milk products co-exist in the South African market. However, dairy milk is frequently preferred due to a multitude of factors. These include, but are not limited to, its widespread accessibility, especially in areas where alternatives might be limited, its recognised nutritional value that is essential for overall health, and the price difference between non-dairy alternatives and dairy milk. These factors, along with the familiarity and taste of dairy milk, contribute to its frequent preference over non-dairy milk options in South Africa. The effect of non-dairy alternatives on the South African market is a research area that is overlooked and in need of more development.

1.4.1 Dairy supply chain

The dairy supply chain consists of farm milk suppliers (producers), processors, distributors, retailers, and consumers. A generic process flow diagram for the production and distribution of dairy products is shown in Figure 1.5. The NATSURV documents review the status of the South African manufacturing industries therefore, this report focused on dairy processors, excluding agricultural processes and packaging. Dairy processors in South Africa use a combination of local milk suppliers and imported milk concentrates to produce a variety of dairy products (Midgley, 2016).

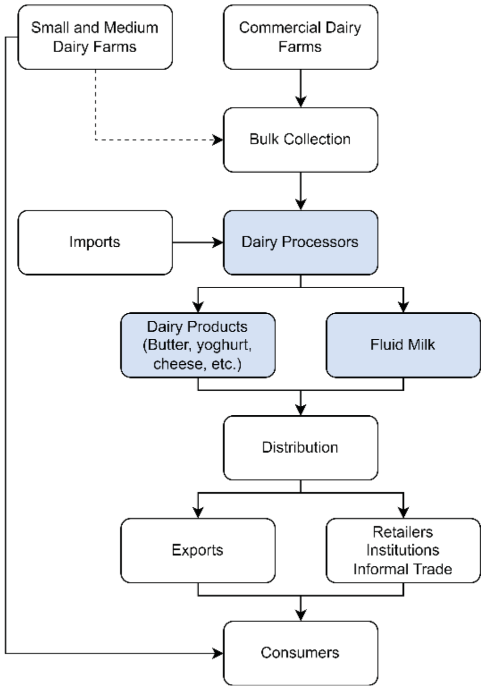


Figure 1.5: Generic process flow along the dairy supply chain (DAFF, 2019)

The entire dairy supply chain is heavily dependent on public sector services such as electricity, roads, water, inspection services, security, prevention, and control of animal diseases at the national, provincial, and local levels (SAMPRO, 2022). South Africa has experienced electricity shortages since 2007, and this has put strain on all industries, including the dairy industry. The recent increase in power outages, especially in 2022, forced the industry to adapt and invest in backup power supplies to keep up with production demands. Figure 1.6 shows the significant increase in hours of load-shedding from 2021 to 2022 (Labuschagne, 2022). Without a reliable power supply for plant operations and pumping, attempts to improve water systems may appear fruitless (Kaplan, 2023). This has the potential to hinder growth in processing and water management by diverting resources toward energy management (Kaplan, 2023). Nevertheless, effective leadership can drive proactive water management initiatives, even in the face of power outages.

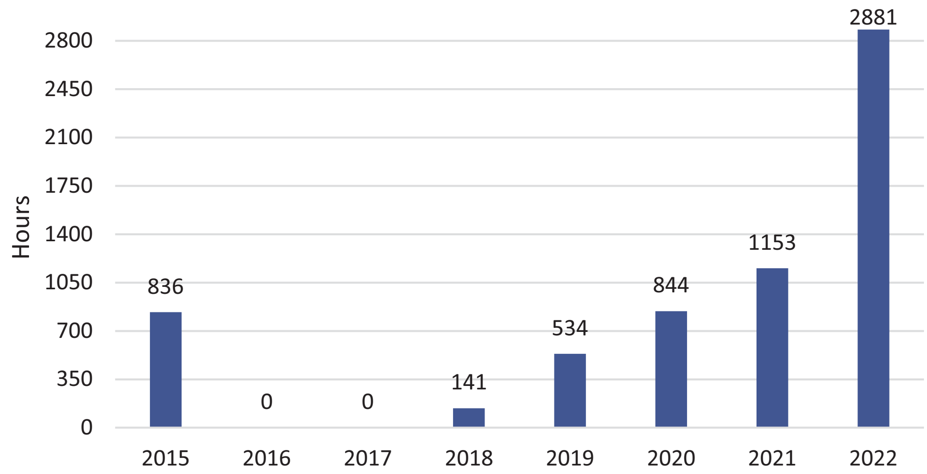


Figure 1.6: Hours of load-shedding over the years 2015 to 2022 (Labuschagne, 2022)

1.4.2 Dairy industry size and position

Since 1997, there has been an overall movement of milk producers from the central provinces to the coastal provinces. The Western Cape is currently the major milk-producing province in the country because the drier and hotter inland regions, which require intensive high-cost feedlot (animal feeding) systems, are not as well suited to dairy production (Bryden, 2021). However, milk processors can be found all over South Africa, because of the market location and concentrations of consumers in the inland regions (Midgley, 2016). Figure 1.7 shows that the highest concentration of milk processors in 2022 was in Gauteng. The Western Cape and Gauteng collectively account for approximately 55% of the national milk processing capacity. Most of the major pasteurised milk and product factories are in urban areas, from which extensive distribution networks flow. The stress on freshwater resources and urban water systems increases as processors relocate from rural to urban areas.

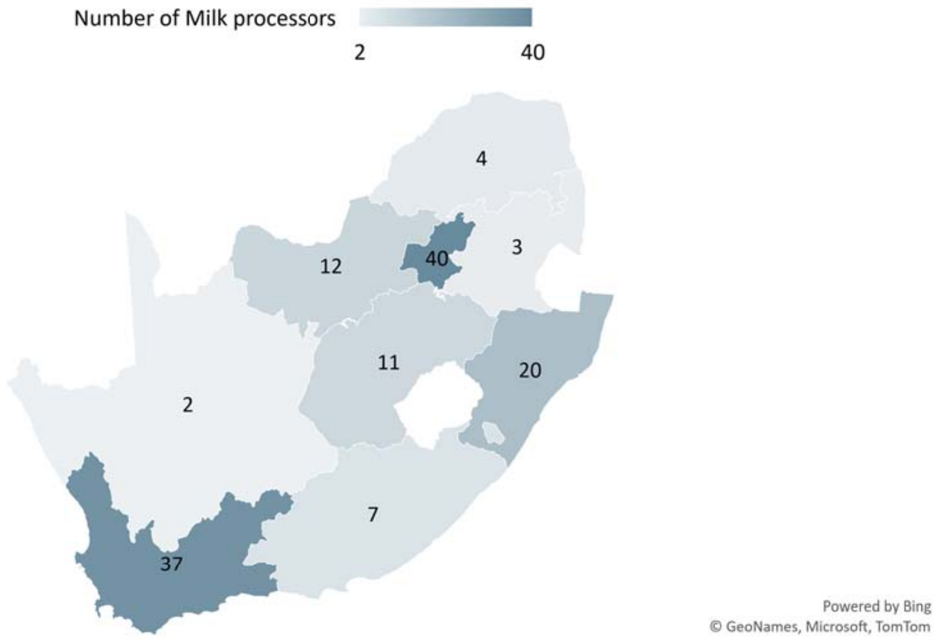


Figure 1.7: Number of processors per province (Milk SA, 2022)

The 1989 NATSURV 4 reported that there was in excess of 150 dairies in South Africa; nevertheless, the dairy market size has changed since then (Steffen Robertson and Kirsten Inc, 1989). Over the past 13 years, the number of milk processors has declined significantly, falling by 24% overall between January 2009 and January 2022. The decline is associated with several factors including consequences due to drought, liquidations, or production sizes being too small for new technologies to be cost-effective (Bryden, 2021). The number of milk processors per province between 2009 and 2022 is given in Table 1.2. The number of milk processors in the Eastern Cape declined from 12 in 2015 to 7 in 2022. The ongoing drought that began in 2015 potentially contributed to the significant decline in the number of processors in the Eastern Cape, making it challenging to operate and expand with the growing demand (Bryden, 2021; Archer *et al.*, 2022). The Northern Cape's small number of processors may be explained by the fact that it is a sparsely populated province with a smaller consumer market, and it is also a water-scarce province with ongoing droughts (Alexander, 2018; Mwendera *et al.*, 2018).

Table 1.2: The number of milk processors per province, Jan 2009-Jan 2022 (Milk SA, 2022)

Province	Jan-09	Jan-15	Jan-16	Jan-17	Jan-18	Jan-19	Jan-20	Jan-21	Jan-22
Eastern Cape	13	12	13	12	8	12	9	9	7
Free State	19	15	13	13	12	15	12	12	11
Gauteng	34	51	48	46	42	51	39	40	40
KwaZulu-Natal	28	16	18	21	20	16	20	19	20
Limpopo	6	4	4	4	4	4	3	4	4
Mpumalanga	4	6	6	6	5	6	4	4	3
North West	16	16	16	14	11	16	11	10	12
Northern Cape	3	1	1	1	1	1	2	2	2
Western Cape	46	39	39	38	35	39	31	33	37
Total	169	160	158	155	138	160	131	133	136

The overall decline in the number of milk processors stems from a range of potential external economic influences, including factors such as load-shedding, COVID-19, stagnant gross domestic product (GDP) growth, weather-related events, or shifts in consumer preferences. However, summarising these intricate economic trends is beyond the scope of this report. Another possible explanation for the decrease in the number of milk processors is a trend toward consolidation of small independent processors into larger processors, which is supported by the fact that the four largest milk buyers collectively purchase more than 50% of total milk production (Milk SA, 2022). The larger processors have the advantage of being able to efficiently and cost effectively purchase and process large volumes of milk. Therefore, even though the number of processors in South Africa has decreased, the annual amount of unprocessed milk purchased increased from 2008 to 2021, as shown in Figure 1.8.

The total unprocessed milk to market in 2021 amounted to approximately 3.40 million tons, down 0.71% from 2020 (Van Heerden, 2021). This volume is more than triple the volume recorded in 1989, which stood at just over 1.04 million tons (Steffen Robertson and Kirsten Inc, 1989). However, despite this substantial increase, a per capita perspective paints a different picture. With a population of 38.7 million in 1989, the per capita milk to market was roughly 0.027 tons (The World Bank, 2021). In 2021, with a population of 59.4 million, the per capita milk to market has risen to around 0.057 tons (The World Bank, 2021). While the overall volume has increased, per capita growth has been slower, suggesting a possible shift in consumption patterns. Through the years of 2015 to 2017, South Africa suffered from severe droughts; however, milk demand remained stable despite the water shortages. There was a slight decrease of 0.5% from 3,173,000 t in 2015 to 3,158,000 t in 2016; however, the fact that they were not severely affected shows the resilience of the dairy producers.

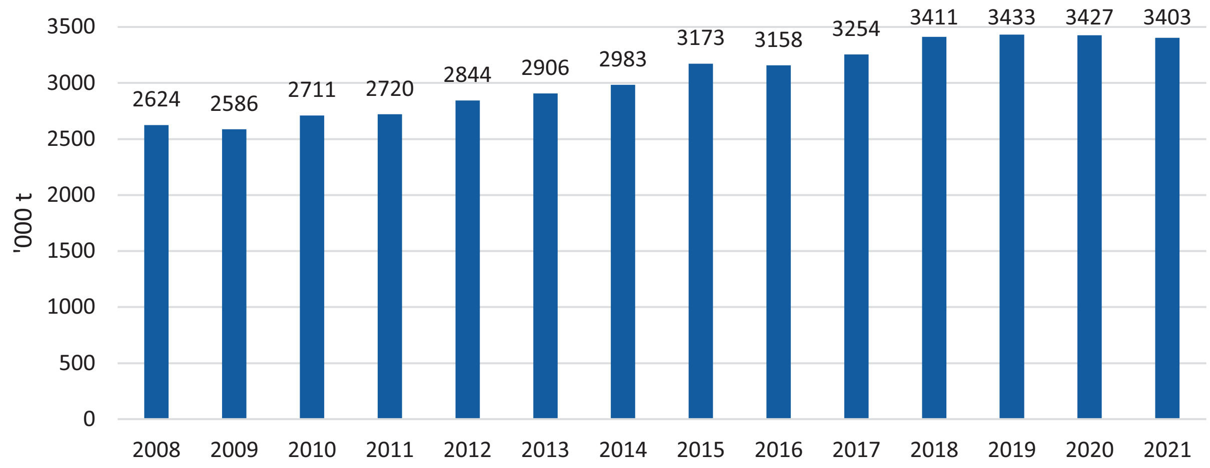


Figure 1.8: Annual unprocessed milk purchases, 2008-2021 (Milk SA, 2022)

The unprocessed milk is purchased by dairy processors and used to create a variety of products. The national production and sales of these products in volume are given in Table 1.3. Different dairy products perform differently in markets, and in the South African market, UHT and sterilised milk sales have surpassed the pasteurised and extended shelf life (ESL) milk sales volumes. South African consumers prefer the convenience of UHT milk since it can be stored for longer periods of time.

Table 1.3: Retail sales plus non-retail sales volumes between January 2021 and December 2021 (Data taken from Le Roux et al. (2022))

Product	Unit	Estimated total demand*
Pasteurised and ESL milk	L	479 527 183
UHT and sterilised milk	L	995 941 071
Yoghurt	L	249 075 229
Maas	L	266 075 192
Cheese**	kg	95 378 429
Butter	kg	18 839 089

*The estimated figures are calculated by SAMPRO based on unprocessed milk allocations for manufacturing of dairy products as supplied by Milk SA.
**Includes hard -, semi-hard -, pre-packaged cheese and other

The South African dairy sector showed remarkable resilience during the COVID-19 pandemic's regulations and restrictions in 2020, effectively meeting market demands. This is noteworthy considering how severely other product supply chains were disrupted, which clearly highlights the resilience of the South African dairy value chain (Milk SA, 2022). The volume of dairy products sold in the retail market during 2021 was marginally lower compared to sales in 2020 (Van Heerden, 2021). Over the twelve-month period from January 2021 to December 2021, the sales quantities of all monitored dairy products declined in comparison to the period from January 2020 to December 2020 (Van Heerden, 2021).

The increased inflation rate is placing consumer demand under pressure. As depicted in Figure 1.9, the retail prices of fresh milk per litre, packaged in 2 L plastic containers, are compared against producer prices. The producer price of unprocessed milk increased from R3.20/L in January 2012, to R5.13/L in September 2020, which is slightly below R2.00/L increase, while the retail price increased by over R6.00/L from R8.35/L to R14.73/L during the same period (Van Heerden, 2021). It is important to acknowledge that the dynamics of dairy pricing and price spreads can be complex and influenced by a variety of internal and external factors, often differing across regions, and change over time. Internal factors include resource management (for example, water and energy), software systems, and equipment while external factors include changes in consumer behaviour, new competition, and unpredictable events such as war, economic crisis, global pandemics (Sherman, 2019). However, considering the impact of these factors on the final product cost is beyond the scope of this report. Nevertheless, one noteworthy observation is the rapid increase in prices and the growing price spread from about R5.00/L in 2012 to nearly R10.00/L in 2020 between farm and retail, which leaves room for a potential increase in producer prices (Van Heerden, 2021).

The South African population grew by an annual average of 1.5% from 2018 to 2021 (Stats SA, 2022). However, Figure 1.8 shows that during the same period, milk demand remained relatively stable (Milk SA, 2022). This could likely be attributed to intensified competition within the dairy industry, coupled with a growing interest in dairy alternatives observed over the past decade. Several key factors drive the increasing consumer preference for dairy alternatives, including allergies and intolerances, the adoption of plant-based diets, and environmental concerns (Soutter, 2020). Additionally, factors such as product diversity and the influence of marketing and education on the benefits of dairy milk consumption also play a noteworthy role. Another possible factor contributing to the stagnation of milk demand could be the increase in milk retail prices as depicted in Figure 1.9.

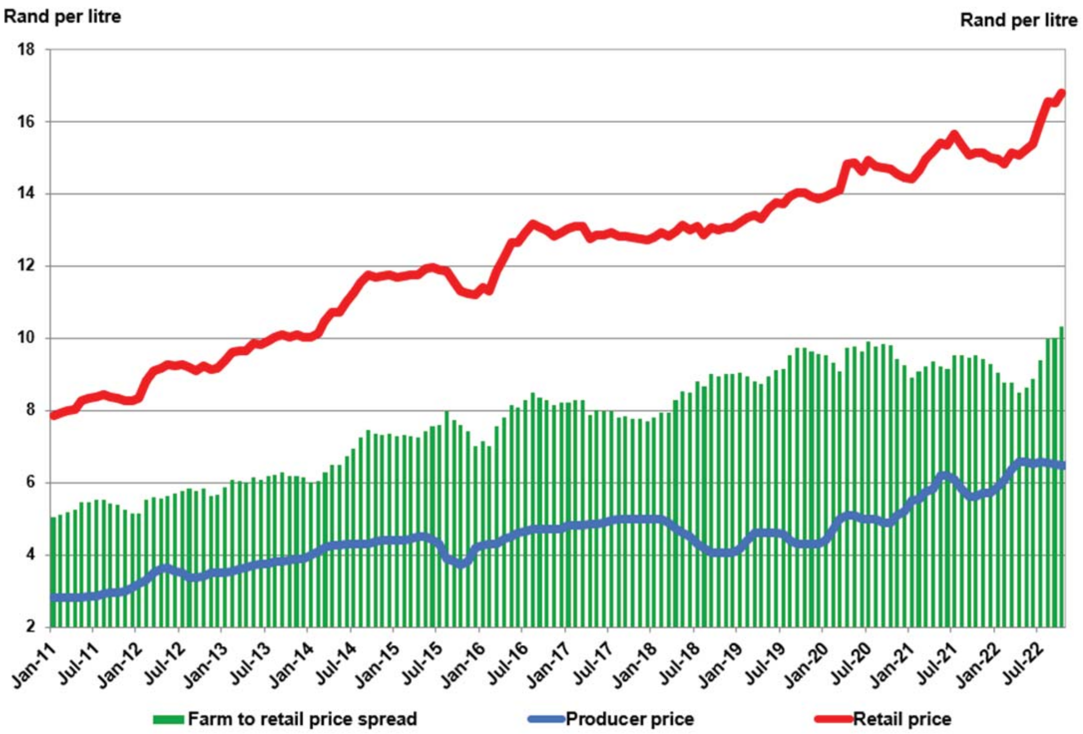


Figure 1.9: Monthly producer and retail prices, 2011-2022
(Graph reproduced with permission from MPO; (Van Heerden, 2021))

1.4.3 Global and local dairy industry

Dairy products are produced all over the world. The global production of unprocessed milk increased from 884 × 10^6 t in 2019 to 910 × 10^6 t in 2020 (IDF, 2021). This is a noteworthy increase of 3% in 2020 relative to the 2.2% compounded annual growth rate over the previous ten years (2010-2020; IDF, 2021). South Africa produces approximately 0.4% of global milk production (Milk SA, 2022). The largest milk producer is India, which accounts for approximately 25% of global dairy production. It produces more than double that of its closest competitor, the United States (Statista, 2022). The solid-corrected milk (SCM) production of the ten highest global producers in 2020 is given in Figure 1.10. South Africa is also included in the graph for comparison.

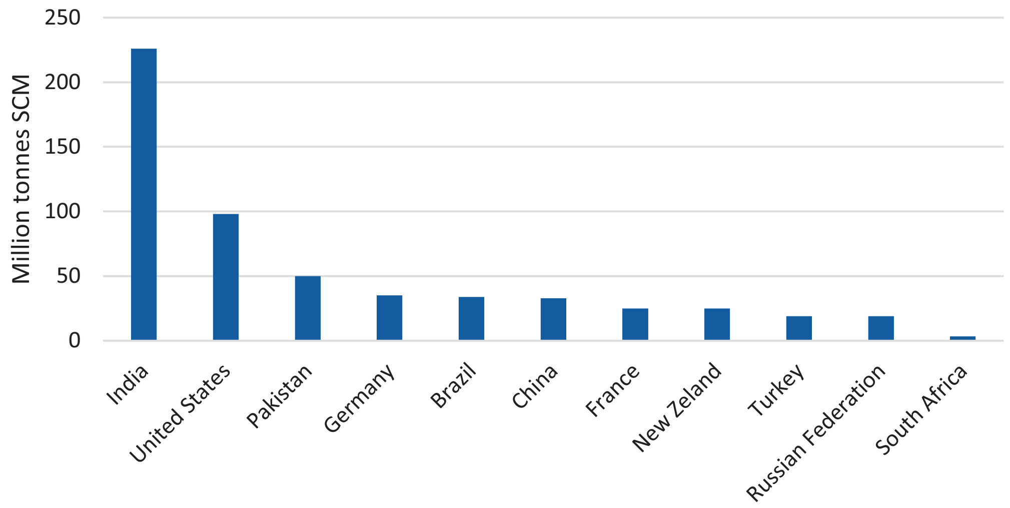


Figure 1.10: Milk production figures for the ten highest global producers and South Africa (Statista, 2022)

The milk production trends in India, Germany, the USA, and South Africa are illustrated in Figure 1.11. Like South Africa, these countries saw an increase in milk production over the years 2014 to 2020. Certain countries experienced more growth than others and this can likely be attributed to population growth. Between 2014 and 2020, India's population increased by 89 million, compared to a 14 million increase in the USA and a 0.8 million decrease in Germany (IndexMundi, 2022).

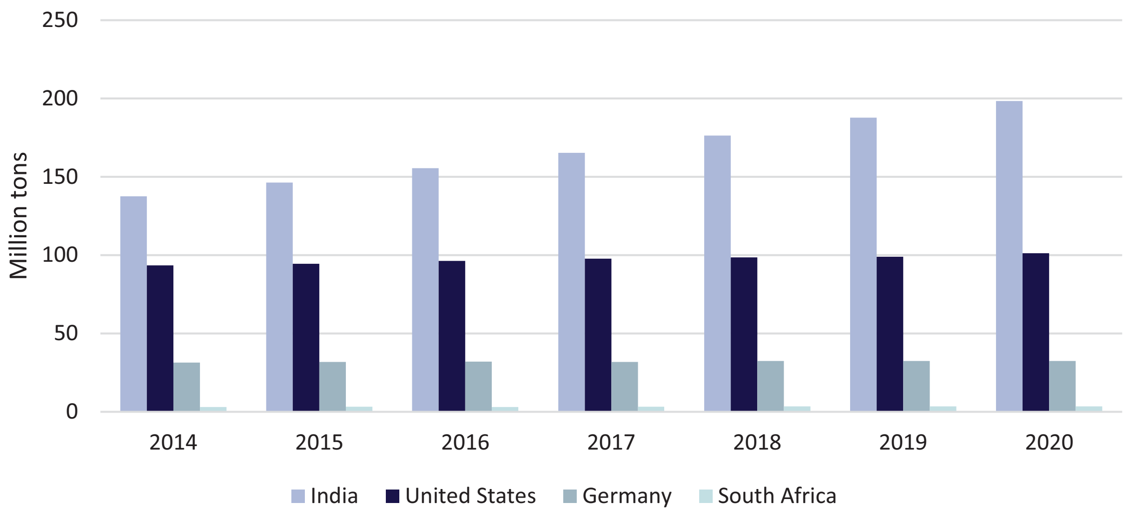


Figure 1.11: Milk production trends from 2014 to 2020 (IndexMundi, 2022; Statista, 2022)

The USA experienced a decline in milk consumption per capita of 18% between 2010 and 2018 (Wolf *et al.*, 2020). Despite their population growth, milk production did not increase significantly, possibly due to demand stagnation with the rise of alternative milk products. Regardless, the USA remains one of the countries with the highest per capita milk consumption, as shown in Figure 1.12. India's dairy industry is struggling to meet its growing demand for milk; therefore, per capita consumption is lower than in other countries. The fact that India is a country with an extremely high water risk could hinder dairy producers and processors' growth (Dormido, 2019). Countries such as Russia, the USA, and Canada are considered low water risk areas and have high per capita milk consumption (FAO, 2017; Dormido, 2019).

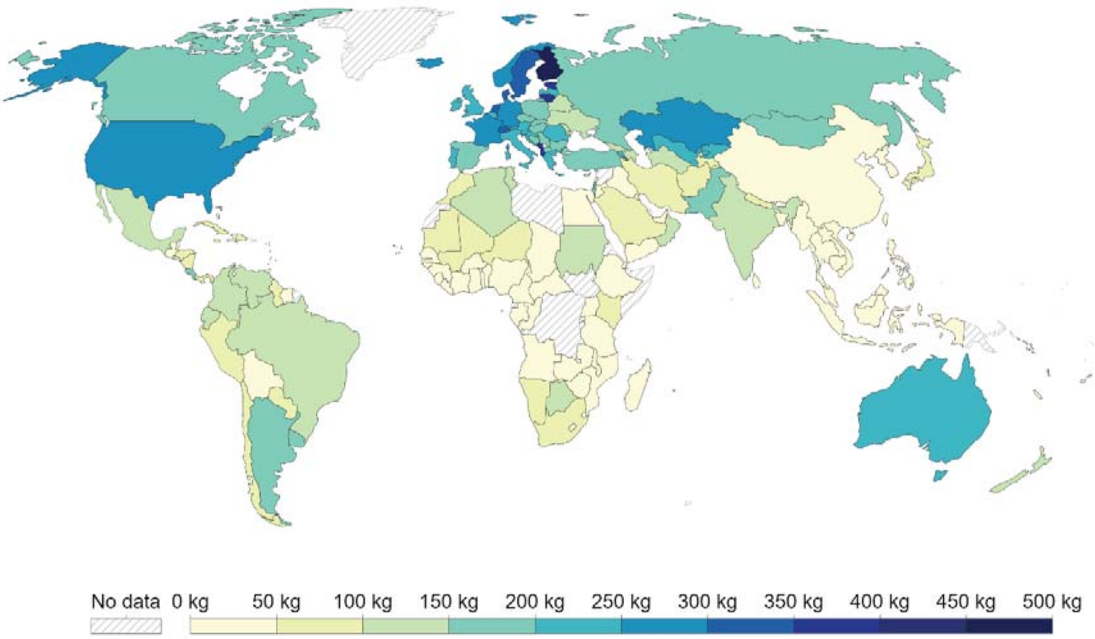


Figure 1.12: Average per capita milk consumption (kg/person/year) over the world*
(© Our World in Data; data source United Nations Food and Agricultural Organization, 2017)

*This includes the milk equivalents of dairy products made from milk ingredients excluding butter.

Note: Data is based on per capita food supply at the consumer level but does not account for food waste at the consumer level.

Unprocessed milk is produced seasonally in South Africa and other nations. In South Africa, the months of September, October, and November are the peak time for production while April, May, and June have the lowest daily production, as shown in Figure 1.13 (SAMPRO, 2022). The rest of the world follows a similar seasonal trend where production is lower in the winter months versus the summer months (SAMPRO,2022).

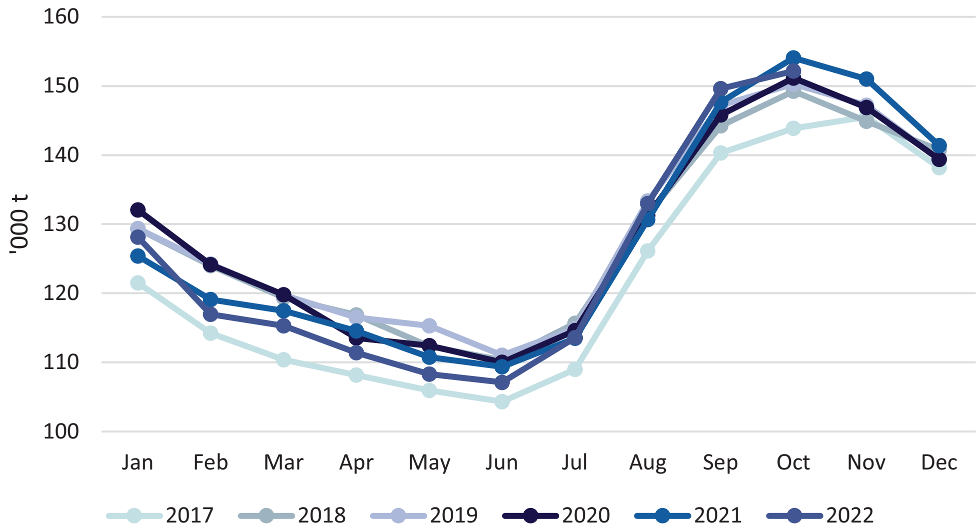


Figure 1.13: Average unprocessed milk purchased per month in South Africa between 2017 and October 2022 (Index: January 2008 = 100) (SAMPRO, 2022)

Total dairy product imports and exports between 2010 and 2021 are shown in Figure 1.14. In 2021, 75,600 t of products were imported, and 51,000 t were exported. The mass of exports was 9.2% higher in 2021 than in 2020, while the mass of imports was 24.8% higher in 2021 than in 2020 (SAMPRO, 2022). South Africa was a net exporter of milk and cream, buttermilk, and yoghurt in 2021; and a net importer of concentrated milk, whey, butter, and cheese (SAMPRO, 2022).

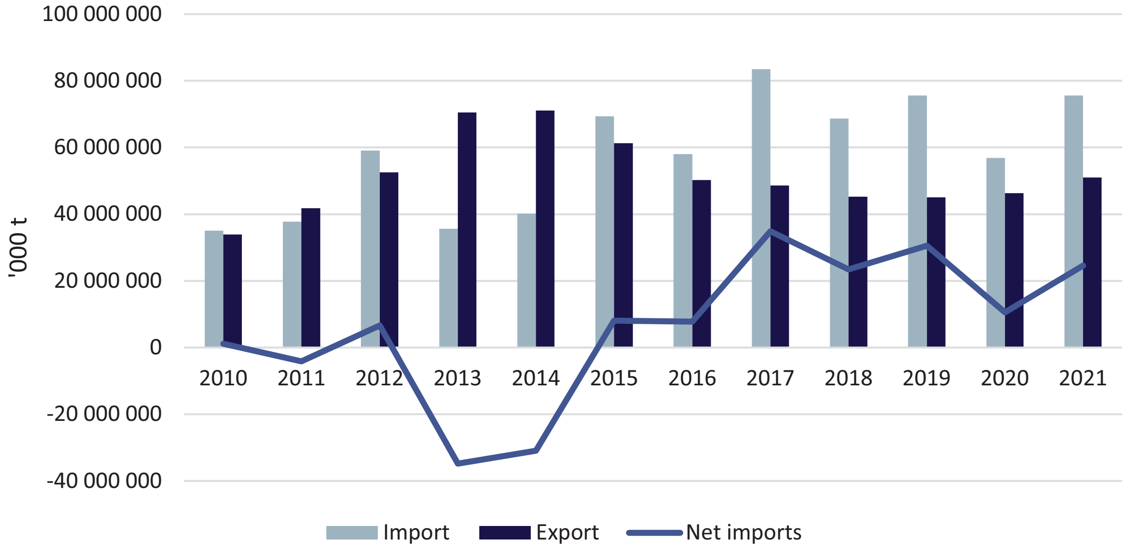


Figure 1.14: Total dairy product imports and exports between 2010 and 2021 (source: SARS data as supplied by Milk SA (2022))

1.5 CONCLUSIONS

The landscape of South Africa's dairy processing industry has undergone significant changes since 1989, as discussed in this chapter. These changes were driven by consumer demand, increased competition, rising popularity of dairy alternatives, increased production costs, recurring droughts, and various other factors. Despite these challenges, the dairy processing industry has demonstrated remarkable resilience and growth. However, this industry relies heavily on water for processing and maintaining hygiene standards. Therefore, the following sections provide insight into the water and wastewater management practices adopted by this industry, considering their importance in ensuring both efficiency and environmental sustainability.

CHAPTER 2: DAIRY PROCESS OVERVIEW

This section provides an overview of the generic processes and principles used in the South African dairy industry. The processes selected depend on the product and the type of packaging to be used, as the dairy processes are as diverse as the dairy products. The processing steps described in this section include the production of milk, butter, and plain yoghurt. In general, the processes described in the first edition of NATSURV 4 are still valid (Steffen Robertson and Kirsten Inc, 1989). However, there have been some changes to the process steps due to technological advances made since 1989 that include an increase in automation, increased production throughput and reduced labour requirements.

2.1 MILK PRODUCTION PROCESSES

Pasteurised full cream milk and associated products are produced through a series of processing stages that collectively influence the quality of the product and the water consumption. Figure 2.1 illustrates these major process steps, providing an initial overview. The following sections will shed light on the significance of every stage and its role in ensuring a quality product.

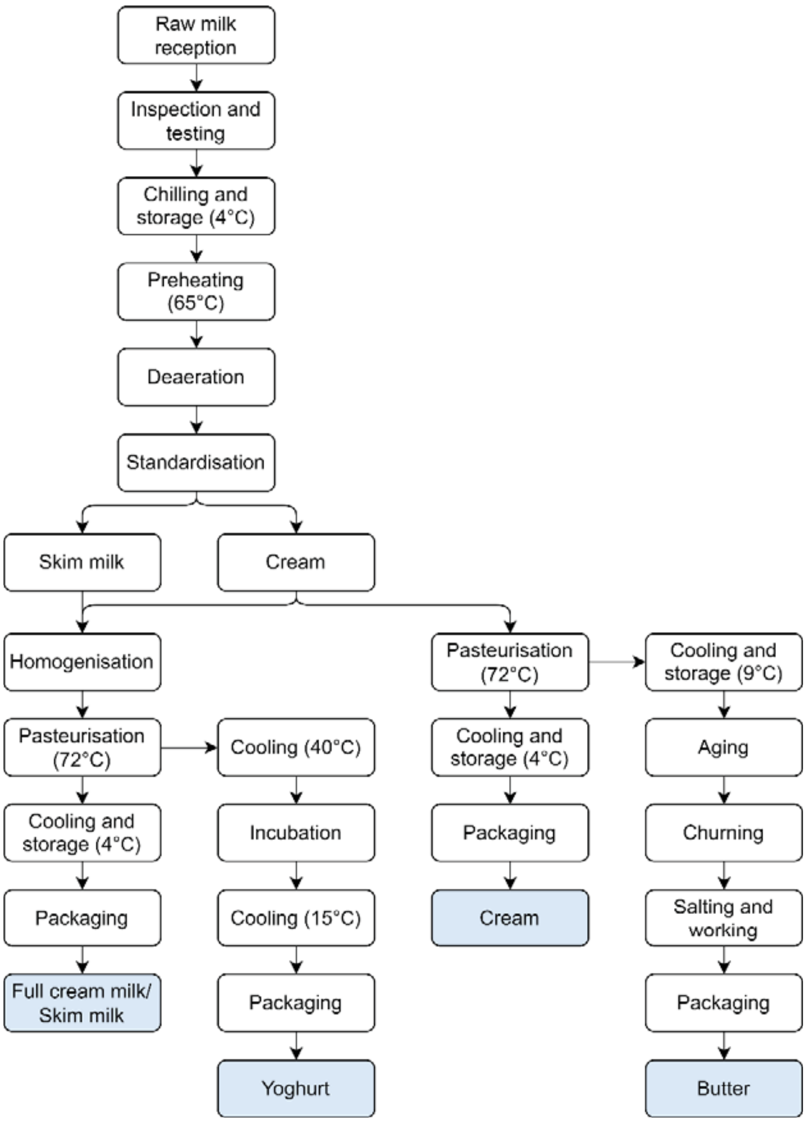


Figure 2.1: Typical major steps in the production of pasteurised milk, pasteurised skim milk, yoghurt, cream, butter, and buttermilk

2.1.1 Milk reception

The reception of milk is common to all dairy processing, regardless of the final product. Generally, milk is supplied via tank cars and is passed through a rough inline filter before storage and further processing (DSA, 2022). This filter is used to ensure the quality of the incoming milk by removing larger impurities of approximately 100 μm that could potentially hinder the efficiency of downstream processing (DSA, 2022). Additionally, the filter acts as a safeguard, protecting the pumps from potential damage (DSA, 2022). Simultaneously, the volume of the milk is measured with a flowmeter as it is pumped into the storage tanks at the manufacturing plant. The storage tanks need to be cooled to keep the milk below 4°C and gentle agitation is required to prevent separation of the milk and cream. Thereafter, the milk may be pumped directly from the storage tanks to the preheater.

2.1.2 Inspection and testing

The composition and hygienic quality of the milk are determined by a variety of tests on arrival at the dairy. The most common tests carried out on the milk supplies are taste and smell, temperature, cleaning checks, sediment tests, pH, hygiene tests, somatic cell count, bacteria count, protein content, fat content, and freezing point (Bylund, 2015). Milk that does not fully comply with the requirements of Regulation R 1555 should not be accepted for further processing (DSA, 2022). The milk reception requirements as stated by Regulation R 1555 are summarised in Table 2.1 and Table 2.2.

Table 2.1: Milk reception acceptability (DSA, 2022)

Test	Specification
Inhibitory substances	Negative (reject if positive)
Alizarol (confirm with Resazurin)	As recommended by unprocessed milk specifications – 68% (75% UTH, 72% fresh, 70% all other)
Resazurin	Disk 6, 10 minutes should milk fail Alizarol
Temperature	≤7°C
Titratable acidity (if >0.19 but pass all other tests, accept)	0.15 - 0.18%
pH (if outside specifications, but pass all other tests, accept)	6.70 - 6.80
Organoleptic (smell)	No taints or odours
Freezing point	≤ -0.512°C
Added water	0%
Aflatoxin	M1 <0.5 ppb
TB and Brucellosis certificates	Valid
Butterfat	>3.3%
Lead	<0.02 ppm
Melamine	Absent
Pesticide residues	Absent

Table 2.2: Microbiological specification for unprocessed milk for further processing (DSA, 2022)

Standard	Requirement (cfu/mL)
Total bacterial count (TBC) for tanker milk delivered at the processing facility	<200,000
Coliforms	<20 (MPN)
Escherichia coli	Absent in 1 mL
Pathogens	Absent

2.1.3 Preheater

The milk comes from the storage tank at 4°C and should be heated before being subjected to clarification. In general, the viscosity of liquid decreases as the temperature increases; therefore, the milk is heated to 63-65°C for about 15 seconds (Bylund, 2015). This is a time/temperature combination that does not inactivate the phosphatase enzyme, as high temperatures affect the creaming property of milk.

2.1.4 Deaeration

Due to turbulence experienced during transportation, the gas concentration in unprocessed milk received at a commercial milk factory can vary from 4.92 to 8.50% by volume (Noll *et al.*, 1941; Bylund, 2015). To address this, a deaeration step is often included to expel finely dispersed unwanted gases and malodorous substances. This process removes gases such as oxygen (O_2), nitrogen (N_2) and carbon dioxide (CO_2) from the milk (Mokhtar, 2019). The temperature in the deaerator is adjusted to 8°C below the pre-heating temperature (Tomasula *et al.*, 2013). The pressure drop expels the dissolved gases which are removed from the vessel by the vacuum (Tomasula *et al.*, 2013).

2.1.5 Standardisation

Unprocessed milk as received from the farm contains varying quantities of solids and milk fat. To produce a standard product, the milk is fed to a centrifugal separator where the cream and skimmed milk are separated. Inside the centrifuge, the fat globules or cream move inward towards the axis of rotation because of their lower density (Mokhtar, 2019). The lower-density cream moves inward to the cream outlet while the higher-density skim milk moves outward to the skim milk outlet. The amount of cream produced will vary with the fat content of the incoming milk and the fat content desired in the end product. Any excess cream is separated to storage for incorporation into other dairy products or for retail purposes.

2.1.6 Homogenisation

After the cream and skim milk separation, the appropriate amount of cream is added back to the skim milk. For the production of whole milk, 3.5% fat is added to skim milk while 2% is added for low fat (semi-skimmed), and less than 0.5% to produce skim milk (Bylund, 2015). Homogenisation involves passing the milk through a narrow gap at high velocity to break down fat droplets into small particles thus ensuring uniform fat distribution throughout. This prevents the cream from rising to the top and forming different layers. Homogenisation ensures quality and consistency in appearance, and taste for all products.

2.1.7 Pasteurisation

Raw milk has the potential to carry harmful bacteria, such as *Brucella*, *Campylobacter*, *Cryptosporidium*, *E. coli*, *Listeria*, and *Salmonella*, which can pose serious health risks and lead to diseases such as listeriosis, typhoid fever, tuberculosis, diphtheria, Q fever, and brucellosis (Bunk *et al.*, 2022; DSA, 2022). Pasteurisation destroys pathogens which can often be found in unprocessed milk. Due to the destruction of these bacteria and parasites, the shelf-life of pasteurised milk is increased beyond that of unprocessed milk (Steffen Robertson and Kirsten Inc, 1989). This process involves heating the incoming milk in a plate heat exchanger to approximately 72°C and maintaining the temperature for 15 seconds, or alternatively, heating it to a lower temperature to about 63°C and holding for 30 minutes (Bylund, 2015). Ultra-high temperature (UHT) processed milk is heated to 140°C for one to two seconds. The higher the temperature, the longer the milk's shelf life, thus UHT milk can last months without refrigeration (Steffen Robertson and Kirsten Inc, 1989; DSA, 2022). After passing through the holding cell, the milk is cooled with water to a filling temperature before packaging.

2.1.8 Cooling and packing

Since pasteurised milk still contains several bacteria and enzymes, the further biological reaction leads to milk going off. As with most common biological phenomena, a reduction in temperature results in a reduction in reaction rate and hence a longer shelf life (Steffen Robertson and Kirsten Inc, 1989; Bylund, 2015). After undergoing the process of pasteurisation, the milk is cooled to a temperature suited for filling and packaging. Filling may occur in plastic bottles, insulated cardboard cartons or plastic sachets. Pasteurised milk products are stored and transported at approximately 4°C.

2.1.9 Cleaning-in-place

Due to the biodegradable nature of milk and milk products combined with their tendency to cause fouling of process equipment, regular cleaning of the plant is necessary (Steffen Robertson and Kirsten Inc, 1989; DSA, 2022). This is done without dismantling any equipment using a process known as cleaning in place (CIP). Figure 2.2 shows that all process steps require CIP processes after each processing run.

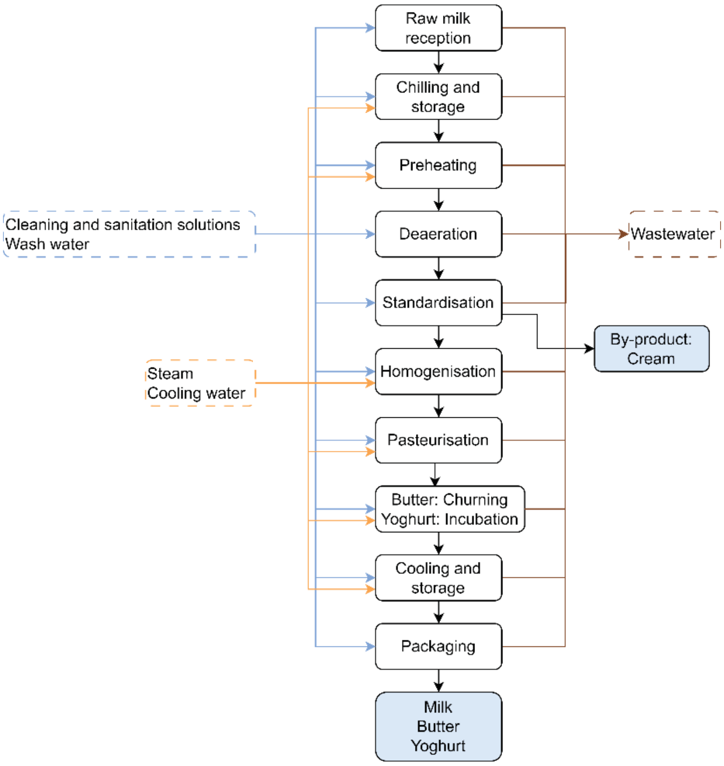


Figure 2.2: High-level process overview of water use in milk, butter, and yoghurt production

Cleaning-in-place is necessary to maintain the standard of hygiene that the food industry must comply with as stated in SANS 10049:2019 (Edition 5). To verify the effectiveness of cleaning and disinfection procedures, SANS 5763:2006 (Edition 2) should be used. Cleaning-in-place systems typically involve five major steps (Bylund, 2015):

1. **Warm water pre-rinse:** Warm water is circulated for approximately 10 minutes to dislodge loosely adhered solids and to remove any residue of raw materials or products (Bylund, 2015). Since water is a dipolar solvent, the use of warm water aids in the effective removal of sugars by dissolution, and emulsifies milk fat residues, detaching them from surfaces (Bylund, 2015).
2. **Alkaline detergent wash:** A hot alkaline detergent solution, typically caustic soda ($NaOH$) at a concentration of 0.5-1.5%, is circulated for about 30 minutes at 75°C to thoroughly clean the equipment

(Bylund, 2015). Cleaning with alkaline detergent should be performed at a temperature equivalent to or greater than the temperature of the product exposure, with a minimum of 70°C (DSA, 2022).

3. **Warm water rinse:** Water at 45°C is circulated for approximately 10 minutes to remove any residual alkaline detergent (Bylund, 2015). This rinse is to purge dissolved solids and remove any residues of the alkali (DSA, 2022).
4. **Acid wash:** A nitric acid solution with a concentration ranging from 0.5% to 1.0% is circulated for about 20 minutes at 70°C (Bylund, 2015). This rinse is to dissolve mineral salts and deposits left by hard water.
5. **Cold post-rinse:** Cold water is circulated for 10 minutes to ensure complete removal of any remaining traces of nitric acid from the system. This rinse is also purging dissolved solids (DSA, 2022).

2.2 YOGHURT PRODUCTION PROCESSES

Every dairy process has standardisation, homogenisation and pasteurisation in some order or another. The production of yoghurt follows the same sequence of processes described in the milk production train. However, after pasteurisation a process of fermentation and chilling takes place.

2.2.1 Incubation and fermentation

The milk is cooled to 40°C and then a starter culture is added. The starter culture consists of healthy bacteria that digest the sugars (lactose) and create lactic acid, which leads to fermentation (Bylund, 2015). This mixture is kept at a precise temperature for the desired period (the incubation period) to allow the growth of the culture organisms (Bylund, 2015). For stirred yoghurts the typical incubation temperature is 42-43°C for 2.5 to 3 hours. The incubation time will vary depending on the starter culture's lag phase (Bylund, 2015).

2.2.2 Chilling

As soon as the optimum pH (typically 4.5) is achieved, the yoghurt is cooled to 15-22°C to stop the growth process of the culture organisms (Bylund, 2015).

2.3 BUTTER PRODUCTION PROCESSES

2.3.1 Raw materials

Butter manufacturers do not use milk as a raw material. The major raw material for butter manufacture is cream which is either obtained from other processes carried out on the same dairy site as shown in Figure 2.1 or from other dairies.

2.3.2 Churning

In the production of butter, the cream is mixed with salt and then passed to a continuous churn. The mechanical action causes the cream to separate into butter and buttermilk (DSA, 2022). The butter is extruded continuously while the buttermilk is drained into a storage vessel. The butter is then packed and stored for distribution while the buttermilk may either be powdered, cooled, and packed for sale or in some instances, discharged as an effluent (Steffen Robertson and Kirsten Inc, 1989; DSA, 2022).

CHAPTER 3: REGULATORY ENVIRONMENT

Several pieces of legislation aimed to protect the environment have been promulgated in South Africa since the 1980s. For instance, the South African legal system was only relevant at national level when the first edition of NATSURV 4 was released, however after the passage of a new constitution in 1996, this situation significantly changed. South Africa's transition to a three-tiered administration has also raised the issue of the by-laws within which these sectors now operate and are required to follow at provincial and local levels of government (Tibane, 2021).

South Africa's three-tier system of government is separated into national, provincial, and local government (Tibane, 2021). The national government has authority over economic regulation, high level security functions, and social development while the provincial government oversees rural livelihoods and human development, housing, regional economic planning, environmental management (SA Government, 1996). The local government tier is responsible for providing essential services and for creating an environment that is supportive of local businesses (SA Government, 1996). These three spheres of government maintain a relationship based on co-operative governance which requires each sphere to recognise the authorities and duties of the others, work together, and coordinate actions and legislation (SA Government, 1996).

Local governance is carried out through municipalities who govern all urban and rural areas (Tibane, 2021). Municipalities are separated into three different types namely local, district, and metropolitan (Tibane, 2021). Metropolitan municipalities manage the largest metropolitan areas and have exclusive municipal executive and legislative authority in those areas (Tibane, 2021). The rest of the country is divided into district municipalities, each of which is made up of several local municipalities. In South Africa, there are 226 local municipalities, 44 district municipalities and 8 metropolitan municipalities (Tibane, 2021).

Integrated Water Resource Management (IWRM) enables resource- and source-directed actions to manage the aquatic environment (NWA, 1998). The source-directed measures try to reduce the impact on the receiving environment by preventing pollution, reusing water, and treating wastewater, while the resource-directed measures intend to manage and protect the environment that receives water. The hierarchy of decision-making originated from the integration of resource- and source-directed interventions (DEA, 2011). This hierarchy aims to reduce the impact of waste generation by prioritising prevention and to shun discharge or disposal as shown in Figure 3.1.

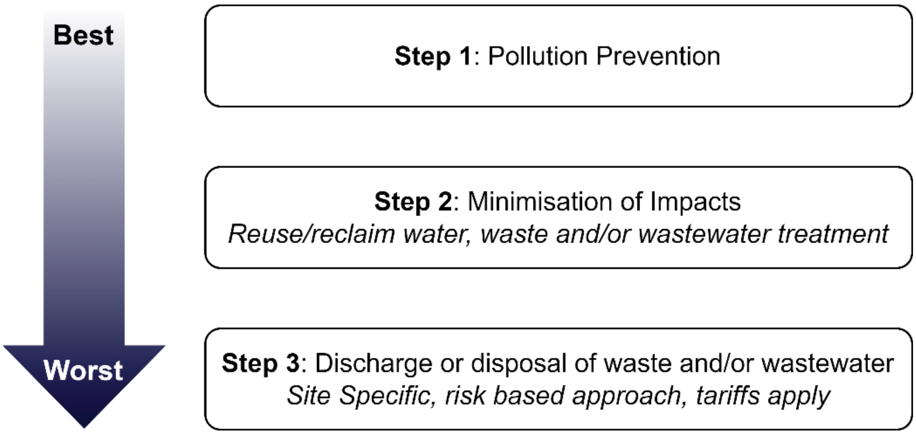


Figure 3.1: Hierarchy of decision making to protect water resources (DEA, 2011)

3.1 NATIONAL LEGISLATION

All elements that have the potential to have an impact on the environment must be managed or addressed by increasingly stringent national legislation. This can only be accomplished by implementing efficient environmental management systems. Legislation is one factor that determines whether an operational environment is enabling or disabling.

3.1.1 Water

The Department of Water and Sanitation (DWS), formerly the Department of Water Affairs (DWA) and the Department of Water Affairs and Forestry (DWAF), is the regulator of South Africa's water and sanitation sector. The Water Services Act (WSA), the National Water Act (NWA), and South Africa's water resources are all managed by the DWS.

The concept of sustainability is inscribed in the Bill of Rights in the Constitution of the Republic of South Africa (Act 108 of 1996), in particular section 25 which grants all South Africans the right to an environment, water, access to information, and just administrative action (NWA, 1998). The NWA (Act 36 of 1998) focus on establishing these rights and ensuring sustainability (NWA, 1998). The NWA offers the legal framework necessary for the efficient and sustainable management of water resources within South Africa (NWA, 1998). While the WSA (Act 108 of 1997) focus on providing access to water. The WSA primarily deals with water services, such as potable (drinkable) water and sanitation services, which municipalities provide to homes and other municipal water users (WSA, 1997). It outlines guidelines for how municipalities should deliver sanitary and water supply services (WSA, 1997). The different municipal areas establish their own by-laws that specify the water supply and wastewater discharge regulations and tariffs for that area.

3.1.2 Wastewater

The NWA has established regulations and standards for the treatment of wastewater or effluent before discharge (NWA, 1998). It consists of specific standards and establish upper and lower bounds for variables such as pH, suspended solids, temperature, metals, chemical oxygen demand (COD), etc. The NWA standards also stipulate the tests that may be used to establish these levels (NWA, 1998). These restrictions apply to all businesses, municipalities, and private wastewater treatment facilities that discharge to rivers or the ocean. The entity in charge of managing the wastewater treatment facility must also impose restrictions on the industries that discharge to the facility to ensure that the DWS achieve the acceptable final discharge limits (NWA, 1998).

3.1.3 Environmental

According to the South African constitution, everyone has the right to an environment that is not harmful to their health or well-being (SA Government, 1996). This includes the right to protect the environment for the benefit of current and future generations through reasonable legislative and other measures to stop pollution and ecological degradation, promote conservation, and ensure the development and use of natural resources in a way that is ecologically sustainable (SA Government, 1996). These rights must be balanced with the advancement of justifiable economic and social development. The Department of Forestry, Fisheries, and the Environment (DFFE), formerly the Department of Environmental Affairs (DEA), oversees regulations that address these rights.

The regulations that are most applicable to the dairy industry are the National Environmental Management Act, 1998 (Act 107 of 1998), in particular the National Environmental Management: Waste Act (Act 59 of 2008) which provide guidelines for the processing and storage of waste on-site, licensing requirements, the formation of waste management plans, and the National Environmental Management: Air Quality Act (Act no. 39 of 2004) which outlines the setting of limits for air emissions, and sludge disposal (1998 as amended in 2000) by the DWAF which provide guidelines for sludge disposal (Herselman *et al.*, 2009), and the setting of penalties for offences (NEMA, 1998).

The release of land-derived effluent into the coastal environment via pipelines was previously governed by the National Water Act of 1998. The responsibility was transferred to the DEA in 2008 by the passage of the Integrated Coastal Management Act (ICMA). The ICMA restricts effluent discharges into coastal waters from any source on land by requiring such discharges to be authorised by a permit (ICMA, 2008). These rights aim to achieve usable coastal water quality and a healthy aquatic system that can be sustained and balanced with the advancement of justifiable economic and social development (ICMA, 2008).

Water quality management decision-making concentrates on waste prevention, waste minimisation, and waste disposal. The General Permits do not cover wastewater discharge to marine outfalls, groundwater resources, or water resources with closed drainage systems. Water quality and quantity must be measured, metered, monitored, and documented; relevant precautionary practices must be implemented to protect human and environmental health (ICMA, 2008). Additionally, consumers must register their water consumption.

Sensitive river systems and catchments are subject to special restrictions, or discharge constraints. Industries must monitor compounds that are introduced to or concentrated by industrial processes, in addition to general restrictions (ICMA, 2008). All analyses must be performed on grab samples taken at the site of discharge and processed in laboratories accredited by South African National Accreditation System (SANAS). The pH, electrical conductivity, and faecal coliforms are the minimum parameters that must be measured for discharge volumes ranging from 10 to 100 kL/day. Concentrations of COD, ammonia, and suspended solids must also be measured for discharge volumes ranging from 100 to 1,000 kL/day. While discharge volumes of 1,000 to 2,000 kL/day require additional measurements of nitrate/nitrite, free chlorine, and ortho-phosphate.

In general, international regulations are considered when national acts are enacted, thus the ICMA generally corresponds with legislation in other countries. In the United States, industry must also obtain a valid permit before discharge directly to the environment (DEA, 2014). Primary treatment is required as a minimum rule for offshore coastal outfalls in the United States, Australia, and the European Community, but only for service populations of 50,000 to 150,000 (DEA, 2014). For larger service populations these countries require at least secondary treatment, which in many cases includes disinfection (DEA, 2014). Both the United States and Australia have implemented a charge system similar to the Waste Disposal Charge System being developed by the DWS as an incentive to reduce waste loads in municipal effluent (DEA, 2014).

3.2 MUNICIPAL BY-LAWS, AND WATER AND EFFLUENT TARIFFS

The WSA oversees the legal framework for the organisations in charge of water services (WSA, 1997). The act provides the opportunity to establish different water service institutions such as the water services authority (i.e. the responsible Municipality), and the water services provider whose responsibility is to physically provide consumers with water supply and sanitation services.

Municipal regulations and by-laws determine how water and sanitation services are provided, how water services develop, and how sewage is disposed of. These services have municipally regulated rates, which are typically updated annually. All industries that want to discharge to a wastewater treatment facility must apply for a trade effluent permit to the local Municipality. If the trade effluent contains substances with concentrations that exceeds the declared limits, the Municipality may reject it. The stated limits vary from Municipality to Municipality since wastewater treatment facilities have different capacities and coastal municipalities have discharge to sea outfalls.

According to some by-laws, municipalities may take random or planned samples of effluent to verify compliance with municipal effluent permits (WSSA, 2023). The requirements for obtaining permits may include upfront assessments of potential ways to reduce water consumption and wastewater generation at source and schedule of discharge days and/or times, however this may vary depending on local by-laws. Punitive fines for exceeding set limitations may be added to wastewater discharge cost. However, rather than enacting punitive measures, many governments aim to collaborate with business to achieve acceptable water usage and wastewater discharge quality.

The South African local by-laws were developed with international regulations in mind and are in line with those of other countries. Germany, like South Africa, has varying conditions for wastewater discharge into receivers based on local administrative regulations (Preisner *et al.*, 2020). Germany has the authority to establish regional effluent standards that may be more stringent than European standards and consider the unique characteristics of the receivers (Preisner *et al.*, 2020).

The formulae used by each Municipality to determine tariffs, discharge restrictions, and punitive fines vary considerably. The majority of the dairy processing facilities are situated in Gauteng and the Western Cape as shown in Chapter 1, therefore an example of the tariffs, policies and by-laws on water and sanitation services are presented for the City of Cape Town Municipality and City of Tshwane Municipality. The survey received participation from KwaZulu-Natal and the Eastern Cape as well, therefore two additional examples are given for eThekwini Metropolitan Municipality and Buffalo City Municipality.

3.2.1 City of Cape Town Metropolitan Municipality

The City of Cape Town Industrial Wastewater and Effluent By-law of 2006, which was revised in 2014, established the discharge of industrial effluent (City of Cape Town, 2022). The Municipality determines the quantity of industrial wastewater discharged after subtracting “fair” quantities for atmospheric losses, water used for agriculture, and water present in product. Equations 1 and 2 are used to determine the fee for industrial wastewater discharge to a sewer (City of Cape Town, 2022).

$$Vw(SVC) + \frac{VieT(COD - 1000)}{1500} + VieT(SF) \qquad [1]$$

Where:
V_w = Total volume of water discharged
SVC = Sewage volumetric charge
$V_{ie}T$ = Total industrial effluent discharged
SF = Surcharge factor calculated according to equation 2

$$SF = Y(X - L)/Ls \qquad [2]$$

Where:
Y = is the appropriate factor applicable to such parameters as stipulated in the miscellaneous tariffs
X = concentration of one or more parameters from schedule
L = limit applicable to parameter
Ls = DWA licence standard for a particular parameter

The City of Cape Town Municipality has set limits for effluent discharge with respect to general pollution loads, chemical substances, heavy metals, and inorganic content as shown in Table 3.1. A surcharge factor is applied if these limits are not met (City of Cape Town, 2022).

Table 3.1: Maximum limits of permitted effluent discharge

General quality limits	Units	
Temperature (°C)	°C	> 0°C; < 40°C
Electrical Conductivity at 25°C	mS/m	500
pH at 25°C	pH units	5.5 < pH < 12
COD	mg/L	5,000
Chemical substances – maximum concentrations		
Settleable solids (60 minutes)	mL/L	50
Suspended solids	mg/L	1,000
Total dissolved solids at 105°C	mg/L	4,000
Chloride (as Cl^-)	mg/L	1,500
Total sulphates (as $SO_2{}^{-4}$)	mg/L	1,500
Total phosphates (as P)	mg/L	25
Total cyanides (as CN^-)	mg/L	20
Total sulphides (as S^{2-})	mg/L	50
Phenols index	mg/L	50
Total sugar and starch (as glucose)	mg/L	1,500
Oils, greases, waxes, and fat	mg/L	400
Sodium (as Na)	mg/L	1,000
Metals and inorganic content – maximum concentrations for Group 1		
Total iron (as Fe)	mg/L	50
Total chromium (as Cr)	mg/L	10
Total copper (as Cu)	mg/L	20
Total zinc (as Zn)	mg/L	30
Total collective concentration of metals in Group 1 shall not exceed 50 mg/L		
Metals and inorganic content – maximum concentrations for Group 2		
Arsenic (As)	mg/L	5
Boron (B)	mg/L	5
Lead (Pb)	mg/L	5
Selenium (Se)	mg/L	5
Mercury (Hg)	mg/L	5
Titanium (Ti)	mg/L	5
Cadmium (Cd)	mg/L	5
Nickel (Ni)	mg/L	5
Total collective concentration of metals in Group 2 shall not exceed 20 mg/L		

3.2.2 eThekwini Metropolitan Municipality

The eThekwini Municipal Council and Water Services Act outlined policies and procedures regarding trade effluent in the Sewage Disposal By-law (eThekwini, 2016). To discharge to a wastewater treatment facility the company is required to pay the charge for the use of sewage disposal system (eThekwini, 2016). If a company wants to discharge to a wastewater treatment facility, they must apply for a trade effluent permit. If the volume exceeds the minimum volume of 'T' kilolitres per month, the permit holder will be liable for a minimum charge per kilolitre of trade effluent (eThekwini, 2016). If the permit holder discharge trade effluent with a strength or quality greater than standard domestic effluent, the permit holder will be liable for additional charges in respect of high strength sewage calculated with Equation 3 (Ramukhwatho *et al.*, 2016).

$$Volume\ based\ charge + V\left(\frac{COD}{360} - 1\right) + Z(\frac{SS}{9} - 1) \quad [3]$$

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 <9 ml/L)

The trade effluent will be rejected if it does not comply with the limits set out in Table 3.2. The quality limits are divided into effluent discharge going to sewage works with more than 25 ML/day capacity and less than 25 ML/day capacity (eThekwini, 2016).

Table 3.2: Quality limits for trade effluent for discharge into sewage disposal system (eThekwini, 2016)

General quality limits	Units	Large works >25 ML/d	Small works <25 ML/d
Temperature (°C)	°C	< 44°C	< 44°C
pH	pH units	6 < pH < 10	6,5 < pH < 10
Oils, greases, waxes of mineral origin	mg/L	50	50
Vegetable oils, greases, waxes	mg/L	250	250
Total sugar and starch (as glucose)	mg/L	1,000	500
Sulphates in solution (as S02-4)	mg/L	250	250
Sulphides, hydrosulphides, and polysulphides (as S2-)	mg/L	1	1
Chlorides (as Cl-)	mg/L	1,000	500
Fluoride (as F-)	mg/L	5	5
Phenols (as phenol)	mg/L	10	5
Cyanides (as CN-)	mg/L	20	10
Settleable solids	mg/L	Charge	Charge
Suspended solids	mg/L	2,000	1,000
Electrical conductivity	mS/m	400	400
Anionic surfactants	mg/L	-	500
COD	mg/L	Charge	Charge
Metal limits			
Copper (as Cu)	mg/L	50	5
Nickel (Ni)	mg/L	50	5
Zinc (Zn)	mg/L	50	5
Iron (Fe)	mg/L	50	5
Boron (B)	mg/L	50	5
Selenium (Se)	mg/L	50	5
Manganese (Mn)	mg/L	50	5
Lead (Pb)	mg/L	20	5
Cadmium (Cd)	mg/L	20	5
Mercury (Hg)	mg/L	1	1
Total chrome (Cr)	mg/L	20	5
Arsenic (As)	mg/L	20	5
Titanium (Ti)	mg/L	20	5
Cobalt (Co)	mg/L	20	5
Colour as measured by American Dye Manufacturer™ Index	ADMI	450	450
Benzene, toluene, ethyl benzene and xylene	mg/L	4	4

3.2.3 City of Tshwane Metropolitan Municipality

The City of Tshwane Sanitation and Water Tariff Policies outline the water and sanitation charges approach. There are three different categories for industrial effluent charge (City of Tshwane, 2022):

3.2.3.1 Normal Conveyance and Treatment Costs

This cost covers wastewater of quality equal to domestic wastewater discharge (City of Tshwane, 2022). The cost is calculated by multiplying volume of wastewater discharged into the sewer system by the unit transportation and treatment cost. All wastewater discharged into the system will be paid for by the industrial consumer at the tariff cost with a rebate of 10%.

3.2.3.2 Extraordinary Treatment Costs

This cost covers wastewater that have a pollution loading that exceeds the pollution loading of normal wastewater. The extraordinary treatment cost is calculated using Equation 4:

$$Tc = Q_c . t\, [0.6 \frac{(COD_c - COD_d)}{COD_d} + 0.25 \frac{(P_c - P_d)}{P_d} + 0.15 \frac{(N_c - N_d)}{N_d}] \quad [4]$$

Where:
T_c = extraordinary cost to the consumer,
Q_c = wastewater volume (kL),
t = unit treatment cost of wastewater (94c/kL in 2022),
COD_c = total measured COD (mg/L),
COD_d = COD of domestic wastewater (700 mg/L),
P_c = measured orthophosphate (mg/L),
P_d = orthophosphate concentration of domestic wastewater (8 mg/L),
N_c = measured ammonia concentration (mg/L),
N_d = ammonia concentration of domestic wastewater (31 mg/L)

3.2.3.3 Non-Compliance with By-laws' Limits

Where the pollution loading of wastewater exceeds the limits of allowable load as defined by the Sanitation By-law, the formula given in Equation 5 will be applicable:

$$T_c = \frac{Q}{D} \times N[\, C_{AP} - \frac{B_{LL}}{W_{PL}}] t_{NC} \quad [5]$$

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} = the concentration of parameters exceeding by-law,
B_{LL}= by-law limit,
W_{PL}= Water Affairs standard limitation on parameter exceeding by-law,
t_{NC} = tariff (R1.01/kL in 2022)

3.2.4 Buffalo City Metropolitan Municipality

The Buffalo City Metropolitan Municipality has annual sewerage tariffs for industrial and commercial users that are based on a pan charge per pan (R4,479 VAT included, 2022), plus an area charge based on the area of the land in square metres (Buffalo City, 2022). The area charge is calculated by the square root of the area of land in square metres times a rate of R498 (VAT inclusive) in 2022.

Where the quality of wastewater discharged into the sewerage system exceeds the allowable pollution loading of ordinary domestic wastewater, the user will be charged additional treatment costs (Buffalo City, 2022). This additional charge shall be billed monthly and is calculated by using Equation 6 as stipulated in the Sanitation by-law.

$$K1 + K2A + K3B + K4C + K5D \quad [6]$$

Where:

K1 = R949.58 (Buffalo City, 2022)
K2 = R24.07 (Buffalo City, 2022)
K3 = R24.07 (Buffalo City, 2022)
K4 = R18.75 (Buffalo City, 2022)
K5 = R18.75 (Buffalo City, 2022)
A = Volume in millilitres of settleable matter in one litre of trade effluent up to a volume of 10 ml
B = Volume in millilitres of settleable matter in one litre of trade effluent more than 10 ml
C = Permanganate Value (settled trade effluent) more than 30mg/l up to 1000 mg/l
D = Permanganate Value (settled trade effluent) more than 1000 mg/l

The terms K2A and K3B only applies if the service includes settlement of any form of sludge treatment, while the terms K4C and K5D applies if the service includes treatment of the aqueous phase.

3.3 INDUSTRY STANDARDS AND SPECIFICATIONS

The dairy industry is subject to a range of standards and specifications that play a crucial role in driving improvements in water usage within the sector. These standards cover various aspects of dairy production and safety. Some prominent standards commonly applied in the dairy industry include SANS 10330:2020 (Edition 3.00) for Hazard Analysis and Critical Control Point System (HACCP) requirements, SANS 1828:2017 (Edition 2.10) for cleaning chemicals in the food industry, ISO 22000 for food safety management systems, and SANS 289:2022 (Edition 2.00) for product labelling and legal metrology control (Burger, 2023). Of particular relevance to this report, ISO 14001 for environmental management and SANS 241-1:2015 are briefly elaborated on in Section 7.1.4 and Section 3.3.1, respectively. For further exploration of these standards, the Dairy Standard Agency (DSA) provides a valuable resource summarizing the standards related to food safety and quality in milk and dairy product production (Burger, 2023).

3.3.1 Potable water standards

The specific guidelines for the quality of acceptable drinking water are defined by South African National Standard (SANS) 241-1: 2015 and is classified into microbiological, physical, aesthetic (Table 3.3), and chemical determinants (Table 3.4). The water used for cleaning contact surfaces within dairy production must comply with the requirements of SANS 241-1:2015 (DSA, 2022). The water quality should be monitored regularly at the point of use to ensure that it does not pose a contamination risk (DSA, 2022). This applies to any source of water including municipal water.

Table 3.3: General microbial limits for potable water (SABS Standards Division, 2015)

Microbial determinands	Unit	Risk	Limits
E. coli or faecal coliforms	Count/100 mL	Acute health	Not detected
Cryptosporidium species	Count/10 L	Acute health	Not detected
Giardia species	Count/10 L	Acute health	Not detected
Total coliforms	Count/100 mL	Operational	≤10
Heterotrophic plate count	Count/1 mL	Operational	≤1,000
Somatic coliphages	Count/10 mL	Operational	Not detected

Table 3.4: General physical and aesthetic, and chemical limits for potable water (SABS Standards Division, 2015)

Physical and aesthetic determinands	Unit	Risk	Limits
Colour	mg/L Pt-Co	Aesthetic	≤15
Conductivity at 25°C	mS/m	Aesthetic	≤170
Total dissolved solids	mg/l	Aesthetic	≤1,200
Turbidity	NTU	Operational	≤1
	NTU	Aesthetic	≤5
pH at 25°C	pH units	Operational	≥5 to ≤9.7
Chemical determinands – macro-determinands			
Free chlorine	mg/L	Chronic health	≤5
Monochloramine	mg/L	Chronic health	≤3
Nitrate as N	mg/L	Acute health	≤11
Nitrite as N	mg/L	Acute health	≤0.9
Sulphate as SO_4	mg/L	Acute health	≤500
	mg/L	Aesthetic	≤250
Fluoride	mg/L	Chronic health	≤1.5
Ammonia as N	mg/L	Aesthetic	≤1.5
Chloride	mg/L	Aesthetic	≤300
Sodium as Na	mg/L	Aesthetic	≤200
Zinc as Zn	mg/L	Aesthetic	≤5
Chemical determinands – micro-determinands			
Antimony as Sb	µg/L	Chronic health	≤20
Arsenic as As	µg/L	Chronic health	≤10
Barium as Ba	µg/L	Chronic health	≤700
Boron as B	µg/L	Chronic health	≤2400
Cadmium as Cd	µg/L	Chronic health	≤3
Chromium as Cr	µg/L	Chronic health	≤50
Copper as Cu	µg/L	Chronic health	≤2000
Cyanide	µg/L	Acute health	≤200
Iron as Fe	µg/L	Chronic health	≤2000
	µg/L	Aesthetic	≤300
Lead as Pb	µg/L	Chronic health	≤10
Manganese as Mn	µg/L	Chronic health	≤400
	µg/L	Aesthetic	≤100
Mercury as Hg	µg/L	Chronic health	≤6
Nickel as Ni	µg/L	Chronic health	≤70
Selenium as Se	µg/L	Chronic health	≤40
Uranium as U	µg/L	Chronic health	≤30
Aluminium as Al	µg/L	Operational	≤300
Chemical determinands – organic determinands			
Total organic carbon as C	mg/L	Chronic health	≤10
Chloroform	µg/L	Chronic health	≤300
Bromoform	µg/L	Chronic health	≤100
Dibromochloromethane	µg/L	Chronic health	≤100
Bromodichloromethane	µg/L	Chronic health	≤60
Combined trihalomethane	µg/L	Chronic health	≤1
Total microcystin	µg/L	Chronic health	≤1
Phenols	µg/L	Aesthetic	≤10

CHAPTER 4: WATER USE AND WATER MANAGEMENT

4.1 OVERVIEW OF PARTICIPATING DAIRY PROCESSORS IN SOUTH AFRICA

There are more than 130 dairy processors in South Africa. Out of the 31 dairy processors invited to contribute to NATSURV 4, 13 expressed willingness to participate; ultimately, 10 dairy representatives returned completed questionnaires. Given that only 7.7% of South African dairy processors participated in this study, this survey is based on a small sample size and does not necessarily provide a complete representation of the national industry. Information on water and wastewater management practices was collated from the online survey results and site visits. A profile of the companies surveyed is provided in Table 4.1.

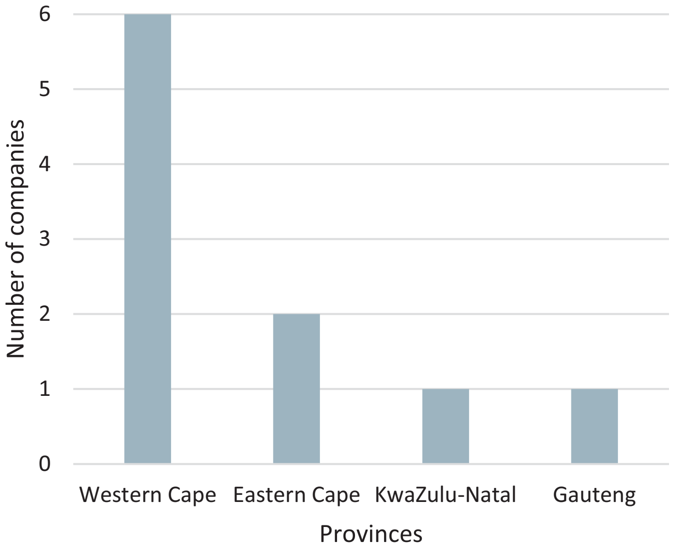
When dealing with responses from mixed dairy facilities, where various products were involved, more than one dataset was collected as each product received a separate response. As a result, although ten dairy facilities participated, 19 sets of data were collected. Therefore, the number of respondents and the presented data may not always corelate.

Table 4.1: Profile of companies participating in the survey

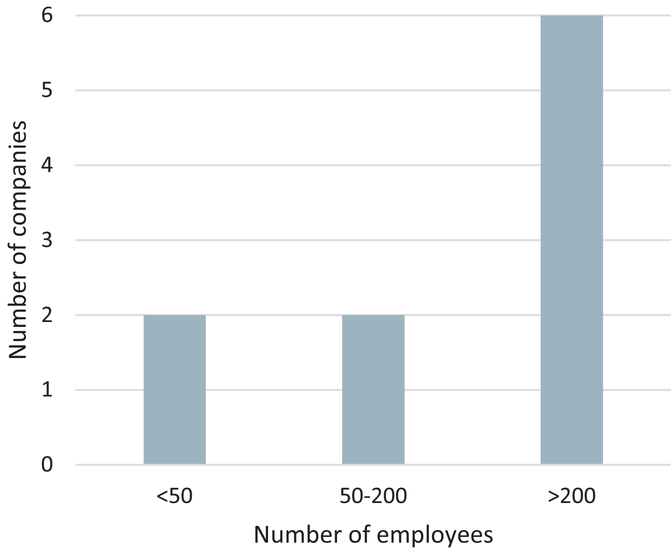
	Company reference	X = Questionnaire Y = Site visit/ Interview	Region	Size	Production (kL/year)	Products' production % of total production
Milk	1	x	WC	50-200	8,000 - 9,000	30 - 40%
	2	x	EC	>200	70,000 - 80,000	10 - 20%
	3	x, y	WC	>200	-	50 - 60%
	4	x	KZN	>200	45,000 - 50,000	30 - 40%
	5	x	WC	>200	15,000 - 20,000	50 - 60%
UHT Milk	6	x	EC	>200	140,000 - 150,000	70 - 80%
	7	x	EC	>200	130,000 - 140,000	20 - 30%
	8	x	WC	>200	60,000 - 80,000	90 - 100%
Yoghurt	9	x	EC	>200	100,000 - 110,000	20 - 30%
	10	x	WC	>200	-	10 - 20%
	11	x	KZN	>200	45,000 - 50,000	50 - 60%
	12	x	WC	>200	15,000 - 20,000	80 - 90%
	13	x	GP	>200	35,000 - 40,000	90 - 100%
Butter	14	x	EC	>200	40,000 - 50,000	20 - 30%
	15	x	EC	>200	3,000 - 4,000	<10%
	16	x	KZN	>200	45,000 - 50,000	<10%
Cheese	17	x, y	WC	<50	600 - 700	40 - 50%
	18	x, y	WC	<50	700 - 800	90 - 100%
	19	x	WC	50-200	-	90 - 100%

The larger the population to be studied, the more difficult representative sampling becomes; however, this survey was able to obtain representatives from three different provinces, from at least two processors of each product category, and from a combination of small, medium, and large facilities. Figure 4.1 gives an overview of the participating dairy processors. Approximately 60% of the companies that participated in the survey were situated in the Western Cape. Production volumes of the participating companies varied from <2,000 kL/year for a small plant, to approximately 140,000 kL/year for a large dairy company.

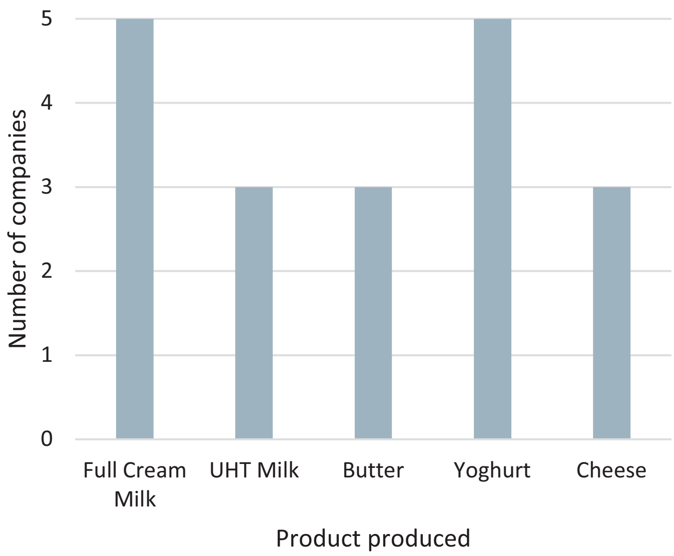
As this project was limited to plain milk, butter, and plain yoghurt, a detailed discussion of each dairy product category and subcategory would be beyond the scope of this document. It is important to note that the survey results presented in this section do not cover the entire industry and all its potential products. Instead, it serves as a tool to present available data that can aid in understanding your own resource utilisation and facilitate the application of water management strategies. This report therefore only serves to provide insight to the resource utilisation, thereby encouraging users to leverage the presented data to improve water management practices. The categories covered in this document should be taken as general guidelines; however, it should not be misinterpreted as a reflection of the entire industry. Due to the small sample size, statistical conclusions cannot be reliably drawn. Therefore, when commenting on trends, it is important to recognize that they are only indicative of participating dairies and do not necessarily represent all dairies in South Africa.



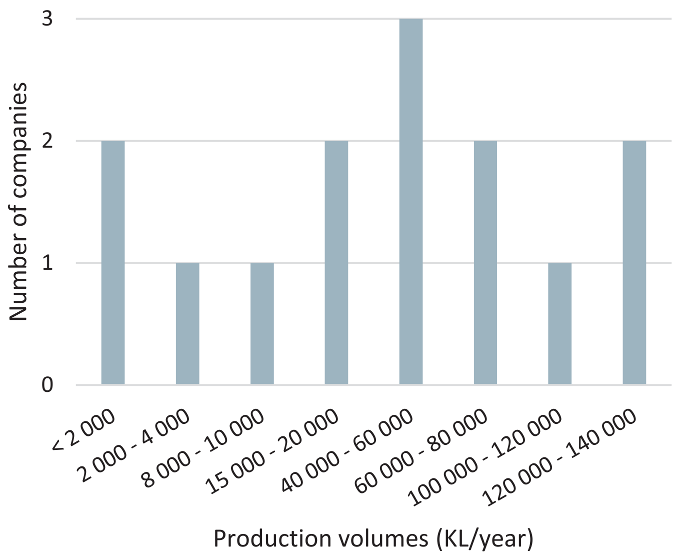
(a) Location of participating companies



(b) Size of participating companies



(c) Categorisation of participating companies



(d) Profile of company production volumes

Figure 4.1: Profile of participating companies (a) location; (b) size; (c) sector; (d) annual production volume

4.2 WATER USE

To assess the water consumption status within the dairy sector, participants were asked to provide information on the source of water, production volumes, water quality and average water use per unit production. The accumulated data was subsequently and analysed and compared to current international benchmarks.

4.2.1 Source of water

Water used in the participating dairies is obtained from diverse sources namely: dams, rivers, boreholes, municipality tap supplies, and freshwater springs. Figure 4.2 shows that dairies that participated in this survey generally source water directly from the municipality. The cost of municipal water for respondents that use a water service provider ranged from R21.78/kL to R52.72/kL in 2022/23. Water prices remain relatively low in comparison to Europe, the USA, and Australia, which could contribute to the slower improvement in water efficiency within South African industries, especially when contrasted with progress in other environmental metrics (Statista, 2021). However, the country faced severe droughts from 2015 to 2017 and the water consumer price inflation rate consequently increased by 213% since the start of 2010 (BusinessTech, 2020). As a result, 60% of respondents use alternatives to tap water to lower the demand for municipal supply. One dairy used 60% municipal water and 40% borehole water. Three participants implemented rainwater harvesting to reduce freshwater usage. This water is captured and used to offset water used for non-product purposes such as irrigation, floor cleaning, and toilet flushing. Due to the heightened risk of contamination when using alternative water sources such as rainwater, they require a higher level of pre-treatment to meet water quality standards for application on product contact surfaces.

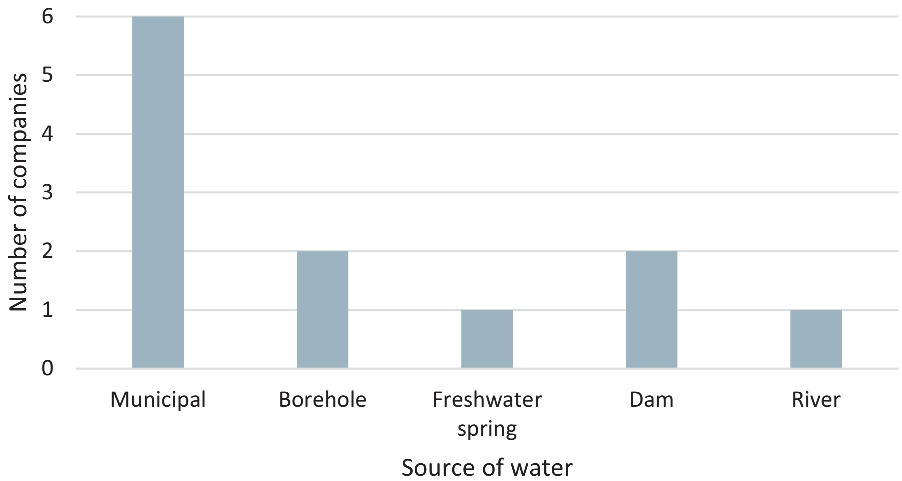


Figure 4.2: Water sources used by participating dairy processors.

4.2.2 Water pre-treatment

Water is not the main raw material for most dairy processing operations; however, it is used in the cleaning of all operational equipment and therefore comes into secondary contact with the product. The quality of the cleaning water used is paramount to maintaining hygiene standards that comply with the food industry stipulated by SANS 241-1:2015. Most dairy companies have their own water quality standards which meet or exceed SANS 241-1:2015 and treat the incoming water using a variety of processes. A summary of the water pre-treatment processes used by the participating dairy process is presented in Figure 4.3.

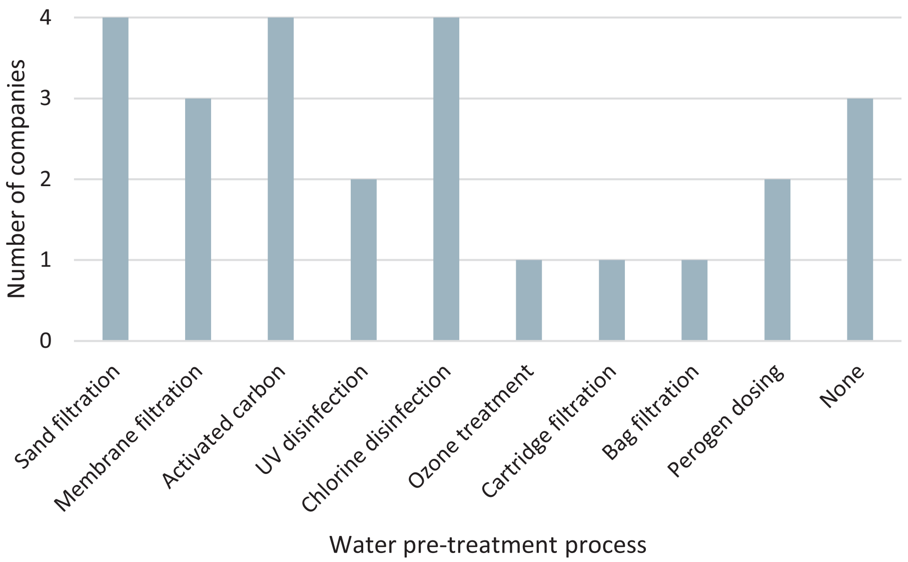


Figure 4.3: Summary of water treatment processes used by participating dairy processors.

Chlorine disinfection, sand filtration and activated carbon are commonly used water pre-treatment processes among the dairy participants. Disinfection is one of the critical steps in water treatment as it inactivates or kills pathogens including bacteria, viruses, parasites, and fungi. The most common disinfection method is chlorine or Perogen® dosing; however, there has recently been a shift towards ultraviolet light and ozone disinfection (Hydrotech, 2018). Ultraviolet light and ozone are growing in popularity as they are considered to be safe and environmentally friendly alternatives to chemical disinfectants. However, chlorine is still the most cost-effective disinfection method, and hence the most used among participating dairy processors.

Some of the participating dairy processors who source from boreholes, dams, rivers, and freshwater spring use a variety of filtration methods to improve the water quality to meet SANS 241-1:2015 regulations. The different pre-treatment strategies used among the dairy participants based on the source of the water available is presented in Table 4.2. The applied pre-treatment processes are dependent on the quality of the water sources available. Groundwater from boreholes, for example, requires less pre-treatment than surface water from rivers and dams that contain more sediment, microbial contamination, and chemicals.

Table 4.2: Summary of water sources and pre-treatment processes used by participating dairy processors

Water source	Water pre-treatment
River	Sand filtration Chlorine disinfection Ozone treatment
Municipal Water recycling	Sand filtration Membrane filtration Activated carbon Chlorine disinfection Cartridge filtration Bag filtration
Municipal	Membrane filtration Activated carbon Perogen®* dosing
Borehole Rainwater	Chlorine disinfection
Dam	Sand filtration Activated carbon Chlorine disinfection Perogen®* dosing
Borehole Freshwater spring	UV disinfection
Municipal Borehole	Sand filtration Membrane filtration Activated carbon UV disinfection
Municipal	None
Municipal	None
Municipal	None

*Perogen® is a blend of Peracetic Acid, Hydrogen Peroxide, Acetic Acid, and surfactant in a stabilised aqueous solution (Narouva, 2018). It is a disinfectant cleaner and deodoriser and is highly effective against a range of pathogenic microorganisms including bacteria, antibiotic resistant bacteria, viruses, fungi, mould, and mildew.

4.2.3 Water used per process unit

Water is used for processing and cleaning, utilities such as cooling water and steam production, and for auxiliary uses such as amenities and gardens. The distribution of the average water used in Figure 4.4 shows that for the majority of the participating dairies, CIP and floor washing are the main water users, accounting for approximately 54% of the total water consumption. In certain cases, product transfer used a significant proportion of the water consumed on the plant following CIP. Additionally, even within the group of participating dairies, there were variations in the reported percentages for CIP, ranging from 5% to 85%.

Considering the reported averages, the water usage distribution is similar to that of a mixed dairy facility situated in another middle-income country, India, as illustrated in Figure 4.5 (Tiwari *et al.*, 2016). It is important to note that this comparison is based on findings from a single company in India and is intended to underscore the parallels in water usage distribution. Cleaning-in-place and floor washing remain the most water-intensive steps, emphasizing that these are areas where there are opportunities for water conservation.

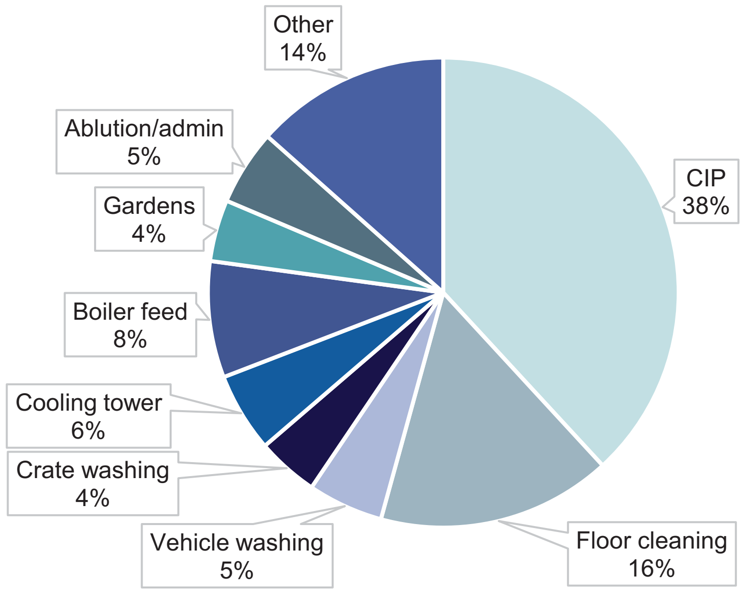


Figure 4.4: Breakdown of the average water usage for all the South African participating dairies

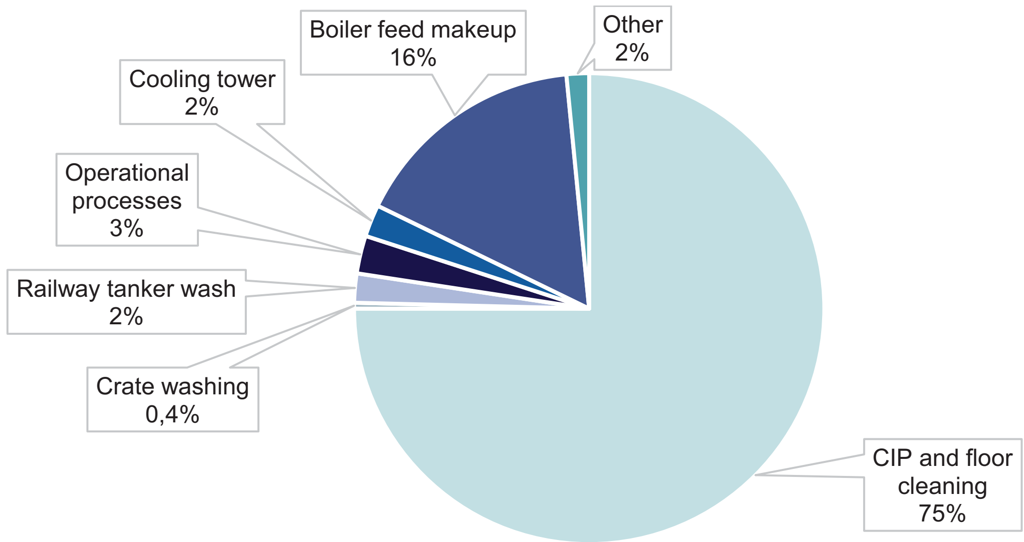


Figure 4.5: Breakdown of average water usage at international dairies (Tiwari *et al.*, 2016)

4.2.4 Specific water intake

Many dairy processors evaluate the overall water consumption by monitoring the specific water intake (SWI) which is the volume of external water used to produce one litre of milk or other dairy products. The SWI can be calculated using Equation 7:

$$SWI = \frac{Total\ volume\ water\ consumption\ (litres)}{Total\ volume\ product\ produced\ (litres)} \qquad [7]$$

To accurately account for the volume of water used, it is essential for sub-metering to be installed in the main water-using areas. The participating companies were asked to supply the percentage of water used per process step and to indicate whether the water usage is metered or estimated. Only two participating companies monitored every process step's water intake with meters. As such, SWIs reported in Table 4.3 only reflect estimated ranges for each product in liquid and concentrated product categories.

Sterilised or UHT milk had the lowest reported SWI, which was also significantly lower than the SWI stated in the first edition NATSURV 4 published in 1989. This could be attributed to technology breakthroughs and process optimisation. The SWI values for yoghurt and cheese were also much lower than the 1989 values. In the case of milk and butter, some companies improved their SWI ratio to below the reported values in 1989, while others are now generating a higher SWI. Nevertheless, the range of SWI ratios reported in Table 4.3 suggest that dairy processing plants have the potential to significantly reduce water consumption.

Table 4.3: Specific water intake of participating dairies

Product	Company reference	Production (kL/year)	Region	Size	Specific water intake* (current survey)	Specific water intake* (1989)
Milk	1	8,000 - 9,000	WC	50-200	1 - 1.5	1.6
	2	70,000 - 80,000	EC	>200	2 - 2.5	
	3	-	WC	>200	1 - 1.5	
	4	45,000 - 50,000	KZN	>200	3 - 3.5	
	5	15,000 - 20,000	WC	>200	1.5 - 2	
UHT Milk	6	140,000 - 150,000	EC	>200	1 - 1.5	3.7
	7	130,000 - 140,000	EC	>200	1.5 - 2	
	8	60,000 - 80,000	WC	>200	1.5 - 2	
Yoghurt	9	100,000 - 110,000	EC	>200	2 - 2.5	10.2
	10	-	WC	>200	1 - 1.5	
	11	45,000 - 50,000	KZN	>200	3 - 3.5	
	12	15,000 - 20,000	WC	>200	3 - 3.5	
	13	35,000 - 40,000	GP	>200	3.5 - 4	
Butter	14	40,000 - 50,000	EC	>200	1 - 1.5	1.5
	15	3,000 - 4,000	EC	>200	4.5 - 5	
	16	45,000 - 50,000	KZN	>200	3 - 3.5	
Cheese	17	600 - 700	WC	<50	2 - 2.5	23
	18	700 - 800	WC	<50	3 - 3.5	
	19	-	WC	50-200	-	

***L water/L product for liquid products (milk, UHT milk, yoghurt) and L water/kg product for concentrated products (butter, cheese)**

Table 4.3 illustrates the variability of SWI within product categories and highlights the instances where the SWI for certain products is either higher or lower than the ratios recorded in 1989. This fluctuation cannot be attributed to a single factor because the SWI can be influenced by a variety of factors including the type and variety of products manufactured, the scale of the plant, age and type of processing equipment, interruptions caused by load-shedding, business location, high and low production months, legislation, operator practice, as well as other social, economic, and environmental factors that encourage lower usage rates. In the sections that follow, some of the factors that influence water consumption in processing plants are discussed in detail.

4.2.4.1 Type and variety of products manufactured

Operating a mixed dairy that frequently switches between various production systems introduces a higher level of complexity to calculating water usage per product, making it challenging to distinguish water consumption for individual products. The intricacies of multi-product production, compared to single-product processes, contribute to increased water usage due to mandatory cleaning procedures before changeovers between different flavours or products.

Facilities that use the reconstitution process require substantially more water, especially in the winter months. Some South African dairies have surplus milk during summer which is subsequently stored in powdered form for utilization in the winter. As a result, the demand for water increases in winter. This is frequently the case for yoghurt, for example.

4.2.4.2 Scale and age of the plant

While the level of production does impact water usage efficiency, the age of the equipment or technology, and the type of technology, has a significantly greater influence (Boguniewicz-Zablocka *et al.*, 2019; Greig *et al.*, 2023). Modern systems are typically more water efficient when compared to their older counterparts, which is a consequence of technological progress (Tetra Pak, 2021).

4.2.4.3 Load-shedding

Load-shedding could impact water usage on-site. In cases where the plant lacks backup generators, water consumption may decrease due to production downtime during load-shedding hours. Conversely, load-shedding could also cause an increase in water consumption. When production is forced to shut down during power outages and subsequently restarted, it can lead to water waste that falls beyond the plant operator's control.

4.2.4.4 Location

According to the results obtained during this survey, the milk processing companies in the Western Cape had lower SWI ratios for milk than the companies in the Eastern Cape and KwaZulu-Natal. However, two companies in the Eastern Cape with similar sizes and production volumes had different SWI ratios for UHT milk. This suggested that water usage is less strongly tied to the location and more dependent on the individual company. Individual dairy processors review the effectiveness of onsite water usage in response to regional water shortages, water supply costs, corporate social responsibility, and consumer preference for sustainable products.

4.2.4.5 High and low production months

Seasonal fluctuations have an impact on the supply and demand of most industries, including the dairy industry. The fluctuations between high and low production months are demonstrated in Figure 4.6, revealing that the months of May, June, and July are lower production months, while the months of October, November, and December are characterised by higher production. During months of lower production, higher SWI values might be observed. This is because certain fixed water-related activities such as cooling systems, sanitation and cleaning, and employee facilities, remain consistent regardless of the production volume. Consequently, the SWI tends to fluctuate correspondingly to higher and lower production months.

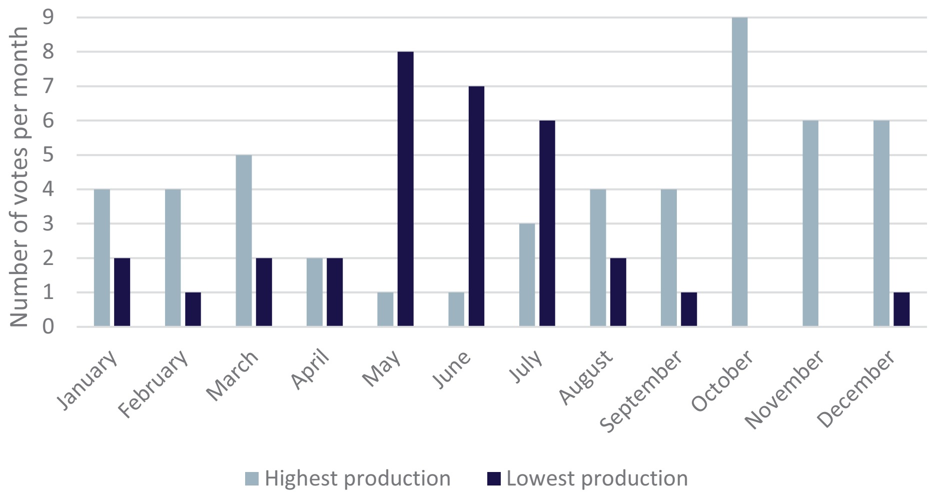


Figure 4.6: Breakdown of high and low production months for participating dairies

4.2.4.6 Legislation

The NWA was promulgated in 1998 (Act 36 of 1998), 10 years after the publication of the original NATSURV 4. The NWA governs water licensing for commercial use as well as the sustainability of water consumption. The NWA's enforcement, municipal water and effluent tariffs, CSR, and water stewardship activities could be among the various factors that influenced the decrease in the SWI of cheese, UHT milk, and butter. Water consumption sustainability is a global concern, and countries around the world continually revise their water consumption legislation. South Africa is frequently lauded for the high standard of legislation governing water consumption and its emphasis on sustainability (AgriOrbit, 2021). However, a major concern is the lack of implementation and good governance of these laws (AgriOrbit, 2021), which could partially explain why some dairy processors have higher SWI ratios for specific products in 2022 than in 1989.

South Africa currently consumes 98% of its available water supply (AgriOrbit, 2021). Since 1989, the population has grown significantly as did the demand for dairy products as discussed in Section 1.4.2 (The World Bank, 2021; Milk SA, 2022). The increase in milk demand has driven an increase in milk production, consequently leading to increased water consumption within the dairy industry, given the water-intensive nature of milk production (Milk SA, 2022). As a result, South African dairy processors are driven to minimise the water intensity of their production processes to remain financially sustainable and competitive, and to promote environmental sustainability and corporate responsibility. The limited public literature sources on water use at the dairy processing level are summarised in Table 4.4, allowing for a comparison between South African industry SWI ratios and its global counterparts. International SWI values range from 0.6 to 9.44 L/L product, while SWI ratios for South African processors producing any combination of milk, yoghurt, butter, or cheese range from 1 to 5 L/L product. The upper limit of 9.44 L/L product could potentially be a consequence of outdated technology in 2003, given that the remaining reported values are from subsequent years, with the majority below 5 L/L product.

The benchmark for 2022 was established by calculating the average of all the international SWI values provided in Table 4.4, which is subsequently presented as the benchmark for 2022 in Table 4.5. These newly derived benchmarks can now be compared to the benchmarks from 1989. Additionally, the average SWI of all South African survey participants is also given in Table 4.5 for reference. Given that the benchmark figures were derived from dairies across various regions, the average might appear relatively high, especially when compared to the 1989 benchmark. However, an overly aggressive benchmark could potentially serve as a hygiene or quality warning, as water is essential to meet hygiene standards. It can be argued that the South African dairy industry might not yet be at a mature stage in terms of upgrading technologies and achieving production sizes that can compete with international optimal benchmarks without compromising hygiene (Das Nair, 2011). Over a 14-year period (2008-2017), the water intensity of Australian dairy processors remained in the range of 1-3.5 L/L milk (Dairy Australia, 2019). South African dairies are aligned with the international trends and on par with dairy processors in Europe and Australia.

Table 4.4: Specific water intake from international studies

Category	Country	Specific water intake*	Reference
Milk	Denmark	2.21 - 9.44	(Bosworth *et al.*, 2003)
	Poland	3.2 - 3.8	(Boguniewicz-Zablocka *et al.*, 2019)
	United Kingdom	0.6 - 2.9	(Rad *et al.*, 2014; Ajiero *et al.*, 2018; Dairy Australia, 2019)
	Australia	0.98 - 2.98	(Wojdalski *et al.*, 2013; Dairy Australia, 2019)
	Canada	1 - 5	(Wojdalski *et al.*, 2013)
	France	1.2 - 4	(Vourch *et al.*, 2008 ; Ajiero *et al.*, 2018)
	Sweden	0.98 - 2.80	(Wojdalski *et al.*, 2013)
	Finland	1.2 - 2.9	(Wojdalski *et al.*, 2013)
	Norway	1 - 1.5	(Ajiero *et al.*, 2018)
	South Africa	1 - 3.5	This report
Yoghurt	Iran	4.4	(Ebrahimi *et al.*, 2019)
	Spain	3.6	(Vasilaki *et al.*, 2016)
	South Africa	1 - 4	This report
Butter	Lithuania	3.99	(Wojdalski *et al.*, 2013)
	Global	0.8	(GWI, 2020)
	South Africa	1 - 5	This report
Cheese	United Kingdom	0.7	(Rad *et al.*, 2014)
	Australia	0.64 - 2.9	(Wojdalski *et al.*, 2013)
	Australia	1.6 - 2.28	(Dairy Australia, 2019)
	South Africa	2 - 3.5	This report

***L/L for liquid products and L/kg for concentrated products**

Table 4.5: SWI NATSURV benchmarks of 1989 and 2022

	Milk	UHT milk	Yoghurt	Butter	Cheese
Benchmark 1989	1.5	2.0	6.3	1.3	20.0
Benchmark 2022	2.6	-	4	2.4	1.8
Participating dairies 2022	2.25	1.5	2.5	3	2.75

The previous 1989 NATSURV provided a target SWI of 1.5 L/L for milk and 2 L/L for UHT milk based on the average SWI for packaged milk (Steffen Robertson and Kirsten Inc, 1989). Two of the participating milk processors and all the UHT milk processors exhibited an average SWI lower than the benchmark provided in the original NATSURV 4. Additionally, all but one milk processor had a SWI lower than the 2022 benchmark. Notably, the SWI ratio of all participating yoghurt processors are lower than both the 1989 and 2022 benchmark. A consequence of South African respondents potentially implementing technologically advanced, low-water production processes.

While the butter processors typically exhibited higher SWI ratios compared to both the 1989 and 2022 benchmarks, cheese processors demonstrated significant improvements since the 1989 benchmark. However, SWI ratios from South African participating companies appear relatively high when compared to international SWI values. This might be attributed to the fact that the participating cheese dairies were generally smaller sized manufacturers, often producing more artisanal types of cheese rather than being large-scale companies generating substantial volumes. Whey water from cheese production can be further processed and sold as a by-product. This can potentially also affect the SWI of the cheese processors because if the whey is sold as a different product, then it will have its own SWI, separate from the water used for cheese.

CHAPTER 5: WASTEWATER GENERATION AND MANAGEMENT

5.1 WASTEWATER GENERATION

The dairy processors were asked to provide an overview of their wastewater generation volume, typical pollutant loads, and to provide details regarding their wastewater treatment operations prior to discharge. The volume of wastewater generated at each site varied according to the type and size, the location, and the daily milk processing capacity. With the exception of two participating companies who do not measure their wastewater quantities, Table 5.1 gives a comprehensive overview of the total annual water consumption and wastewater generation among the participants.

Table 5.1: Total water consumption and wastewater discharge volumes of participating dairy processors

Facility type	Total wastewater volume (kL/year)	Total water consumption volume (kL/year)
Cheese	1,000 - 2,000	2,000 - 3,000
Cheese	2,000 - 3,000	5,000 - 6,000
Cheese	15,000 - 16,000	15,000 - 16,000
Yoghurt	750,000 - 800,000	2,000,000 - 2,100,000
Full cream milk	-	50,000 - 60,000
Mixed dairy	230,000 - 240,000	400,000 - 500,000
Mixed dairy	1 900,000 - 2,000,000	2,200,000 - 2,400,000
Mixed dairy	-	110,000 - 130,000
Mixed dairy	110,000 - 120,000	110,000 - 130,000
Mixed dairy	80,000 - 100,000	100,000 - 120,000

Given that almost all the water consumed at dairy plants ultimately becomes effluent, the breakdown of specific wastewater discharge volume among the participating dairy processors mirrors the water usage distribution presented in Figure 4.4. Even though there are water losses due to evaporation and with floor cleaning, these were rarely monitored and are difficult to quantify. Consequently, wastewater volumes per unit of milk produced are often in the same range as the water used per unit of milk produced. The CIP processes contribute most to effluent volumes, a finding consistent with the original NATSURV, where CIP was identified as the most water-intensive processing step. The wastewater generated from dairy processing contains milk and milk products lost during production, as well as detergents and acidic and caustic cleaning agents. Milk loss can be as high as 3-4%, with the main sources of loss being residues that remain on the internal surfaces of vessels and pipes, accidental spills, and overflowing vessels (Bosworth *et al.*, 2003).

5.2 EFFLUENT POLLUTANT LOADS

The wastewater COD concentration is one of the most closely monitored characteristics to ensure compliance with municipal discharge limits. Each municipality have their own set of standards for effluent quality, including COD limits. These COD limits are typically in the range of 1,000 to 5,000 mg/L, for example, in the City of Cape Town, the maximum allowable COD limit for effluent discharge is set at 5,000 mg/L (City of Cape Town, 2022). Among the participants, 60% responded that COD was the most concerning parameter, with organic loads varying according to cleaning practices. Nevertheless, most wastewater generated in dairies exhibit high levels of COD and total suspended solids (Bosworth *et al.*, 2003).

In most cases, wastewater streams from the dairy processing plants were combined and discharged as a single effluent stream. In view of the wide variety of processes involved in the dairy industry, it is difficult to generalise about dairy wastewater streams. The participating companies had limited information on their effluent stream characteristics; therefore, only a few provided data on determinant concentrations.

The quality of dairy effluent varied greatly among processing plants, especially in cases where a variety of products were manufactured on a single site (Table 5.2). Typically, alkaline effluent pH values were reported in the range from 7 to 11 with COD concentrations ranging from 100 to 8,000 mg/L, total dissolved solids (TDS) in the range of 50 to 2,000 mg/L, and total suspended solids (TSS) between 10 to 400 mg/L.

The 1989 NATSURV reported a COD of 2,757 mg/L and a TDS of 1,885 mg/L at a milk production dairy site. There was no information provided in the 1989 NATSURV about the characteristics of mixed dairy effluent. The TDS of dairy effluent does not appear to have changed much, while the COD of dairy effluents has increased; however, dairies with higher production volumes have managed to reduce their effluents' COD and TDS concentrations.

Table 5.2: Summary of effluent characteristics from participating companies

Facility type	Total effluent volume (kL/year)	pH	COD (mg/L)	TDS (mg/L)	TSS (mg/L)
Cheese	1,000 - 2,000	Not known	Not known	Not known	Not known
Cheese	2,000 - 3,000	Not known	Not known	Not known	Not known
Cheese	15,000 - 16,000	Not known	Not known	Not known	Not known
Full cream milk	-	Not known	Not known	Not known	Not known
Mixed dairy	-	8-9	Not known	Not known	Not known
Mixed dairy	110,000 - 120,000	8-9	2000-4000	Not known	Not known
Yoghurt	750,000 - 800,000	10-11	6000-8000	Not known	Not known
Mixed dairy	230,000 - 240,000	7-8	0-2000	Not known	0-20
Mixed dairy	80,000 - 100,000	8-9	2000-4000	1000-2000	200-400
Mixed dairy	1 900,000 - 2,000,000	7-8	2000-4000	0-500	180-200

Due to the limited data on pollutant concentrations provided by the companies, data were sourced from publicly available literature. Global values for typical milk processing effluent pollution loads presented in Table 5.3 highlight that wastewater quality varies greatly between companies, especially in instances involving diverse product ranges. This variation makes a direct comparison of survey results with international trends difficult. Nevertheless, Table 5.3 offers a general insight, indicating that South Africa is on par with international facilities.

Regarding COD wastewater discharge limits, South Africa's General Authorisations are on par with other countries, if not stricter in some cases (Preisner *et al.*, 2020). For example, some German regions have higher COD wastewater discharge limits than those specified in South African general authorisations (Preisner *et al.*, 2020). The United States primarily uses BOD limits as opposed to COD limits which are primarily used in South Africa and Europe, making comparisons difficult.

Table 5.3: Composition of milk processing effluents

Milk processing effluent	pH	COD (g/L)	TDS (g/L)	TSS (g/L)	Reference
Mixed dairy	4 - 11	0.5 - 10.4	0.71 - 7	0.06 - 5.80	(Janczukowicz *et al.*, 2008)
Milk reception	7.18	2.54	-	0.65	(Janczukowicz *et al.*, 2008)
Mixed effluent	7.7	1.3	2.4	0.6	(Mostafa, 2015)
Dairy effluent	7.2 - 8.8	1.9 - 2.7	0.9 - 1.35	0.5 - 0.74	(Deshannavar *et al.*, 2012)
Fluid milk	5 - 9.5	0.95 - 2.4	-	0.09 - 0.45	(Demirel *et al.*, 2005)
Fluid milk	6 - 8	-	-	0.14 - 2	(GWI, 2020)
Yoghurt	4.53	6.5	-	-	(Tezcan Un *et al.*, 2013)
Butter	12.08	8.93	-	0.7 - 5.07	(Janczukowicz *et al.*, 2008)
Cheese	3.4 - 9.5	1 - 63.3	1.92 - 53.2	0.19 - 2.5	(Janczukowicz *et al.*, 2008)
Cheese	6-8	-	-	0.07 - 2	(GWI, 2020)
Cheese whey	3.9 - 6.5	50 - 102.1	55 - 70.9	1.3 - 22.1	(Demirel *et al.*, 2005)
Milk permeates	5.6 - 6.5	52.9 - 57.5	11.6 - 15.4	1.9 - 3.4	(Karadag *et al.*, 2015)
Washing wastewater	10.4	14.64	-	3.82	(Janczukowicz *et al.*, 2008)

Six dairies in this survey discharge their effluent into municipal sewers, which can pose significant load on certain municipal sewage treatment plants (Figure 5.1). Before being discharged into municipal sewer systems, the dairy effluent should be pre-treated to adhere to authorised municipal effluent discharge limits described in Table 3.1 and Table. Failure to meet these limits requires dairies to pay effluent tariffs. These tariffs range from R12.52/kg to R31.24/kg COD and serve as a financial penalty for noncompliance with municipal regulations.

In contrast, three of the participating dairies located in rural areas manage their effluent through land irrigation or manmade wetlands. Dairy processors that take water from and/or discharge wastewater directly into water bodies such as marine outfalls, groundwater resources, sensitive river systems or water resources with closed drainage, are subject to water use authorisation requirements in terms of the NWA (Act 36 of 1998) (ICMA, 2008). Processors authorised in terms of Section 21(e) of the National Water Act are permitted to irrigate domestic and biodegradable industrial wastewater, subject to specific conditions. The General Authorisation (No. 36820) which was published on 6th September 2013 provides a volume allowance of up to 2 000 m^3 if the COD does not exceed 75 mg/L, up to 500 m^3 with a COD limit of 400 mg/L, and 50 m^3 if the COD does not exceed 5 000 mg/L, among other specified limits (Molewa, 2013). Any processor undertaking an activity (irrigation with wastewater) which exceeds a volume of 2 000 m^3 needs to apply for a water use licence in terms of Section 40 of the NWA. Among the participants, dairies that discharge wastewater into manmade wetlands or for land irrigation, monitoring data related to wastewater volumes and pollution loads were limited. The limited data from participants in this respect might be attributed to the lack of knowledge, inspections, and implementation of these regulations.

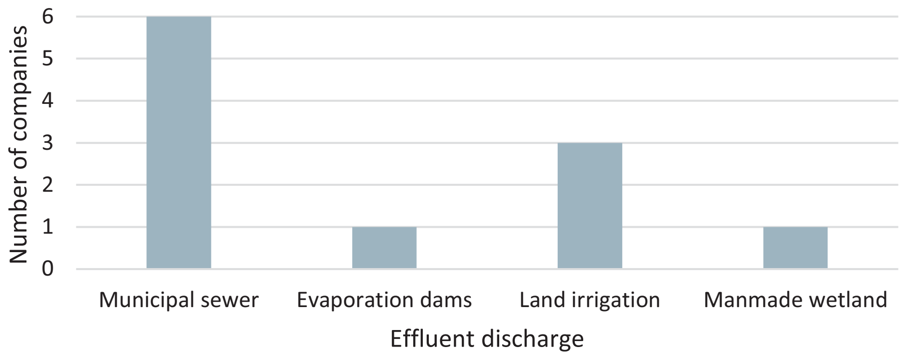


Figure 5.1: Effluent discharge destination

As illustrated in Figure 5.2, 50% of the dairy processors transfer their effluent to holding tanks as the large variation in wastewater volume and quality poses a challenge. Additionally, wastewater management costs vary depending on factors such as the location of the processing plant, the source of water, and the treatment requirements (Dairy Australia, 2019). Among the participants, two processors indicated that they discharge their wastewater directly into evaporation dams or repurpose the water for land irrigation without prior treatment. The most commonly used effluent treatment processes among the participants are pH adjustments, screening, and flocculation. Primary treatments, such as screening and dissolved air flotation (DAF) are commonly used to remove suspended solids. However, there has recently been a shift toward secondary treatment methods such as anaerobic digestion in other countries (Dairy Australia, 2019).

Anaerobic digestion is growing in popularity as an environmentally friendly method to supplement energy supply via combined heat and power (CHP) plants. Anaerobic digestion relies on micro-organisms to convert organic material in the wastewater into biogas that can be used for gas-powered energy generation by exploiting the methane present in the gas. Given the significant increase in energy costs, biogas has the potential to be sustainable and cost-effective. Tertiary treatment processes such as reverse osmosis and membrane filtration could be used to produce water that meets SANS 241-1:2015 potable standards. Water purified to this standard is suitable for reuse within the processing operations, for instance, two of the participants used reverse osmosis to generate water for reuse in manufacturing. Some of the participating dairy processors use a variety of wastewater treatment methods in combination to meet municipal effluent quality limits. The wastewater treatment processes differed depending on the end use and local municipal criteria.

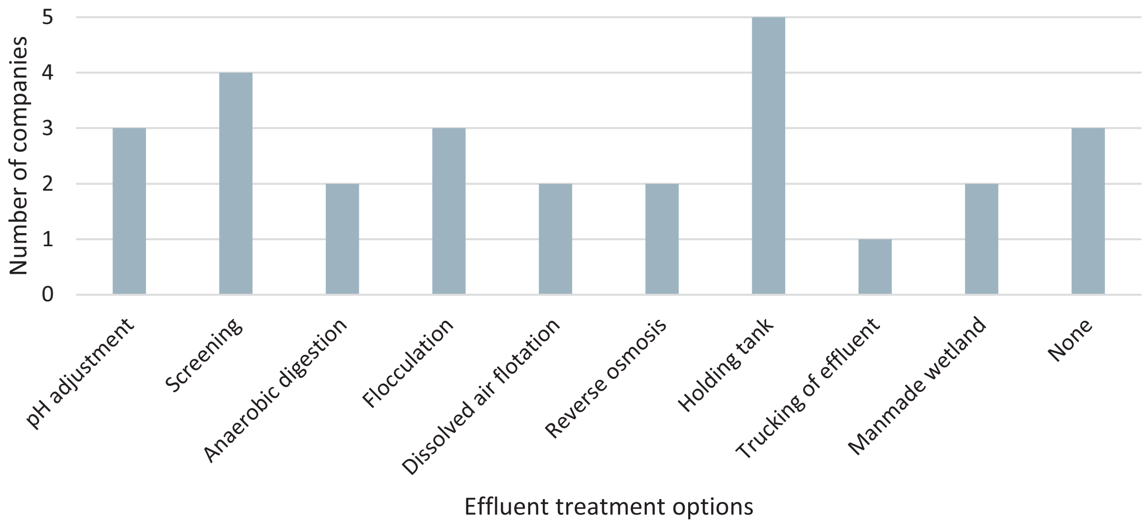


Figure 5.2: Type of effluent treatment processes used by participating dairy processors

Three participating processors stated that water was not reused at their facilities. Among these, one company stated that they plan to reuse all wastewater by 2030. Two participants stated that some wastewater was used for irrigation, while another company purified wastewater and used it for appropriate applications. One company recycles 60% of its wastewater using reverse osmosis, while another recovers the caustic rinse from one CIP cycle for reuse as the pre-rinse on the next cleaning cycle. Similarly, two participants reuse the last rinse from CIP for the first rinse in the next washing cycle. The majority of the South African participants displayed significant interest in improving their wastewater quality as a strategy to reuse water which will reduce effluent volume and promote sustainable practices.

5.3 STORMWATER MANAGEMENT

Stormwater should be separated from process facility effluent since stormwater runoff goes directly to the nearest river or ocean, whereas dairy site effluent is sent off for treatment before being discharged into the nearest river or ocean. Among the ten respondents, three dairy facilities have marked their stormwater drains, while four have not. Therefore, participants had implemented a stormwater plan to effectively prevent contamination of stormwater by dairy effluent. The remaining companies either did not have a stormwater plan or did not have one that was applicable due to the location of the site. Companies implementing stormwater plans enforced formal policies such as separating stormwater from wastewater by promptly cleaning up spills and preventing runoff water from entering stormwater drains.

CHAPTER 6: ENERGY USE AND MANAGEMENT

While the focus of this report is water and wastewater management, a new section has been added to Edition 2, dedicated to energy usage and management. Complementary to the comprehensive water and wastewater questionnaire, a short supplementary survey was distributed to gather insights into energy consumption and management practices within dairy plants. However, it is important to note that only three companies chose to contribute data to this section.

There is a clear relationship between energy usage and both water consumption and wastewater generation. Minimizing water consumption, for example, results in lower energy requirements for pumping, heating, and treating water. However, a detailed exploration of this topic is beyond the scope of this report.

The participants utilise diverse energy sources, including electricity from the grid, solar, diesel, coal, steam, liquified petroleum gas (LPG), and heavy fuel oil (HFO), as shown in Figure 6.1. All respondents use electricity from the grid and incorporate solar power to supplement municipal supply. The recent increase in power outages led them to invest in backup power supplies to keep up with production demands. Consequently, two of the participating diaries utilise diesel stand-by generators for managing these power outages, with one dairy consuming approximately 300 L of diesel per hour of load-shedding.

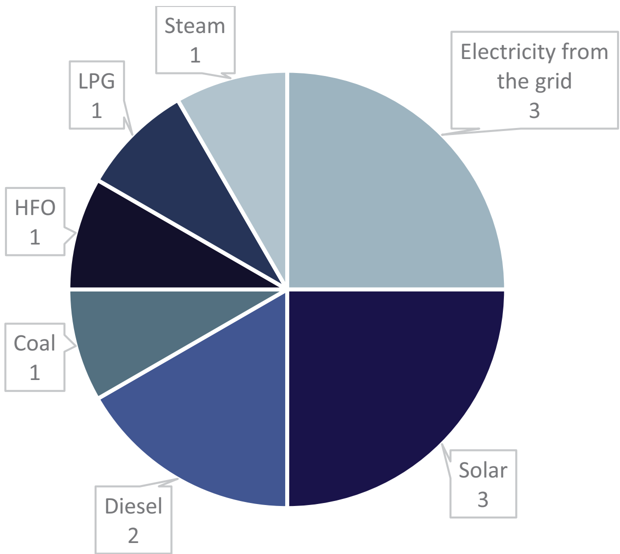


Figure 6.1: Different energy sources used by participating dairy companies

Table 6.1 provides the range of electricity consumption for the three participating dairy companies. Energy usage, like water consumption and wastewater generation, is determined by various factors such as the size of the plant, age of processing equipment and level of automation, range of products produced, packaging type and many more. Table 6.1 effectively demonstrates the impact of size of the plant on energy consumption.

Table 6.1: Annual energy consumption and energy distribution of participating companies

Size	Annual energy consumption		Energy %
>200	3,500,000	kWh/year	Grid 78% Solar 22%
<50	144,000	kWh/year	Grid 50% Diesel 30% Solar 20%
>200	275,500,000	kWh/year	Grid 60% Solar 40%

The three participating dairies implement various tools to monitor their energy usage. These tools include solar system software for solar power monitoring, analysis of incoming electricity bills for grid-supplied electricity monitoring, and utilisation of programmable logic controllers (PLC) and fuel bills for monitoring the generators. One dairy in particular adopts methods such as distributed real-time metering and cloud-based databases for information capturing and analysis.

During the water and wastewater survey, participants were asked about their implementation status of energy submetering. Out of the ten respondents, three have already implemented energy submetering, one is currently in progress, the majority plan for future implementation, and one did not provide an answer. These monitoring techniques serves as a tool to identify the energy intensive areas, potentially highlighting areas in need of maintenance or upgrades for improve energy efficiency. The energy survey revealed that the most energy-intensive processes are the cooling and storage systems, pasteurisation, spray drying, homogenisation, pumping, CIP, packaging. Notably, cooling was rated as the main energy consumer by all three dairies.

6.1 ENERGY CONSUMPTION AND MANAGEMENT

The anticipated progressive increase in the carbon tax by 2025 has generated a sense of urgency for the integration of more sustainable carbon sources, driving processing facilities to take proactive measures (Arnoldi, 2023). Consequently, many participating processing facilities are exploring renewable energy sources such as solar power, compressed natural gas (CNG) and biogas generated from anaerobic digestion of dairy effluent. All three participating dairies have already implemented solar power systems, and each of them has plans to increase their solar capacity in the coming years. Furthermore, one facility indicated that they plan to use CNG as an additional fuel source in the future. Implementing renewable energy sources reduces reliance on municipal power supply, leading to a decrease in carbon emissions, and presents the opportunity to generate excess electricity that can be exported back into the grid.

Several factors have contributed to an increase in energy efficiency over the past decade. Rising energy costs have driven several industries, including the dairy industry, to evaluate opportunities to improve energy efficiency, aiming to reduce fuel consumption (Illidge, 2023). Simultaneously, ongoing power outages have prompted dairies to investigate energy saving measure and improved energy management. The three participating dairies have made progress in energy saving initiatives by implementing some of the following energy efficiency solutions:

- Light emitting diode (LED) lighting
- Shifting from freon to ammonia refrigeration systems
- Optimised maintenance practices
- Improved insulation
- Compressed air and steam leak detection and elimination
- Energy efficient equipment

- Utilisation of low-grade energy
- Energy use targets in place
- Comprehensive program targeting each aspect of energy consumption.
- Progress aligned with bonus determination for personnel.
- Specifically upgraded infrastructure to reduce emissions or save energy.

During the water and wastewater survey, participants were asked about their implementation status of heat recovery. Out of the ten respondents, one has already implemented energy submetering, one is currently in progress, the majority plan for future implementation, and three did not provide an answer. The participating dairies can achieve reduced overall energy consumption by implementing efficient heat recovery systems.

6.2 INTERNATIONAL TRENDS

The cleaner production guide from the United Nations Environment Programme's Division of Technology, Industry and Economics (UNEP DTIE) provides typical energy consumption figures per tonne product, with reported values of 0.2 GJ/tonne milk, 0.76 GJ/tonne cheese, 1.43 GJ/tonne milk powder and 0.71 GJ/tonne butter (Bosworth *et al.*, 2003). These figures clearly highlight the significant influence of the product type on energy demands.

According to the United States Environmental Protection Agency report on enhancing energy efficiency in the dairy industry, it was determined that the United States dairy industry consumed approximately 35 trillion British thermal units (TBtu) of energy in 2006 (Brush *et al.*, 2011). Figure 6.2 shows this energy distribution, revealing that machine drive applications that power pumps, compressors, fans, and motors accounted for 40% of the electricity usage. Furthermore, 31% of the energy was utilised for cold storage, freezing, and process cooling (Brush *et al.*, 2011). Similar to the scenario in the South African participating dairies, the USA has high energy demand from cooling processes. This similarity indicates a potential area that could benefit from increased energy efficiency.

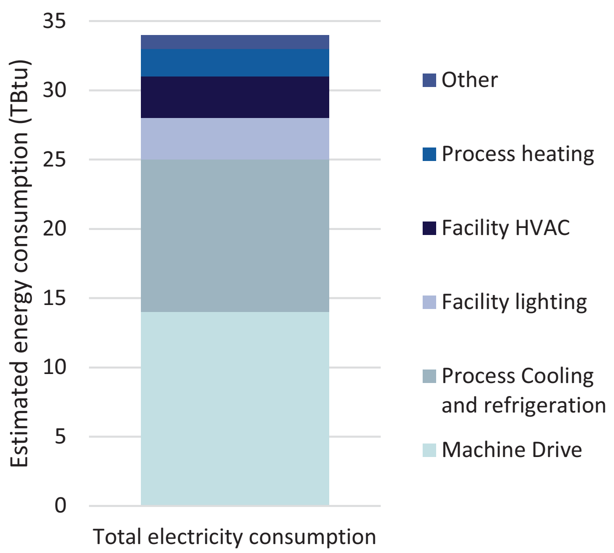


Figure 6.2: Estimated Energy Consumption in the USA Dairy Processing Sector, 2006 (Brush *et al.*, 2011)

CHAPTER 7: WATER AND WASTEWATER BEST PRACTICE

7.1 STATUS OF BEST PRACTICE IN INDUSTRY

There are a variety of best practices that can be implemented to improve water and wastewater management. Table 7.1 summarises the responses of the participating companies to questions about the status of implementation of various water management best practices. The following sections will shed light on the significance of each best practice and elaborate on additional best practices in management.

Table 7.1: Summary of best practices implemented by participating companies

Description	Number surveyed	Planned	In progress	Implemented	No answer
Water sub-metering	10	5	2	2	1
Energy sub-metering	10	5	1	3	1
Water use targets in place	10	1	1	5	2
Wastewater targets in place	10	1	1	5	2
CIP recovery	10	1	2	5	2
Condensate recovery	10	1		5	4
Heat recovery	10	5	1	1	3
Water foot printing	10	2	4	2	2
Carbon foot printing	10	2	2	3	3
Life cycle analysis	10	4	1	1	4
Water pinch analysis	10	5	1		4
Reduced weight packaging	10	2	3	3	2
Use of recycled content in packaging	10	1	4	3	2
Rainwater harvesting	10	4	2	3	1
Water leak prevention program	10	3	1	4	2
Hoses fitted with high pressure nozzles	10			5	5
Automatic shut off hoses	10			4	6

7.1.1 Metering, monitoring, and targeting.

In response to whether water use targets are in place and to what extent these were being met, three companies had no water use targets in place, however one company stated that they intend to implement them in the future. The others set specific targets for average water consumption per litre of milk produced and are monitoring and managing the water usage.

With respect to wastewater quality and quantity targets and whether these are being met, four companies indicated that there were no current wastewater targets in place, although one company did measure the wastewater quality before discharge. The rest of the surveyed companies had specific wastewater quantity targets. These included a 1% annual reduction in wastewater generation and a recycled water target of more than 60%. Quality targets were less prominent with, one participant stating that the wastewater was balanced for pH before discharge, while another indicated that the dissolved air flotation is monitored and managed daily.

Water and energy sub-metering was lacking among the participants, with only two respondents having water sub-metering. In many instances, inadequate metering was likely the reason for a general lack of water related targets.

7.1.2 Cleaner Production

Dairy processors are transitioning to cleaner production methods to reduce water consumption and wastewater costs. Aside from the potential commercial drivers, the industry has recognised that demonstrating the principles of sustainability and CSR is critical to maintaining a social licence to operate, which is increasingly influencing consumer behaviour.

It is critical for dairy processors to continuously integrate preventative environmental strategies to increase efficiency and reduce risk to the environment. In view of this, the companies were questioned as to whether any major changes had been made in the past ten years to save water, energy, or limit emissions. More than 90% of the participants responded affirmatively, highlighting their adoption of preventative strategies. These include the installation of gasifier and UHT filler machines, as well as the replacement of the homogeniser, separator, and cooling towers, all aimed at reducing water and energy consumption. Participants also implemented improved chlorine disinfection of the water supply system, switching from freon to ammonia and replacing the boiler to switch from oil to paraffin. Five companies made significant progress in solar panel installations; one in particular produce 40% of its energy through solar panels with the intension to expand the solar system in the future.

7.1.3 Water Management investigations

Participants can conduct a water pinch analysis, a life cycle assessment and water footprinting to develop a water management program. Life cycle assessment and water footprinting go beyond the water used during production. A life cycle assessment provides an understanding of the overall environmental impact of dairy products along its entire supply chain, including agriculture, raw material extraction, product manufacturing and waste disposal. While water footprinting considers the total volume of water consumed along the entire supply chain to produce a product (Owusu-Sekyere *et al.*, 2016). Milk has a large water footprint, however, most of the water used for milk production is used during agriculture. Demonstrating that the largest potential to reduce water consumption in the dairy industry is in enhancing the efficiency of milk production at the farm (Dairy Australia, 2019). Nevertheless, there are still improvements to be made and it is critical that dairy processors minimise water consumption within factories.

Water pinch analysis originates from the concept of energy pinch analysis and corresponding parallels between each of these analyses are presented in Table 7.2. In an energy pinch, the objective is to optimise energy recovery opportunities in a process (Klemeš *et al.*, 2014). For this analysis, data such as input and output temperature and heat capacity are required (Nemati-Amirkolaii *et al.*, 2019). However, in a water pinch, the goal is to find the optimal trade-off between different water sources and water demands (Nemati-Amirkolaii *et al.*, 2019). For this analysis, data such as the purity of water and water flow rate of water are required (Nemati-Amirkolaii *et al.*, 2019).

Table 7.2: Analogies between energy pinch and water pinch (Nemati-Amirkolaii *et al.*, 2019)

Energy pinch	Water pinch
Heat exchanger network design	Water network design
Temperature	Purity of water
Heat capacity flowrate	Water flowrate
Heat flow	Pollutant flowrate
Cold stream	Sink water
Hot stream	Source water
Heat-pump	Purification unit

Water pinch is a systematic technique used to achieve water minimisation, by maximising water reuse opportunities (Klemeš *et al.*, 2014). This systematic technique includes steps such as identifying water-saving opportunities, collecting data, establishing minimum utility targets, and designing a water network, with data extraction being the most important step for performing an optimal analysis (Klemeš *et al.*, 2014). The potential savings from water pinch analysis applications have been widely reported with benefits ranging from 13% to 85% in freshwater reduction (Klemeš *et al.*, 2014). Even though there is a clear advantage in performing water pinch analysis, it was not adopted by any of the participating dairy processors. This is potentially due to the variability in water source characteristics and the imposed constraints on water quality by regulations such as SANS 241-1:2015.

Table 7.3: Applications of water pinch analysis (Klemeš *et al.*, 2014)

Industry	Flow reduction	Reference
Corn refinery	30%	(Bavar *et al.*, 2018)
Sugar cane	85%	(Poddar *et al.*, 2017)
Sugar cane	59%	(Chetan *et al.*, 2015)
Pulp and paper	13%	(Manan *et al.*, 2007)
Citrus	30%	(Thevendiraraj *et al.*, 2003)

In this survey, two participating dairies used water footprinting in their water management programme, while another performed a life cycle analysis. Given that fresh water supply is severely stressed with increasing urban growth, which competes with agricultural and industrial needs, water management investigations such as water pinch analysis and water footprinting is paramount. Dairy processors should therefore consider various future scenarios and have a water management plan in place to increase resilience against future water scarcity.

7.1.4 International Organization for Standardisation (ISO) 14000

The International Organization for Standardisation (ISO®) issues ISO 14000, a set of standards designed to assist businesses all over the world in reducing their environmental impact. It is a framework for organisations of all sizes to improve and become more environmentally conscious in their quality management systems. The survey did not ask participants whether they were ISO 14000 certified. However, some businesses have made significant efforts to reduce their environmental impact, including the use of recycled content in packaging, lighter packaging, water leak prevention programs, heat recovery, carbon footprinting, rainwater harvesting, and water recovery and reuse. Monitoring, targeting, life cycle analyses, water footprinting, and cleaner production are all examples of environmental management under the ISO 14001 standards.

The ISO standards are globally recognised, and as the number of companies that meet these standards increases, ISO 14000 will become a prerequisite for doing business in the industry (Rabin, 2003). Companies pursue ISO 14000 certification to gain a competitive advantage while also improving environmental management (Rabin, 2003). Nestle, for example, is ISO 14000 certified and part of the Strategic Water Partners Network (Intertek, 2010). This encourages water stewardship and environmental best practice throughout the entire supply chain. As a result, dairy processors and producers who want to supply to Nestle must adhere to Nestle's water stewardship and environmental management principles (Nestle, 2013). Nestle, in conjunction with the ISO 14 001 certification, influences dairy processors to implement best practices and thereby reduce their water footprint in this manner (Nestle, 2013). Furthermore, ISO 14000 certified businesses benefit from increased profitability, quality improvements, cost reduction, and access to new and growing markets, all while avoiding potential liabilities (Rabin, 2003). If ISO 14000 is adopted on a national scale, it has the potential to reduce South Africa's dairy water footprint and incentivise best practice implementation.

7.2 BEST MANAGEMENT PRACTICES

There are several best practice opportunities for optimising water use within the dairy sector. The term best practice refers to the accepted or prescribed procedures, approaches or strategies that have been shown through research and evaluation to be effective and/or efficient (Oxford, 2022). The best practice programme should follow the water conservation hierarchy shown in Figure 7.1. This is the approach promoted by South African legislation (DEA, 2011). The goal of the conservation hierarchy is to prevent any avoidable wastewater generation. Stopping water use where possible, optimising systems to reduce water use and treat water before disposal are conservation options that offer the most opportunities and have the lowest inherent risk. Conservation methods such as reuse and recycle carry greater risk and complexity, making them more difficult to implement, especially given that good manufacturing practice (GMP) limits water reuse unless it meets potable water standards. Consequently, there are more opportunities available for water conservation and demand management than for water recycling. This is reflected in the recommendations that follow, which have been curated to conform to the requirements of legislation, regulations and GMP.

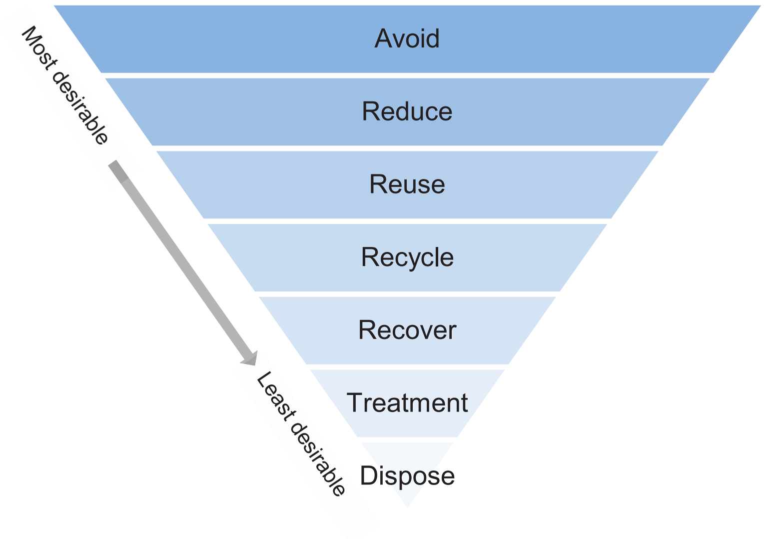


Figure 7.1: Water management best practice hierarchy (Axil, 2021)

General management practices, equipment modifications, and operating and maintenance procedures are all methods for reducing water consumption. However, examining cleaning methods and operator techniques can also result in significant advantages. Efforts to minimise product loss to the wastewater stream are a key strategy for lowering the organic load of dairy wastewater. The application of the following approaches may be considered as industry best practice since they can reduce water use, and the organic content of effluents.

7.2.1 Water reduction

Dairy processors can use the following strategies, however, they are only effective if they are constantly reviewed, especially as processes and operations change over time. The best practices recommendations outlined in this section are offered as opportunities for improvement, however, the extent of water savings resulting from these improvements will vary for each individual dairy site. Although the individual water savings may not appear to be significant, the combined savings of many activities result in a significant reduction in water use (Dairy Australia, 2019).

7.2.1.1 Metering, monitoring, and targeting.

Metering and monitoring are critical aspects of water resource management. Installing sub-metering, monitoring, and control devices can provide a clear indication of the water-intensive processes to the dairy processor (Bosworth *et al.*, 2003). Metering and monitoring specific processes enable management to review water consumption, trend it over time, and increase data granulation (Dairy Australia, 2019). Regular analysis of data through comparison of internal monitoring data with municipal records can improve process control by identifying water losses due to leaks and possible product losses, and thereby reduce production costs (Dairy Australia, 2019). Dairy processors can use monitoring to set performance indicators as a metric to indicate good or bad performance. Metering and monitoring guidelines proposed by the NCPC for the agri-processing sector may provide valuable insight into metering schematics (NCPC, 2022).

7.2.1.2 Optimisation of CIP

Cleaning-in-place was identified as the largest consumer of water by all participants. Optimising CIP therefore has the potential to affect the greatest individual water savings. An automated CIP system also improves production by increasing CIP efficiency and reducing downtime. Adopting the most recent automated and computerised CIP control systems results in significant water savings and optimised water use. With this knowledge, the participants were asked if they had automated CIP equipment. A variety of responses were provided and are summarised in Table 7.4.

Table 7.4: Automated CIP survey responses

Do you have automated CIP equipment?	Comments
Yes	Fully automated
Semi-Automated	Automated milk tank wash but rest is manual
Yes	Only pasteurisers
Yes	Fully automated, all milk processing and filling equipment
Yes	Fully automated and instrumentation-base switching
Semi-Automated	Manual mixing and automated washing
Semi-Automated	
Yes	Fully automated, CIP plants with some recovery and re-use
Yes	Fully Automated, with rinse water reclaim
Yes	Fully Automated

Cleaning-in-place water demand can be reduced by fine-tuning process timings . The last CIP rinse water can be reused; for example, the caustic rinse can be returned to its holding tanks, and the post-rinse from one cycle can be used as the pre-rinse for the next cycle (Bosworth *et al.*, 2003). Other water-saving techniques include reducing rinse time, using spray nozzles, and pre-soaking equipment to loosen dirt prior to the final clean. Keeping the CIP system close to the processing equipment reduces pipe runs and saves resources. The addition of conductivity monitoring to CIP operations can also provide security and refinement (Dairy Australia, 2019).

Employing water efficient techniques such as dry cleaning or burst rinsing for pre-cleaning tanks and tankers can maximise product recovery before CIP. Depending on the properties of the product being cleaned, a series of bursts rather than a continuous rinse can reduce water consumption.

7.2.1.3 Staff training and engagement

Water reduction should be considered standard practice throughout the process, and all dairy processor employees should be involved. Staff awareness of the target water usage and encouragement to conserve water should be driven as a priority endeavour (Bosworth *et al.*, 2003). Employee engagement is essential, and there are various strategies to foster participation. Encouraging employees to share innovative ideas for water-saving practices, monitoring water usage in different processes, or even organizing friendly competitions between teams can all drive enthusiasm. Furthermore, whenever process modifications or upgrades occur, it is vital to provide comprehensive training to employees and establish a system for continuous performance evaluation (Steffen Robertson and Kirsten Inc, 1989).

A simple yet effective way of increasing employee awareness can be achieved through reminders to turn off taps after use. Moreover, it is crucial to ensure that water-conscious behaviours are embraced at all levels of the organization. Providing relevant training to management personnel is paramount; for instance, supervisors overseeing specific areas should be well-versed in water-saving practices to lead by example during their regular plant walkthroughs (Bosworth *et al.*, 2003).

While water usage in kitchens and gardens might constitute a smaller fraction of overall factory consumption, the potential for substantial savings remains noteworthy (Dairy Australia, 2019). By implementing straightforward, cost-effective measures, dairies convey a powerful message of commitment to their employees and external stakeholders alike.

7.2.1.4 Maintenance

Significant water savings can be achieved with good management practices. Installing and regularly inspecting meters allows for the detection of spikes in consumption and the timely detection and repair of leaks. Leak detection at large-volume water-handling equipment is especially important and justifies the cost of installing meters (Dairy Australia, 2019). During routine site walkthroughs, it is important for staff to remain vigilant for any damp areas surrounding water pipes, this can assist in early detection of potential water leaks. Pumps, valves, and hoses, for example, require regular maintenance and should be repaired quickly not only to save water, but also to set a good example to staff about the importance of water conservation and good housekeeping (Bosworth *et al.*, 2003). During production shutdowns, all water users can be disconnected, and the meter monitored for leaks.

7.2.1.5 Other process optimisation methods

Consumption can be reduced by optimising flow pressure. Trials should be conducted to determine the lowest usable flow rate for the equipment or to compare the flow rate to the manufacturer's specifications (Dairy Australia, 2019). Dairies need to consider installing a flow regulator to keep the flow rate constant and optimal (Dairy Australia, 2019).

Scrubber dryers and vacuum cleaners can be used to remove gross soiling before washing with water to reduce the amount of water used to clean cold stores and warehouses. This is a quick and efficient way to reduce water and chemical use.

Another approach to conserve water and minimise water losses involves utilising automatic shut off hoses (Bosworth *et al.*, 2003). High-pressure water cleaners are commonly used to cut down on the amount of water required to clean floors and equipment (Dairy Australia, 2019). Water consumption can be further reduced by optimising the overall pasteuriser-separator-homogeniser configuration and design. Several dairies waste both energy and water by individually heating and cooling the three steps listed above (Steffen Robertson and Kirsten Inc, 1989).

7.2.2 Water reuse and recycling

While there are clear and simple ways to lower water use, there are several additional factors that should be considered with reuse and recycling. Any water reused or recycled back into the process poses a potential risk to food safety, as well as an additional cost and energy demand (Dairy Australia, 2019). There are still a few opportunities for water reuse for cleaning surfaces that do not come into direct contact with food.

7.2.2.1 Boiler condensate

Water recovered from the boiler system in the form of steam condensate should be reused whenever possible (Bosworth *et al.*, 2003). Reduced condensate loss reduces make-up water supply, chemical use, and operating costs significantly (Dairy Australia, 2019). A condensate return system also saves energy because the already hot condensate requires less energy to reheat (Dairy Australia, 2019). Steam traps, condensate pumps, and lines should be inspected on a regular basis, and boiler systems should be maintained to reduce blowdown and maintain boiler efficiency (Dairy Australia, 2019).

7.2.2.2 Full recycle of wastewater

Due to the cost of implementation versus local tap water tariffs, dairy processors generally do not consider this option. However, future drought and water restrictions remain a concern, therefore, investing in recycling opportunities may be prudent in the long run. To achieve full water recycling, wastewater must typically be treated at three levels: primary, secondary, and tertiary (Dairy Australia, 2019). To remove suspended solids, primary treatments such as screening and DAF are used. Secondary treatment methods include biological treatments such as anaerobic digestion, which uses microorganisms to convert organic material in wastewater into biogas. Finally, the tertiary treatment processes use membrane filtration and disinfection to produce potable water that meets SANS 241-1:2015 standards.

7.2.2.3 Other reuse opportunities

Depending on the water source, some wastewater can be reused in processes where lower quality water is acceptable. If necessary, wastewater can be treated and used for garden watering, outdoor dust suppression, and floor cleaning.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

This edition of NATSURV 4 encountered difficulties in securing complete industry engagement, leading to a restricted dataset. The limited participation from dairy industry players has limited the capacity to formulate universal deductions and establish nationwide patterns with confidence. Despite the insightful contributions from the participants, a more extensive dataset is necessary to draw meaningful inferences that pertain to the entire South African dairy industry.

It is noteworthy that the industry currently processes over three times the quantity of milk recorded in 1989, indicating growth in the sector, while also achieving a reduction in SWI across a diverse range of products. This trend underscores progress in water efficiency over the past three decades. This survey found that South Africa aligns with international water usage patterns, although there is still opportunity for improvement. However, the extent of SWI reduction is constrained due to the hygiene prerequisites binding the dairy sector.

There is greatest potential for dairies to enhance their wastewater management, as evidenced by the gaps in knowledge concerning pollution loads from participating facilities. The government could enhance the use of financial mechanisms to incentivise water savings and wastewater quality targets. This is particularly important when only some of the participating dairies have established and executed water consumption and wastewater objectives. It is important to ensure that setting up water abstractions and discharge fees is not just a matter of implementation but also effective enforcement. Such regulations would incentivise the dairy industry to adopt better practices of water, wastewater and energy reuse and recycling.

8.1 RECOMMENDATIONS

8.1.1 Research

Future research should broaden its scope to consider a wider variety of dairy products, such as different varieties of cheese, by products, a variety of milk concentrated products, and powdered dairy products. This expansion could be helpful to provide a deeper understanding of water and wastewater management within the dairy industry. There is an opportunity for the dairy industry to be further segmented to determine efficiencies within the value chain and product lines in follow on Natsurvs.

8.1.2 Practice

While some dairies are adopting best practices, it is evident that such practices are not uniformly embraced across the sector. Future endeavours are required to enhance awareness and support companies in identifying avenues for reduction. Stakeholders should start with implementing short-term water management strategies such as measuring, monitoring, and raising staff awareness in order to optimise water use through preventative measures. However, after considering the short-term possibilities, stakeholders should consider the long-term cost of being water inefficient. The long-term cost of inefficiency might include reduced productivity, wasted resources, and financial losses. Moreover, consider all of the long-term benefits of being self-sufficient, as competition for clean water will intensify in the future.

Water scarcity justifies water management practices, as unlike energy, there is no backup for water shortages. Stakeholders could prepare for water scarcity proactively, recognising its intrinsic value rather than focusing solely on financial return on investment. Greater emphasis on business resilience and self-sufficiency of water and energy supplies would tip the balance of decision-making in favour of adopting best practices more widely.

8.2 CONCLUSIONS

The best practices recommendations outlined in this report are offered as opportunities for improvement, however, whether these improvements will be effectively implemented depends on the unique characteristics of each dairy site. Sites can vary significantly based on factors such as the plant size and layout limitations, the ownership structure (whether it is owned or rented), and adherence to local municipal regulations, among others. Regular revisitation of these practices, preferably on an annual basis, is essential to assess the need and feasibility of their implementation based on changing circumstances.

REFERENCES

AGRIORBIT (2021) *Water supply, legislation and consumption trends in SA*. https://agriorbit.com/water-supply-legislation-and-consumption-trends-in-sa/. (Accessed 15th December 2022).

AJIERO I AND CAMPBELL D (2018) Benchmarking Water Use in the UK Food and Drink Sector: Case Study of Three Water-Intensive Dairy Products. Water Conservation Science and Engineering 3(1) 1-17. doi:10.1007/s41101-017-0036-0.

ALEXANDER M (2018) *The nine provinces of South Africa*. South Africa Gateway. https://southafrica-info.com/land/nine-provinces-south-africa/#:~:text=Northern%20Cape%3A%201.2%20million%20people,of%20South%20Africa's%20total%20population). (Accessed 13th September 2023).

ARCHER E, DU TOIT J, ENGELBRECHT C, *ET AL.* (2022) The 2015-19 multi year drought in the Eastern Cape, South Africa: it's evolution and impacts on agriculture. Journal of Arid Environments 196 104630.

ARNOLDI M (2023) *Carbon fuel levy for 2023/2024 increases by 1c.* Creamer Media's Engineering News. https://www.engineeringnews.co.za/article/carbon-fuel-levy-for-202324-increases-by-1c-2023-02-22#:~:text=Since%20January%202022%2C%20the%20carbon,least%20%2430%2Ft%20by%202030. (Accessed 28th August 2023).

AXIL (2021) *What is a waste management hierarchy?* https://axil-is.com/blogs-articles/waste-management-hierarchy/. (Accessed 14th November 2022).

BAVAR M, SARRAFZADEH MH, ASGHARNEJAD H, *ET AL.* (2018) Water management methods in food industry: Corn Refinery as a case study. Journal Food Eng. 238 78-84.

BOGUNIEWICZ-ZABLOCKA J, KLOSOK-BAZAN I AND NADDEO V (2019) Water quality and resource management in the dairy industry. Environmental Science and Pollution Research 26(2) 1208-1216. doi:10.1007/s11356-017-0608-8.

BOSWORTH MED, HUMMELMOSE B, CHRISTIANSEN K, *ET AL.* (2003) *Cleaner Production Assessment in Dairy Processing.* Denmark.

BRUSH A, MASANET E AND WORREL E (2011) *Energy Efficiency Improvement and Cost Saving Opportunities for the Dairy processing Industry.* Berkeley.

BRYDEN N (2021) *Manufacture of Dairy Products in South Africa*. African Business Information – Who owns whom.

BUFFALO CITY (2022) *Buffalo City Metropolitan Municipality Tariff policy.* South Africa.

BUNK J AND BOTHA R (2022) Milk Pasteurisation – Increasing the shelf-life. GEA.

BURGER J (2023) *Combined list of acts, regulations and standards relating to food safety and quality aspects of milk and other dairy products*.

BUSINESSTECH (2020) *This graph shows huge price hikes for municipal water, lights and other taxes*. https://businesstech.co.za/news/finance/439361/this-graph-shows-huge-price-hikes-for-municipal-water-lights-and-other-taxes/. (Accessed 15th December 2022).

BYLUND G (2015) *Dairy processing handbook*. Tetra Pak Processing Systems AB, Lund.

CHETAN S AND VIKAS K (2015) Analysis of the volume of the main water and wastewater in a sugar manufacturing process followed by the suggestion regarding the reutilisation of the wastewater. International Journal of Current Engineering and Technology 5(3) 1757-1761.

CITY OF CAPE TOWN (2022) *City of Cape Town tariff policy*. Special council policy. South Africa.

CITY OF TSHWANE (2022) *City of Tshwane metropolitan municipality water supply by-laws.* City of Tshwane Metropolitan Municipality, South Africa.

DAFF (2019) *A Profile of the South African Dairy Market Value Chain.* Pretoria.

DAIRY AUSTRALIA (2019) *Eco-efficiency for the dairy processing industry.* North Sydney.

DEA (2011) *National waste management strategy.* South Africa.

DEA (2014) *National Guideline for the Discharge of Effluent from Land based Sources into the Coastal Environment.* Pretoria.

DEMIREL B, YENIGUN O AND ONAY TT (2005) Anaerobic treatment of dairy wastewaters: a review. Process Biochemistry 40(8) 2583-2595.

DESHANNAVAR UB, BASAVARAJ RK AND NANDINI MN (2012) High-rate digestion of dairy industry effluent by upflow anaerobic fixed-bed reactor. Journal of Chemical and Pharmaceutical Research 4(6).

DORMIDO H (2019) *These countries are the most at risk from a water crisis*. Bloomberg. https://www.bloomberg.com/graphics/2019-countries-facing-water-crisis/?leadSource=uverify wall. (Accessed 13th December 2022).

DSA (2022) *Code of practice for the Secondary Industry.* Dairy Standard Agency.

EBRAHIMI E, SHIRAZI B AND MAHDAVI I (2019) Measuring the wastewater in a Yoghurt Production Plant and Redesigning the Cleaning in Place Process (Case Study: Kalleh Dairy Factory). In: *15th Iran International Industrial Engineering Conference* (IIIEC)IEEE 43-46. doi:10.1109/IIIEC.2019.8720618.

ETHEKWINI (2016) *Sewage disposal by-law*. KwaZulu-Natal Provincial Gazette. South Africa.

FAO (2017) *Per capita milk consumption*. https://ourworldindata.org/grapher/per-capita-milk-consumption?time=latest. (Accessed 12th December 2022).

FORTUNE BUSINESS INSIGHTS (2021) *Dairy alternatives market research report*. https://www.fortunebusinessinsights.com/industry-reports/dairy-alternatives-market-100221. (Accessed 12th December 2022).

GREIG R, MCCOMB D, CHEN R, *ET AL.* (2023) South Africa Dairy Processing Resource efficiency benchmarking study. NCPC-SA and IFC, Cape Town.

GWI (2020) *Global water Intelligence water data for dairy sector*. https://www.gwiwaterdata.com/industries/food-beverage/dairy#overview-48744. (Accessed 16th December 2022).

VAN HEERDEN B (2021) Dairy Market Trends. Milk Producers Organisation. https://www.mpo.co.za/wp-content/uploads/2022/01/Dairy-Market-Trends-December-2021.pdf. (Accessed 24th June 2022).

HERSELMAN JE AND SNYMAN HG (2009) *Guidelines for the utilisation and disposal of wastewater sludge: Volume 3 of 5: Requirements for the on-site and off-site disposal of sludge.* Pretoria.

HYDROTECH (2018) *Chlorine, ozone and UV light: How is wastewater disinfected?* https://www.hydrotech-group.com/blog/chlorine-ozone-or-uv-light-how-is-wastewater-disinfected. (Accessed 15th December 2022).

ICMA (2008) *National Environmental Management: Integrated Coastal Management Act.* Government Gazette, South Africa.

IDF (2021) *The world dairy situation 2021*. International Dairy Federation Bulletin No. 517.

ILLIDGE M (2023) *South Africa's electricity price nightmare*. My Broad Band. https://mybroadband.co.za/news/energy/485175-south-africas-electricity-price-nightmare.html. (Accessed 15th September 2023).

INDEXMUNDI (2022) *Milk production per year*. https://www.indexmundi.com/agriculture/?country=us&commodity=milk&graph=production. (Accessed 13th December 2022).

INTERTEK (2010) *Nestle targets worldwide registration of all plants to ISO 14 001, OHSAS 18001*. Quality Digest. https://www.qualitydigest.com/inside/standards-news/nestl-targets-worldwide-registration-all-plants-iso-14001-ohsas-18001-032410. (Accessed 19th December 2022).

JANCZUKOWICZ W, ZIELIŃSKI M AND DĘBOWSKI M (2008) Biodegradability evaluation of dairy effluents originated in selected sections of dairy production. Bioresource Technology 99(10) 4199-4205.

KAPLAN S (2023) *Water supply, sewage and loadshedding collide – but where is the plan?* Civil Engineering. https://journals-co-za.ezproxy.uct.ac.za/doi/epdf/10.10520/ejc-civeng_v31_n2_a1. (Accessed 13th September 2023).

KARADAG D, KÖROĞLU OE, OZKAYA B, *ET AL.* (2015) A review on anaerobic biofilm reactors for the treatment of dairy industry wastewater. Process Biochemistry 50(2) 262-271.

KLEMEŠ JJ, VARBANOV PS, WAN ALWI SR, *ET AL.* (2014) Introduction to water Pinch analysis. In: *Process integration and intensification,* Ed. 1, Walter de Guyter, Berlin, Germany.

LABUSCHAGNE H (2022) Scary load-shedding statistic revealed. My Broad Band. https://mybroadband.co.za/news/energy/470217-scary-load-shedding-statistic-revealed.html. (Accessed 21st August 2023).

MANAN ZA, TAN YL, FOO DCY, *ET AL.* (2007) Application of water cascade analysis technique for water minimisation in a paper mill plant. International Journal of Pollution Prevention 29(1-3) 90-103.

MIDGLEY SJE (2016) *A commodity value chain analysis of dairy.* South Africa.

MILK SA (2022) *Lacto Data,* Pretoria. https://milksa.co.za/sites/default/files/2022-06/Lacto-Data-May-2022 Final.pdf. (Accessed 16th September 2022).

MOKHTAR NF BINTI (2019) Modelling and Simulation of Milk Production Using SuperPro Designer. University of Malaysia Kelantan.

MOLEWA B (2013) *Revision of General Authorisations in terms of Section 39 of the National Water Act, 1998 (Act No. 36 of 1998)*. No. 36820, Department of Water and Sanitation, South Africa.

MOSTAFA MK (2015) Impact of Improving Water Quality at the Tala Drain on the Rosetta Branch Water Quality. Journal of Environmental Protection 06(10) 1149-1157. doi:10.4236/jep.2015.610102.

MWENDERA E AND ATYOSI Y (2018) A Review of Water Storage for Socio-Economic Development in South Africa. Journal of Water Resource and Protection 10(03) 266-286. doi:10.4236/jwarp.2018.103016.

DAS NAIR R (2011) *Inclusive industrialisation in agro-processing: Challenges faced by small and medium-sized dairy processors in South Africa*. Innovation & Inclusion in Agro-processing.

NAROUVA (2018) *Perogen*. https://narouva.com/water-treatment/perogen-wt/. (Accessed 14th December 2022).

NCPC (2022) *Metering and monitoring guideline for the Agri-Processing sector in South Africa*. https://www.industrialefficiency.co.za/wp-content/uploads/2022/05/Metering-Monitoring-Guideline-1.pdf. (Accessed 25th August 2023).

NEMA (1998) *National Environmental Management Act.* South Africa.

NEMATI-AMIRKOLAII K, ROMDHANA H AND LAMELOISE ML (2019) Pinch methods for efficient use of water in food industry: A survey review. Sustainability (Switzerland)MDPI. doi:10.3390/su11164492.

NESTLE (2013) *The Nestle Policy on Environmental Sustainability*. Nestec Ltd. Switzerland.

NOLL CI AND SUPPLEE GC (1941) Factors affecting the gas content of milk. Journal of Dairy Science 24(12) 993-1013.

NWA (1998) *National Water Act*. Government Gazette. Government gazette, South Africa.

OWUSU-SEKYERE E, SCHEEPERS M AND JORDAAN H (2016) Water Footprint of Milk Produced and Processed in South Africa: Implications for Policy-Makers and Stakeholders along the Dairy Value Chain. Water 8(8) 322. doi:10.3390/w8080322.

OXFORD (2022) *Definition of best practice*. https://www.google.com/search?q=best+practices+meaning&oq=best+practice&aqs=chrome.2.0i512j69i57j0i512l8.7149j0j7&sourceid=chrome&ie=UTF-8. (Accessed 15th December 2022).

PODDAR PK AND SAHU O (2017) Quality and management of wastewater in sugar industry. Applied Water Science 7(1) 461-468. doi:10.1007/s13201-015-0264-4.

PREISNER M, NEVEROVA-DZIOPAK E AND KOWALEWSKI Z (2020) An Analytical Review of Different Approaches to Wastewater Discharge Standards with Particular Emphasis on Nutrients. Environmental Management 66(4) 694-708. doi:10.1007/s00267-020-01344-y.

RABIN E (2003) *ISO 14000: A Worldwide blueprint for environmental management?* GreenBiz. https://www.greenbiz.com/article/iso-14000-worldwide-blueprint-environmental-management. (Accessed 19th December 2022).

RAD SJ AND LEWIS MJ (2014) Water utilisation, energy utilisation and wastewater management in the dairy industry: A review. International Journal of Dairy Technology 67(1) 1-20. doi:10.1111/1471-0307.12096.

RAMUKHWATHO FR, SEETAL A, PIENAAR H, *ET AL.* (2016) *NATSURV 1: Water and wastewater management in the malt brewing industry*.

LE ROUX M, JONKER DW AND KRAAMWINKEL AP (2022) *Trends in the retail sales of dairy products (SAMPRO)*.

SA GOVERNMENT (1996) *Constitution of the republic of South Africa.* SA Government, South Africa.

SABS STANDARDS DIVISION (2015) *SANS 241-1: Drinking water.* SABS Standards Division.

SAMPRO (2022) *Summary of the key market signals for the dairy industry*.

SHAHBANDEH M (2020) *Per capita consumption of fluid milk in South Africa from 2010 to 2017*. https://www.statista.com/statistics/974191/south-africa-per-capita-consumption-of-fluid-milk-products/. (Accessed 10th December 2022).

SHERMAN F (2019) *What Are Internal & External Environmental Factors That Affect Business?* Effective Business Communication. https://smallbusiness.chron.com/internal-customer-external-customer-11698.html. (Accessed 13th September 2023).

SOUTTER T (2020) *Are plant-based alternatives a real threat to Dairy?* https://www.czapp.com/analyst-insights/are-plant-based-alternatives-a-real-threat-to-dairy/. (Accessed 10th December 2022).

STATISTA (2021) *Water prices of tap water in cities worldwide*. https://www.statista.com/statistics/478870/leading-cities-by-highest-freshwater-prices/. (Accessed 15th December 2022).

STATISTA (2022) *Annual consumption of fluid cow milk worldwide*. https://www.statista.com/statistics/272003/global-annual-consumption-of-milk-by-region/. (Accessed 12th December 2022).

STATS SA (2022) *South Africa population*. https://www.statssa.gov.za/?p=15601#:~:text=The%20population%20of%20South%20Africa, the%20end%20of%20June%202022. (Accessed 12th December 2022).

STEFFEN ROBERTSON AND KIRSTEN INC (1989) *NATSURV 4: Water and wastewater management in the Dairy Industry*. Water Research Commission Pretoria. https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT-38-89.pdf. (Accessed 19th December 2022).

TETRA PAK (2021) *Mastering efficient water use*. Tetra Pak Perspectives. https://www.tetrapak.com/about-tetra-pak/stories/reduce-water-usage-food-beverage-industry. (Accessed 15th September 2023).

TEZCAN UN U AND OZEL E (2013) Electrocoagulation of yogurt industry wastewater and the production of ceramic pigments from the sludge. Separation and Purification Technology 120 386-391. doi:10.1016/j.seppur.2013.09.031.

THE WORLD BANK (2021) *Demographics – Population in South Africa*. https://datacommons.org/tools/timeline#place=country%2FZAF&statsVar=Count_Person&chart=%7B%22count-none%22%3A%7B%22pc%22%3Afalse%7D%7D. (Accessed 31st August 2023).

THEVENDIRARAJ S, KLEMES J, PAZ D, *ET AL.* (2003) Water and wastewater minimisation study of a Citrus Plant. Resources, Conservation and Recycling 37 227-250.

TIBANE E (2021) *Official guide to South Africa.* Pretoria.

TIWARI S, BEHERA CR AND SRINIVASAN B (2016) Simulation and experimental studies to enhance water reuse and reclamation in India's largest dairy industry. Journal of Environmental Chemical Engineering 4(1) 605-616. doi:10.1016/j.jece.2015.12.001.

TOMASULA PM, YEE WCF, MCALOON AJ, *ET AL.* (2013) Computer simulation of energy use, greenhouse gas emissions, and process economics of the fluid milk process. Journal of Dairy Science 96(5) 3350-3368. doi:10.3168/JDS.2012-6215.

VASILAKI V, KATSOU E, PONSÁ S, *ET AL.* (2016) Water and carbon footprint of selected dairy products: A case study in Catalonia. Journal of Cleaner Production 139 504-516. doi:10.1016/j.jclepro.2016.08.032.

VOURCH M, BALANNEC B, CHAUFER B, *ET AL.* (2008) Treatment of dairy industry wastewater by reverse osmosis for water reuse. Desalination 219(1-3) 190-202. doi:10.1016/j.desal.2007.05.013.

WOJDALSKI J, DRÓŻDŻ B, PIECHOCKI J, *ET AL.* (2013) Determinants of water consumption in the dairy industry. Polish Journal of Chemical Technology 15(2) 61-72. doi:10.2478/pjct-2013-0025.

WOLF CA, MALONE T AND MCFADDEN BR (2020) Beverage milk consumption patterns in the United States: Who is substituting from dairy to plant-based beverages? Journal of Dairy Science 103(12) 11209-11217. doi:10.3168/jds.2020-18741.

WSA (1997) *Water services act*. Government gazette. South Africa.

WSSA (2023) *Water and Sanitation Services By-Law*. Western Cape Provincial Gazette. Drakenstein, South Africa. https://openbylaws.org.za/akn/za-wc023/act/by-law/2023/water-and-sanitation-services/eng@2023-07-28. (Accessed 14th September 2023).

APPENDIX A: Questionnaire

NATSURV 4 - Water and Wastewater Management in the Dairy Industry

This survey takes +- 30 min to answer
The survey consists of 6 sections and 45 questions.

General information

- Welcome to the on-line survey to determine water and wastewater management practices within the South African Dairy Industry.
- Please read through the document attached below for clarification on participation. All company information will be held as confidential, and any data provided will be reported anonymously.
-

WRC request for participation

WATER RESEARCH COMMISSION

Lynnwood Bridge Office Park, 2nd Floor, Bloukrans Building,
4 Daventry Street, Lynnwood Manor, Pretoria

Private Bag X03, Gezina, 0031, South Africa

Tel: +27 (0)12 761 9300
Email: info@wrc.org.za
Web: www.wrc.org.za

11 MAY 2022

Dear Stakeholder

Request for participation: National Survey (Natsurv) research project titled "Water and wastewater management in the dairy industry".

In the 1980s the Water Research Commission (WRC) and Department of Water and Sanitation (DWS) embarked on a series of national surveys (Natsurvs). The purpose of the Natsurvs was to document a snapshot of current water use and wastewater generation and management within a particular industry. This project intends to update Natsurv 4 on water and wastewater management in the dairy industry, published in 1989.

Your organization has been identified as an important stakeholder in this industry, and we would like to humbly request for your assistance to the project team, led by Prof Joanna Burgess at Isle Utilities in collaboration with the University of Cape Town. The requested assistance will include granting permission to the project team to access your organization datasets in support of the current project.

Although the report will be published at the end of the project, it is important that you are aware that **your organization datasets will not be published**, nor even reported to the WRC. The project team will hold the information in confidence and the records will be deleted at the end of the contract.

You will also be provided with a preview of the report prior to its final copy-editing and publication.

Your support of the project team as requested is appreciated in advance, and do not hesitate to contact the WRC for any further clarification regarding this request.

Yours sincerely

John Ngoni Zvimba

Prof John Ngoni Zvimba
Research Manager: Sustainable Integrated Wastewater Resources Futures
KSA3: Water Use, Wastewater Resources and Sanitation Futures

Supporting sustainable development through research funding, knowledge creation and dissemination

1. 1. Provide the **company name** (Optional)

You do not need to supply the company name, but it would be helpful for any follow-up questions or uncertainties

2. 2. Indicate the **size of the company** based on number of employees *Mark only one oval.*

- Small <50
- Medium 50-200
- Large >200

3. 3. Indicate in which **province** your manufacturing site is located (Optional) *Mark only one oval.*

- Eastern Cape Free State
- Gauteng
- KwaZulu-Natal
- Limpopo
- Mpumalanga
- Northern Cape
- North West
- Western Cape
-

4. 4. Indicate the **city** your manufacturing site is located in (Optional)

5. 5. Provide the **name** of the **contact person**

6. 6. Provide the **position** in company of the **contact person**

7. 7. Provide the **email** of the **contact person**

Overview

Please use average values over the last **3 years (2019-2021)**

We are only considering products **prior to flavouring** or colourants, i.e. **plain yoghurt** and unflavoured milk **of**

To be classified as a yoghurt, the product should contain a **production** minimum of 2 g of milk protein per 100g. (i.e. this survey is not covering dairy snacks)

8. 1. Indicate which **dairy products** are manufactured at your site

Check all that apply.

- [ ] Full Cream Milk
- [ ] UHT Milk
- [ ] Yoghurt
- [ ] Butter

9. 2. What is the **annual production range** of each product? (kL/year)

Product prior to flavouring, e.g. Plain yoghurt: 10,000-20,000 kL/year

10. 3. Over which months of the year is **production the highest**?

Check all that apply.

- [ ] January
- [ ] February
- [ ] March
- [ ] April
- [ ] May
- [ ] June
- [ ] July
- [ ] August
- [ ] September
- [ ] October
- [ ] November
- [ ] December

11. 4. Over which months of the year is **production the lowest**?

Check all that apply.

- [ ] January
- [ ] February
- [ ] March
- [ ] April
- [ ] May
- [ ] June
- [ ] July
- [ ] August
- [ ] September
- [ ] October
- [ ] November
- [ ] December

12. 5. Indicate the products' production as a **percentage of total production** at your site

Check all that apply.

	< 10%	10 - 20%	20 - 30%	30 - 40%	40 - 50%	50 - 60%	60 - 70%	70 - 80%
Full Cream Milk	☐	☐	☐	☐	☐	☐	☐	☐
UHT Milk	☐	☐	☐	☐	☐	☐	☐	☐
Yoghurt	☐	☐	☐	☐	☐	☐	☐	☐
Butter	☐	☐	☐	☐	☐	☐	☐	☐

13. 6. Indicate which **process steps** are carried out at your site

If others apply, please specify

Check all that apply.

- [ ] Vehicle washing
- [ ] Raw material storage
- [ ] Standardization
- [ ] Homogenization
- [ ] Pasteurization
- [ ] De-aeration
- [ ] Incubation
- [ ] Churning
- [ ] Cleaning-in-place (CIP)
- [ ] Filling
- [ ] Labelling
- [ ] Chilling
- [ ] Product storage
- [ ] Bottle washing
- [ ] Crate washing
- [ ] Floor washing
- [ ] Plank washing
- [ ] Steam supply & cooling plants
- [ ] production
- [ ] Other: ______________________

Water consumption and Wastewater generation

Please use average values over the **last 3 years (2019-2021)**

14. 1. What is the **total annual water consumption** on site? (kL/year)

Water consumption related to both process and non-process operations (i.e. municipal meter reading)

____

15. 2. What are the **municipal water tariffs** in your area? (R/kL)

____

16. 3. What is the **total annual effluent generated** on site? (kL/year)

Effluent generated related to both process and non-process operations

____

____

____

____

____

17. 4. What are the municipal **tariffs of effluent disposal** in your area? (R/kL)

____

18. 5. Indicate the **source of water** to your factory

Check all that apply.

- ☐ Municipal
- ☐ Borehole
- ☐ Rainwater
- ☐ Freshwater spring
- ☐ River
- ☐ Dam
- ☐ Water recycling
- ☐ Other: ______________________

19. 6. If more than one applied in Question 5, please specify the **percentages** below:

____
____
____
____
____

20. 7. Indicate the **percentage** of **water used** for the different process stages. Also indicate if the data is metered or estimated.
Check all that apply.

	Metered	Estimated	<10%	10-20%	20-30%	30-40%	40-50%
Cleaning in place (CIP)	☐	☐	☐	☐	☐	☐	☐
Crate washing	☐	☐	☐	☐	☐	☐	☐
Vehicle washing	☐	☐	☐	☐	☐	☐	☐
Floor cleaning	☐	☐	☐	☐	☐	☐	☐
Cooling tower makeup	☐	☐	☐	☐	☐	☐	☐
Boiler feed makeup	☐	☐	☐	☐	☐	☐	☐
Gardens	☐	☐	☐	☐	☐	☐	☐
Ablutions/admin	☐	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐	☐

21. 8. Indicate the **percentage** of **wastewater generated** from each specific process step.
Also indicate if the data is metered or estimated.

Check all that apply.

	Metered	Estimated	<10%	10-20%	20-30%	30-40%	40-50%
Cleaning in place (CIP)	☐	☐	☐	☐	☐	☐	☐
Crate washing	☐	☐	☐	☐	☐	☐	☐
Vehicle washing	☐	☐	☐	☐	☐	☐	☐
Floor cleaning	☐	☐	☐	☐	☐	☐	☐
Cooling tower makeup	☐	☐	☐	☐	☐	☐	☐
Boiler feed makeup	☐	☐	☐	☐	☐	☐	☐
Gardens	☐	☐	☐	☐	☐	☐	☐
Ablutions/admin	☐	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐	☐

22. 9. What is the **average** amount of **water used per litre of product produced**? (Litres water/litres product)

For butter: litres water used per kilogram of product produced

Water usage include: Product production until the end of processing including reception and vehicle washing but NOT including packaging.

Check all that apply.

	<1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5
Full Cream Milk	☐	☐	☐	☐	☐	☐	☐	☐
UHT Milk	☐	☐	☐	☐	☐	☐	☐	☐
Yoghurt	☐	☐	☐	☐	☐	☐	☐	☐
Butter	☐	☐	☐	☐	☐	☐	☐	☐

23. 10. What is the **average** amount of **wastewater produced per litre of product produced**? (L/L or L/kg)

Check all that apply.

	<1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5
Full Cream Milk	☐	☐	☐	☐	☐	☐	☐	☐
UHT Milk	☐	☐	☐	☐	☐	☐	☐	☐
Yoghurt	☐	☐	☐	☐	☐	☐	☐	☐
Butter	☐	☐	☐	☐	☐	☐	☐	☐

Wastewater composition

Please use average values over the last **3 years (2019-2021)**

24. 1. What is the **average pH** of the effluent from your factory?

Mark only one oval.

- Don't know
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 -11
- 11 - 12
- 12 - 13
- 13 - 14

25. 2. Indicate the average monthly **Chemical Oxygen Demand** (COD) effluent loading (mg/L)

If other, please specify *Mark only one oval.*

- Don't know
- 0 - 2 000
- 2 000 - 4 000
- 4 000 - 6 000
- 6 000 - 8 000
- 8 000 - 10 000
- 10 000 - 20 000
- 20 000 - 30 000
- 30 000 - 40 000
- 40 000 - 50 000
- 50 000 - 60 000
- 60 000 - 70 000
- 70 000 - 80 000
- 80 000 - 90 000
- 90 000 - 100 000
- 100 000 - 110 000
- 110 000 - 120 000
- 120 000 - 130 000
- 130 000 - 140 000
- 140 000 - 150 000
- 150 000 - 160 000
- 160 000 - 170 000
- Other: ____________________

26. 3. Indicate the average monthly **Total Dissolved Solids** (TDS) effluent loading (mg/L)

If other, please specify *Mark only one oval.*

- 0 - 500
- 500 - 1 000
- 1 000 - 2 000
- 2 000 - 3 000
- 3 000 - 4 000
- 4 000 - 5 000
- 5 000 - 6 000
- 6 000 - 7 000
- 7 000 - 8 000
- 8 000 - 9 000
- 9 000 - 10 000
- Don't know
- Other: ______________________

27. 4. Indicate the **average** monthly **Total Suspended Solids** (TSS) effluent loading (mg/L)

If other, please specify *Mark only one oval.*

- Don't know
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 - 180
- 180 - 200
- 200 - 400
- 400 - 600
- 600 - 800
- 800 - 1 000
- 1 000 - 1 200
- 1 200 - 1 400
- 1 400 - 1 600
- 1 600 - 1 800
- 1 800 - 2 000
- Other: ______________________

28. 5. Indicate the average monthly **Total Kjeldahl Nitrogen** (TKN) effluent loading (mg/L)

If other, please specify *Mark only one oval.*

- Don't know
- 0 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 1 000
- 1 000 - 1 500
- 1 500 - 2 000
- > 2 000
- Other: ______________________

29. 6. Indicate the average monthly **Biological Oxygen Demand** (BOD) effluent loading (mg/L)

If other, please specify *Mark only one oval.*

- Don't know
- 0 - 2 000
- 2 000 - 4 000
- 4 000 - 6 000
- 6 000 - 8 000
- 8 000 - 10 000
- 10 000 - 20 000
- 20 000 - 30 000
- 30 000 - 40 000
- 40 000 - 50 000
- > 50 000
- Other: ______________________

30. 7. Indicate the average monthly **Total Organic Carbon** (TOC) effluent loading (mg/L)

If other, please specify *Mark only one oval.*

- 0 - 10 000
- 10 000 - 20 000
- 20 000 - 30 000
- 30 000 - 40 000
- 40 000 - 50 000
- > 50 000
- Don't know
- Other: ______________________

31. 8. What **impurity** is the **most prominent** in the effluent streams?

Mark only one oval.

- COD
- TDS
- TSS
- TKN
- BOD
- TOC
- Other: ______________________

Water and Wastewater Management

32. 1. Indicate the type of **raw water pre-treatment** carried out on site.
If other, please specify.
Check all that apply.

- [ ] Sand filtration
- [ ] Membrane filtration
- [ ] Activated carbon
- [ ] UV disinfection
- [ ] Chlorine disinfection
- [ ] Ozone treatment
- [ ] Cartridge filtration
- [ ] Bag filtration
- [ ] Coagulation and locculation
- [ ] Settling
- [ ] None
- [ ] Perogen dosing
- [ ] Other: ______________________

33. 2. Indicate the type of **effluent treatment processes** carried out on site prior to discharge
If other, please specify.
Check all that apply.

- [ ] pH adjustment
- [ ] Screening
- [ ] Anaerobic digestion
- [ ] Flocculation
- [ ] Dissolved air flotation
- [ ] Reverse osmosis
- [ ] Holding tank
- [ ] Segregation of concentrated process streams
- [ ] Trucking of effluent for offsite disposal
- [ ] None
- [ ] Separation plant and dam
- [ ] Manmade wetland
- [ ] Other: ______________________

34. 3. Indicate which best practice initiatives are implemented, in progress or planned for future.

Check all that apply.

	Implemented	In progress	Planned for future
Water sub metering	☐	☐	☐
Energy sub metering	☐	☐	☐
Cleaning in Place (CIP) recovery	☐	☐	☐
Heat recovery	☐	☐	☐
Water footprinting	☐	☐	☐
Carbon footprinting	☐	☐	☐
Life cycle analysis	☐	☐	☐
Water pinch analysis	☐	☐	☐
Condensate recovery	☐	☐	☐
Reduced weight packaging	☐	☐	☐
Use of recycled content in packaging	☐	☐	☐
Rain water harvesting	☐	☐	☐
Water leak prevention program	☐	☐	☐
Other	☐	☐	☐

35. 4. Do you have automated CIP equipment? Please give some detail.

____

____

____

____

____

36. 5. How old is the bulk of your equipment?

Mark only one oval.

- 0-10 years
- 10-25 years
- 25-50 years
- >50 years

37. 6. Has any of the major equipment been replaced in the last 10 years specifically to save water, save energy or to limit emissions? Please specify briefly.

38. 7. If hoses are used, are these fitted with high pressure nozzles?

Mark only one oval.

- Yes
- No

39. 8. If hoses are used, are these fitted with self-closing mechanisms?

Mark only one oval.

- Yes
- No

40. 9. Are water use targets and practices in place? To what extent are these being met?

41. 10. Where is the final effluent being discharged to?

Check all that apply.

- Municipal sewer
- Evaporation dam/s
- Land irrigation
- Water course (river)
- Marine outfall
- Manmade wetland
- Other:

42. 11. Are wastewater quality and quantity targets in place? To what extent are these being met?

43. 12. Is any wastewater being re-used? If so, please explain.

44. 13. Are storm water drains marked?

Mark only one oval.

- Yes
- No

45. 14. Is there a storm water plan to prevent storm water from contamination? If so, please explain.

Involvement

46. 1. Indicate to what level you would like to participate in this project.

Check all that apply.

- [ ] This on-line survey only
- [ ] Attendance at workshops
- [ ] Telephonic interview
- [ ] Online/Virtual interview
- [ ] In person interview
- [ ] E-mail interview
- [ ] Site visit
- [ ] Review of updated NATSURV Document